Final Report

Veritide BluMax Scanning System: On-site Validation & Process Integration

Ovine carcase Inspection/Contamination Management

Project Code
2023-1050

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1.0 Executive Summary

Safe food supplies support national economies, trade and tourism, contribute to food and nutrition security, and underpin sustainable development.

The safety of meat and meat products is impacted by the presence of microbiological or other pathogenic contaminants continuing to be a major societal concern (Lianou 2017). Changes in animal production, product processing, and distribution; increased international trade; increased worldwide meat consumption; changing consumer needs for minimally processed foods; higher numbers of consumers at risk for infection; and increased interest, awareness, and scrutiny by consumers all contribute to the increased importance of meat safety (Yoon & Sofos, 2008).

Sources of contamination present during the slaughter and boning process include faeces, pelts, oil, water, air, and intestinal contents. Both cattle and sheep can carry E. coli, Salmonella, Listeria and Clostridium strains in the intestinal tract which is excreted in the faeces. During the slaughter process, this contamination is often transferred to the carcase (Reid et al. 2002; Nightingale et al. 2004; Bell 1997). A primary focus of meat processing is the clean and hygienic dressing of carcases to present them acceptable and safe for human consumption. Sanitation processes, hygienic practices, and application of food safety interventions - such as visual inspection and carcase trimming to remove identified contaminates - are control points in management to acceptable food safety standards.

Green plant material contains chlorophyll, an optically active compound that yields strong fluorescence signals. Veritide, a New Zealand based company, have developed sensors and models for use in red meat processing plants to identify chlorophyll as an indicator of faecal material or ingesta, which are known to be strongly correlated with the presence of pathogenic and spoilage bacteria. Several markets have zero tolerance for faecal contamination or E. coli. Hence, if faecal contamination is detected, carcases are cleaned, trimmed or condemned. Bacterial contamination like E. coli is responsible for the majority of the meat industry recalls.

Veritide’s existing hand-held BluLine Scanning technology has been expanded into a wide-area, modular camera-scanner system (BluMax) [Figure 1] that can be mounted or manipulated into various positions to inspect specific sections of an ovine carcase.

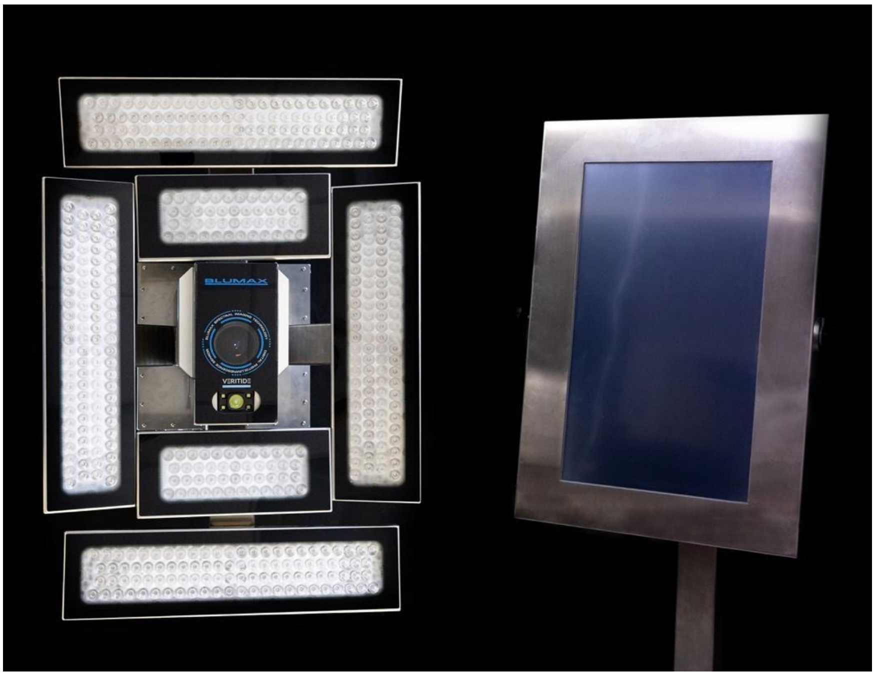


Figure 1: The latest commercial version of Veritide's BluMax Scanner and Industrial Monitor System

The identification of faecal contamination in real time provides opportunities for immediate, precise and accurate intervention, along with a range of other benefits quantified during the project that are not possible through microbiological swabbing. Such techniques inform one to two days post the event, negating many of the benefits Veritide can deliver.

When we set out, the original objectives of the project were to:

- Send BluMax scanned partial carcase images to an industrial monitor that precisely informs and guides a designated and trained operator to specific contaminated locations for manual removal via knife or steam-vac.
- Send BluMax scanned partial carcase images to Augmented Reality lenses that precisely informs and guides a designated and trained operator to specific contaminated locations for manual removal via knife or steam-vac.
- Compare and contrast the two potential solutions in terms of operator preference, efficacy, speed, accuracy, line integration, etc. Validate the various techniques by applying the Veritide BluLine Scanner and laboratory testing for the microbiological status of carcases before and after contamination detection and intervention.
- Build a database of images and reports that enables processors to “track and trace” their specific contamination risk profile (by carcase/hour/day/mob/shift according to the processors requirements); whereby operational and quality control staff have actionable data for lowering contamination risks over time, improving operational outcomes.
- Determine if this Industry 4.0 system of digital contamination management delivers on the core operational improvement objectives and primary goals (detailed below).
    - Reduce labour or utilise labour more efficiently.
    - Reduce trimming of the carcase and lower trim waste.
    - Reduce energy and/or chemical and/or water utilization, improving environmental and sustainability outcomes.
    - Lower pathogenic and spoilage bacterial cell counts, improving food safety outcomes and extending product shelf-life.
    - “Track and Trace” the specific contamination risk profile of the plant (by carcase/hour/day/mob/shift according to the processors requirements); whereby operational and quality control staff have actionable data for lowering contamination risks over time and improving operational outcomes.

While we were able to deliver on many of these objectives, as we progressed through the project, we discovered that the trial site was starting to contemplate operational uses for the technology that we hadn’t necessarily considered earlier. Of course, with any new and disruptive innovation, the best laid plans/ideas often get recalibrated once the technology gets placed in the hands of the customer; this was certainly the case at this trial facility when the BluMax was deployed on site for a longer term.

We noted that the trial site started to gravitate to the utility of the introductory daily reporting programme. They became very focused on the mob-tracking and carcass heat-mapping data [Figure 2] and infographics [Figure 3] as a way of informing themselves about their standard operating procedures (SOPs) and operational improvements that could be extracted from the harvest and evisceration floor vs guiding trimming operations on the trim floor.

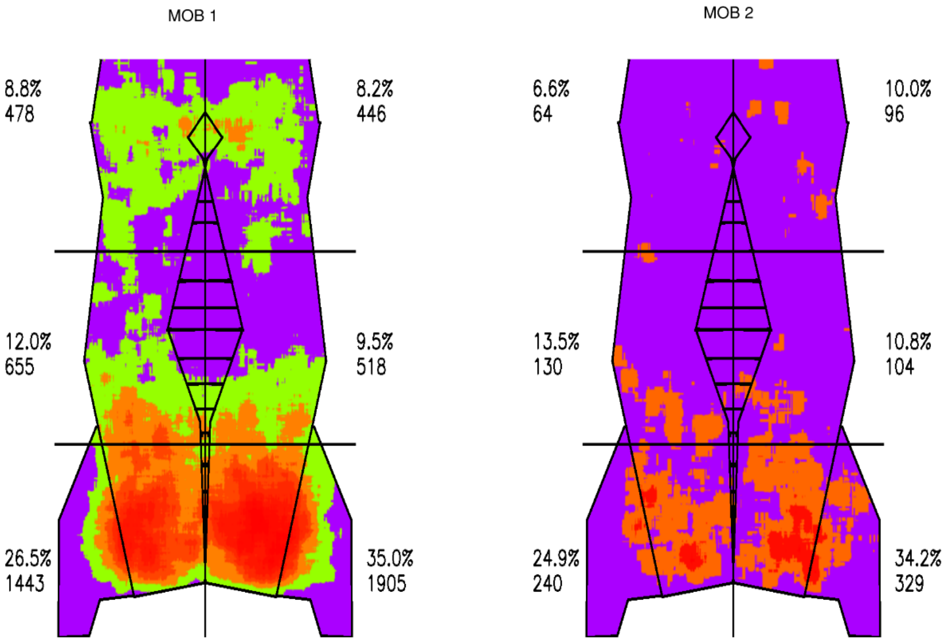


Figure 2: Heat map of carcase example.

