

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

Bovine carcase Inspection/Contamination
Management

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1.0 Abstract

This project trialled Veritide's BluMax Scanner in a bovine processing facility to detect chlorophyll-based faecal contamination and ingesta (strongly correlated with increased pathogenic activity), in real time; aiming to improve food safety, reduce waste and enhance operational efficiency.

While initial goals focused on guiding trimming, the most valuable outcome was the system's potential to drive upstream process improvements and provide rich data for quality control and traceability.

The harnessing of the BluMax technology requires the industry to consider the implications of increased rigour in potential E. coli contamination identification, intervention and change in processes for validating the extension of shelf life via improved hygiene standards. The project revealed broader commercial opportunities, including a Data-as-a-Service (DaaS) model and future applications in automation and broader contaminant detection.

2.0 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).

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 carcass (Reid et al. 2002; Nightingale et al. 2004; Bell 1997). A primary focus of meat processing is the clean and hygienic dressing of carcasses to present them acceptable and safe for human consumption. Sanitation processes, hygienic practices, and application of food safety interventions - such as visual inspection and carcass trimming to remove identified contaminants - 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, carcasses 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 a bovine carcass.



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 this 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 carcasses 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.

One of the core elements that the trial site started to focus on was the “sensitivity” of the BluMax Scanning System. The theory proposed on site, but untested prior to this operational deployment, was that the BluMax technology could be modulated to differentiate between “clearly visible, near visible or invisible” faecal contamination or ingesta.

With this directive from the trial site, and with the support of AMPC, the Veritide technical team explored ways in which we could manipulate the “sensitivity settings” of the BluMax Scanner. The processor determined that being able to separate out and display “clearly visible and near visible” contamination detections only, would assist them to better manage and/or mitigate any risks associated with positive BluMax contamination detections.

- The beef plant provided Veritide with various samples which had been deemed as clearly visible and borderline visible (i.e. near visible) from the kill floor supervisors [Figure 2].

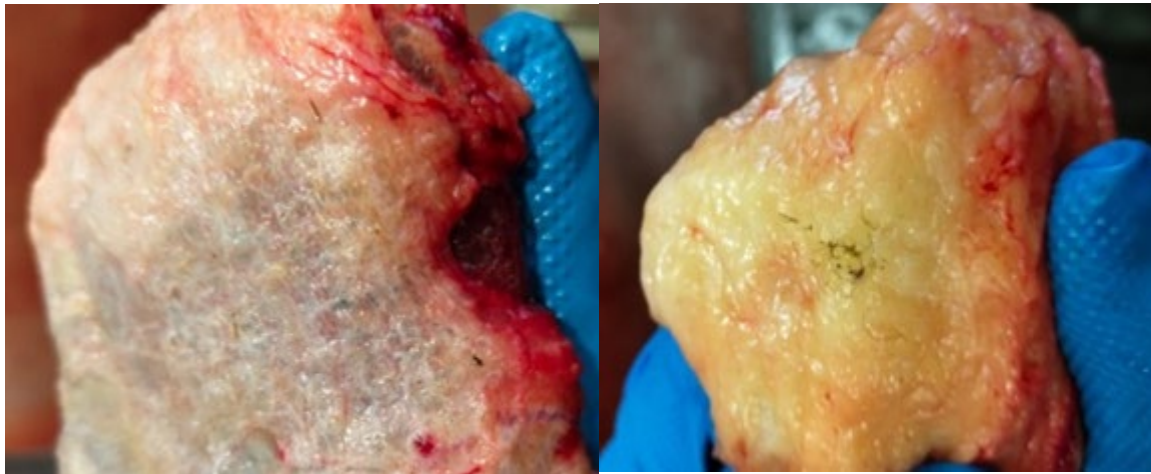
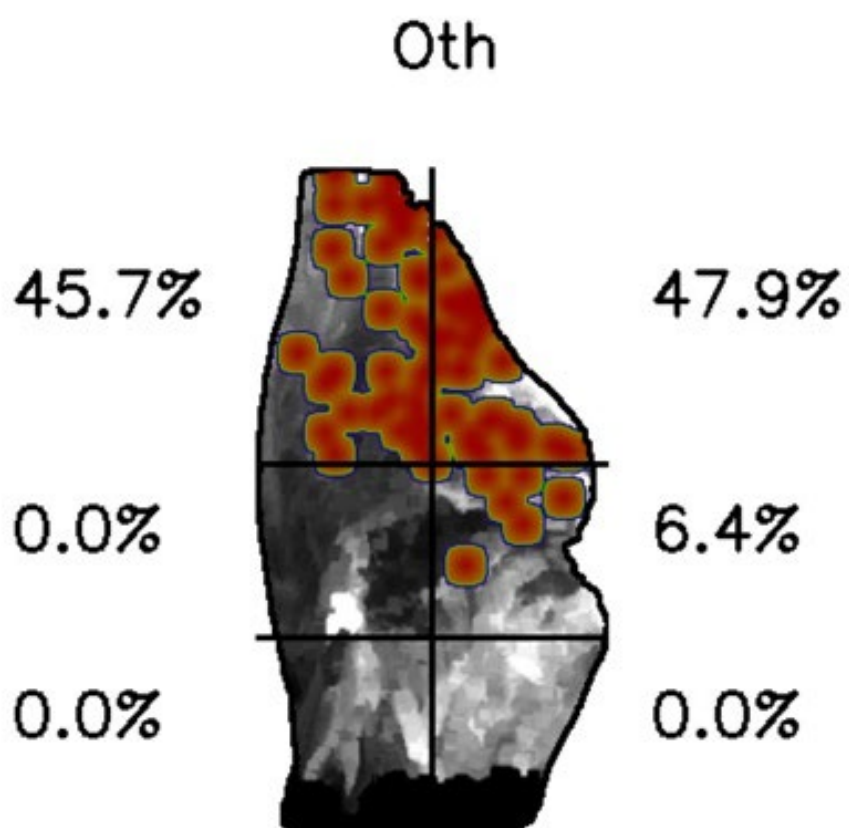
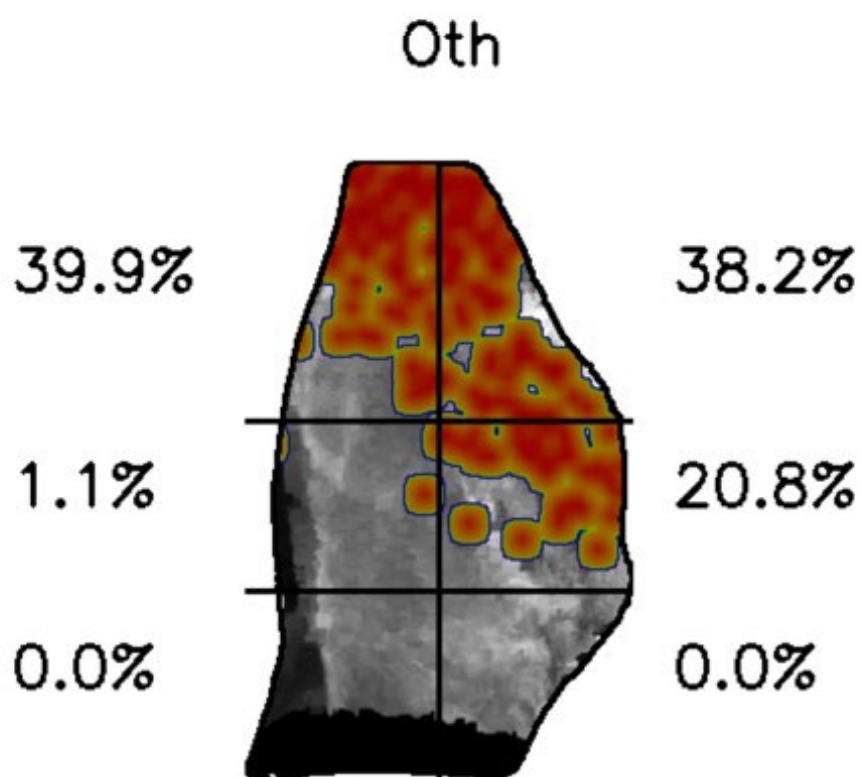


Figure 2: Samples provided, with contamination deemed as borderline visible [left] and visible [right].

