Final Report

AMPC
AUSTRALIAN MEAT PROCESSOR CORPORATION

Robot Implementation on the Casino Food Coop site

AGVs (with articulated legs) - Stage 2 & 3 Services

Project Code
2021-1271

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1.0 Executive Summary

To find ways to improve the health and safety of workers, AMPC has engaged DroneDeploy (formerly Rocos) to assist them in undertaking a Proof-of-Concept trial to identify potential use cases of ground robotics and how these robots may benefit the meat processing industry.

Through the workings of Project 2021-1270, the team from AMPC and DroneDeploy selected and purchased a Boston Dynamics Spot Enterprise robot with corresponding Docking Station and Robotic Arm Payload. This robot was shipped first to the DroneDeploy office in New Zealand where it was configured, setup and tested prior to being deployed on the selected Casino Food Coop site in Casino, New South Wales.

Following the successful setup of the robot in New Zealand, the robot was shipped in December of 2021 to the Casino Food Coop site where it was set up and tested thoroughly in its walking and mission capabilities around selected areas on site by selected representatives Jade Baker and Brian Armstrong. The initial testing and generous time allocation from the Casino Food Coop is incredibly valuable for the success of the project and this is acknowledged by the projects delivery team. Following these initial lessons learnt and after COVID restrictions were lifted, plans were put in place to do dedicated testing on site by a DroneDeploy representative.

The Casino Food Coop was visited by a DroneDeploy representative for a 3-day visit in March of 2022. During the visit, several use cases were defined, and missions were completed to prove out aspects of the defined use cases. This included the concept of using Spot to take images from a still camera and push them to DroneDeploy for reporting and viewing, but this camera could easily be replaced with a thermal camera or other gas imaging device. Missions

were executed that included inspection, transportation, and cattle interaction aspects. Use cases that were defined and included are:

- Confined areas and restricted areas
- Emergency Response
- Planned inspections of Veal floor or similar Processing area (non-active)
- Ammonia Detection
- Engine Room Maintenance Inspection
- Thermal Imagery of Servers, Switches, and Computers.
- Lairage - Working with live animals
- Transporter Robot - Moving consumables around the site
- Last Check Pallet Scanning and Truck loading Inspection
- Geospatial Data (Point Cloud) LiDAR gathering

Although there were some challenging conditions, Spot managed to successfully navigate, both manually operated and autonomously, around the facility without any major issues, including challenging areas in the lairage. The biggest constraint during the visit was the availability of site-wide Wi-Fi which created challenges and unnecessary delays when the team ran into technical issues. This was a minor challenge, overall, in operational areas, the Wi-Fi proved satisfactory for successful teleoperation, mission monitoring, and data uploads.

The project was conducted over a 5-month period of testing and trialling and concluded that while Spot is a very capable robot, the value-adding tasks and missions for Spot (in particular) tend to be outside of the live operation area and would act as an extension or tool for the current maintenance and support teams. The potential for Spot may be limited in its autonomous capability on the Casino Food Coop site due to the site's particular construction, layout and topography but there are still great productivity potentials available for other task-specific autonomous ground vehicles in other forms.

The next steps to prove the value of using Spot as an inspection robot should include working on agreed selected use cases, performing them in a repeatable and reliable way to document and numerically determine their value to the operation, and determining on which site this should happen.

Other recommendations include investigating other robot form factors that could add value in other operational areas such as the pallet packing areas, organising the storage areas, and loading products into the delivery vehicles. This may have a high potential to reduce some of the health and safety risks of workers working in these usually very chilled and forklift busy areas.

2.0 Introduction

This document details the methodologies, discoveries, and findings of the project. The purpose of this Project was to investigate and bring awareness to the meat industry on the current capabilities of the robotic industry as well as how these may be applied into the current operations to augment or improve the current processes and make the day-to-day operations safer for workers who engage in manual handling tasks.

A separate Project under 2021-1270 was undertaken separately for the selection of the robotic solutions. In this case a Boston Dynamics Spot Enterprise with Docking Station, Spot Core and EAP, and actuating Arm was selected and used for the project.

The scope of this project included robot setup, training, site visits from the DroneDeploy team (COVID restrictions dependant) as well as the deployment of a robot on an active site to validate and prove out potential use cases.

3.0 Project Objectives

AMPC called out Hands-off Processing as one of its areas of focus within the recently released AMPC Strategic Plan 2020-2025 (page 7). An initiative within Hands-off processing is to identify alternatives to existing ways of product movement. Specifically, in this year's AMPC 2020-2021 Annual Operating Plan, AMPC's role in this area is to ensure there is improved safety for workers who engage in manual handling tasks.

The below are the overall project objectives:

- ‘Educate’ AMPC, processors and providers of possible use-cases
- Ascertain industry readiness level (ability and mindset) to adopt and leverage AGVs
- Document possible use cases now and in the future
- Demonstrate use cases identified on a single host site

4.0 Methodology

4.1 Education Workshops and Brainstorming

There was an initial workshop run for the AMPC team by DroneDeploy. During this workshop, discussions were had on where the robotic technology currently is and after hearing about current processes, the group collaborated to find some potential use cases. These can be seen in the use cases report found in the Appendix. Below, a list of the original potential use cases can be found which formed the base of our project direction:

- Inspecting Ammonia Leaks
- Electrical Thermal Sensing
- Lairage Application
- Visual Inspection

Further use cases are expected to come from having the robot on site and leveraging the expertise of subject matter experts.

4.2 Initial Robot Deployment on a Site

The chosen site was the Casino Food Coop in Casino NSW. Two site champions were selected to drive this (Jade Baker and Brian Armstrong). Boston Dynamics Spot had arrived on site and was set up in the IT area.

Spot has been set up and the payloads, including a 360 camera as well as the standard Spot payloads, installed and configured. Jade and Brian received basic orientation and training on the DroneDeploy Ground Robotics platform and started to get familiar with both Spot and the platform workings. The next stage was to select an area for the most viable use case, namely being a visual inspection.

During this stage in the project, the uptake and interest from the Casino Food Coop site had been great. It had drawn interest from across the business and there were a few great comments and use cases noted by the Casino Food Coop team. The team on the Casino Food Coop site did a great job at testing Spot on various areas of the site. Their initial testing of Spots walking capabilities and arm function capabilities proved very valuable for the success of the project. Due to the nature of this testing and its time requirements we sadly had to limit the time they were able to be involved in order to not take away from their current important day to day activities. This put the project on a short pause until COVID restrictions allowed a DroneDeploy representative on site to join the team and continue deeper testing.

The findings of this phase were that a project of this nature would need a full-time resource to obtain full utilization of the robot and to generate valuable use case metrics and feasibility.

4.3 Site Visit and Use Case Definitions

To further define and test potential use cases for Spot the quadruped robot, the Casino Food Co-op was visited by a DroneDeploy representative for a 3-day visit and robot implementation. This visit allowed the robot to receive full-time attention with the support of the selected Casino Food Coop team and allowed the project the opportunity to cover a great deal of the project objectives.

During the visit, subject matter experts were consulted, several use cases were defined, and missions were completed to prove out aspects of the defined use cases.

A summary list of the use cases brainstormed can be found below, these will be explained in detail in the next section:

- Confined areas and restricted areas
- Emergency Response
- Planned inspections of Veal floor or similar Processing area (non-active)
- Ammonia Detection
- Engine Room Maintenance Inspection
- Thermal Imagery of Servers, Switches, and Computers.
- Lairage - Working with live animals
- Transporter Robot - Moving consumables around the site
- Last Check Pallet Scanning and Truck loading Inspection
- Geospatial Data (Point Cloud) LiDAR gathering

4.3.1 SME Discussions

Discussions where had with the following team members on the Casino Food Coop site to evaluate use cases and to understand pain points in the current operations.