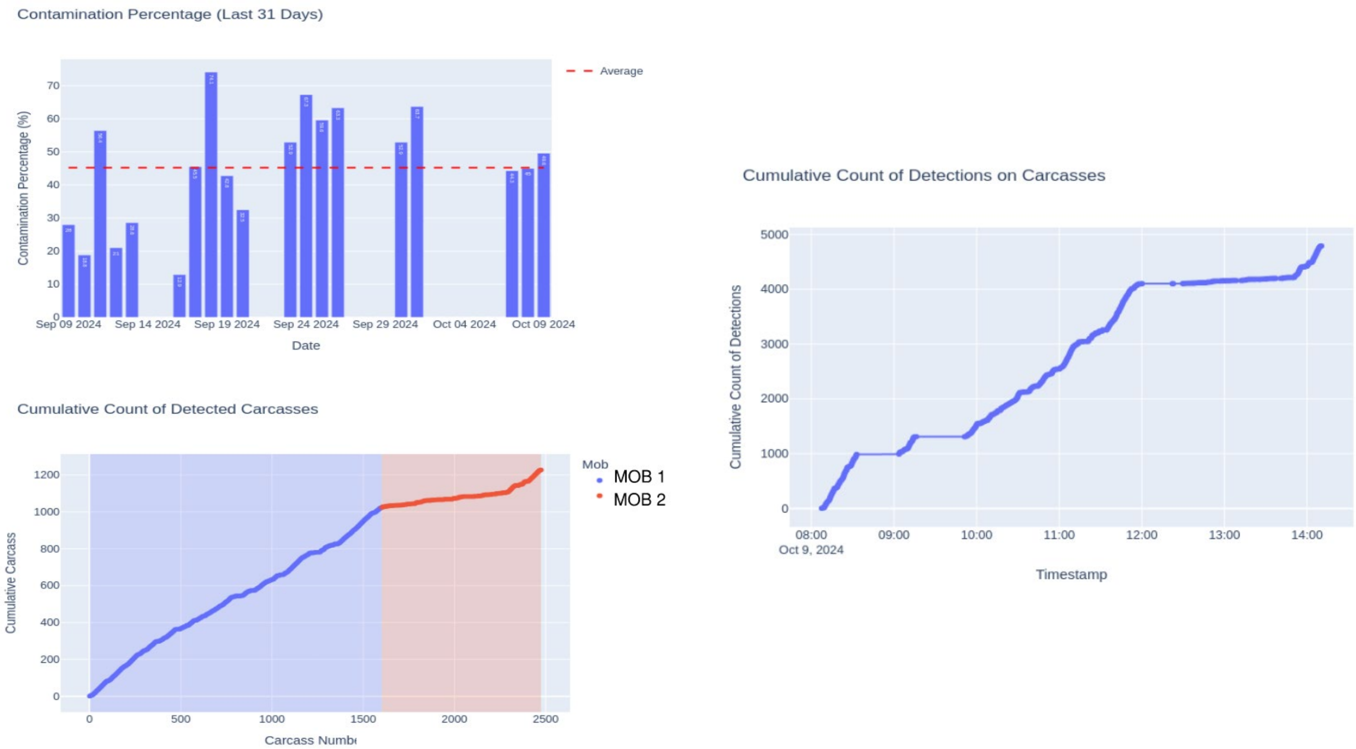


Figure 3: Example of ovine daily reporting.

For this facility and trial, and potentially for the ovine species generally, we discovered that an intermediate step needs to be considered, whereby the BluMax System could be leveraged to deliver powerful, real-time operational improvements and behavioural change on the harvest and evisceration floor first, prior to deployment on the trim floor. The trim floor use case is still entirely valid, but only after deploying the technology to improve upstream, standard operating procedures first.

With this in mind, the conclusion of the processor plant was to initially use the BluMax System in a way that we hadn't prescribed earlier, as outlined below:

i) *The processor would still like to conduct their Blumax Scanning on the main trim floor; investing in equipment that allows the carcasses to be appropriately stabilised and orientated while being scanned through the BluMax field-of-view i.e. to ensure good data integrity and image quality, like we have in the current location.*

ii) *Their objective would be to strategically place large scale monitors back down the line, whereby the key hide removal and evisceration team personnel can see a very simplified and impactful version of the carcass heat map displayed (showing the real-time results of the previous c.100 carcasses scanned).*

iii) *To keep the operating team laser-focused on the highest risk portion of the carcasses, the industrial monitor might simply display a running tally of a percentage of carcasses scanned with contaminations in one critically identified area or zone (as determined by management/operations) i.e. they don't display all percentages across the whole scanned area (as we do with the heat map today). Only show critical data or images from the highest risk, targeted portion of the 100 previously scanned carcasses.*

iv) *In using the BluMax System in this way, the floor supervisors can more actively manage and monitor key personnel regarding SOPs, hide removal techniques, evisceration and cutting techniques, knife and hand cleaning, carcass handling/touching. They can then concentrate on changing selected behaviours and SOPs and monitor the impacts in real-time, in some ways, experimenting with what works best.*

v) *This revised deployment technique would allow ovine processors to focus on lowering the larger scale quantum of contaminants that are occurring at the time and place where the contamination event is happening.*

vi) *As far as using the BluMax to guide trimmers or steam-vac operations, this will likely come later, once the processor has made substantial progress in the areas detailed above.*

Contained within this major learning, the stakeholders in this trial realised that the power of the Veritide BluMax technology was not limited to its ability to illuminate and detect faecal contamination (in real-time, at line speeds); we collaboratively discovered that the underlying data and analytics platform is where substantial residual value and operational utility lies. Commercially, there is a substantial Data-As-A-Service (DaaS) offer that can be delivered to the Ovine processing industry; it's embedded within the BluMax technology now, and can be leveraged for strategic and operational purposes in the future.

Going forward, it is envisaged that the BluMax DaaS offer (or specific sub-components contained within it) will provide powerful operational, quality management, product verification and traceability insights that will cascade value throughout the supply chain. Initially, this will be engineered to the needs of executive and senior level managers and on-site, operational processing personnel. Later on, specific elements of this reporting/analytics programme could be shared with industry auditors, regulatory agencies and downstream supply chain clients.

In conclusion, Veritide, AMPC and the ovine processor are enthusiastic about collaborating on the alternative deployment concepts detailed above. While the DaaS offer is in its early developmental stages, strategically and operationally, this may well be where the value of the BluMax technology can be optimally leveraged.

The harnessing of the BluMax technology requires the industry to consider the implications of increased rigour in potential E. coli contamination identification, intervention, and changes in policies and processes for validating the extension of shelf life via improved hygiene standards. It is recommended that an industry-level approach be taken for the integration of Veritide technologies. This approach should aim to assess the utility and management of data created during the deploying of Veritide's BluMax System [Figure 3] and handheld BluLine Scanners, as well as how the previously identified digital modernisation reforms could be enabled. A number of further bodies of work have been described in the report and summarised below; these form the foundations of our recommendations (outlined below) for future collaborative development initiatives with AMPC and the Ovine processing sector.

Recommended Research Area 1: Integration of BluMax into an ovine slaughter floor for process improvement

Rather than focusing on contamination removal, this approach aims to minimise the amount of contamination from the harvest and evisceration floor - before trimming - in real time. This could be done by feeding data back to harvest and evisceration floor workers. How this data is displayed and monitored is crucial to keeping workers engaged and focussed on best practices.

A 2025 project that delivers this commercial outcome within an Australian ovine processing facility is currently being scoped with the collaborative support of AMPC and a primary processor.

Recommended Research Area 2: Identification of other zero tolerance contaminations

Faecal matter is normally the largest of the zero tolerance contaminations found on ovine carcases. To detect other contaminants, various spectroscopic techniques could be used in combination with a hyperspectral camera. This would enable a wider range of precision trimming and removal of the other contaminations.

Recommended Research Area 3: Develop Veritide automated inspection and automated carcase cleaning

Removing contamination from carcases is a laborious process, even after Veritide technologies identify which areas require trimming. The Veritide system generates x/y/z coordinates for each carcase scanned, and therefore the exact locations within the three-dimensional space that requires cleaning. The project proposes to investigate how this three-dimensional data could be used to drive some form of automation that removes contaminants.

2.0 Introduction

Cattle and sheep are ruminants, thus faecal samples contain green plant material. At a cellular level, green plant material contains chlorophyll. Chlorophyll is an optically active compound that yields strong fluorescence signals when exposed to particular excitation wavelengths of light. Veritide have developed sensors and models which can identify chlorophyll present in faecal material, which is strongly correlated with the presence of E. coli and other pathogenic and spoilage bacteria. Several international export markets have zero tolerance for such contamination. If detected, carcases are cleaned and trimmed or condemned, with costs borne by the exporter. Bacterial contamination like E. coli is responsible for the majority of the meat industry recalls.

A previous proof-of-concept (PoC) project sponsored by AMPC illustrated the technical and scientific credibility of the technology platform in a large format configuration. This was done by leveraging the technology found in the handheld 'BluLine' scanners, which Veritide have been selling internationally for 6 years.

With the BluMax technology now ready for commercialisation, this project has focused on its operational deployment and has taken a "deep dive" approach to explore where the value proposition lies for this technology within the ovine processing environment.

3.0 Project Objectives

This project will allow the ovine processing sector to further evaluate, analyse, and optimise a selection of approaches for automated end-of-line (slaughter) carcase inspection, as well as contamination removal / management practices. In completing this project, the ovine operator will be able to:

- Send BluMax scanned partial carcase images to an industrial monitor that precisely informs and guides a designated and trained operator to specific contaminated locations for manual removal via knife or steam-vac.
- Send BluMax scanned partial carcase images to Augmented Reality lenses that precisely informs and guides a designated and trained operator to specific contaminated locations for manual removal via knife or steam-vac.
- Compare and contrast the two potential solutions in terms of operator preference, efficacy, speed, accuracy, line integration, etc. Validate the various techniques by applying the Veritide BluLine Scanner and laboratory testing for the microbiological status of carcases before and after contamination detection and intervention.
- Build a database of images and reports that enables processors to “track and trace” their specific contamination risk profile (by carcase/hour/day/mob/shift according to the processors requirements); whereby operational and quality control staff have actionable data for lowering contamination risks over time, improving operational outcomes.
- Determine if this Industry 4.0 system of digital contamination management delivers on the core operational improvement objectives and primary goals (detailed below).

3.1 Primary Goals

To further develop and refine the BluMax Scanning technology for ovine end-of-line (slaughter) carcase inspection and contamination management, enabling the processor to:

- Reduce labour or utilise labour more efficiently.
- Reduce trimming of the carcase and lower trim waste.
- Reduce energy and/or chemical and/or water utilization, improving environmental and sustainability outcomes.
- Lower pathogenic and spoilage bacterial cell counts, improving food safety outcomes and extending product shelf-life.
- “Track and Trace” the specific contamination risk profile of the plant (by carcase/hour/day/mob/shift according to the processors requirements); whereby operational and quality control staff have actionable data for lowering contamination risks over time and improving operational outcomes.

