AMPC

FINAL REPORT

Container Loading Pilot Installation

Final Report

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1.0 EXECUTIVE SUMMARY

The overall objective of this project is to develop, install and test an automated container loading system for the packing of meat cartons into a refrigerated shipping container. This will be a pilot system, which will run extended trials for development purposes.

A Proof of Concept for Automated Container Loading was developed in project A.TEC.0102. Upon completion of that project and following demonstration there was feedback from industry and a list of risks and issues learnt during the course of project were compiled. There were addressed in this project

It was identified that the majority of Australian meat is exported in cartons and packed in refrigerated shipping containers. This shipping method produces a number of challenges including OH&S and loss of product and an automated solution would be of great value to the Australian Industry.

The packing of cartons into a shipping container shows good potential as an area of investment for the red meat industry. Mechanical equipment has the ability to lift, rotate and place cartons in a set location; this is already carried out by palletizing and de-palletizing systems. There is already a system available in Europe which can load shipping containers. However the system has constraints which prevent use in a meat processing facility. They are:

- The operational speed of the system being too slow for meat processing plants.
- The ability of the system to operate in cold environments.
- The capability of the suction cap when handling wet, slippery and icy cartons.

The main capabilities required of any system to load shipping containers in a red meat processing facility would be as follows:

1. Scan cartons as they enter the shipping container.
2. Reject any product which is out of spec.
3. Port mark the cartons prior to stacking.
4. Hold cartons to load the last for ease of customs checks.
5. Load cartons in any orientation.
6. Allow the container to be loaded to the roof.
7. Photograph every carton or row of stacked product for order of loading proof.

The current system has successfully demonstrated proof of concept. Scott personnel and stakeholders have identified some areas which should be considered in the next phase of this project.

Improvement areas for future concept are:

- A concept that can receive pallets or cartons via a conveyor and convert those to a block of cartons to be moved into container.
- Port marking to be added.

- Cartons to be scanned and proof of load report to be issued.
- Pictures of cartons to be taken for proof of load.
- Rejection stage.
- How to address different size of cartons.
- How to address different sizes in container, variation in dimensions of container.
- A de palletizing and palletizing system and create new known working volume. The new AGV system that could be bigger will handle a new known volume from point A to point B.
- Perhaps new specially pallets to be designed for this operation.
- Using bigger AGV will increase the rate and minimize cycle time.

Figure 1: Placement of an adjacent stack within the containerusing the current Scott Automated Guided Vehicle (AGV)

The figure below is an overview of the current system.

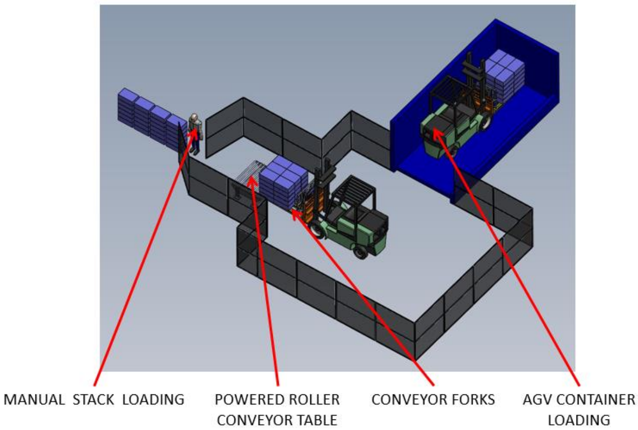


Figure 2: AGV Container Loading System – for site trial

A box stack of up to 6 boxes to a layer and up to 6 layers high (36 boxes in total) is presented to the system on the powered roller conveyor table. The whole stack is then moved to the driverless AGV forklift, which then automatically loads the container with the box stack and then return to the waiting positions. This process is then repeated until the container is full.

Key points to note are the elimination of pallet use and the relatively large stack size (36 boxes) per AGV forklift move. Stability was found to be an issue and the boxes were strapped. A design change has been identified which will increase stability, allow an even greater load per move and reduce cycle time. This will form part of the next phase of the project.

Other improvements include a concept that can receive pallets or cartons via a conveyor and convert those to a block of cartons to be moved into container, this modification to the current concept will also allow different size of cartons to be used,

Whilst ultimately successful and supported by the stakeholders who attended a demonstration at the trial site, this project had numerous challenges. The structure of the milestones were such that the design was constantly challenged and when it became apparent that the original concept proposed was probably not going to deliver the required results, the Scott team were able to use the knowledge gained and re-design the system.

The original design was found to have significant project risks, including:

// Restricted real estate at site.