Marcus Frith - Production manager

Discussion with Marcus on where robots or automation may be of value

Ben Collison - Lead Fitter who performs inspections on equipment on site

Walkthrough of items to inspect on the Veal Floor

Haydon Benn - Engine Room Driver and Operator

Walkthrough of items to inspect in the Engine Room

Jeremy - Lairage Leading Hand

Guide whilst testing the robot in the Lairage and when herding cattle

4.3.2 Use Case Discovery and Definition

Results from the discovery workshop, initial testing on site and consultation with the SMEs during the site visit, the below section highlights potential use cases defined during the project.

Confined areas and restricted areas

Intended Purpose

Use a robot to access areas that are small and confined for humans to either collect data or recover an object with the gripper on an actuating arm. The control of this robot would be done by a remote operator and there is no reliance on autonomy in this case.

Expected Constraints

- The robot's capability to navigate the environment, including robot size, floor obstacles, and floor friction.
- The robot's ability to use the gripper
- Connectivity to the robot (controller direct is limited vs Wi-Fi control needs full coverage on the site)

Emergency Response

Intended Purpose

Use a robot to access areas that are subject to an emergency where it may be dangerous for humans. These types of missions would include the control of the robot by a remote operator paired with sensors to suit the emergency. These could be gas detection sensors, thermal imagery, or high-resolution photos.

Expected Constraints

- Restrictions on robots operating around potentially flammable gasses. (ammonia)
- The robot's capability to navigate the environment, including robot size, floor obstacles, and floor friction.
- The robot's ability to use the gripper
- Connectivity to the robot (controller direct is limited vs Wi-Fi control needs full coverage on the site)

Planned inspections of Veal floor or similar Processing area (non-active)

Intended Purpose

Use a robot to autonomously navigate the processing floor area in a shutdown or pre-work state to perform and record a visual inspection of areas of interest. This data could then be pushed to DroneDeploy to create a photo report and record the areas in a timeline. The inspection content would be in the form of both a 360 walkthrough and individual point and shoot images.

Expected Constraints

- The robot's ability to navigate the environment, including robot size, floor obstacles, and floor friction.
- Robotic access to the site, including doorways, and sterilization stations.
- Small walkways and tight staircases

Ammonia Detection

Intended Purpose

Use a robot to access areas that are subject to an Ammonia leak where it may be dangerous for humans. These types of missions would include the control of the robot by a remote operator paired with an ammonia detecting sensor. The robot could be used to assess the area for damage, use the actuating arm and gripper to open doors for ventilation, and to use advanced sensors to potentially pinpoint the source of the leak without the need for a human to enter the affected area.

Expected Constraints

- Restrictions on robots operating around potentially flammable gasses.
- The robot’s capability to navigate the environment, including robot size, floor obstacles, and floor friction.
- The robot’s ability to use the gripper
- Connectivity to the robot (controller direct is limited vs Wi-Fi control needs full coverage on the site)

Engine Room Maintenance Inspection

Intended Purpose

Use a robot to autonomously navigate the Engine Room in an active operation state to perform and record a visual inspection of areas of interest. This data could then be pushed to DroneDeploy to create a photo report and record the areas in a timeline. The inspection content would be in the form of both a 360 walkthrough and individual point and shoot images. Advanced functionality could include thermal sensors or other gas monitoring equipment whose data is pushed to machine learning and results could then be integrated into the operation control systems of the facility.

Expected Constraints

- The robot's capability to navigate the environment, including robot size, floor obstacles, and floor friction.
- Wi-Fi or internet coverage on the site to have live machine learning notifications (otherwise this can be done at a later stage when internet connectivity is restored)
- The robot’s ability to deal with small access areas and potentially blocked pathways
- Limitations of the current sensor setup (no thermal image or zoom images for gauge readings)

Thermal Imagery of Servers, Switches, and Computers.

Intended Purpose

Perform Thermal inspections of electrical and mechanical equipment to detect anomalies and faults for preventative maintenance (as per the below image extracted from the *2021 February THERMOGRAPHIC INSPECTION REPORT)* (Dravsnik, 2021)


Fig. 5 – Large Stock Sub-Board – NCMC 03354

Fig. 6 – Large Stock Sub-Board – 250A Fuse

Fig. 7 – Large Stock Sub-Board – 250A Fuse Top Connection

Fig. 8 – 250A Fuse Top Connection – Thermogram (10125)

The purpose of this would be to perform these inspections more regularly and on larger areas throughout the year to ensure there are no potential faults and to optimize areas to reduce electricity usage in the long term.

Expected Constraints

- Spot's ability to open doors and operate under the Australian electrician code
- Spot's thermal camera capabilities and its ability to replicate the current high precision hand measurements currently done as the industry standard

Lairage - Working with live animals

Intended Purpose

Use the robot in a remote-controlled way to be in the danger area whilst herding cattle in the lairage area. This removes cattle handlers from direct hazards in the lairage area when managing an aggressive animal who may charge or bump steel gates that might result in crushing and injuring the human that is herding them.

Expected Constraints

- How do the animals respond to the robot and their reaction to it?
- Can the robot navigate the area successfully and with enough speed and presence to perform the task?
- The range on the controller connected to the robot might be limiting.

Security Patrolling - looking for animals and people

Intended Purpose

Use the robot to autonomously navigate the property to perform a security patrol of the facility. This could include Machine Learning integration to detect humans and animals, including pests and other animals that should not be on site. A remote operator could then receive notifications of findings and take over manual control of the robot to address the issue or situation without them entering the danger.

Expected Constraints

- How do the animals respond to the robot while patrolling animal holding areas?
- Can the robot navigate the area successfully?
- Wi-Fi or internet coverage on the site to have live machine learning notifications and the ability for a Security representative to take over control and deal with the threat or issue remotely.

Fence line Patrol and Rodent control station inspections

Intended Purpose

Use the robot to autonomously navigate the property to perform inspections on the rodent controls of the facility. This could include taking still images with geolocation and pushing them into an inspection report that the maintenance team could use as records to determine which bait stations need refilling or attention.

Expected Constraints

- The robot's capability to navigate the environment, including robot size, floor obstacles, and floor friction.

Transporter Robot - Moving consumables around the site

Intended Purpose

Use robots to autonomously do rounds around the site to deliver consumables from department to department. These could be PPE supplies, Covid testing supplies, IT equipment, or general maintenance tools. The robots would have set waypoints and delivery bays at each department, and either be on schedule or called by a department to collect delivery. In this case, we focused on IT equipment which in some departments needs replacing on a weekly basis and is over 500m away from the IT department.

Figure 2 Spot Delivery Mission

Expected Constraints

- The robot's capability to navigate the environment, including robot size, floor obstacles, and floor friction.
- Connectivity to the robot (the robot can perform these trips offline)
- Extra load on the robot needs to be accounted for in robot settings and avoidance as well as battery usage over longer distances

Last Check Pallet Scanning and Truck Loading Inspection

Intended Purpose

When a receiving delivery truck backs into the loading bays they are opened, and a robot can autonomously navigate into the truck to capture a visual condition and record the inside of the truck. The robot then moves to the packed pallets, walks around the pallets, and uses a sensor or photography and vision systems to document all the barcodes of the items to be loaded.

Figure 3 Casino Food Coop - Loading Area

Expected Constraints

- A robot working in a busy area with many moving forklifts
- The robot's ability to document the pallet state and barcodes accurately and reliably

- The current working methodology needs to be modified to allow for this process

Geospatial Data (Point Cloud) LiDAR gathering

Intended Purpose

Use the robot as a mobile mapping unit to traverse the site and capture the facility in an accurate point cloud. The purpose of LiDAR scanning is to capture geospatially accurate data in the form of high accuracy point clouds to enable the digital team to understand the facility's current geospatial setup and use this point cloud in their CAD systems for design and planning.

Expected Constraints

- Lidar capabilities on stainless steel
- The robot's low point of view and its ability to capture data where height may be required
- Value of this operation in an area where not much change is happening

5.0 Project Outcomes

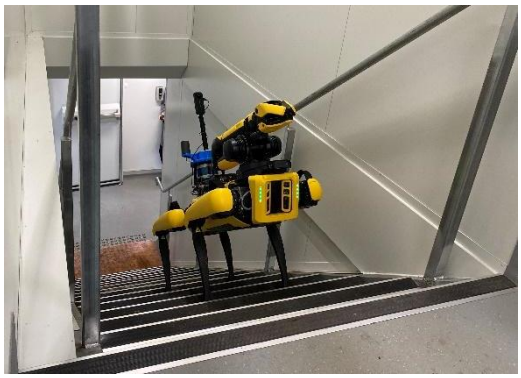
The following section will highlight the missions that were attempted during the site visit. The missions are particular to the above-mentioned use cases and demonstrate a few capabilities which prove the basic concepts above.