4.0 Methodology

The project moved through seven distinct phases:

- **Design:** In consultation with AMPC and the ovine trial facility, Veritide refined the design of a single-module camera-scanning system and AR headset requirements. This included defining in-plant requirements for the BluMax Scanner footprint, H&S, washdown, mechanical support system, data capture, etc. Veritide consulted with AMPC & the processor to understand how best to handle and locate the carcases for inspection/testing.
- **Build:** External components/housings were built, electronic PCB's assembled and integrated with the internal assemblies/camera scanning system [Figure 4].

Figure 4: Completed build of BluMax unit, ready for testing.

- **Commissioning / Testing:** Commissioning / Testing: Once the complete unit was assembled within the Veritide workshop, hardware was tested for heat dissipation and water ingress to ensure that if the BluMax was accidentally sprayed with high pressure water it would not leak and cause failures.
    - Software was modified, adapted and tested. This was to improve the robustness for the trials. The BluMax needed to simply work and require minimal input from an operator. The Networking between the four different computer processors and two cameras had some issues but overtime the software bugs were resolved and a stable system was developed.
    - Additionally, the AR headset was also tested to ensure a demonstration of the technology could be made to ovine test facility and AMPC.
    - The volume of testing and commissioning continued to increase as all aspects of the system were tested and robust, suitable for a 3-month trial in Australia.
    - Real lamb carcases were used in the Veritide workshop to complete the testing, including passing a lamb carcase 500 time past the scanner in just over an hour with no software problems.
- **Installation:** Packed in a shipping crate [Figure 5], the unit was air freighted to the Ovine trial facility. The engineering team at the facility built a moveable / adjustable stand for the BluMax Scanner and Industrial Monitor and constructed black acrylic shading to protect workers from the bright light and give a clean background for the camera. The Veritide team travelled to site, and within half a day the scanner was fully operational.

Figure 5: Photo taken of unit packed ready for air freight to Australia.

- **Commissioning:** The team spent 5 days on site training staff and operators. The BluMax scanner was installed at the entrance to the boning room from the chiller on a manual rail running approx. 700 carcasses per shift. The methodology for the manually feed line was to use a long stainless-steel stick to steadily pass the carcases in front of the BluMax.
- **Off-site support:** Once the team was back in New Zealand the BluMax System was monitored for performance and any software bugs via the remote access functionality built into the scanner.
- **Follow up visits:** An additional three visits to the trial site were conducted, including the demonstration of using the AR headset for precision trimming. During one of the visits, the scanner was moved from the manual rail to the main line just before the X-ray of the automated primal machine. The scanner remained there for the rest of the trial, scanning up to 5000 carcasses per shift.

5.0 Results

5.1 Scanner capabilities

The accuracy and performance of the new BluMax System has enabled a variety of operational features and benefits that were not seen in the PoC trials two years ago. Some of the additional technical and operational features that were developed during the project were:

Scanning the edges of the 3D carcase

The previous BluMax was designed for scanning a carcase, and live-streaming that image into the Industrial Monitor, as it travels across the field-of-view of the camera system. It would simply capture images and calculate the “suitable” carcase image to represent the scan. Yet, this methodology has some limitations. For example, some contamination is only visible at certain points within the field of view.

Another limitation was that once the carcase gets closer to the edge of the scanner’s field-of-view, the scanner can see more of one side than the other [Figure 6]. This is known as parallax error. Having since integrated a depth camera into BluMax, a 3D digital representation of the “snapshots” taken (a single pair of 2D fluorescence image and 3D depth image) can be used to generate a 3D model of the scan. These 3D models can then be combined to form a single coalesced 3D representation of the scanned object. From this, it was realised that a “full scan” (~100 snapshots; taken as the carcase travels across the scanner’s field-of-view) could be distributed into N sections. The best fluorescence image to use is then calculated, and a pair of images sent to the 3D service, for each section. Finally, these images are used to generate the final combined 3D representation [Figure 7]. This solved the problem of edge contamination being found but not appearing in the Industrial Monitor.

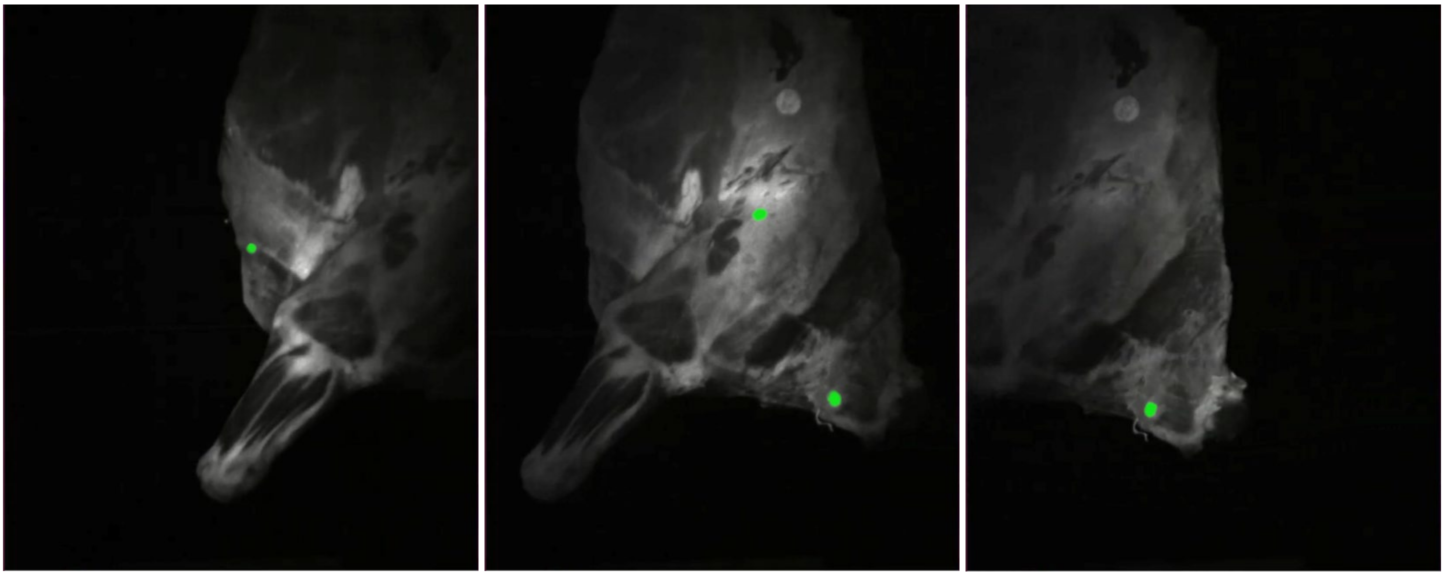


Figure 6: Example of parallax error. Contamination detected as carcase approaches centre of BluMax FOX [left]; whole carcase centred on BluMax, missing initial contamination detection [middle]; view of carcase leaving BluMax FOV [right].

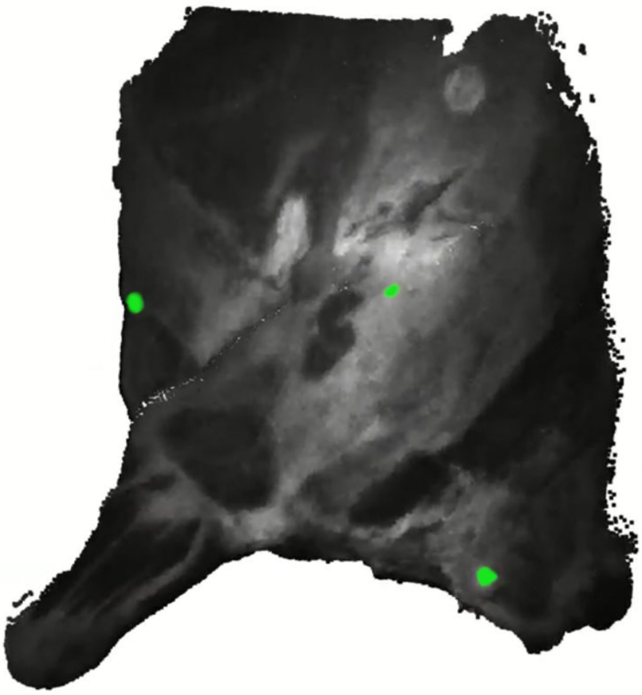


Figure 7: The final 3D representation. A point cloud generated by combining information across multiple images.

Additional BluMax Features

- To assist trimmers, the final 3D image is displayed on the industrial monitor [Figure 8] and can be rotated by the operator using the touch screen.
- Contamination can be displayed through an augmented reality (AR) headset worn by an operator.
- The BluMax scanner is now taking and processing approximately 150 images per second.
- The trial was conducted on a chain processing one carcase approximately every 5 seconds [Figure 9].

Figure 8: Photo of BluMax (in middle) & corresponding display (on right).

Figure 9: Photo of product volume being moved through production facility.

5.2 Precision Trimming

Post-scanning, images of the scanned carcase were displayed on the industrial monitor. This was placed in the field-of-view of the trimmer [Figure 10], allowing the operator to easily switch between trimming carcases and identifying additional areas of contamination based on these images.

Figure 10: Precision trimming based on information from BluMax unit.

5.3 AR development & testing

Augmented Reality (AR) is the name given to the concept of overlaying digital information on top of the "real world" (i.e., what would normally be seen by the naked eye). This is accomplished by applying a variety of semi-transparent or typical LED display technologies. Whether this involves using a mobile phone camera to pass "real-world" information into an AR app (e.g., Pokémon Go), or specialised glass capable of having images projected onto it (e.g., Google Glass), digital and physical information is combined into the same field of view.