// Cycle time. The required cycle time was calculated to be achievable, but only just! There would be no room for future improvements due to the limit of three boxes per push.

// Recovery from a fault. If a box falls or is jammed, system recovery would be difficult. There is no personnel access in front of the loader and the IT process for retrieval, bringing out the boxes and deleting/re-scanning would be complicated.

A new concept for automated container loading, was developed specifically to address the risks listed above, minimize the risks associated with the previous concept by use of the Scott Automation and Robotics Automated Guided Vehicle (AGV). This allows a larger stack to be constructed, hence dramatically improving cycle time, and allows easier recovery from fault conditions.

The hardware/software already purchased was still utilized. Some equipment, such as the customized AGV, was supplied to the project from Scott Automation and Robotics stock and returned to Scott Automation and Robotics stock at completion of pilot trials. This allowed the project to be completed within the original budget, while minimizing the risks associated with the design.

Automation of the container loading process has potential benefits in relation to OH&S issues, traceability and quality, and loading efficiency.

2.0 INTRODUCTION

The overall objective of this project is to develop, install and test an automated container loading system for the packing of meat cartons into a refrigerated shipping container. This will be a pilot system, which will run extended trials for development purposes.

Container loading is currently a manual process. Pallets of boxes/cartons are taken as close to the container as possible, ideally they are lifted into the container, where personnel lift the boxes from the pallet and stack within the container. It is anticipated that automation of the current container loading process will realize benefits in the following areas:

- Reduction in OH&S issues
- Improvement in traceability and quality
- Efficiency

The automated container loading system will deliver and stack cartons into standard refrigerated shipping containers. The Scott Automation and Robotics Automated Guided Vehicle (AGV) forms the basis for this automated system. This design will allow a larger stack to be constructed, hence dramatically improving cycle time, and will allow easier recovery from fault conditions compared to the initial non-AGV, conveyor design.

A box stack of up to 6 boxes to a layer and up to 6 layers high (36 boxes in total) shall be presented to the system on the powered roller conveyor table. The whole stack will be moved to the driverless AGV forklift, which will then automatically load the container with the box stack and return to the waiting position. This process will then be repeated.

Key points to note are the elimination of pallet use and the large stack size (36 boxes) per AGV forklift move. If stability is found to be an issue, the boxes may be strapped for the move.

Fencing in above drawing is conceptual. It could be an electronic safety system or nothing at all, depending on the situation at site.

For the site trial, an operator would manually stack boxes onto the roller conveyor table, using a lift assist and scissor lift as required.

3.0 PROJECT OBJECTIVES

The project objectives as specified in the research agreement were:

1. As directed by AMPC, carry out consultation with AMPC and industry representatives to review findings of Proof of Concept trials completed under project ‘A.TEC.0102 ‘MAR Load Out – Automated Container Loading POC’.

2. As directed by AMPC, confirm pilot site for installation.
3. Design and review process based upon learnings and requirements for confirmed pilot site.
4. Design and manufacture pilot automated container load system.
5. Installation of pilot system on-site.
6. Perform extended production trials.
7. Reports and documentation to confirm findings and next step developments.

4.0 PROJECT OUTCOMES

This section describes how the project was conducted, and details the specific project outcomes for each milestone as worded in the research agreement.

4.1 Consult with Industry and Review Previous Proof of Concept Findings

The milestone objective as worded in the research agreement was 'Consult with industry representatives and processing plants to review findings of Proof of Concept trials completed under project A.TEC.0102 'MAR Load Out – Automated Container Loading POC''.

A Proof of Concept for Automated Container Loading was developed in project A.TEC.0102. Upon completion of that project and following demonstration there was feedback from industry and a list of risks and issues learnt during the course of project were compiled. There are to be addressed in this project.

It was identified that the majority of Australian meat is exported in cartons and packed in refrigerated shipping containers. This shipping method produces a number of challenges including OH&S and loss of product and an automated solution would be of great value to the Australian Industry.

4.2 New Concept Automated Guided Vehicle (AGV) container loading system

The milestone objective as worded in the research agreement was 'Presentation of new AGV container load system concept to AMPC for approval'.

In addition to the cost of manufacturing and delivery time being higher and longer than the previously estimated. The original design was found to have project significant risks, including:

- Restricted real estate at site.
- Cycle time. The required cycle time was calculated to be achievable, but only just! There would be no room for future improvements due to the limit of three boxes per push.
- Recovery from a fault. If a box falls or is jammed, system recovery is difficult. There is no personnel access in front of the loader and the IT process for retrieval, bringing out the boxes and deleting/re-scanning is complicated.