5.1 Initial Site Mobility Testing

The Casino Food Coop's representatives, Jade and Brian initially did some comprehensive testing of Spot's mobility capabilities around the site. This included testing Spot walking ability up staircases, on moving conveyors and recording long Autowalk that the robot could execute in an Autonomous manner.

Staircase

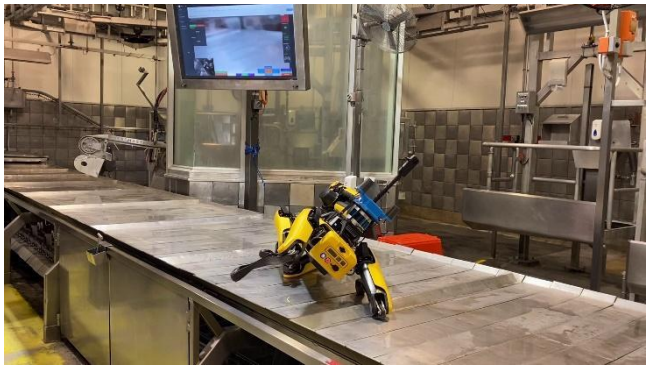
Spot was able to successfully navigate up and down staircases. There were some occasions where the robot mistook its surroundings or its footing resulting in a fall down the stairs. During one of these falls the only damage sustained to the robot was the breakage of a plastic 3rd party bracket that the project team had installed.



Evisceration Table

During a test on the evisceration table the robot happened to collapse on the initial test but succeeded on the follow-up attempt. The first collapse of the robot, upon review of the footage found in the *"General Robot Functions and Testing"* folder in the project media, is attributed to the slippery surface of the conveyor and not solely for the moving

nature of the surface. This functionality is considered incredibly difficult for a robot to complete as there are thousands of stability algorithms being used to compensate for the robot's movements with the assumption that the ground is stable and stationary. Having the robot on a moving platform incorporates a whole new element of a dynamic environment and the success of this test is a testament to the advanced capabilities of the Spot robot.



Long Autowalk Map Missions

Spot has a functionality where the operator can record an Autowalk with predefined pathways and actions. This function allows the robot to create a ***map*** which Spot knows how to navigate around and a ***mission*** which consists of the actions to perform along the map. The integrity of the map and Spots navigation capabilities relies on features in the real world such as ***fiducials*** (April tag reference QR codes). Jade had done an excellent job at distributing these fiducials around the Casino Food Coop site which resulted in excellent autonomous navigation performance.

The Casino Food Coop team recorded multiple Autowalks which tested the robot's autonomous navigation capabilities, including an Autowalk that covered the walkway between the IT offices and the Tannery (CHT) which was over 500m in length. Spot was able to successfully navigate this long mission without any errors or without getting lost or unlocalized (localization is the robot's ability to understand where in its map it is currently positioned and orientated).

The successful results of this testing prove out Spots new navigation capabilities recently released in Spot firmware V3.0.

These Autowalks are an important feature as the DroneDeploy robotic platform can utilize these Autowalks in a few ways:

1. Replay these Autowalks as is, with the addition of extra functions before or after the mission
    a. Examples include activating 3rd party sensors or uploading captured data to a cloud platform
2. Schedule these Autowalks to happen autonomously, unattended, unsupervised, and offline.
3. Use the ***map*** to plan more advanced missions in the platform while still utilizing Spots advanced navigation capabilities.

5.2 Engine Room Inspection

We used the Spot robot in a remote-controlled way to record a mission in the Engine Room. After consultation with the Engine Room driver Haydon, we used Spot to navigate to areas of interest to capture still images and a 360 walkthrough. This included a few gauges and switches as well as documentation of frozen condensation on ammonia cylinders and piping. Once these images are captured and the robot has returned to the docking station, this collected content is then pushed through to the DroneDeploy platform for storage, visualization, and reporting.

The mission was then saved to the robot and the DroneDeploy ground robotics platform and was then able to be triggered on a schedule or remotely from the internet. This functionality removed the requirement for the robot to be in constant connectivity with the on-site controller and could perform the missions autonomously through offline areas unsupervised such as inside the entire engine room. This mission was completed twice, once with the Insta360 R as a point and shoot camera and the second time with the Insta360 One X2 as a 360 Walkthrough.

During the second mission, the Insta360 One X2 360 walkthrough, the mission did not traverse the entire facility as there was an error in the initial recording of the mission where a waypoint at the back of the engine room was omitted. This however did not apply to the point-and-shoot mission where these waypoints were correctly documented.

Challenges

The environment was very confined for the robot to navigate. In some areas, the robot could not rotate and could only move in a forward and backward direction. This had implications for positioning the cameras to take images of particular areas as well as navigating the entire area, including a steep staircase to a landing with tight turns.

As this was an engine room the floors were often wet and coated with oil making the floor very slippery for the robot. This was seen when the robot nearly collapsed but the robot recovered, and the robot was subsequently put into a “low-friction” walking mode.

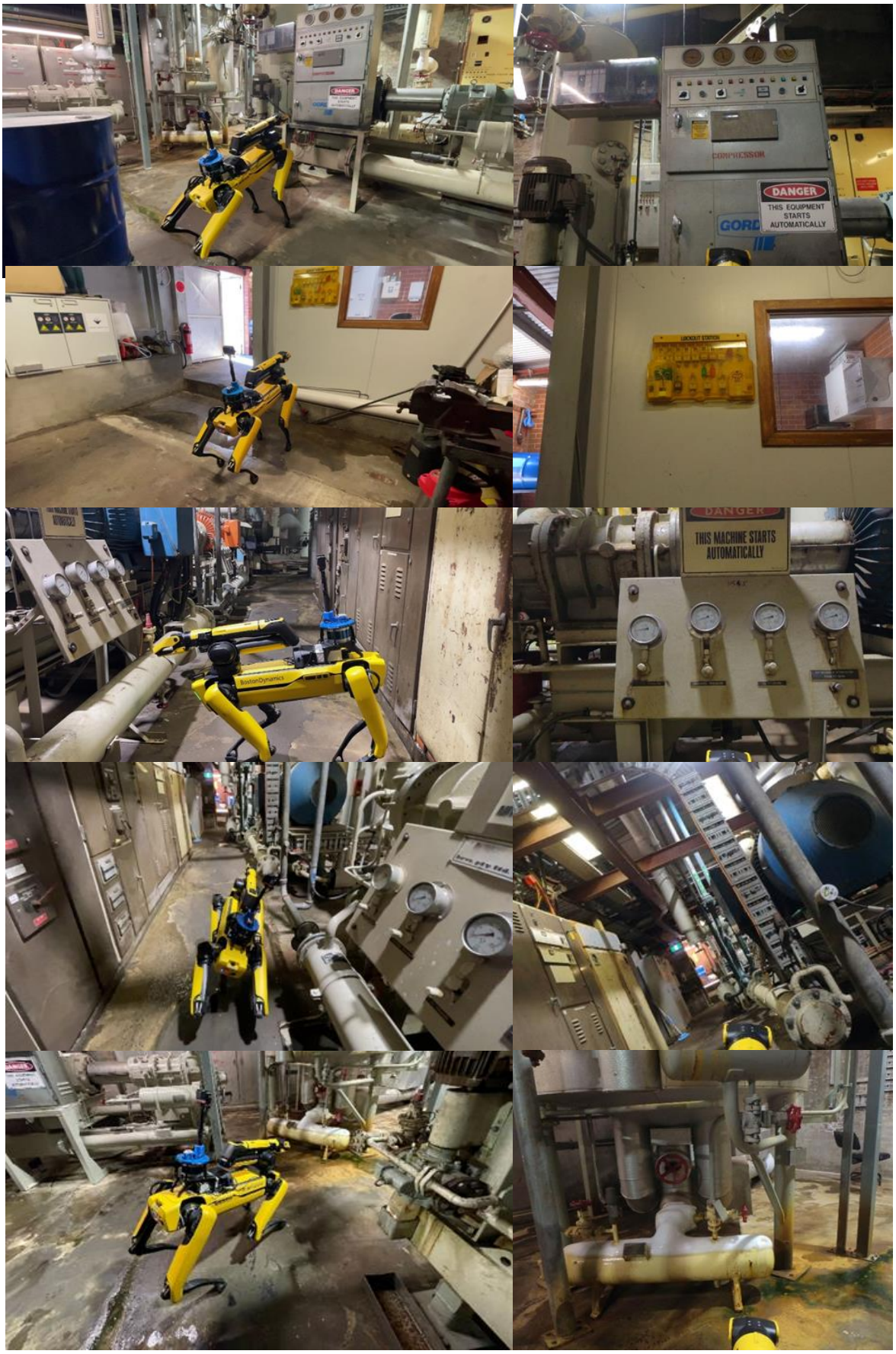
As mentioned above, there were some tight staircases and landings which had doors and narrow access. These areas were omitted but can be further tested to prove the robot's capability to navigate these areas.