The BluMax system is capable of detecting contamination and overlaying the information onto 2D images, which is ideal for basic precision trimming. With the new capability enabled by a 3D TOF (Time-Of-Flight) camera, information can now be detected and overlaid in 3 dimensions, allowing the creation of digital models for each scanned carcase and its respective contamination. This served as the initial inspiration for relaying contamination information to the user via an augmented-reality headset. For this project, the 'Microsoft Hololens 2 - Trimble XR10 Edition' AR headset was used.

Carcases are scanned across the field-of-view of the BluMax unit, each individual scan then being combined into a single carcase model. This data is initially represented in a point cloud format [Figure 11], which is later converted to a triangle-mesh model. This work is done by a new 3D service developed for the BluMax system. Finally, the model is uploaded to an HTTP server, allowing the AR headset to download the 3D models.

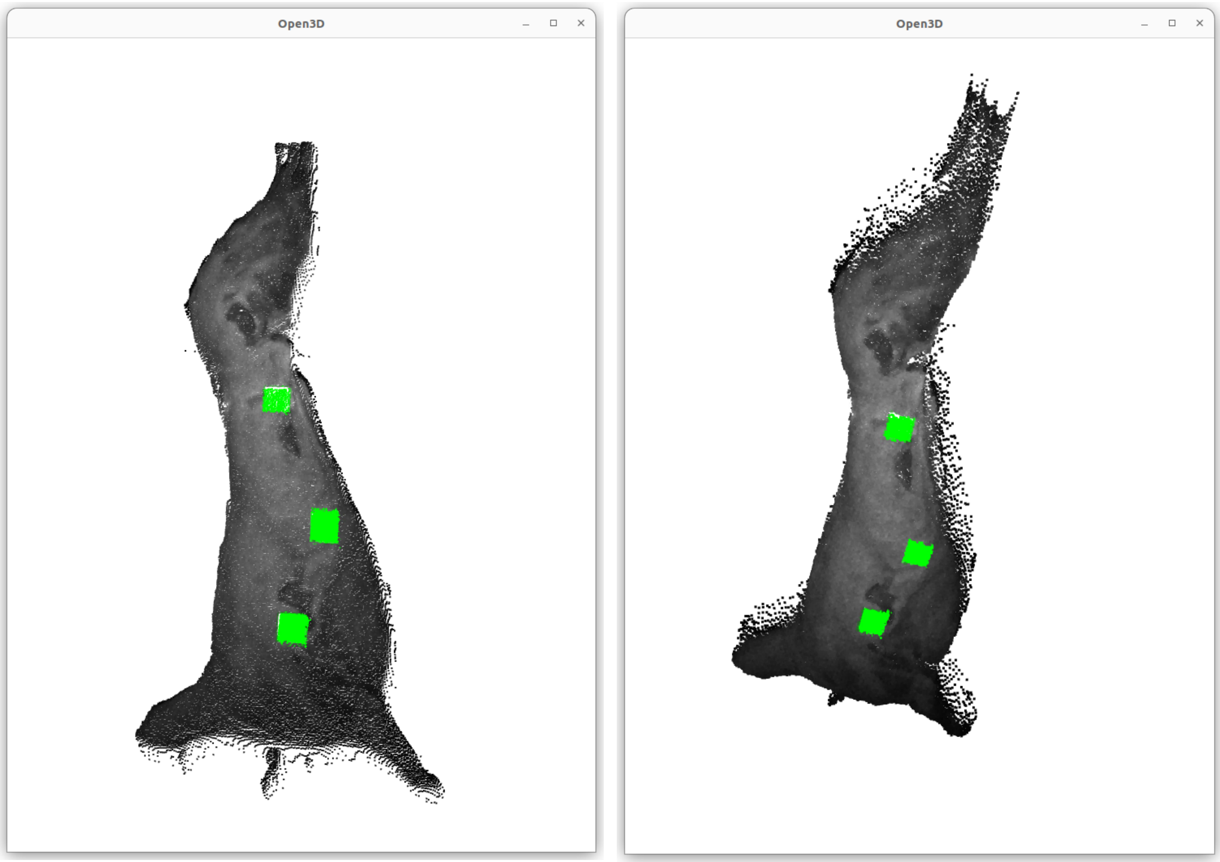


Figure 11: Example of a single point cloud generated from a carcase scan. Both images are of the same carcase, scanned from two angles.

The AR software service was developed using Unity/C# and the OpenXR Framework provided by Microsoft. The AR Service is able to poll a web server for new models, detect and localise QR codes seen by the user, and offset 3D models from the localised QR code. Extra development functionality was added, allowing changes to be made to the QR-code to carcase-offset conversion values via hand-gesture controlled UI.

This proof-of-concept solution was tested at the ovine trial facility [Figure 12]. This testing demonstrated the scanning of a carcase, then downloading and displaying the scanned 3D model after the QR code was viewed by the operator through the AR headset [Figure 13] - having moved the carcase a set distance along the chain so that the carcass and overlaid image aligned.

Figure 12: Possibly the world's first AR trimmer, in action.

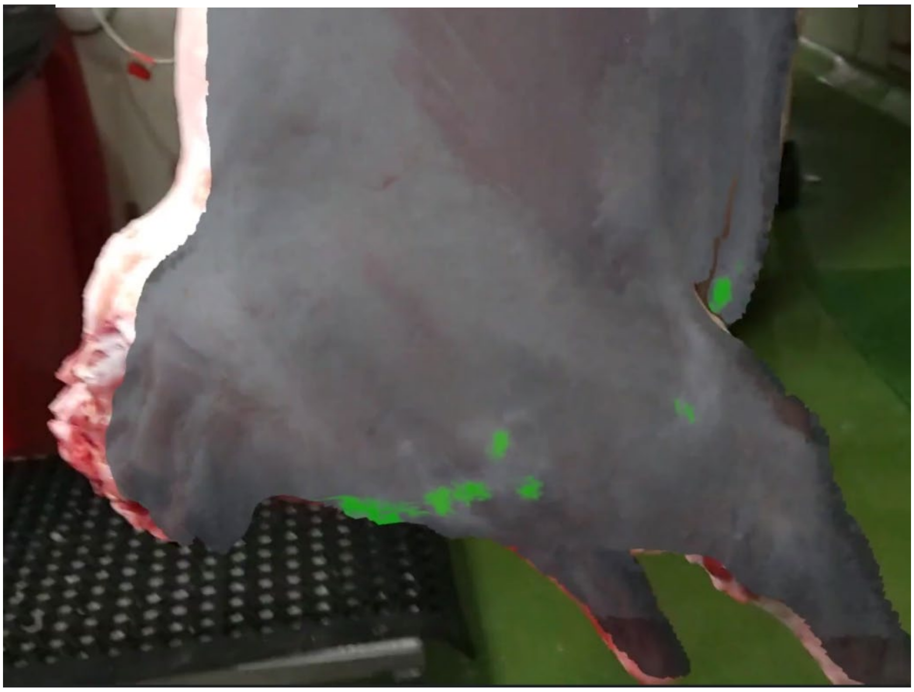


Figure 13: Image taken from the perspective of an operator, looking through the AR headset.

An operational test of AR supported precision trimming was also completed. This involved a skilled trimmer wearing the AR headset to trim the carcase precisely within the target areas using the contamination information displayed. The carcase - and any trim waste - was then scanned by the BluLine hand-held scanner to confirm both the presence of contamination on the trimmed product, and that no contamination was still present on the remaining carcase.

From this AR development work, it was concluded that the AR technology presently available is not yet mature enough to develop a commercially viable solution. This was due to a number of factors:

- At the time, the HoloLens headset was the only headset on the market available for industrial use in this environment.
- The HoloLens has limited battery life; approximately 45 minutes to an hour during use.
- There was large separation between the user's eyes and the AR display due to the hardhat and headset hinge design. This led to a relatively small displayable field of view.
- The accuracy required to position the carcase and hold it perfectly still while overlaying the image is challenging for a chain continuously moving at high speeds.

5.4 Data, Reporting and Analytics

The BluMax system collects a large amount of data from each scan and stores this information in an on-site relational database. With data being captured and stored in a relational database, it is easy to query raw data to be transformed into easy-to-interpret infographics. These can be used to populate report templates to be delivered to the customer via email.

The reporting template started off with a basic information dump from test data collected at the Veritide office. This was created using a blank html document, then populated with html graph files created using a python library. This was done to represent data in various visual formats, enabling discussions on which graphs presented information in a digestible manner, and which should be excluding for being too complex and obscure.

The initial report template [Appendix A] was simplistic as intended, though the chosen colour scheme was less appealing (likely due to the high contrast within the colour palette). Furthermore, the report could only be saved to a file on the computer, then manually downloaded and emailed to people. This encouraged the Veritide team to pursue a more "professional looking" and functional system. This was developed using the python 'ReportLab' library, which enabled a more generalisable system for creating tables, adding images, page formatting, etc. The second graph on page two [Appendix A] was also removed, having been deemed as too obscure as well as unnecessary; the information it was designed to convey to the user is provided by other graphs. The new system also features a custom email server designed to deliver reports to the user over email via a single push of a button on the industrial monitor.

The newly developed template [Figure 14] and reporting system worked well but was prone to edge-case failures. For instance, a report with zero data or zero contamination would fail to generate. Work was also completed to capture mob type data from the BluMax System via manual interaction with the user-interface. This introduced another variable into the dataset and further extended the reporting capabilities of the system. Considering these new requirements, the functionality to support report generation - or sensible failure in cases of 0 scans for the entire reporting time-period - was re-written.