This milestone presented a new concept for automated container loading, developed specifically to address the risks listed above. This new concept will minimize the risks associated with the previous concept by use of the Scott Automation and Robotics Automated Guided Vehicle (AGV). This will allow a larger stack to be constructed, hence dramatically improving cycle time, and will allow easier recovery from fault conditions.

The hardware/software already purchased will still be utilized. Some equipment, such as a customized AGV, will be supplied to the project from Scott Automation and Robotics stock and returned to Scott Automation and Robotics stock at completion of pilot trials. This will allow the project to be completed within the original budget, while minimizing the risks associated with the design.

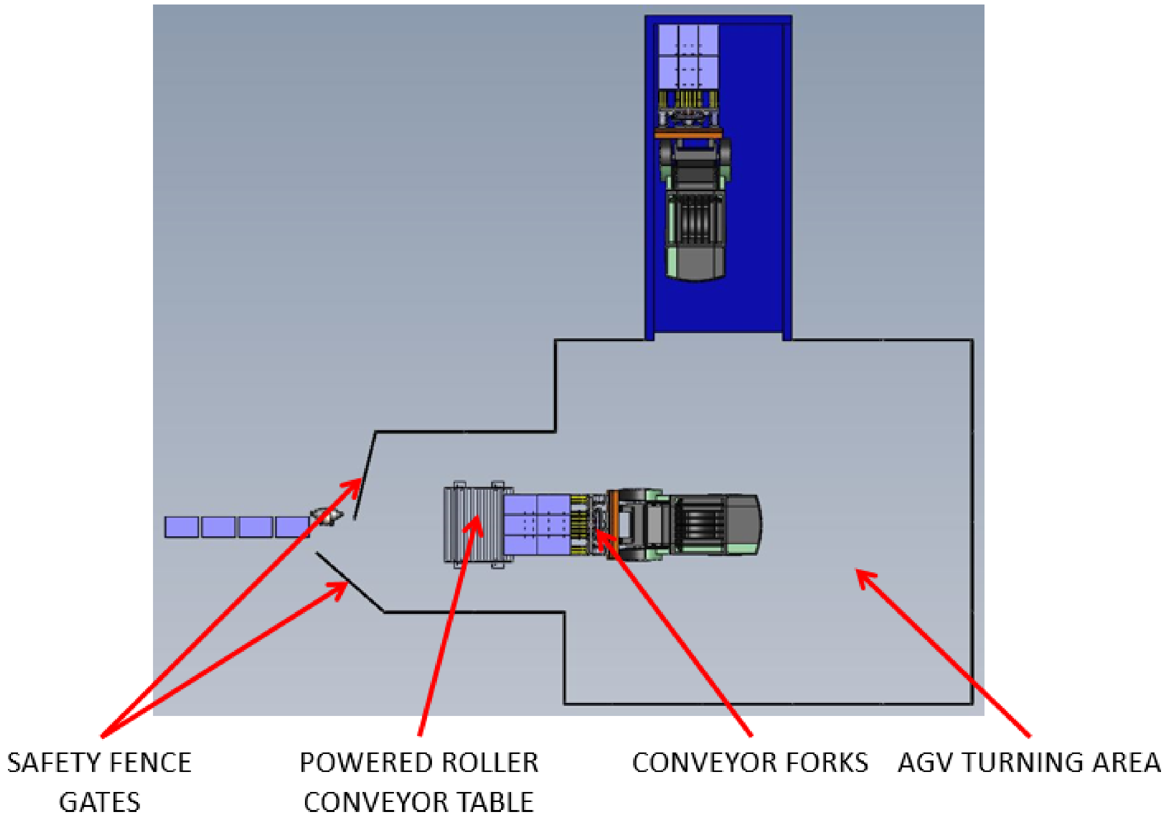


Figure 3: View from above of Trial AGV Container Loading – Manual stacking

4.3 Future Automated Guided Vehicle (AGV) Container Loading Concept

In the future, the system would be added to in order to fully integrate it into a warehouse and loading dock environment. This would include port marking, barcode scanning and stack creation prior to the transfer of boxes onto the AGV tynes.