- After substantial on-site calibration using multiple reference samples, the kill floor supervisory team confirmed that positive detections displayed on the BluMax Industrial Monitor were able to be classified as visible or near visible. Further to this, we were able to isolate out the positive BluMax detections that were invisible to the human eye and prevent these from being displayed to the operating team on site.
- Without doubt, more works need to be done to assess the validity of this technique with regard to the risk profile of positive BluMax detections across these various thresholds. For example, a thorough assessment of the microbiological and pathogenic profile of visible, near visible and invisible contamination detections should be completed before determining if this is a commercially sensible and scientifically sound way forward.
- Due to onsite operational requirements and resource limitations at the trial facility, some other core elements of the trial programme were set aside for future investigations. These included deploying the technology to guide trimming operations, analysing daily reports for trends and operational insights, and assessing the microbial and pathogenic activity across selected BluMax detection thresholds.
- Ultimately, the stakeholders in this trial realised that the power and value of the Veritide BluMax technology was not only 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 Bovine 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, specific elements of this reporting/analytics programme could be shared with industry auditors, regulatory agencies and downstream supply chain clients.

- Carcass Hygiene Heat Map Developments for future deployment and trial (examples below):



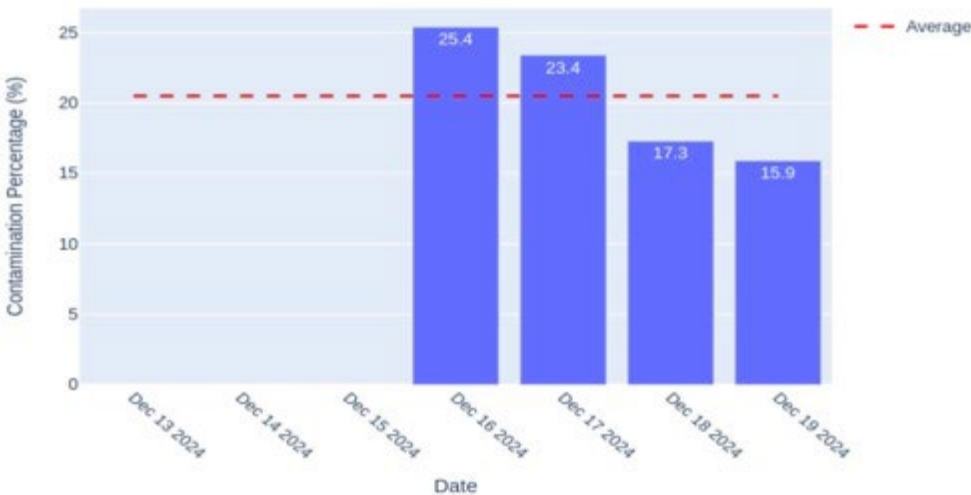
BluMax Report



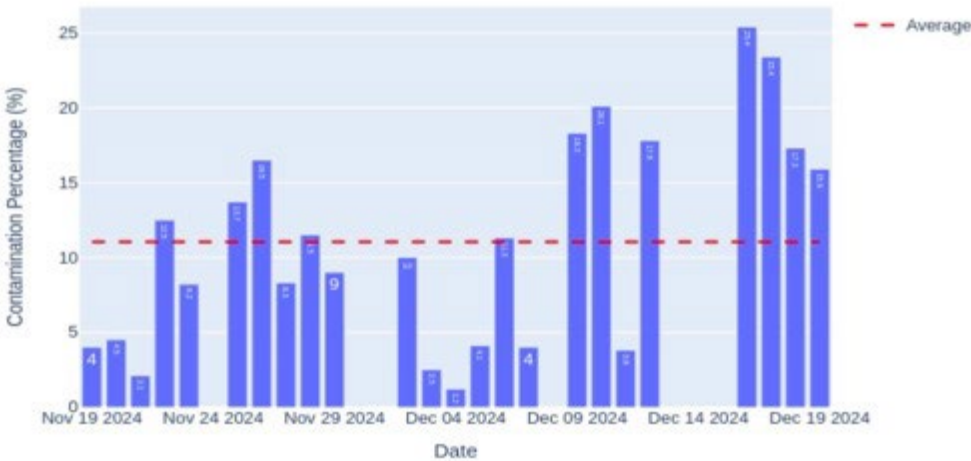
---- BluMax Scanner Report ----

Reporting From Time	2024-12-19 00:00:00 +1100
Reporting to Time	2024-12-19 23:59:59 +1100
Total Number of Sides Scanned	958
Number of Sides Detected	152
Detected Side Percentage	15.9%
Average Detections Per Detected Side	1.151
Average BluMax Sensitivity Setting	4.0

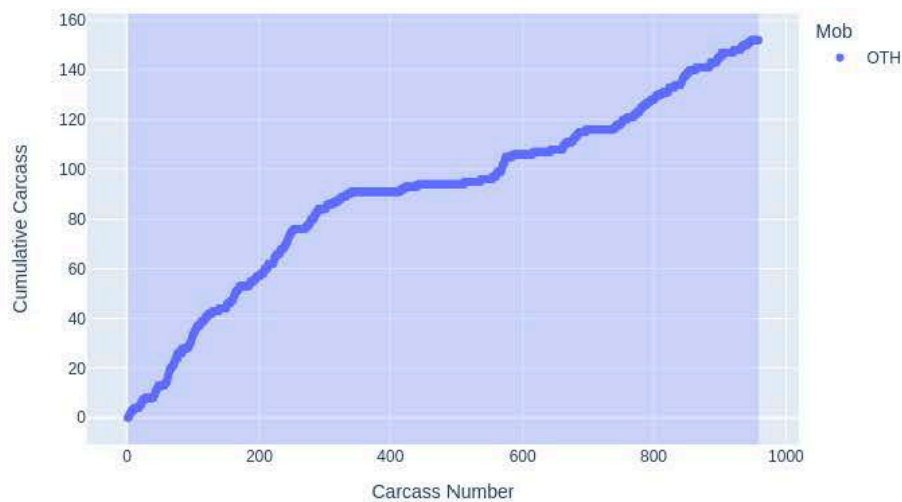
Contamination Percentage (Last 7 Days)



Contamination Percentage (Last 31 Days)