Having completed the base system, functionality was implemented into graphs for mob type information to be overlaid to identify trends across mobs, contamination rates, etc. A daily report template and a weekly report template was also developed [Appendix B]. Once the system was able to identify visible or invisible contamination this needed to be incorporated into the reporting. Although not implemented at the ovine trial facility, the capability was added to have a report of only what is classified as visual contamination, ignoring invisible contamination from the statistics.

The trends and insights that the BluMax reporting and analytics package can deliver are only just beginning to be understood. However, already, there are powerful operational insights that the base level programme can deliver. These include:

- Insights on contamination rates per hour, per day, per shift, per week, per month (etc). Trends, that until now, have been operationally invisible.
- Identifying the specific times of day or specific personnel where hygiene standards or contamination rates are weak vs strong.
- Insights on where staff training and/or SOPs require modification or overhaul.
- Determining shift variances, or mob/supplier variances in real-time.
- Mapping high risk carcass components vs low risk through trend analysis/carcass mapping programmes
- The options and future predictive capabilities of the data and analytics platform are, frankly, mind-boggling.

The data can be displayed in a variety of formats for different requirements and is all connected via the information stored in the Cloud. What a supervisor wants to see might be very different to that of the floor operator vs the national operations manager or a QC manager based in another country looking to monitor inter-site hygiene performance.

Going forward, it is envisaged that the BluMax DaaS offer (or specific sub-components contained within it) will provide powerful operational, quality management, product verification and traceability insights that will cascade value throughout the supply chain. Initially, this will be engineered to the needs of executive and senior level managers and on-site, operational processing personnel. Later on, specific elements of this reporting/analytics programme could be shared with industry auditors, regulatory agencies and downstream supply chain clients.

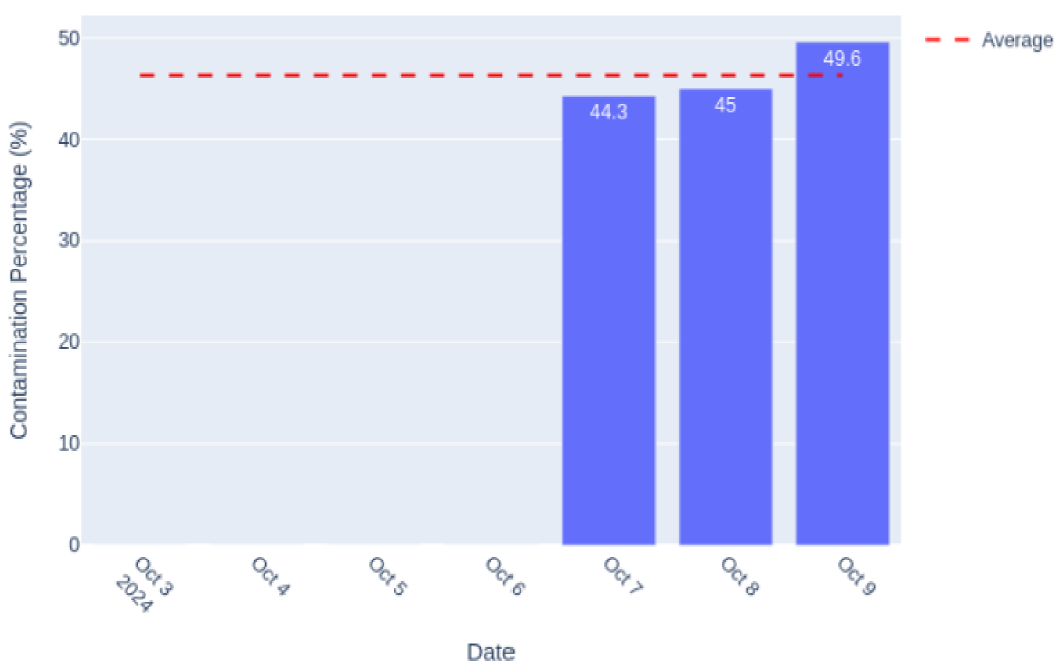
BluMax Report

VERITIDE
BIOLOGICAL DETECTION AND IDENTIFICATION

---- BluMax Scanner Report ----

Reporting From Time	2024-10-09 00:00:00 +1100
Reporting to Time	2024-10-09 23:59:59 +1100
Total Number of Carcasses Scanned	2474
Number of Carcasses Detected	1227
Detected Carcass Percentage	49.6%
Average Detections Per Detected Carcass	3.903
Average BluMax Sensitivity Setting	2.0

Contamination Percentage (Last 7 Days)



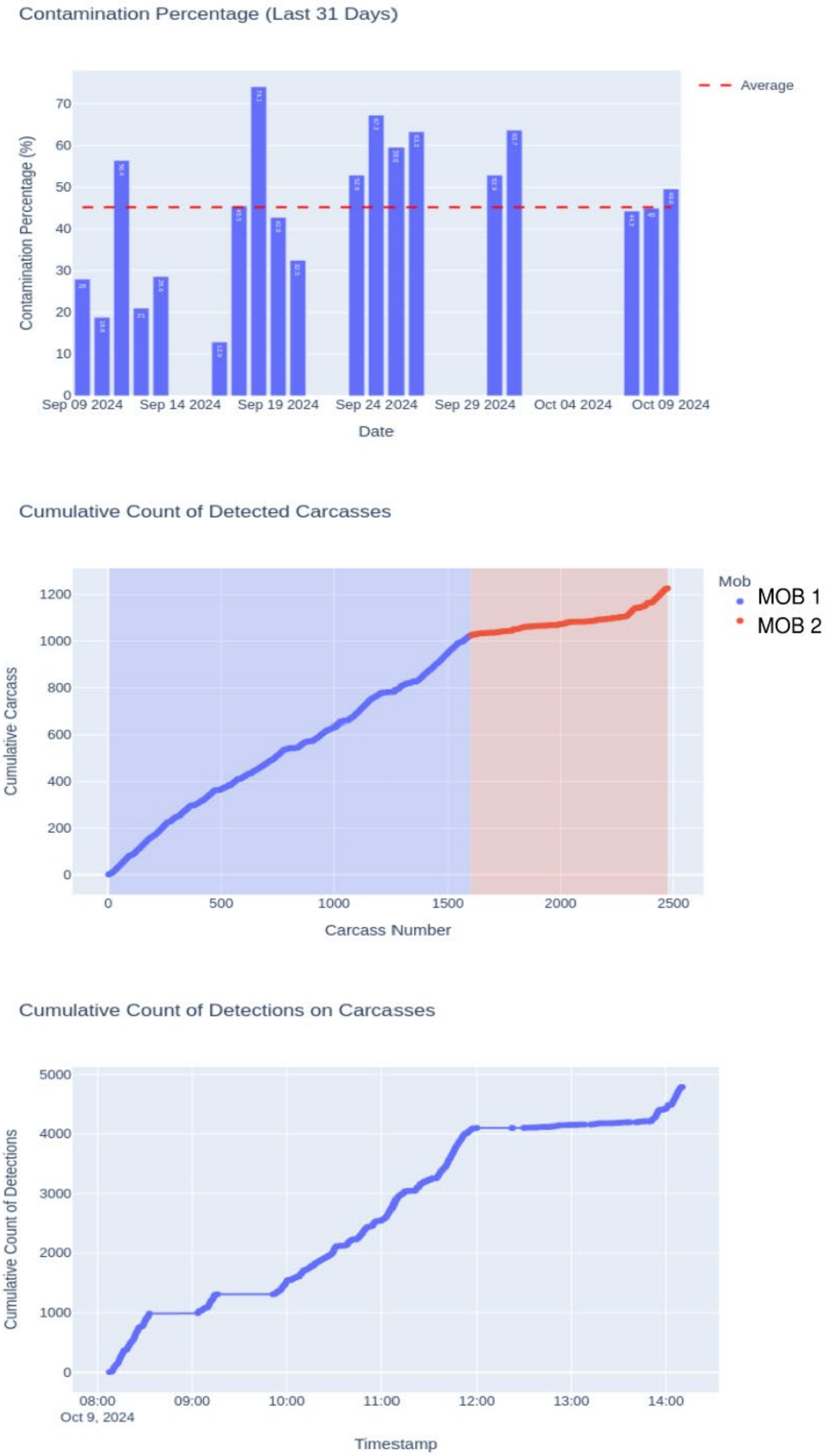


Figure 14: Example of BluMax scanner report.

5.5 Heat Map Development

During the initial visit to the ovine trial facility, both parties raised the idea of introducing a “heatmap” system to visualise the locations of any number of scans on a single template to identify features and trends for process improvement. The heatmap would also be distributed to staff on the harvest floor, evisceration line and trimming to better inform operators about areas of risk.

When collecting contamination data, a “snapshot” image is taken of the generated 3D model as the target, then contamination information (both visible and invisible) is extracted, pinpointing the pixel coordinates of the location. By processing the images, the points can be “normalised” to a shared coordinate system. This can then be applied to a carcase template for data visualisation.

The first iteration of the heatmap [Figure 15] was simple in terms of visualisation. Initially, a carcase template was developed using images collected across the trial, which was later developed into an automated system. On the press of a button, this system collects all the carcase scans over a specified time period and produces a carcase template populated with single points from the contamination locations on the collected carcases. The “dense” areas are of high interest, indicating high levels of contamination. Whereas the “sparse” areas indicate less contamination. During testing, this heatmap had an issue of data existing outside of the template bounds. This was solved by applying a white border outside the template, though this came with the cost of lost data. This idea was built upon for the next iteration.