Improvements

The Spot CAM+IR PTZ (Pan, Tilt, and Zoom) sensor for thermal and high-resolution gauge and detailed images would provide much better image quality, thermal capability, and range of direction to look at certain items.

Higher friction / slip-resistant booties for the robot as the Engine Room has a slippery surface with oils and water

Images


DANGER
THIS EQUIPMENT STARTS AUTOMATICALLY
COMPRESSOR
DANGER
THIS MACHINE STARTS AUTOMATICALLY

Deliverables

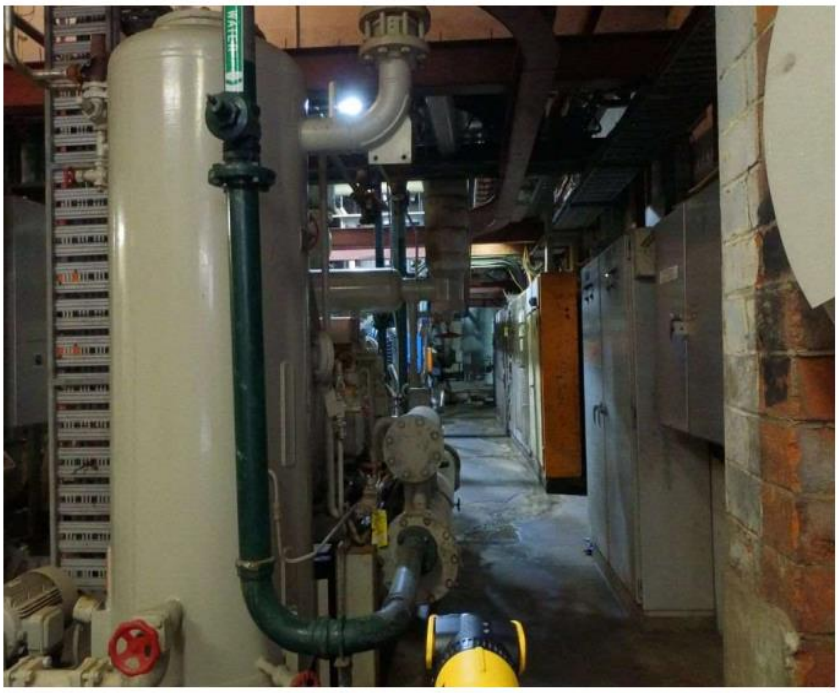
The photo report can be found in the Appendix or this link

In the images below you can see in the DroneDeploy platform the 360 walkthroughs are aligned (pink trajectory) to the facility layout drawings and the point and shoot inspection images (blue icons) are placed along the trajectory where they were taken, although in this case, the 360 walkthroughs failed to extend into the inspected area but the point and shoot missions were comprehensive in that area. The user can then teleport anywhere along the pink trajectory to get a compressive 360 view in that location. Further movement in that photo view is available by clicking the augmented arrows in the image along the path.

Figure 5 DroneDeploy's 360 Walkthroughs and Photos aligned to an aerial image with a Site overlay

Engine Room Inspection

March 23, 2022



Engine Room Entry

Figure 6 DroneDeploy's Photo Inspection Report

5.3 Veal Floor Inspection

We used the Spot robot in a remote-controlled way to record a mission on the Veal Floor. The Veal Floor was not currently operational and was being prepared for operation. After consultation with the lead Fitter, Ben Collison, we used Spot to navigate to areas of interest to capture still images and a 360 walkthrough. This included conveyor belts, the hide puller, and some mechanical tools such as the brisket cutter and carcass saw. In the absence of a docking station, we placed one fiducial in the corridor to act as a starting and ending point for the missions. Once these images are captured and the robot has returned to the starting location, this collected content is then pushed through to the DroneDeploy platform for storage, visualization, and reporting.

The mission was then saved to the robot and the DroneDeploy ground robotics platform and was added to an *Automated Flow* which allowed the mission to be triggered on a schedule or remotely from the internet. The environment had comprehensive network connectivity and the mission could be observed on the platform from any location in the world with an internet connection. This mission was completed twice, once with the Insta360 R as a point and shoot camera and the second time with the Insta360 One X2 as a 360 Walkthrough.

Challenges

There was a very narrow entry to a staircase to get into a hoof cutting and hide pulling preparation area. Spot was able to navigate through this area without a problem.

Where we had established a start and end position with a Fiducial was in a corridor that was quite busy and had to postpone the efforts temporarily while quarter carcasses were being moved to the blast chillers.

Just after the hide puller is a small access track that is on the robot's limit of a trip hazard/step identification. Spot managed to navigate through here on multiple occasions although it was reported that this had caused a crash on previous attempts before this visit. See the images below in the next sections.

Getting in and out of the processing areas is not easy for robots at this stage. There are many doors to prevent airborne pests as well as to control temperature. Entering and exiting the process area requires sterilization and cleaning of hands and boots. This proved challenging for a robot and a new method that allows a robot to safely sanitize and enter the buildings will need to be thought of in the future.

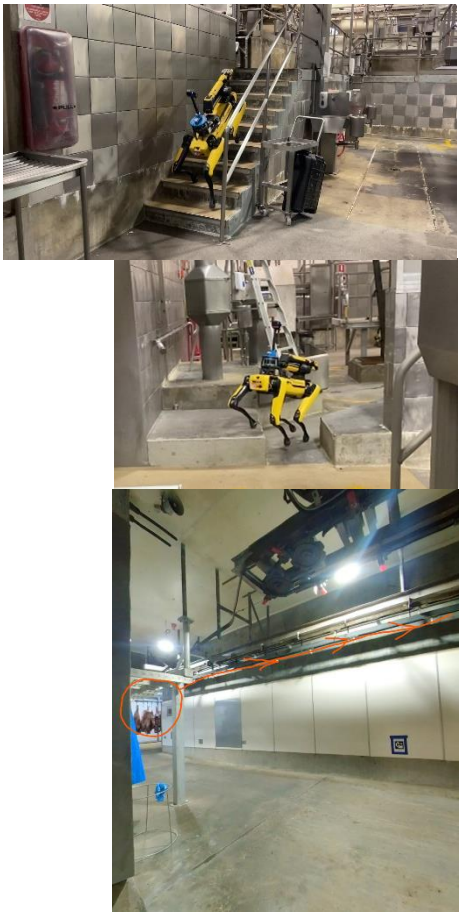


Figure 17 Process Inspection

Improvements

The Spot CAM+IR PTZ (Pan, Tilt, and Zoom) sensor for thermal and high-resolution gauge and detailed images would provide much better image quality, thermal capability, and range of direction to look at certain items.

Improved access for robots into areas with sanitizing methods, allowing the robot to have a door open for it on arrival then walk through a wash bay that is safe for the robot but effective in sterilization.