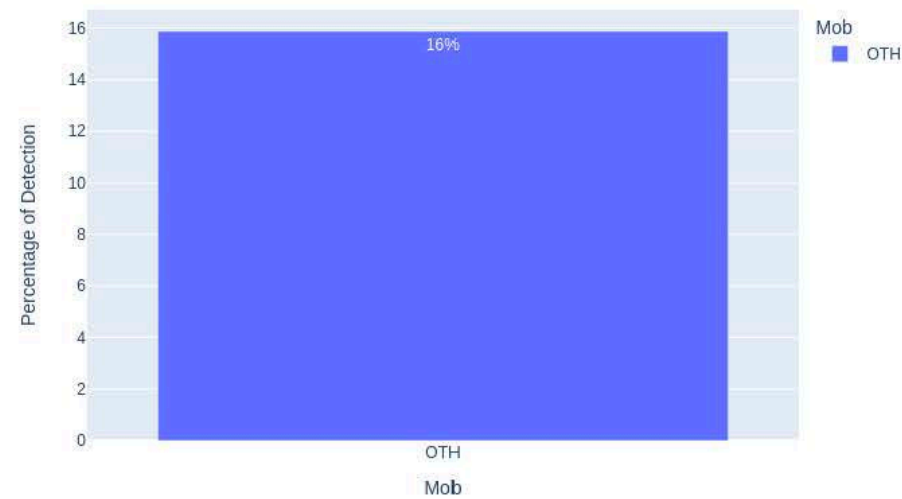
Cumulative Count of Detected Sides

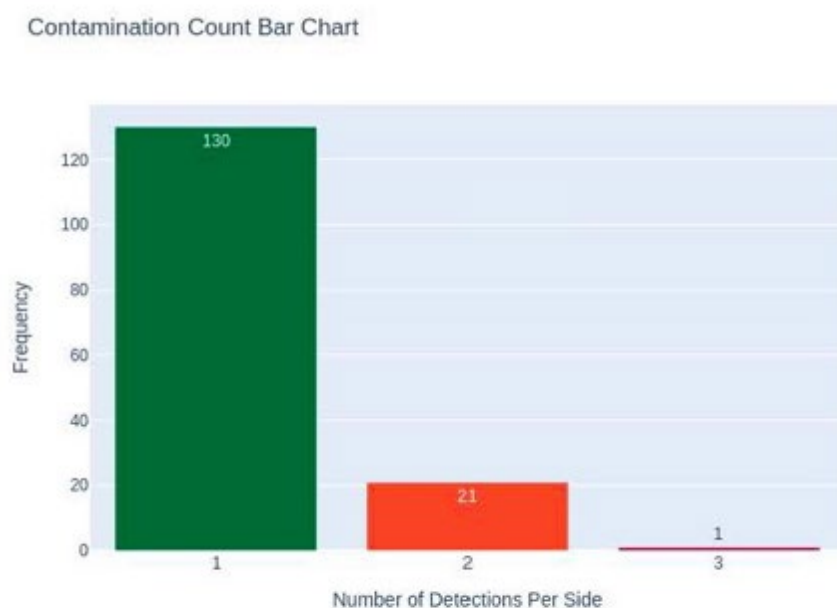


Cumulative Count of Detections on Sides



Percentage of Detections by Mob





In conclusion, Veritide, AMPC and the Bovine processor are enthusiastic about collaborating and continuing to explore the various 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.

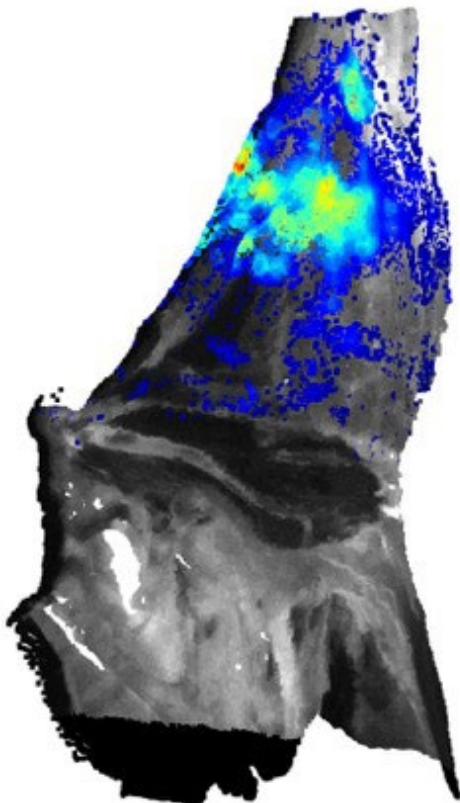
The harnessing of the BluMax technology requires the industry to consider the implications of increased rigour in potential E. coli contamination identification, intervention, and changes in policies and processes for validating the extension of shelf life via improved hygiene standards. It is recommended 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 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 Bovine processing sector.

Recommended Research Area 1: Integration of the BluMax on to the bovine trim floor for real time process improvement assessments across harvest floor operations

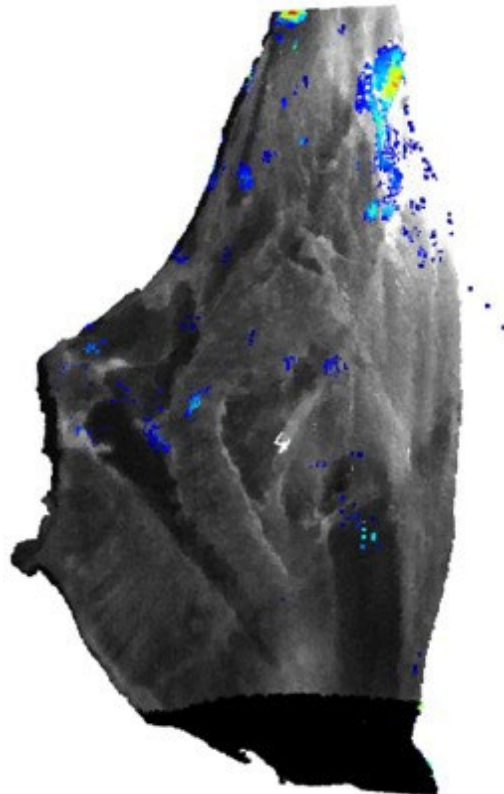
Rather than assessing the contamination status of carcasses just prior to chiller entry, this revised approach would aim to integrate the BluMax technology more actively into operations across the harvest floor (from hide removal and evisceration right through to trimming and CCP assessments).

This could be done by direct trimmer guidance (using the industrial monitor for immediate and individual carcass x carcass contamination removal).

Alternatively, at a more consolidated "trend-analysis" level, real-time data could be fed back to floor supervisors, operations personnel or QA teams (through a digital platform or industrial monitor interface) that informs them of the hygiene status of carcasses scanned over specified/longer periods of time. For example, illustrating a "carcass hygiene heat map" that shows the contamination trend over the last 10, 20, 50 or 500 carcasses scanned.



500 Carcass Scan Heat Map



100 Carcass Scan Heat Map

The examples above of trend-analysis/carcass hygiene heat maps could provide powerful operational insights for the hide removal team, evisceration personnel, trimmers, floor supervisors, QA and management with regard to the efficacy of SOPs, individual staff behaviours, training opportunities, etc.

A 2025 project that delivers this commercial outcome within an Australian bovine 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 bovine carcasses. 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 carcass cleaning

Removing contamination from carcasses is a laborious process, even after Veritide technologies identify which areas require trimming. The Veritide system generates x/y/z coordinates for each carcass 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.

3.0 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, carcasses 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 bovine processing environment.

4.0 Project Objectives

This project will allow the bovine 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 bovine 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 carcasses 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).

4.1 Primary Goals

To further develop and refine the BluMax Scanning technology for bovine 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.

5.0 Methodology

The project moved through seven distinct phases:

- **Design:** In consultation with AMPC and the bovine 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 carcasses for inspection/testing.
- **Build:** External components/housings were built, electronic PCB's assembled and integrated with the internal assemblies/camera scanning system [Figure 3].



Figure 3: 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 bovine 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 beef carcasses were used in the Veritide workshop to complete the testing.
- **Installation:** Packed in a shipping crate [Figure 4], the unit was air freighted to the Bovine 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 4: 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 carcasses 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 to assess performance and modify the sensitivity settings as requested by the trial site.

6.0 Results

6.1 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 carcass

The previous BluMax was designed for scanning a carcass, 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” carcass 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 carcass gets closer to the edge of the scanner’s field-of-view, the scanner can see more of one side than the other [Figure 5]. 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 carcass 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 6]. This solved the problem of edge contamination being found but not appearing in the Industrial Monitor.