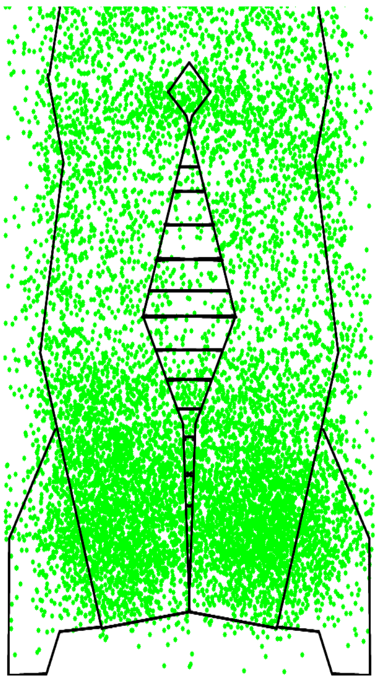


Figure 15: First draft of heat map for lamb [August 2024].

During development of the second iteration heatmap system, a more “general” heatmap was desired. This meant designing a heatmap that looks good with both low and high data visualisation, which the old heatmap struggled to showcase. To implement this, a colour map system was developed to create regions. Each region is coloured, creating an intensity map that represents different amounts of contamination depending on the region colour [Figure 16]. The number of contaminations in each region can also be counted, providing more specific numerical values which can be compared between regions. After presenting the second iteration to the ovine processor, they asked us if it was possible to produce a heatmap for each mob, given the updated system already collects mob information. This capability was quickly developed and can now produce a contamination heatmap over any range of time, and for any combination of mobs. Currently, the heatmap is also automatically issued as part of the daily reporting.

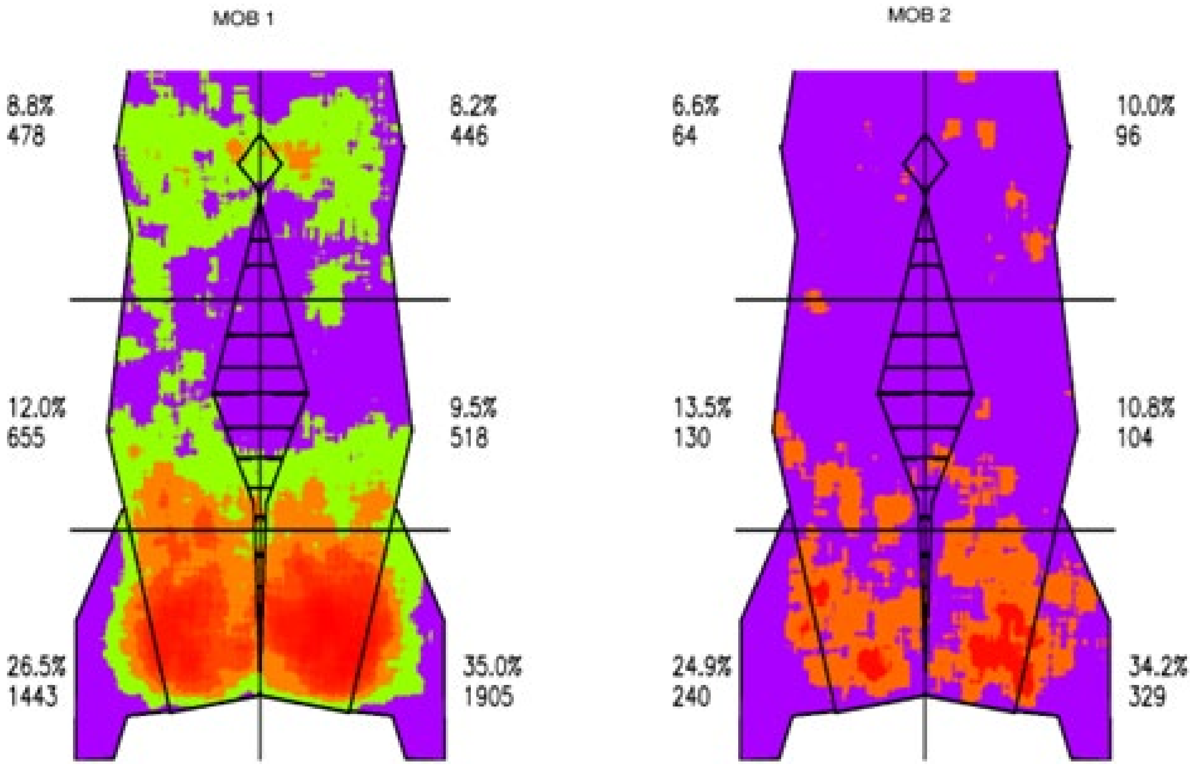


Figure 16: Revised heat map for lamb showing two different mobs from the same day [October 2024].

5.6 Sensitivity

When the BluMax unit was installed at the ovine trial facility to fulfill Milestone 5's requirements on site, the sensitivity selection of faecal detection was only based on the size of chlorophyll fluorescence. Regardless of chlorophyll fluorescence intensity, which can vary depending on the chlorophyll concentration, the underlying fluorescence area was a deciding factor for deciding whether to display on the industrial monitor or not.

For the initial sensitivity scheme, detected chlorophyll fluorescence output signals were first converted to a binary image. Figure 17 and Figure 18 illustrate such a binarization. Various chlorophyll intensity emitting at various sizes on a carcase is shown in Figure 18 and its binary conversion (in green) is shown in Figure 17. Following the binarization a predetermined size, filtering was then applied to select relevant fluorescence sizes to indicate faecal detection for the BluMax operators.

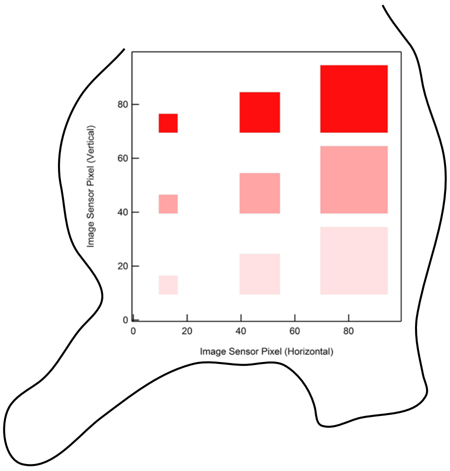


Figure 18: Illustration of chlorophyll fluorescence emitting at different intensities [red = strong, pale pink = weak] at various contamination sizes.

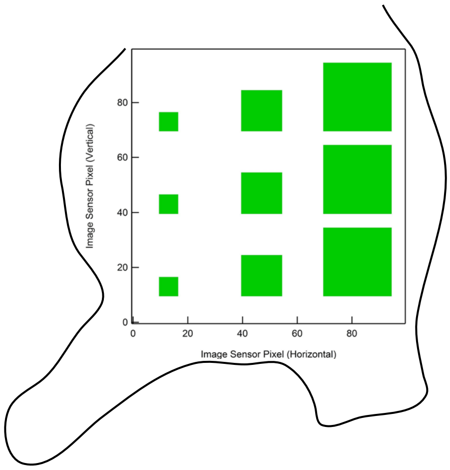


Figure 17: Illustration of a binary image of chlorophyll emission at various sizes on a carcase.

Depending on the sensitivity settings, the BluMax system can display either larger areas or a combination of larger and smaller areas. As depicted in Figure 19, BluMax can display large fluorescence in green colour across three settings. Using the "Low" sensitivity setting, medium and small sized chlorophyll fluorescence is bypassed. Using the "Medium" sensitivity setting, the BluMax can display large and medium sized chlorophyll fluorescence in green colour, while bypassing small chlorophyll "specks". Using "High", the BluMax can display all small, medium and large sized chlorophyll fluorescence. It should be noted that chlorophyll fluorescence is represented as green marks and are superimposed on top of raw carcase images.

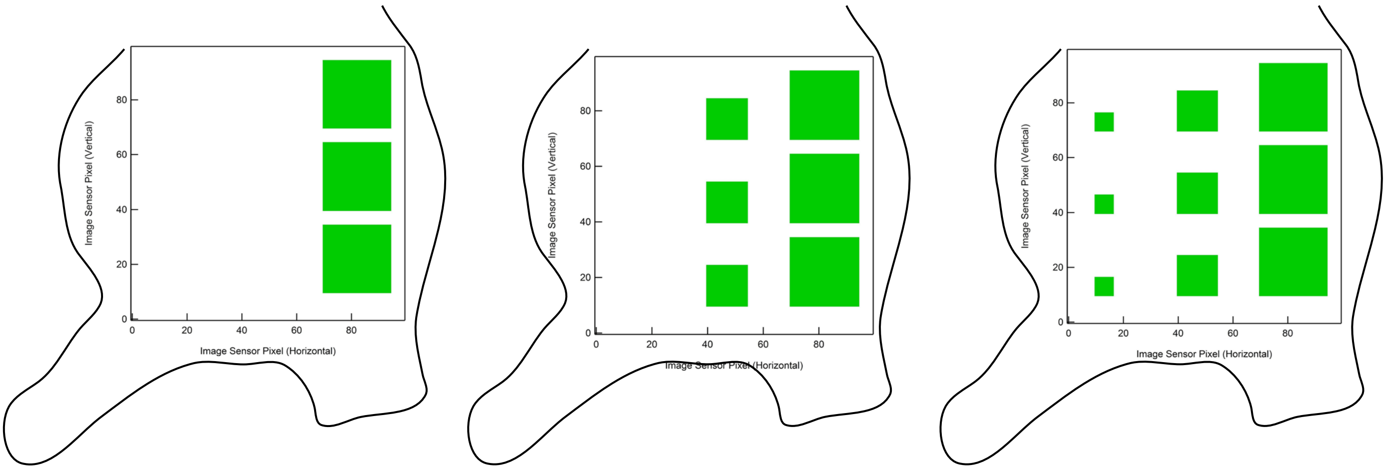


Figure 19: BluMax fluorescence display settings: Low [left], Medium [middle], and High [right].