Images

Figure 8 Veal Floor Mission Inspection Images

Deliverables

The photo report can be found in the Appendix or this link

In the images below you can see in the DroneDeploy platform the 360 walkthroughs are aligned (orange trajectory) to the facility layout drawings and the point and shoot inspection images (blue icons) are placed along the trajectory where they were taken. The user can then teleport anywhere along the orange trajectory to get a compressive 360 view in that location. Further movement in that view is available by clicking the augmented arrows in the image along the path.

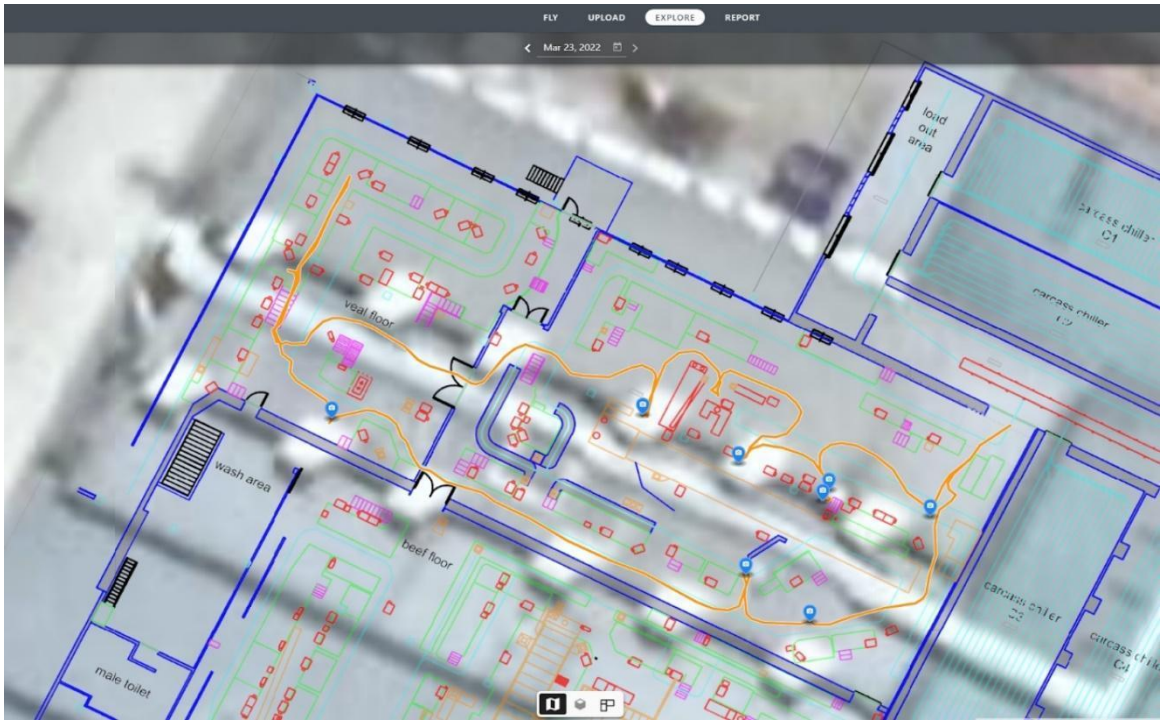


Figure 9 DroneDeploy's 360 Walkthroughs and Photos aligned to an aerial image with a Site overlay