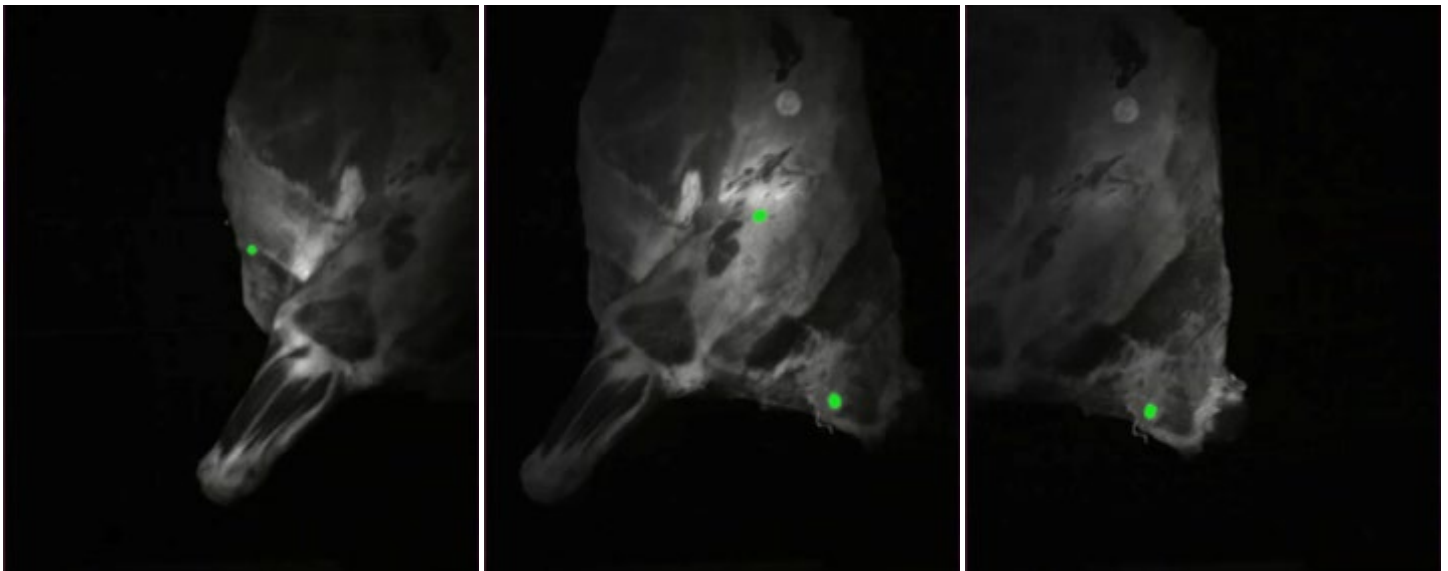


Figure 5: Example of parallax error. Contamination detected as carcass approaches centre of BluMax FOV [left]; whole carcass centred on BluMax, missing initial contamination detection [middle]; view of carcass leaving BluMax FOV [right].

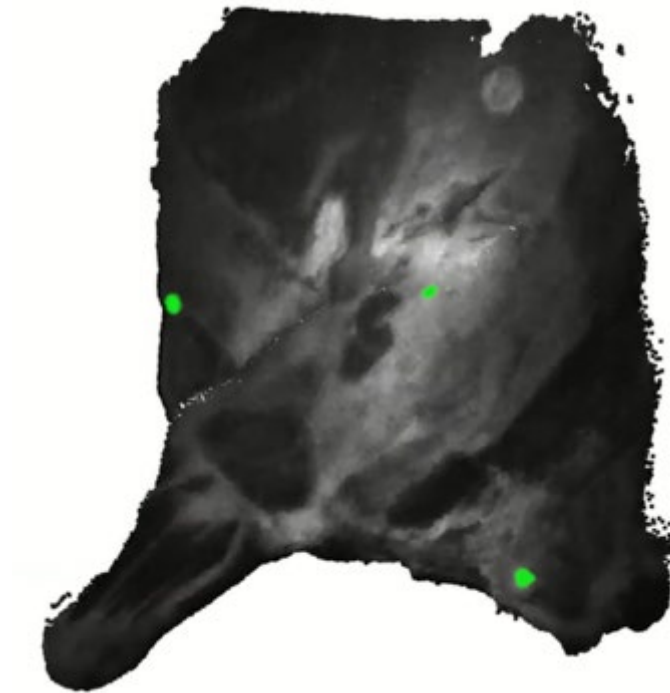


Figure 6: The final 3D representation. A point cloud generated by combining information across multiple images.

Additional BluMax Features

- To assist trimmers, the final 3D image is displayed on the industrial monitor (Figure 6) 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; due to site operational requirements and some previously identified limitations of augmented reality, this particular display mechanism was not demonstrated at the bovine trial site.
- The BluMax Scanner is now taking and processing approximately 150 images per second.

6.2 Precision Trimming

Post-BluMax scanning, images of the (clean or contaminated) carcasses are clearly displayed on the industrial monitor in real time. The initial intention of this project was to place a trimmer at the location of the Industrial Monitor and use the carcass images to guide trimming actions for decontamination purposes. Due to plant operational requirements and resource limitations within this facility throughout the trial period, the precision trimming objectives were unable to be fully tested.

6.3 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 glasses capable of having images projected onto it (e.g., Google Glass); whereby 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 carcass 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.

Carcasses are scanned across the field-of-view of the BluMax unit, each individual scan then being combined into a single carcass model. This data is initially represented in a point cloud format [Figure 7], 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.