During Milestone 7, a new detection sensitivity scheme was trialled and implemented to include chlorophyll fluorescence intensity information. The new detection sensitivity scheme is based on the product of chlorophyll fluorescence and its pixel numbers enclosed by the fluorescence area. In addition, gain control was mathematically applied to fluorescence intensity such that the intensity has more weight when multiplied to the number of enclosed pixels. The expected outcome of the new sensitivity scheme is such that small areas of contamination are not missed when a contamination site has concentrated chlorophyll. To achieve this, an additional image processing step was introduced before binarization (the binarization threshold was also modified). The additional image processing produces an output as a product of the gain-controlled chlorophyll intensity and its enclosed pixel number. The new binarization threshold is also predetermined in accordance with the new output values.

The new detection sensitivity scheme is illustrated below [Figure 20]. When the sensitivity is set to level zero, a gain value of zero is applied to the chlorophyll intensity. As a result, both small medium sized detections with weak chlorophyll intensity were ignored (shown in blue) while the rest was displayed (shown in green). At sensitivity level three, a gain value of three is applied to the chlorophyll intensity. This resulted in small sized detections being ignored with small and medium chlorophyll fluorescence intensities while detecting the rest. As mentioned, this is a case in which small but concentrated chlorophyll is considered detected under the new sensitivity scheme, giving the user more selectivity on detection. At sensitivity level seven, only a small sized detection with weak chlorophyll fluorescence intensity was ignored while the rest was displayed as detected. The entire sensitivity level ranges between zero and nine, and is user configurable [Figure 21]. Currently, the unit at the ovine trial site is set to level four.

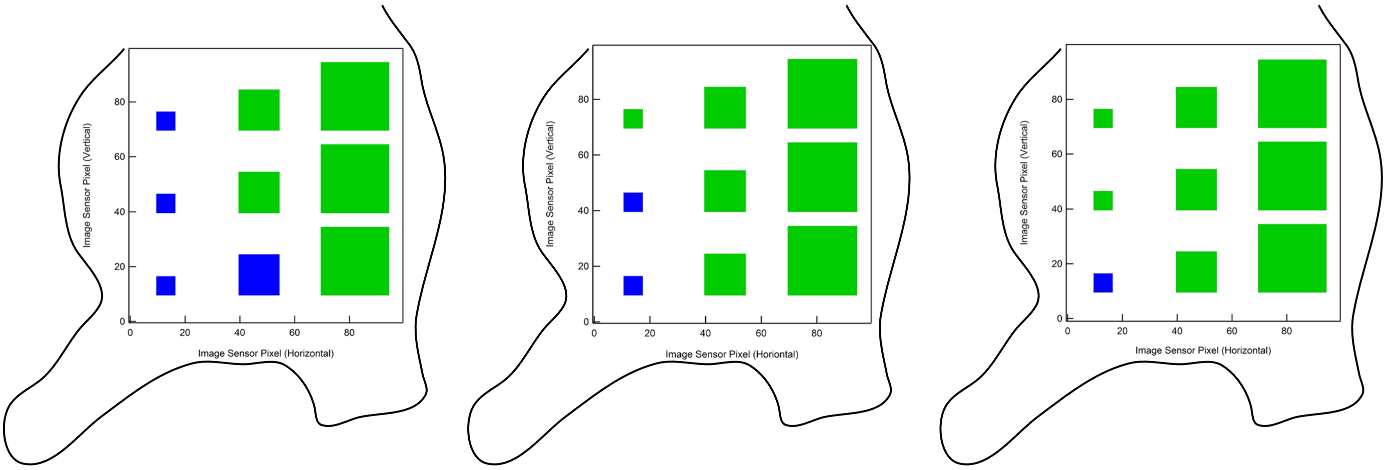


Figure 20: Examples of different detection sensitivity levels. Level Zero [left], Level Three [middle], and Level Seven [right].

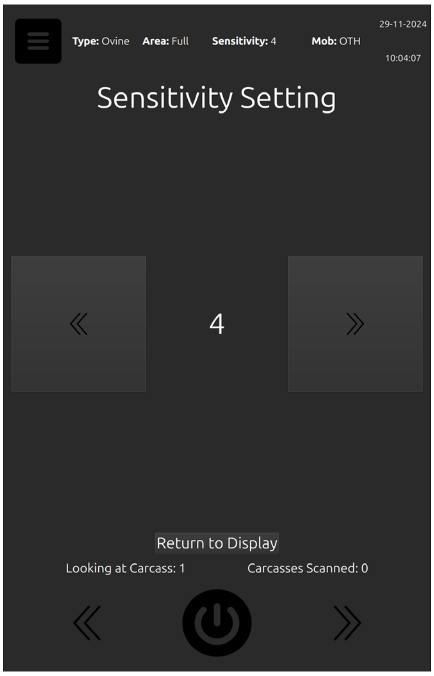


Figure 21: A screenshot taken of the BluMax user interface for sensitivity selection.

It should be noted that BluMax only overlays the green marks on top of raw carcase images as an indication of chlorophyll residue. The blue marks are not shown on the industrial monitor. However, the BluMax system now has a capability of tracking both the green and blue marks. These have been labelled as visible and invisible detections respectively. It is anticipated that this capability will serve future users who wish to track both the visible and invisible detections towards their various intervention programs. Visible and invisible detection is further discussed in the following section.

5.7 Visible / invisible

The summary below illustrates how the BluMax sensitivity was calibrated on site. The calibration was performed at a beef processing plant. Compared to lamb plants, the relatively slower chain speed and larger gaps between carcases made it easier for the Veritide team to fine tune optimal sensitivity by trial and error. However, once the optimal sensitivity was reached, the same software configuration was deployed on the BluMax unit at the ovine trial plant.

- As background, the BluMax software was updated with an improved detection output scheme - combination of pixel area and fluorescence intensity for a given contaminated site such that $detection\ output = pixel\ area\ \times intensity^{gain}$, where the gain is adjustable by changing the ‘scanner sensitivity’ level on the industrial monitor (the operator is able to do this).
- If the detection output for a given contamination site is above a predetermined threshold value, the result is highlighted with a green mark in the 3D model - this indicates a ‘visible’ detection. If the detection output is below the threshold value, the result is highlighted with a blue mark - this indicates an ‘invisible’ detection.
- At the Beef plant, the Veritide team was provided with various samples which had been deemed as visible and borderline visible (i.e. just visible) from the kill floor supervisors [Figure 22].

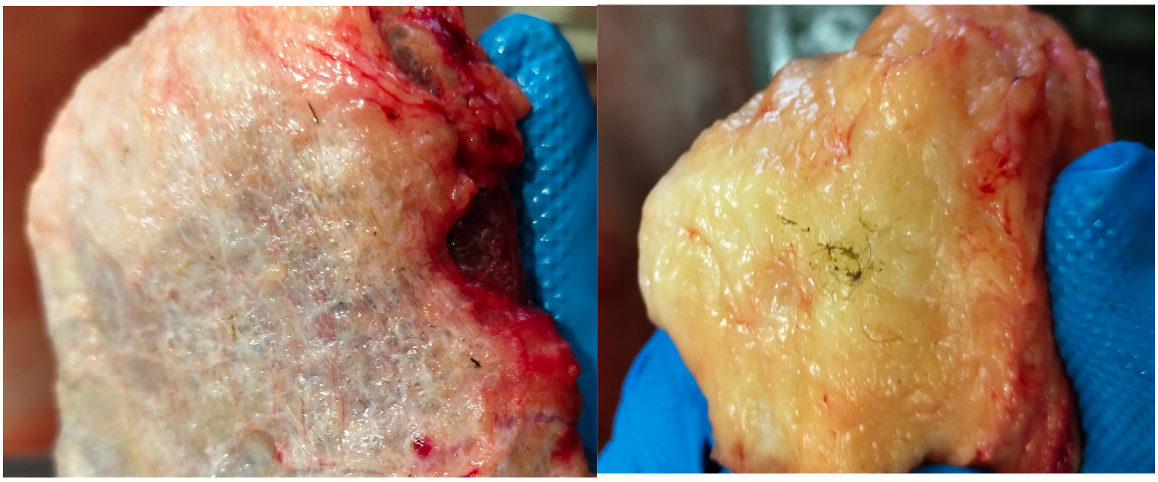


Figure 22: Samples provided, with contamination deemed as borderline visible [left] and visible [right].

- After on-site calibration using the above samples, the kill floor supervisory team confirmed that green marks could be observed on the industrial monitor using a variety of samples [Table 1].
- Although the visible/invisible software was deployed and demonstrated to the supervisors at the ovine site, it was decided that - at this stage - the preference is for all contamination to be displayed and captured. This highlights a discrepancy between how facilities and companies may choose to deploy BluMax. If the ovine trial facility changes how they operate the BluMax scanner over time, this option may become more relevant.

It should be noted that, as each carcase side is scanned, multiple images are used to make up the final image of contamination on the industrial monitor. Due to different light distribution and incident angles for excitation light, some images may record contamination sites as invisible and others as visible. However, the software will compile five snapshots of detection images and record any sites with at least one green mark as ‘visible’.

Table 1: Images of samples with contamination and corresponding BluMax monitor output.

	
Borderline Visible (grain fed faecal residue) and its digital detection on the industrial monitor.	*Visible 1 (grain fed faecal residue) and its digital detection on the industrial monitor.*
	
Visible 2 (grain fed faecal residue) and its digital detection on the industrial monitor.	*Visible 3 (grain fed faecal residue) and its digital detection on the industrial monitor.*

Visible 4 (grain fed faecal residue) and its digital detection on the industrial monitor.

Visible 5 (grain fed faecal residue) and its digital detection on the industrial monitor.