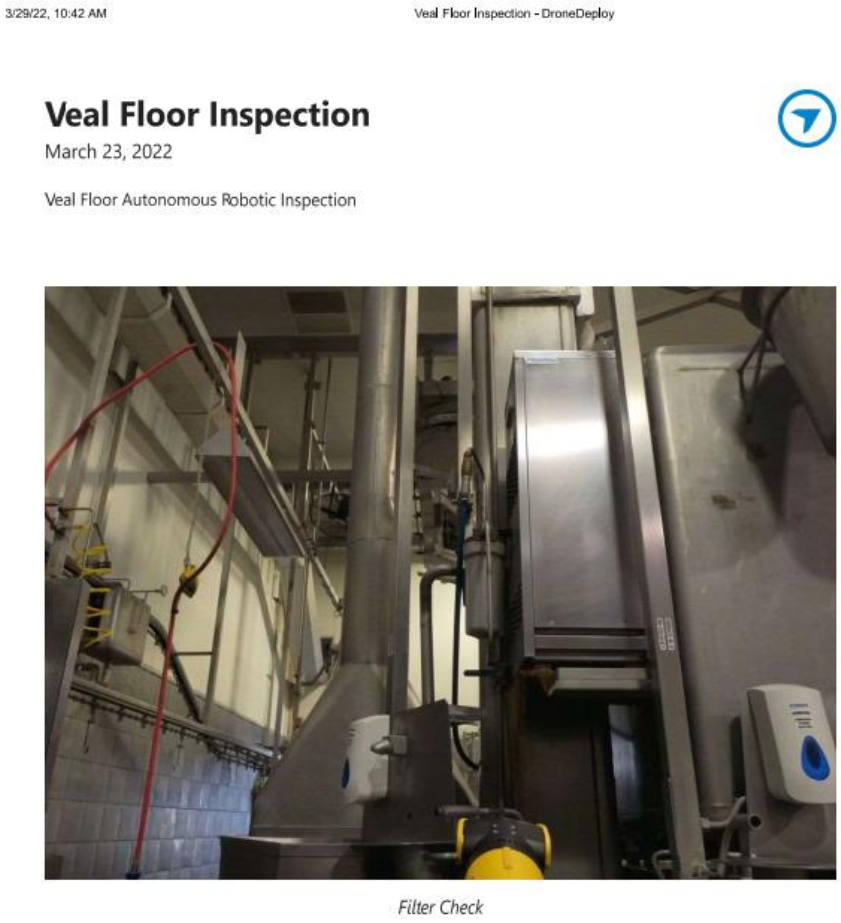


Figure 10 DroneDeploy's Photo Inspection Report

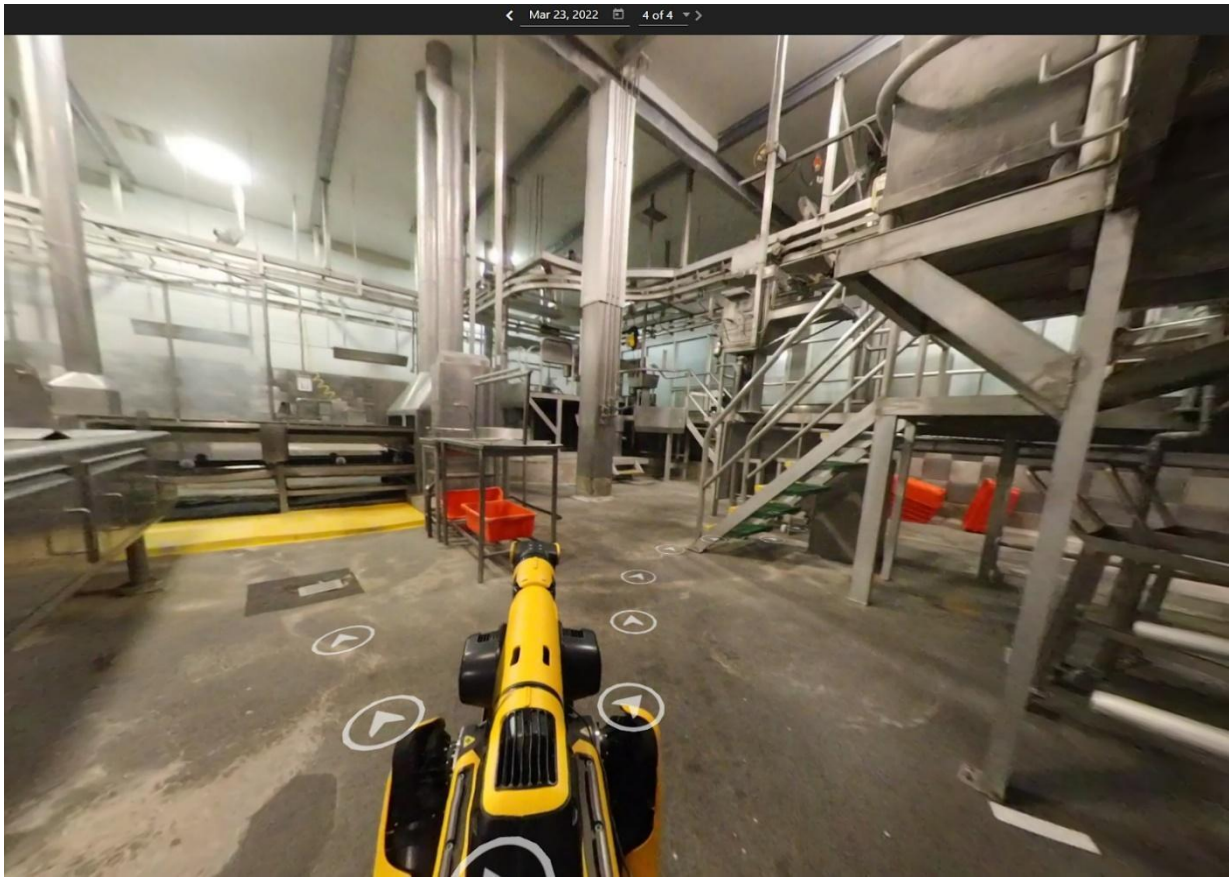


Figure 11 DroneDeploy's 360 walkthrough product

5.4 Delivery Mission

The nature of the chemicals that are used in the Tannery (CHT) results in operator keyboards needing to be replaced almost weekly. This requires a 1km return journey for an IT representative to transport something simple on a weekly basis.

The Casino Food Coop Engineering team was able to quickly construct a transport tray that bolted onto the Spot EAP and under the 360-camera mounting. The purpose of this was to transport keyboards (IT equipment) around the site on long walks to other departments.

We used a previously recorded mission that had been saved in the controller and used its map in the DroneDeploy GR platform to create an Automate Flow which did the following

- Power On and undock the robot
- Load in the correct Map
- Navigate to the IT desk and wait for 1 minute (time to load on supplies)
- Navigate to the Tannery and wait for 2 minutes (time to offload supplies)
- Return to the IT office and Dock

Figure 12 DroneDeploy Robotic Automate Flows

The mission was executed but due to some technical issues and time constraints, this mission was never completely executed successfully.

Challenges

The extra weight and size limits needed to be added to the robot's console to ensure the robot understood its new loadings and bounding box parameters.

Spot seemed to be unable to compute a navigable path between GoTo nodes on the map when the distance was too far apart.

The flow seemed to time out between GoTo nodes if they were too far apart (but the navigable path was calculated)

No internet connection along the 500-meter roadway to the Tannery proved challenging for the team to recover the robot when missions failed midway through.

Improvements

- The issues around the flow engine as the method to execute the mission have been raised with the DD engineering team and have since been resolved.
- The carrying tray could be made from a lighter material to avoid overloading the robot.
- Have an LTE connection backup on the robot when recovery is needed, assuming adequate coverage exists.

Images

Figure 13 Payload Tray

5.5 Cattle Herding in Lairage

Spot was taken into the Lairage area where the robot's walking capability was tested in an environment with the conditions of the floor, gutters, and stairs in the area. The gripper arm was tested on its ability to grip a hose and move this around the site.

Spot walked the area without a problem. Following this, the robot was taken near cattle to understand the cattle's reaction to the robot. It was found that the cattle were very inquisitive but also somewhat fearful and cautious of the robot.

The robot was then placed into a lairage pen with a human but with a fence between the cattle and the robot to move the cattle between pens. The cattle responded positively, and the robot was successful in herding.

Following this, the robot was placed alone in a confined pen with direct contact with the cattle to move them to another pen. The cattle were very cautious and grouped at the rear of the pen until there was enough space for the cattle to make an exit through the pen's gate and onto their next area.

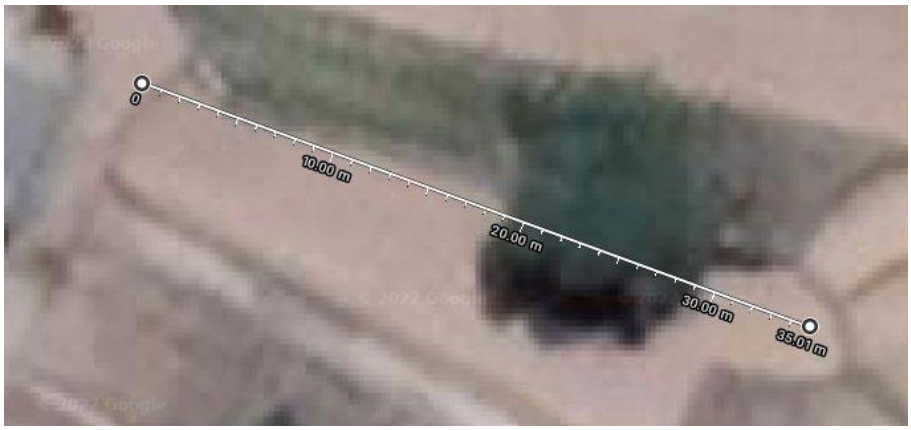
It is important to note that the floor on this occasion is rough concrete with steel gutter covers. Spot walked this area without a missed step and successfully herd cattle proving its ability to remove a human from dangerous environments.

Spot was then moved to a larger outdoor area that was sand based to test the robot's capability in the sand and to see how cattle respond in a bigger environment. Similar results in terms of cattle behaviour before moving to the next area. Spot walked the area without a problem but when the operator tried some beta advanced walk modes like hop and jog, the robot fell over. The robot then proved its capability to "self-right" without human intervention and carry on the mission. There was one bull who remained behind and proved feisty in its demeanour which took a few attempts to herd it with the robot. The bull showed some level of aggression and charged toward the robot but ultimately the remote operator of the robot was able to guide the bull to the rest of the herd.

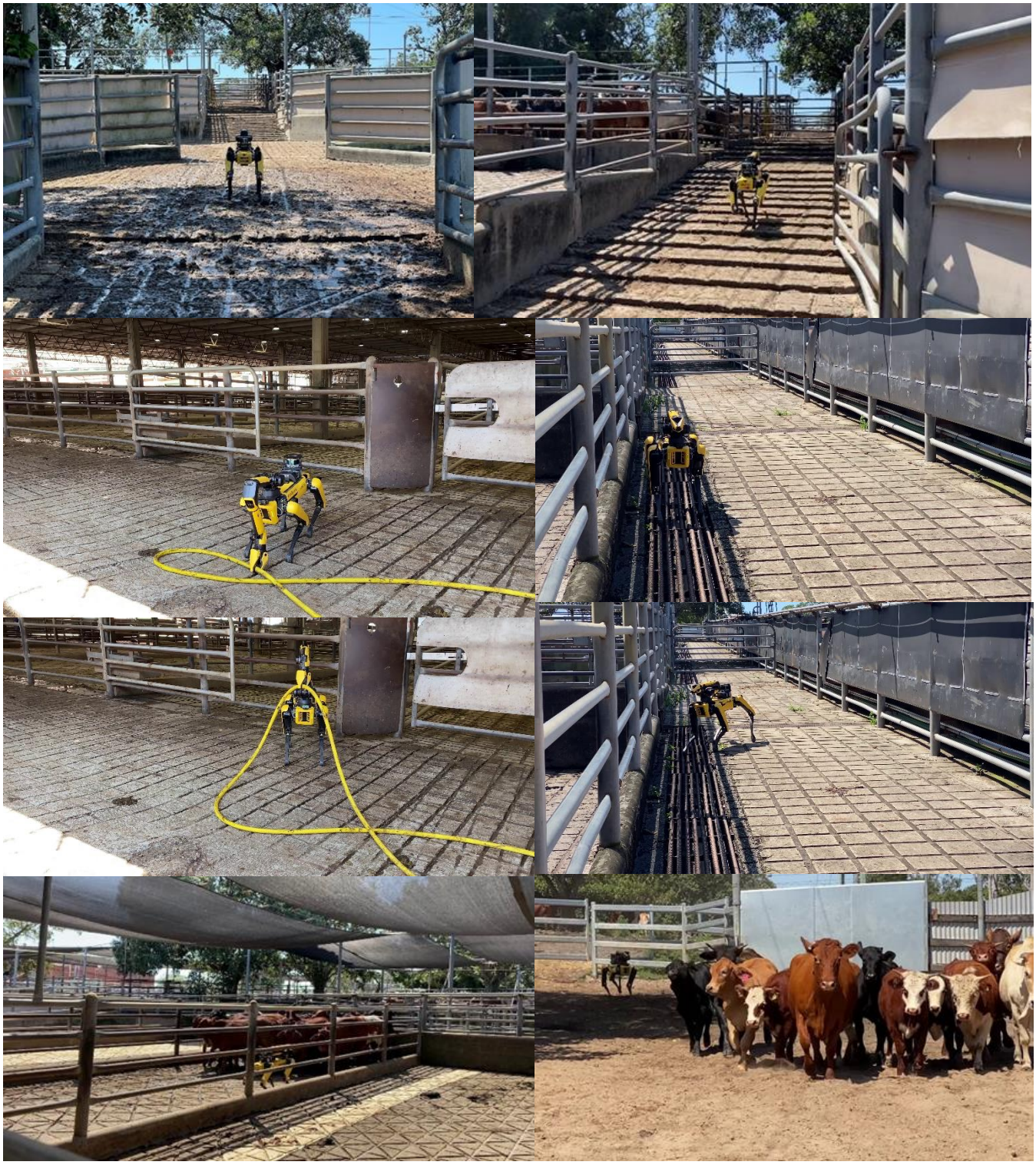
The robot was successful but probably not as efficient as the traditional human herding team in the larger outdoor setting, this could improve with practice.