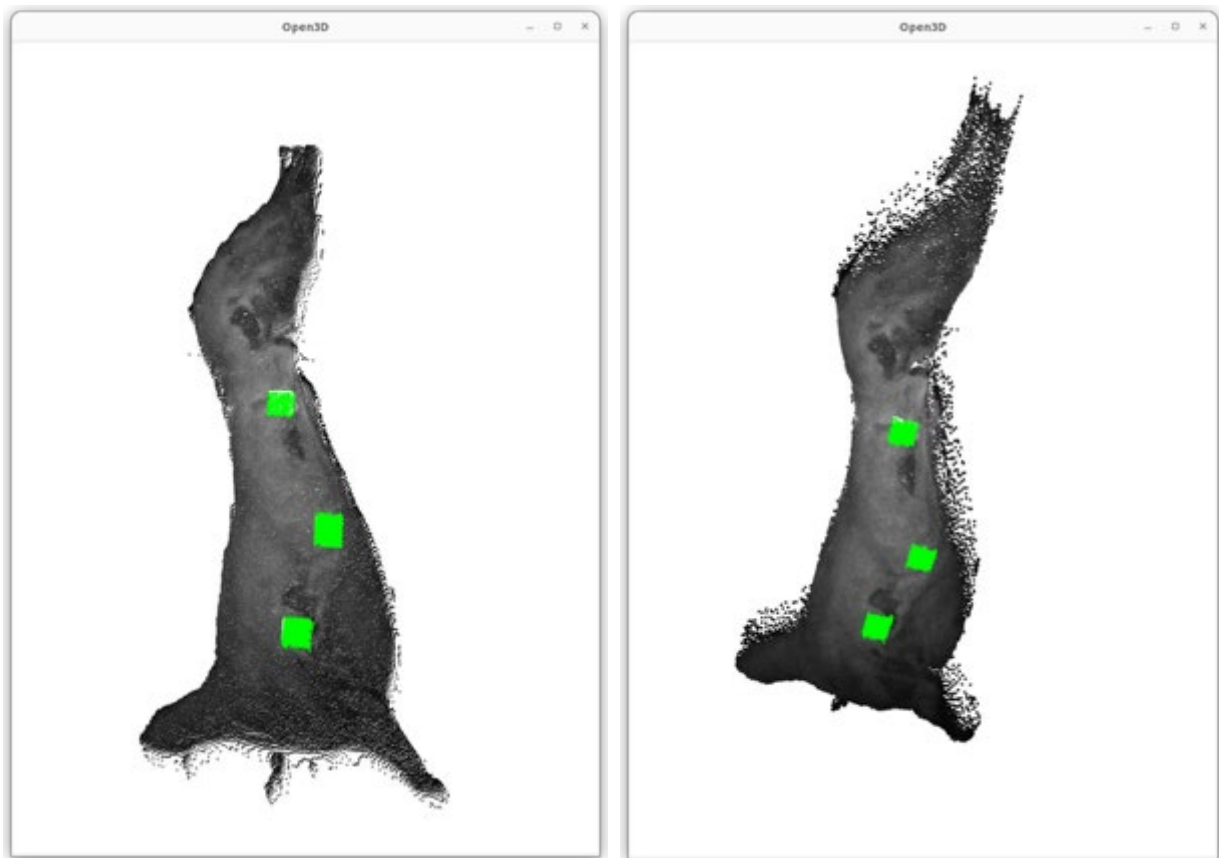


Figure7: Example of a single point cloud generated from a carcass scan. Both images are of the same carcass, scanned from two angles.

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 carcass-offset conversion values via hand-gesture controlled UI.

This proof-of-concept solution was tested and demonstrated within an ovine trial facility. However, for operational and health and safety reasons, the stakeholders concluded that AR testing would not be demonstrated within this particular bovine trial facility and site location.

6.4 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.

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. Once the system was able to identify visible or invisible contamination this needed to be incorporated into the reporting. Although not implemented at the bovine 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

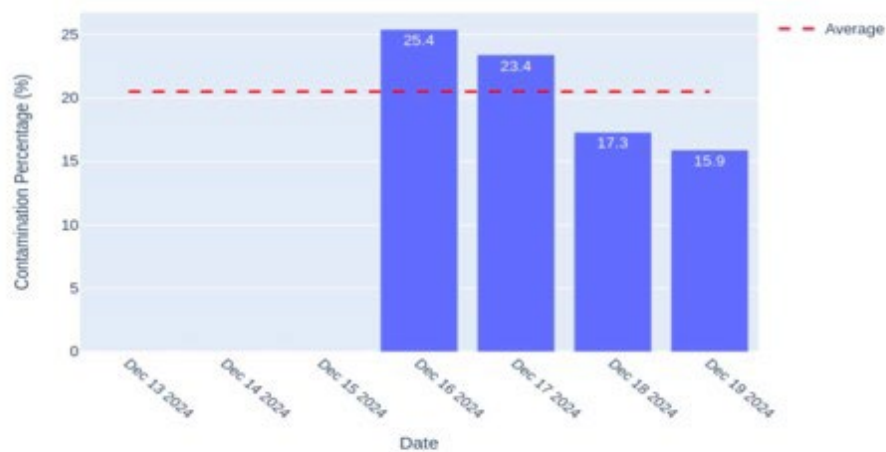
VERITIDE

BIOLOGICAL DETECTION
AND IDENTIFICATION

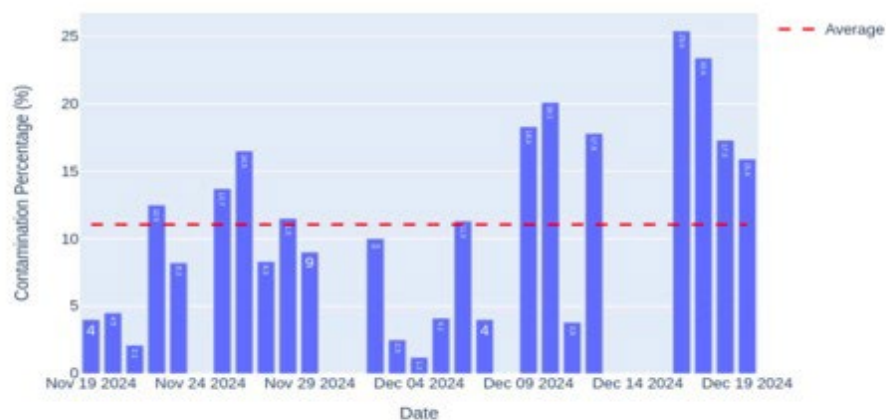
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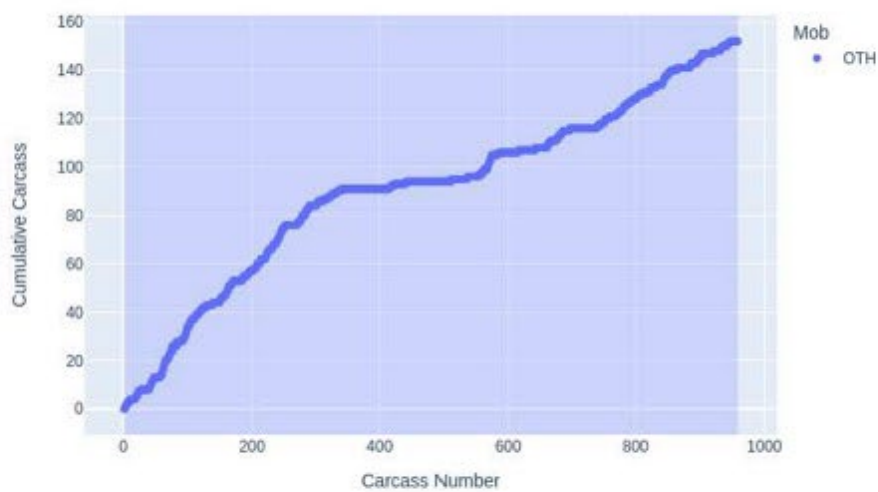
Contamination Percentage (Last 7 Days)



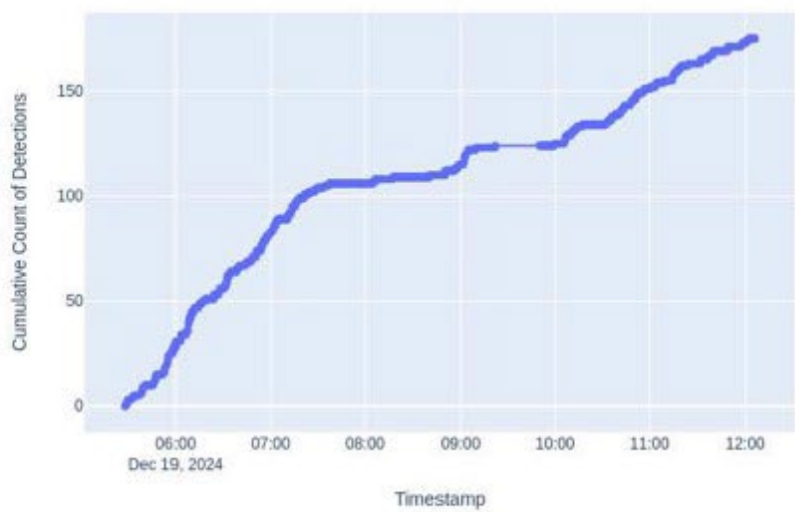
Contamination Percentage (Last 31 Days)