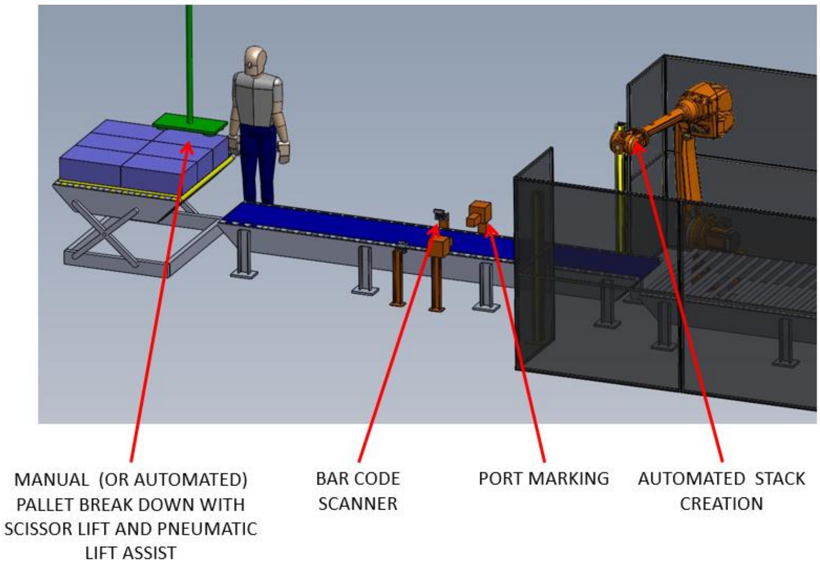


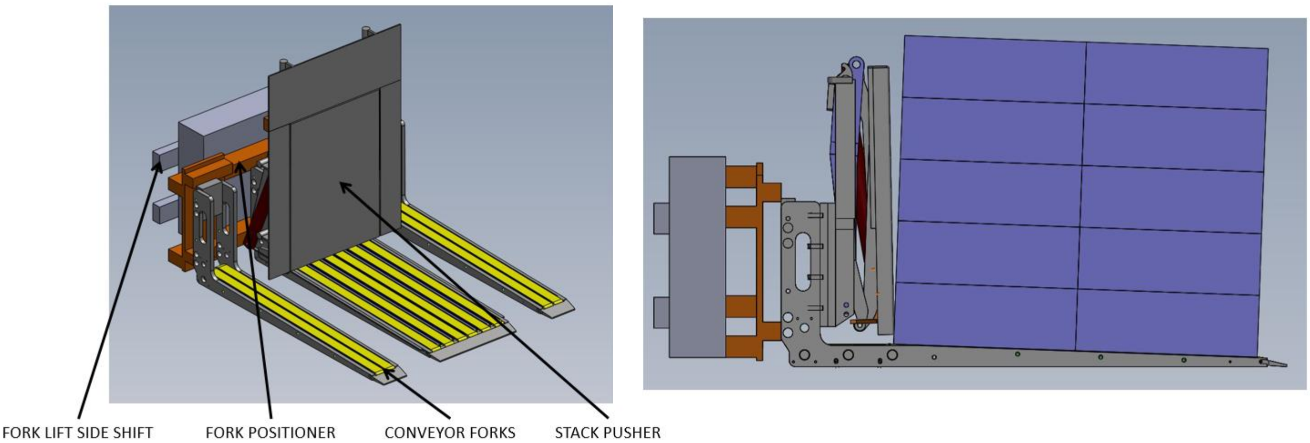
Figure 4: Next Concept for Automated Container Loading System

5.0 SYSTEM DESIGN AND CONSTRUCTION

The milestone objective as worded in the research agreement was 'Completion of design stage for mechanical, electrical, vison guidance system of new AGV container load system. Configure AGV container load system including vehicle and all mechanical parts like AGV tines belt, AGV gripper, ramping, side shifting and electrical, control, vision, guidance software preparation, integration of complete system, all testing required and readiness for internal trials at Scott premises in Silverwater'.

5.1 Mechanical and Electrical Design and Completion

The AGV front end had to be mechanically designed in order to allow for the ability of the AGV to load boxes onto its tynes, and then unload the boxes into a container. The design can be seen in the figure below.