Challenges

Range of the direct connection of the controller to the robot in the outdoor environment. The maximum range noted was around 35 meters until the connection became temperamental and unreliable.



Images



5.6 LiDAR Collection of Data (BETA)

Using the existing LiDAR on Spot the DroneDeploy team ran a test on the solution's capability to record LiDAR for visual mapping purposes. This is a non-colourized point cloud solution which is mainly designed for navigation capabilities of the robot, not necessarily for mapping.

Using the DroneDeploy platform, the Spot controller was extended with services to allow the inclusion of Record LiDAR Scan, Stop LiDAR Scan, and Process LiDAR Scan in an Autowalk recorded offline.

The Robot was then used to teleoperate around both the Engine Room and the Veal Floor to capture raw point cloud information. These were both then processed on the robot to produce a PLY point cloud file which can then be consumed by the digital team to understand the facility's current geospatial setup.

Challenges

LiDAR relies on the return of light that is transmitted by the LiDAR unit. Having dark or highly reflective surfaces influences the return of the light which negatively affects the solution's ability to perform SLAM computations and build an accurate point cloud. As the majority of the Veal Floor is stainless steel this was the only concern.

Calibration of the Beta solution as well as fast and unpredictable movements by the robot will lead to noise and other point anomalies. As this technology is very much still a work-in-progress the quality of the results from this function are not guaranteed.

Images

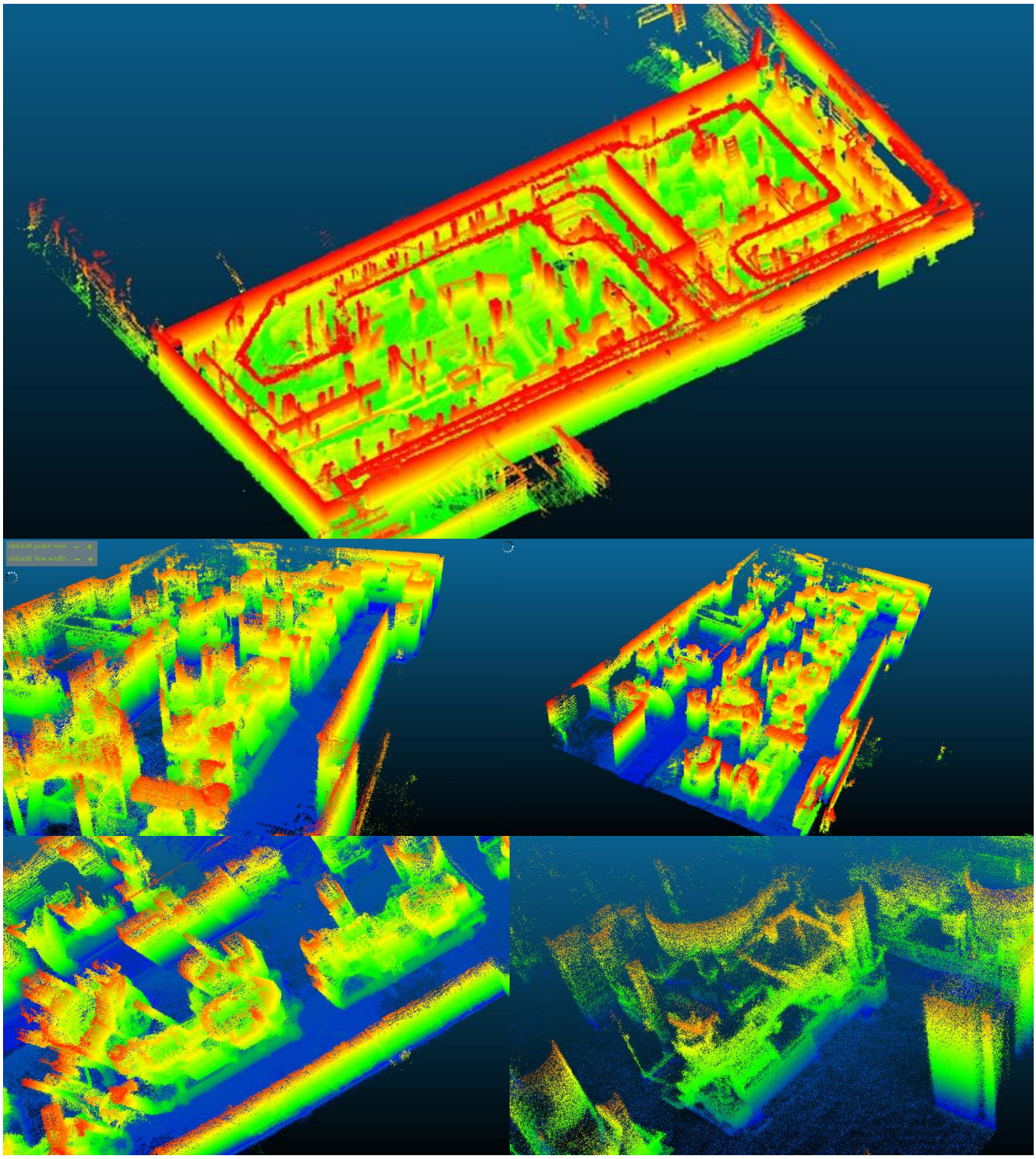


Figure 16 Point Cloud Viewing of Veal Floor and Engine Room

6.0 Discussion

During the site visit and the execution of missions we found that the robot managed to handle the environmental constraints well. These included the stairways and general floor obstructions. Spot as a quadruped robot was functional in all areas tested and proved to be very resilient and robust when collapsing or falling over.

With the robot's current "intelligence" and Casino Food Coop's current topography, slippery environment and the busy worker movements Spot might not be the most suitable robot in an autonomous capacity at this stage of its development. This would include its inability to wait for traffic when moving across site or falling over on an unexpectedly slippery floor which is very common during day-to-day operations. For these advanced features there may be a need to have advanced detection of obstacles, objects, or hazardous situations.