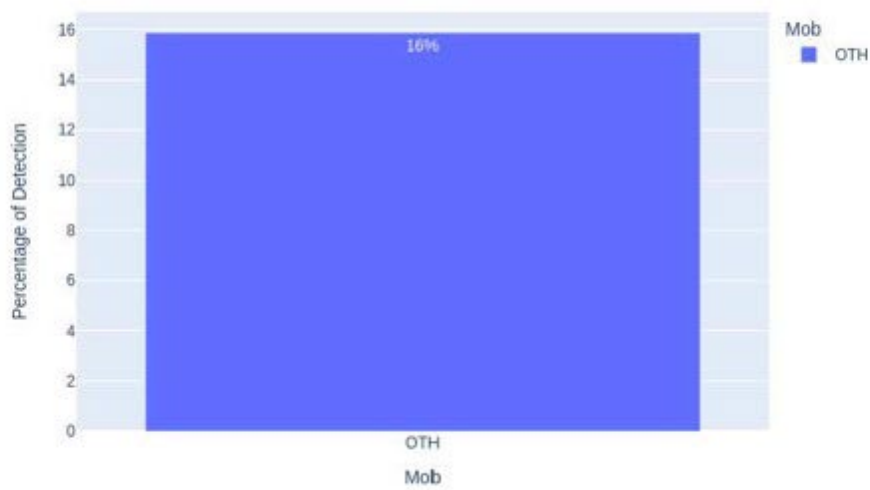
Cumulative Count of Detected Sides

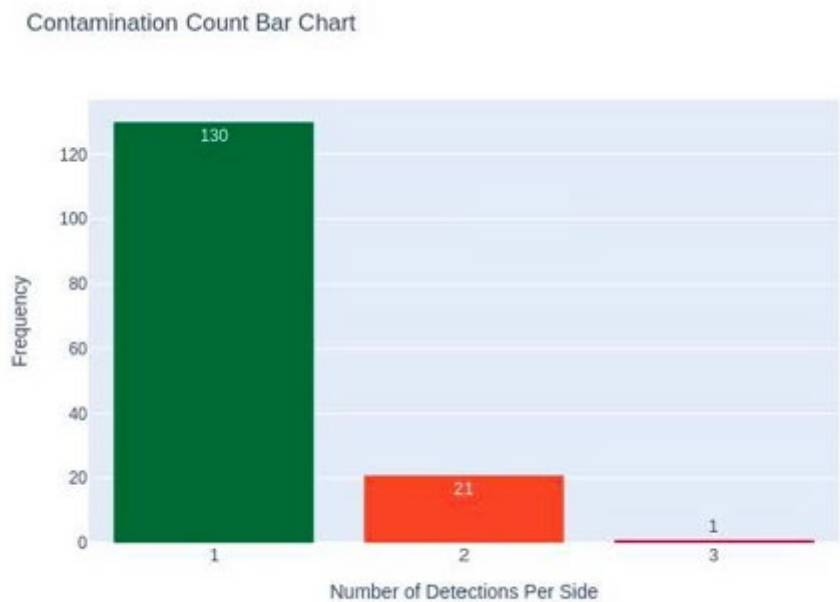


Cumulative Count of Detections on Sides



Percentage of Detections by Mob





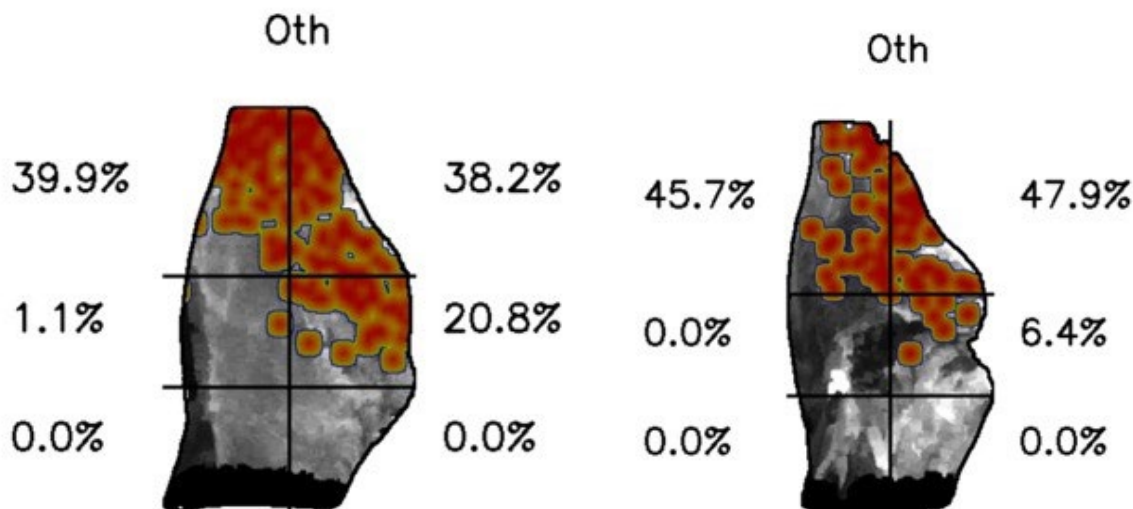
Example of BluMax Daily Report Metrics

6.5 Carcass Hygiene Heat Map Development

During the initial visit to the bovine 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 carcass template for data visualisation. See the images below illustrating the status of the heat maps at the conclusion of this project.

Currently, the heatmap is also automatically issued as part of the daily reporting.



6.6 Sensitivity

When the BluMax unit was installed at the bovine 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 positive contamination detections on the industrial monitor or not.

For the initial sensitivity scheme, detected chlorophyll fluorescence output signals were first converted to a binary image. Figure 8 and Figure 9 illustrate such a binarization. Various chlorophyll intensity emitting at various sizes on a carcass is shown in Figure 8 and its binary conversion (in green) is shown in Figure 9. Following the binarization a predetermined size, filtering was then applied to select relevant fluorescence sizes to indicate faecal detection for the BluMax operators.

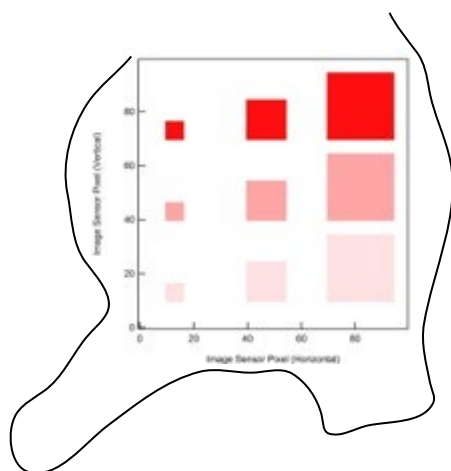


Figure 8: Illustration of chlorophyll fluorescence emitting at different intensities [red = strong, pale pink = weak] at various contamination sizes.