- Upon confirmation of sighting of visible and borderline visible samples as green marks on the monitor, the latest calibration was validated with actual carcases.
- The kill floor supervisory team remained at the BluMax location (Hot Beef Passage) and validated detections whether visible or invisible to the human eye. The results were agreed amongst the Veritide team and the supervisory team (i.e. green detections were mostly visible and blue detections were mostly invisible to both Veritide and the supervisors).
- Each validation was done after BluMax scanning [Figure 23].

Figure 23: BluMax detection as visible [left] and subsequent visual validation [right].

- In addition to a visual inspection, the BluLine Scanner was used when visual validation was infeasible (i.e., when blue marks were displayed). In such cases, the BluLine Scanner was used to locate where the detection was, and a further visual inspection followed to validate whether the detected site was visible or invisible. In general, the actual contamination was either very small or covered in too much blood to be deemed invisible by BluMax, even if the site was located by the BluLine scanner [Figure 24].

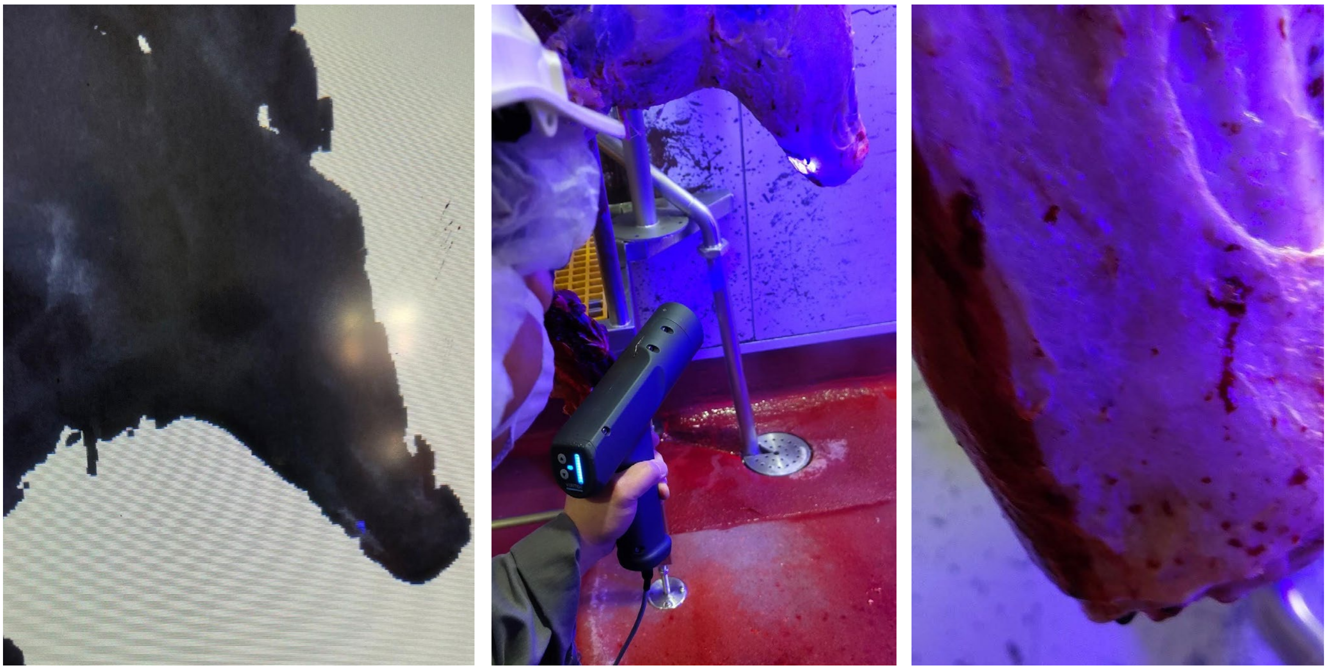


Figure 24: BluMax detection as invisble [left] and BluLine validation [middle]. Visual check [right] was inconclusive.

5.8 Remote access, support and maintenance

Before the BluMax trial began, a remote-access system was developed and integrated into Veritide's service library. This enabled Veritide to establish a reverse-SSH tunnel, providing a secure and lightweight solution for remote access. During the trial, instead of updating software manually, an upgrade system for the service library was developed. This meant that an update could be completed without requiring remote access. It should be noted that any major changes needing additional configuration sections and new library installs still required remote access.

Support was provided and undertaken based on site feedback and Veritide's requirements. An alarm system was built into the logging system to alert Veritide staff members to issues in real time. This enabled faster recovery times and presented great learning opportunities for the team. Veritide could now also view logs from several days' past, allowing situational comparisons to be made to provide even faster solutions.

Over the duration of the trial, no physical maintenance was required. To maintain computer hardware, the CPU temperature limits were set, allowing the system to shut down if overheating. Additional monthly general computer health checks were undertaken. Other general maintenance included covering the BluMax unit at the end of each day [Figure 25]. This was done to prevent water from being sprayed directly onto the unit by cleaners.

Figure 25: BluMax covered at the end of the day.

6.0 Discussion

6.1 Using the BluMax for Process improvement

While we were able to deliver on many of the projects core objectives, as we progressed, we discovered that the trial site was starting to contemplate operational uses for the technology that we hadn't necessarily considered earlier. Of course, with any new and disruptive innovation, the best laid plans/ideas often get recalibrated once the technology gets placed in the hands of the customer; this was certainly the case at this trial facility when the BluMax was deployed on site for a longer term.

We noted that the trial site started to gravitate to the utility of the introductory daily reporting programme. They became very focused on the mob-tracking and carcass heat-mapping data [Figure 2] and infographics as a way of informing themselves about their standard operating procedures (SOPs) and operational improvements that could be extracted from the harvest and evisceration floor vs guiding trimming operations on the trim floor.

For this facility and trial, and potentially for the ovine species generally, we discovered that an intermediate step needs to be considered, whereby the BluMax System could be leveraged to deliver powerful, real-time operational improvements and behavioural change on the harvest and evisceration floor first, prior to deployment on the trim floor. The trim floor use case is still entirely valid, but only after deploying the technology to improve upstream, standard operating procedures first.

Contained within this major learning, the stakeholders in this trial realised that the power of the Veritide BluMax technology was not limited to its ability to illuminate and detect faecal contamination (in real-time, at line speeds); we collaboratively discovered that the underlying data and analytics platform is where substantial residual value and operational utility lies. Commercially, there is a substantial Data-As-A-Service (DaaS) offer that can be delivered to the Ovine processing industry; it's embedded within the BluMax technology now, and can be leveraged for strategic and operational purposes in the future.

Going forward, it is envisaged that the BluMax DaaS offer (or specific sub-components contained within it) will provide powerful operational, quality management, product verification and traceability insights that will cascade value throughout the supply chain. Initially, this will be engineered to the needs of executive and senior level managers and on-site, operational processing personnel. Later on, specific elements of this reporting/analytics programme could be shared with industry auditors, regulatory agencies and downstream supply chain clients.

7.0 Conclusions

This trial has proven the benefit of using Veritide's technology to identify chlorophyll-based contamination - the main source of E. coli and other bacteria present in Ovine primary processing facilities - in real time. Given the number of results which had not been predicted at the project outset, but which have been identified using the BluMax scanner, this could suggest that additional benefits are yet to be discovered. It is difficult to predict what further benefits could result over time, since no precedent has been set for how this new and groundbreaking technology could be used.

Augmented reality technology has not yet matured such that it can be integrated as a precision trimming tool. However, the trial has proven AR-assisted trimming to be a feasible concept which may warrant further investigation in the future.

The quality of the BluMax scanner continues to improve, as does the confidence in the results. Cross checking identified contamination with BluLine handheld scanners demonstrates the high accuracy of both devices. The work completed to improve sensitivity and visible contamination detection is a clear indication of the system's robustness.

The use of data generated by the BluMax scanner continues to be a growing area of interest. How this data is displayed to both management and operational staff has evolved significantly over the course of this project. More work is still required to enable full integration across multiple facilities, and for people to be able to customise the data they see. Additionally, quality alerts could be sent to supervisors on the detection of significant shifts in contamination rates.

With the experience and knowledge gained in the trial, the ovine trial facility has identified the location and methodology which will produce tangible benefits for them. At the start of the trial, this location was not something that AMPC or Veritide had considered. This highlights the potential benefits of industry trials of new technologies - such as those offered by Veritide and AMPC - for the purpose of enhancing the operational performance and international competitiveness of the Australian ovine processing sector.

8.0 Recommendations

Three areas of work that support wider industry benefit have been identified and described below.

Recommended Research Area 1: Integration of BluMax into an ovine slaughter floor for process improvement

Rather than focusing on contamination removal, this approach aims to minimise the amount of contamination from the slaughter floor - before trimming - in real time. This could be done by feeding data back to slaughter floor workers. How this data is displayed and monitored is crucial to keeping workers engaged and focussed on best practices.

A 2025 project that delivers this commercial outcome within an Australian ovine processing facility is currently being scoped with the collaborative support of AMPC and a primary processor.

Recommended Research Area 2: Identification of other zero tolerance contaminations

Faecal matter is normally the largest of the zero tolerance contaminations found on ovine carcases. To detect other contaminants, various spectroscopic techniques could be used in combination with a hyperspectral camera. This would enable a wider range of precision trimming and removal of the other contaminations.

Recommended Research Area 3: Develop Veritide automated inspection and automated carcase cleaning

Removing contamination from carcases is a laborious process, even after Veritide technologies identify which areas require trimming. The Veritide system generates x/y/z coordinates for each carcase scanned, and therefore the exact locations within the three-dimensional space that require cleaning. The project proposes to investigate how this three-dimensional data could be used to drive some form of automation that removes contaminants.

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10.0 Appendices

10.1 Appendix A – The original daily report from ovine trial facility

10.2 Appendix B – The latest daily report from ovine trial facility