Demonstrations on site were able to prove concepts around the ability for inspections and the flow of data and record keeping. We noted that there is generally not much record kept to date of manual inspections and if so, there is not much supporting documentation such as photos and videos stored in an easy to access platform or system. This could be a key area of improvement when incorporating repeatable and regular visual inspections with an autonomous robot. Using a robot on a schedule with the correct sensors to inspect important areas such as the Engine Room would increase the visibility and traceability of the critical assets of the plant, but some deeper work would need to be done on that use case to clearly define what data is important to monitor and what a meaningful and repeatable inspection looks like.

Some key autonomous use cases that could become solutions include the potential to have a continuous delivery network that a robot moves through. This would allow departments to send items around the site without the need for them to waste time walking. This is highlighted in the Transporter Robot demonstration.

For the use cases we performed, we found Spot to be beneficial as an extension to the operator and used in a teleoperation mode. We noted the potential for large Health & Safety benefits in the Lairage area where an operator could jump on a controller to engage with potentially hostel cattle to avoid them ever being exposed to the direct hazard when working with an animal in a confined area.

Overall, Spot was able to achieve most of what we tested at a very high level, however, there are many factors that could ultimately prevent robots from being deployed on a site like Casino Food Coop. This included large doors that manually open, washing bays with steep steps, water ponds that are used for sanitization, the general tight layout of processing equipment and the continuous movement of people and other machinery. The autonomy of a robotic solution depends on the environment in which it lives. As these sites are currently limited in their layout topography, manually focused operation, and limitations of full internet coverage throughout the site (including between facilities), there would need to be some effort and planning needed to truly implement a solution that would provide value. These challenges come from years of industry evolution and how things are generally done.

This is a strong theme around the deployment of the robot on site where it might be considered a "cool" toy by some and an unproductive distraction to operation managers during R&D project executions and evaluations. This perception along with forward thinking innovative industrial design could be the two most important factors in the future success of robotics in this industry.

Along with Spot's performance, there may be some other areas within the current operations that could benefit from more robotic automation that might not necessarily be in the form of an AGV or Spot. This includes palletization, wrapping and loading into delivery trucks. Currently, this was observed to be all manual, including the lifting of heavy boxes onto pallets in a cold environment surrounded by the busy movements of forklifts. Along with Health and Safety and manually handling risks, this manual process can become inefficient as storage of these pallets before loading might not be optimal for truck loading resulting in double handling and shifting to get the correct inventory ready for

collection. A smart packing, storing, and loading robotic solution could potentially have high productivity yields and safety benefits should this be an area of interest to optimize.

7.0 Conclusions / Recommendations

Robots in the form of Spot, in the current Casino Food Coop facility, can be of benefit as an extension to the workforce but may be limited when operating in an autonomous capacity due to the robots' current capabilities as a quadruped to successfully navigate busy areas or access areas where doors or obstacles aren't designed to autonomously open and require human efforts. At this stage, the access tracks, entries into the processing area, and other areas are limiting factors for robot movements. This can be resolved in future and in Stages 3b and 4 where facility layouts are modified to incorporate robots.

The day-to-day operations in the processing areas are still heavily focused on manual efforts and would require the process, in general, to be rethought to accommodate robots and automation where practical and where productivity gains can be identified.

IoT devices may be an easy addition for advanced monitoring and inspection capabilities within areas such as the freezers, engine room, or where other mechanical devices need to be inspected routinely.

From our testing and the described use cases, Spot can be used as a multipurpose robot to automate very repetitive tasks, further research into the numerical and financial value of the selected use cases will need to be done.

Other robot form factors may be of high value, especially in the areas where Order Picking, Palletisation, Storage, and loading into transport vehicles which are still heavily focused on manual labour efforts.

7.1 Summary of Objectives achieved

1. 'Educate': AMPC, processors and providers of possible use-cases

Throughout this report, the findings of Project 2021-1270, on-site hands-on demonstrations and use case testing the project teams have demonstrated to AMPC the current capabilities, potential use cases and limitations of AGVs.

2. Ascertain industry readiness level (ability and mindset) to adopt and leverage AGVs beyond the current single deployment example at Kilcoy Pastoral Company

Having deployed the robot for many months at the Casino Food Coop site, this report documents the limitations of sites in their original or traditional layouts and operation methodologies. At this stage, the access tracks, entries into the processing area, and other areas are limiting factors for robot movements. This can be resolved in future and in Stages 3b and 4 where facility layouts are modified to incorporate robots.

There was some great feedback from within the industry around the exciting implementation and benefits an AGV on site might bring

"Many restricted areas exist on-plant, with limited human entry and egress without protective equipment or entry preparation. Spot could greatly aid our emergency response and inspection times in potentially dangerous situations while data collection is gathered for decisions." (Beef Central, 2022)

Jade Baker, IT technician from The Casino Food Co-Op in NSW, said "Spot was an incredible piece of tech with unprecedented mobility, allowing fully autonomous AI driven missions on plant." (Beef Central, 2022) (Baker, 2022)

"In the short weeks Spot's been onsite, initial trialling looks promising. I'm very interested to see where Spot takes us, and how we can implement this tech into our business." (Beef Central, 2022)

Although with any new technology there is always scepticism around the successfulness or appropriateness of the solution to the wider industry. Robots tend to be seen as a large disruption in the industry with potentially great benefits but also much effort for implementation. For these reasons, many established processes such as the inspections and maintenance have not adapted for a better way of working. For ground robots to become an effective tool in the industry there is collaboration required from the industry and its trades, not to find a means to replace current jobs and tasks, but to innovate together towards newer effective ways to achieve a higher quality result and record.

3. Document possible use cases now and in the future (the later require further developments or third-party value-adds)

This document has detailed use cases found in section 4.3.2 and comprehensive testing of these use case concepts in chapter 5.0. A summary of potential use cases can be seen below:

- Confined areas and restricted areas
- Emergency Response
- Planned inspections of Veal floor or similar Processing area (non-active)
- Ammonia Detection
- Engine Room Maintenance Inspection
- Thermal Imagery of Servers, Switches, and Computers.
- Lairage - Working with live animals
- Transporter Robot - Moving consumables around the site
- Last Check Pallet Scanning and Truck loading Inspection
- Geospatial Data (Point Cloud) LiDAR gathering

4. Demonstrate use cases identified on a single host site

The robot testing was performed on the Casino Food Coop site in Casino, New South Wales. This document has detailed testing of selected use case concepts in chapter 5.0.

5. Develop Stage 3b and Stage 4 pilot programs (technology, software and training)

Next steps and ideas for stages 3b and 4 can be found in the 7.2 Next steps section below

7.2 Next Steps

7.2.1 Stages 3b

Select the most applicable use cases to develop. The intention of this is to achieve reliability in the chosen missions and document the long-term value. This would require a detailed set of tasks to complete and a new project with a schedule of the implementation, value metrics and objectives. This stage would require the project's representation and appointed site representatives to work together in a dedicated capacity on the selected use case(s). The process of appointing resources for these further projects would need to be discussed with the AMPC representatives to allow for time and budget for the resources selected from the selected site.

Ideas for this stage could be:

1. The development of the pallet packing, storage and loading operation where specific robot form factors would be investigated and implemented. This would require modification of the facility and the current process.
2. Select the most applicable use cases that suit Spot on the Casino Food Coop site to further develop and test. The intention of this is to achieve reliability in the chosen missions and document and long-term value.

7.2.1 Stages 4

The supplier of choice should be carefully selected for Stage 3b. Factors should include:

- Location and availability of in person representation
    - During this Project in particular, COVID restrictions proved challenging, but this will hopefully be less of a factor in the years to come
- Dedicated resources of the Project period
- The suppliers' capability in robotic software and their integration ability for many robot form factors and other software to be used.
- Training and support channels from both the robotic hardware and software providers.
- Industry knowledge from both the robotic hardware and software providers of the selected use case.
    - Industrial inspection in an engine room compared to a logistics operation in the palletization process.

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9.0 Appendices

9.1 Appendix 1

The following pages are the output of the initial Discovery Workshop done to define potential use cases

9.2 Appendix 2

Please find below the links to the following Project Media

General Robot Functions and Testing

DroneDeploy Platform

Engine Room Inspection

Veal Floor Inspection

Cattle Lairage Herding and Navigation

Transporter Robot