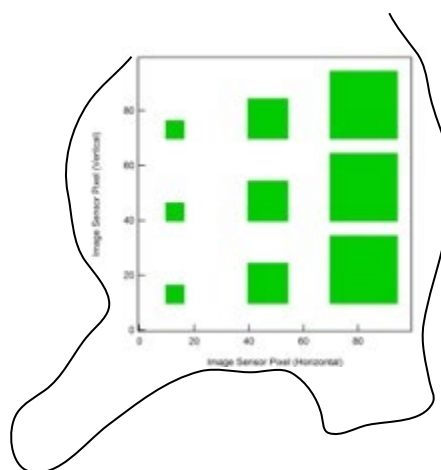
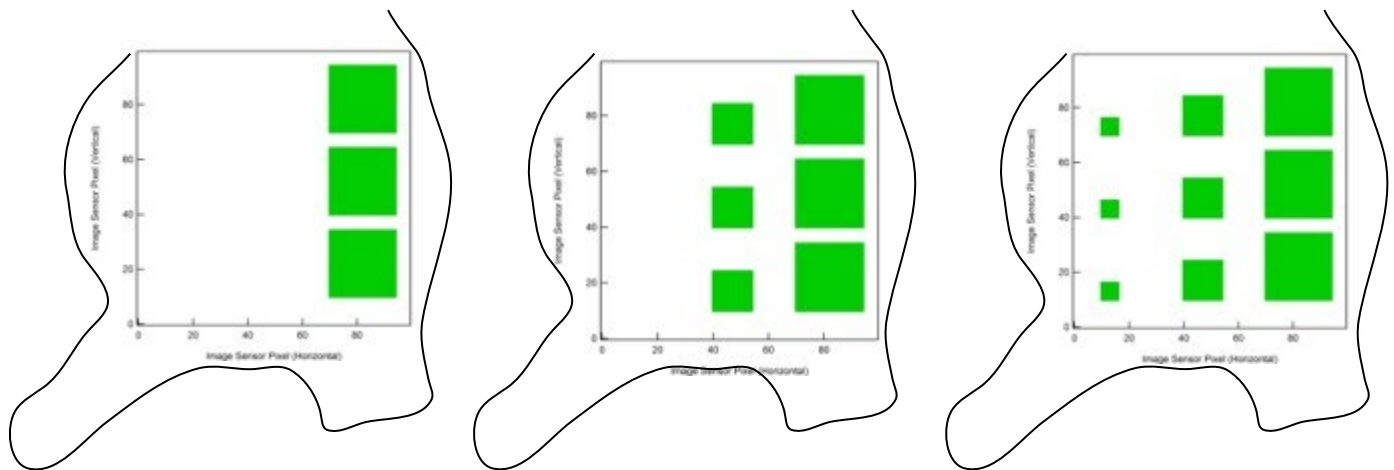


Figure 9: Illustration of a binary image of chlorophyll emission at various sizes on a carcass.

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 10, 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 carcass images.



**Figure 7: BluMax fluorescence display settings:
Low [left], Medium [middle], and High [right].**

During Milestone 7, a new detection sensitivity scheme was trialed 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 11]. 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 12]. Currently, the unit at the bovine trial site is set to level four.

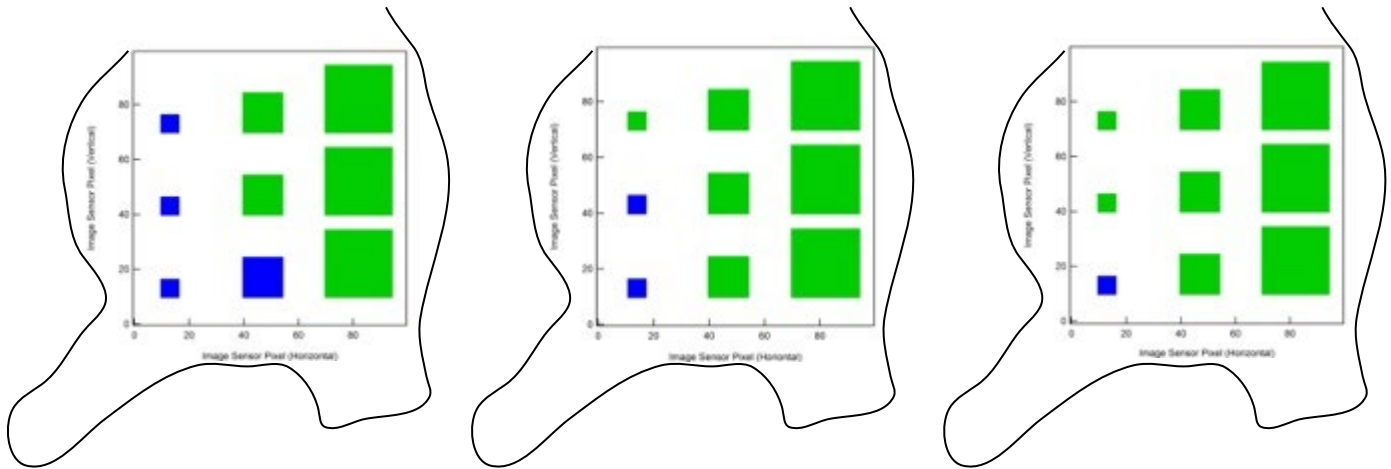


Figure 8: Examples of different detection sensitivity levels. Level Zero [left], Level Three [middle], and Level Seven [right].

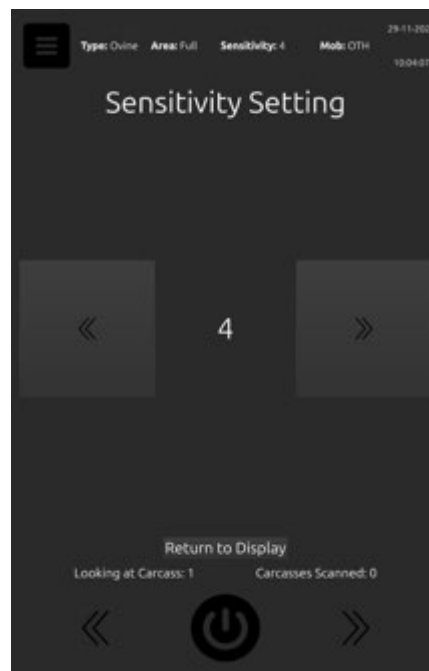


Figure 9: A screenshot taken of the BluMax user interface for sensitivity selection.

It should be noted that BluMax only overlays the green marks on top of raw carcass 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.

6.7 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 carcasses 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 bovine 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 13].

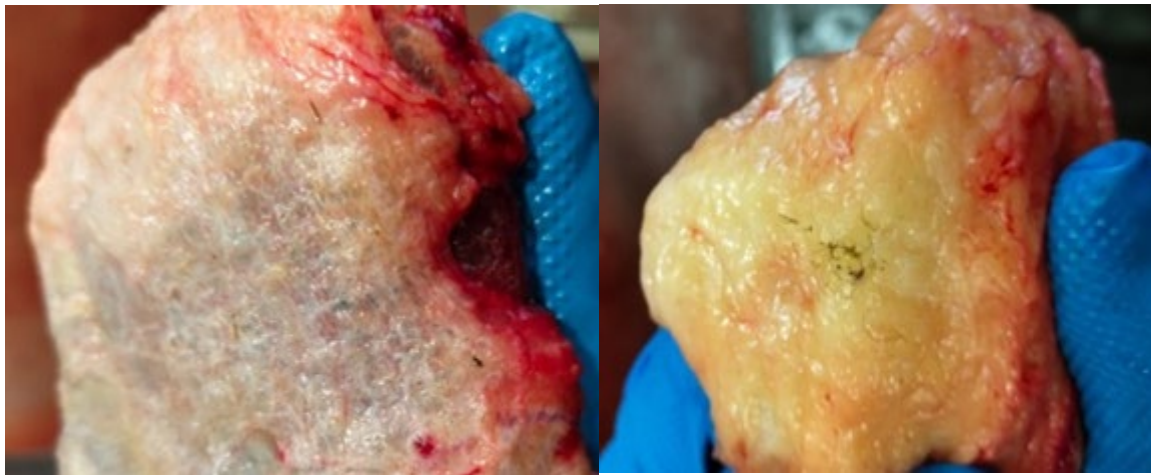




Figure 10: Samples provided, with contamination deemed as borderline visible [left] and visible [right].

- 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 bovine 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 bovine trial facility changes how they operate the BluMax scanner over time, this option may become more relevant.

It should be noted that, as each carcass 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.

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



- Upon confirmation of sighting of visible and borderline visible samples as green marks on the monitor, the latest calibration was validated with actual carcasses.
- 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 14].



Figure 11: 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 15].

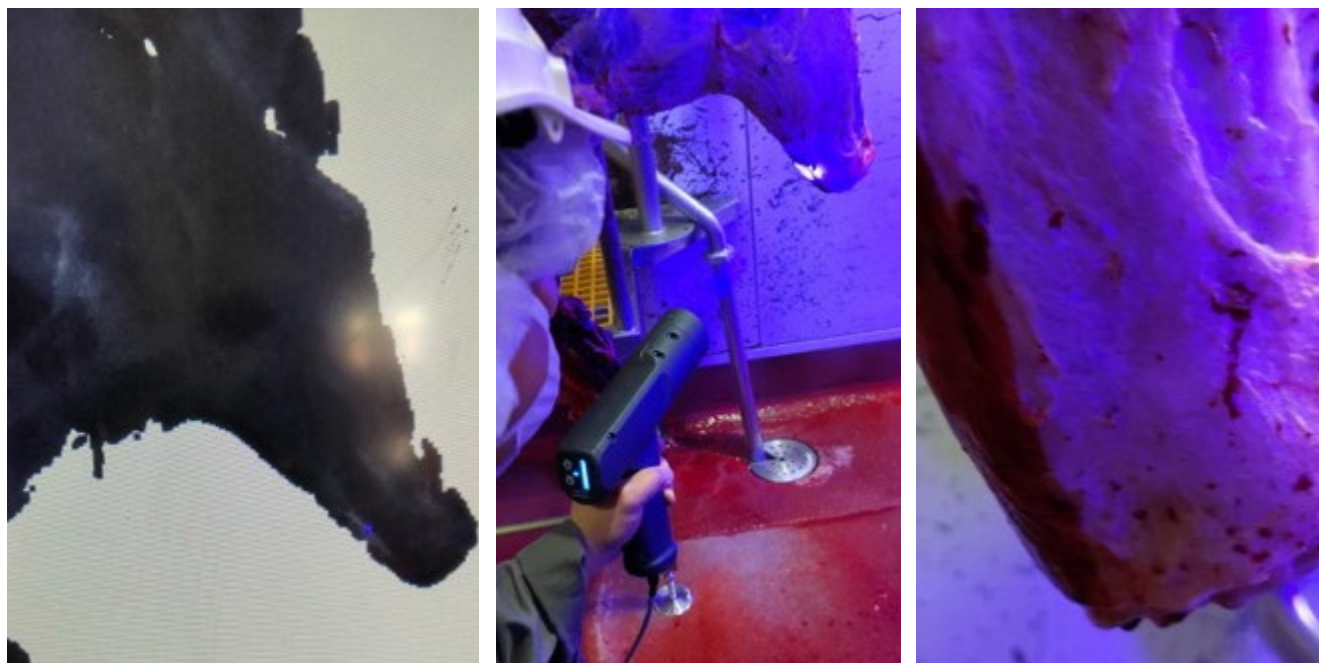


Figure 12: BluMax detection as invisible [left] and BluLine validation [middle]. Visual check [right] was inconclusive.

6.8 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 16]. This was done to prevent water from being sprayed directly onto the unit by cleaners.



Figure 13: BluMax covered at the end of the day.

7.0 Discussion

7.1 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.

One of the core elements that the trial site started to focus on was the "sensitivity" of the BluMax Scanning System. The theory proposed on site, but untested prior to this operational deployment, was that the BluMax technology could be modulated to differentiate between "clearly visible, near visible or invisible" faecal contamination or ingesta.

With this directive from the trial site, and with the support of AMPC, the Veritide technical team explored ways in which we could manipulate the "sensitivity settings" of the BluMax Scanner. The processor determined that being able to separate out and display "clearly visible and near visible" contamination detections only, would assist them to better manage and/or mitigate any risks associated with positive BluMax contamination detections.

Contained within this major learning, the stakeholders in this trial also 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 Bovine 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.

8.0 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 Bovine 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 bovine 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 bovine processing sector.

9.0 Recommendations

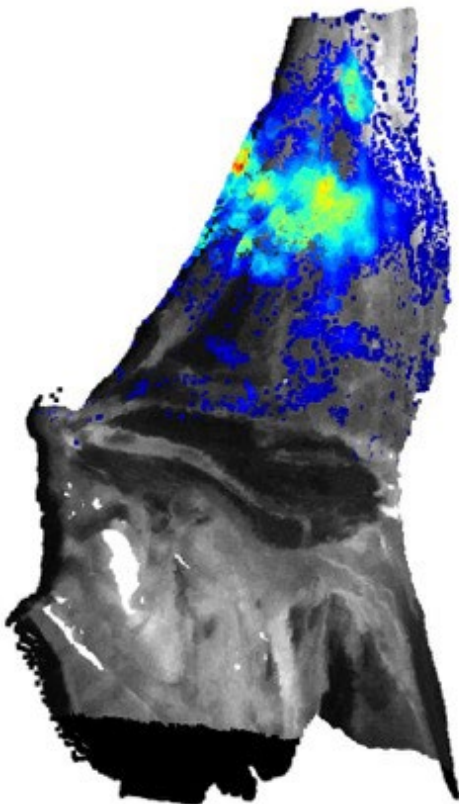
Three areas of work that support wider industry benefit have been identified and described below.

Recommended Research Area 1: Integration of the BluMax on to the bovine trim floor for real time process improvement assessments across all harvest floor operations

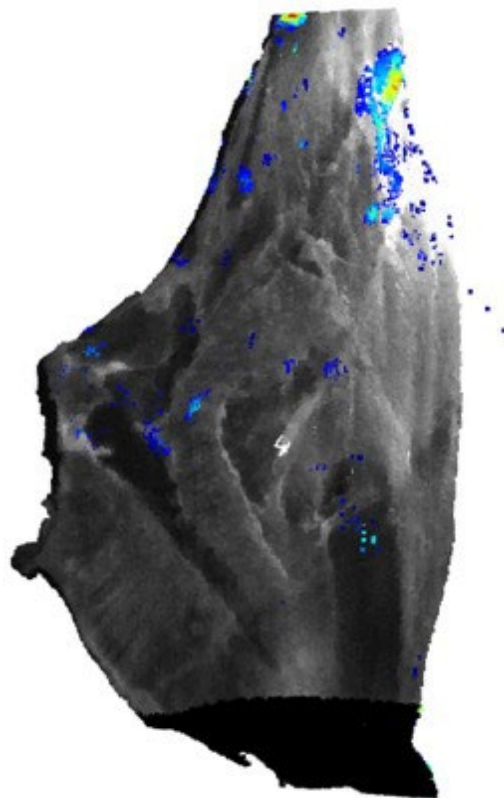
Rather than assessing the contamination status of carcasses just prior to chiller entry, this revised approach would aim to integrate the BluMax technology more actively into operations across the harvest floor (from hide removal and evisceration right through to trimming and CCP assessments).

This could be done by direct trimmer guidance (using the industrial monitor for immediate and individual carcass x carcass contamination removal).

Alternatively, at a more consolidated “trend-analysis” level, real-time data could be fed back to floor supervisors, operations personnel or QA teams (through a digital platform or industrial monitor interface) that informs them of the hygiene status of carcasses scanned over specified/longer periods of time. For example, illustrating a “carcass hygiene heat map” that shows the contamination trend over the last 10, 20, 50 or 500 carcasses scanned.



500 Carcass Scan Heat Map



100 Carcass Scan Heat Map

The examples above of trend-analysis/carcass hygiene heat maps could provide powerful operational insights for the hide removal team, evisceration personnel, trimmers, floor supervisors, QA and management with regard to the efficacy of SOPs, individual staff behaviours, training opportunities, etc.

A 2025 project that delivers this commercial outcome within an Australian bovine 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 bovine carcasses. 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 carcass cleaning

Removing contamination from carcasses is a laborious process, even after Veritide technologies identify which areas require trimming. The Veritide system generates x/y/z coordinates for each carcass 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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11.0 Appendices