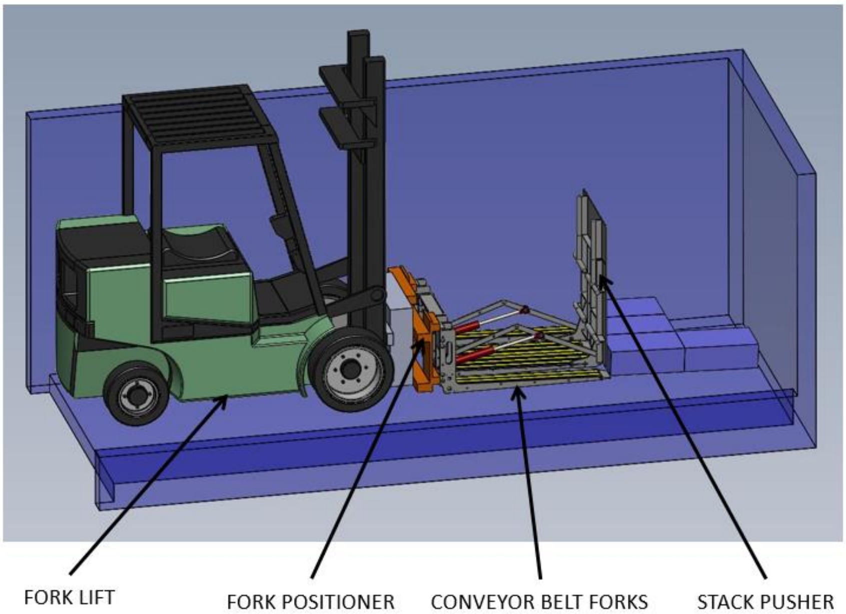


Figure 5: Automated Container Loader Concept –With Stack Pusher

The front end of the AGV is comprised of three independently moving conveyor tynes and a pusher plate on top of a typical forklift carriage containing the functionality of mast height, side shift and tilt angle control. The front end, after the conceptualisation and design was built and completed before initial trials at Scott.

Figure 6: Automated Container Loader Concept –With Stack Pusher Completed

In addition to this, the electrical control cabinet containing the AGV Management System and the controls for the conveyor, along with the conveyor were procured, built and installed for internal trials.

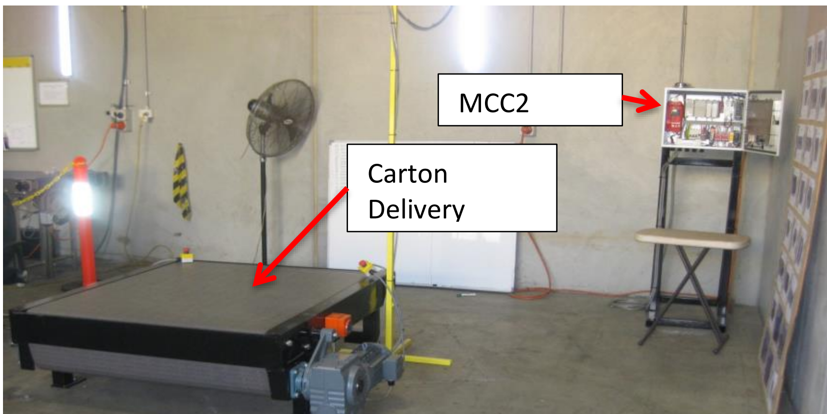


Figure 7: Automated Container Loader Conveyor and Control Cabinet

Finally to complete the mechanical installation, all required sensors were added to the AGV and a container was procured to allow for testing.

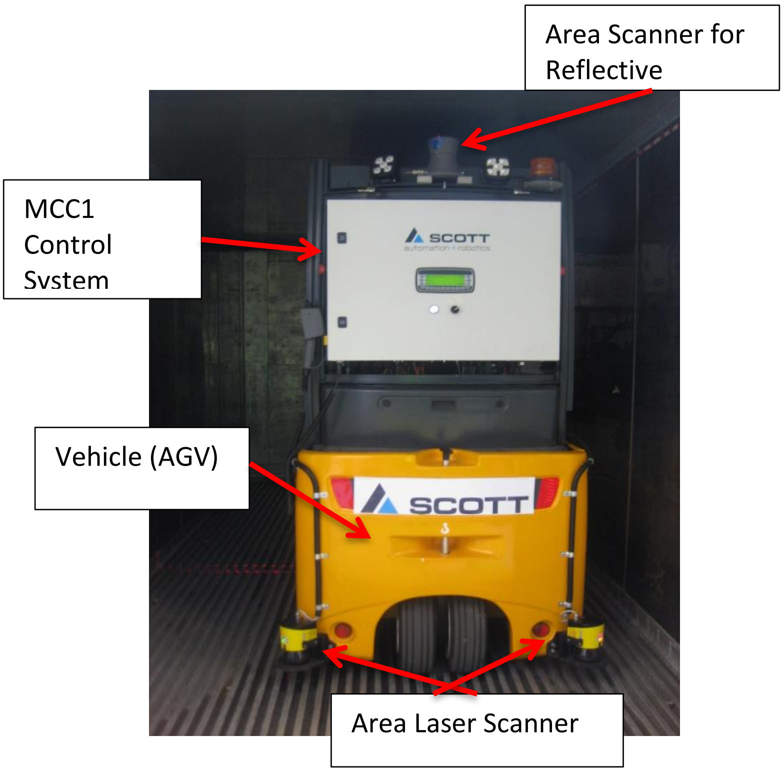


Figure 8: Automated Container Loader Navigation Sensors and Control Cabinet

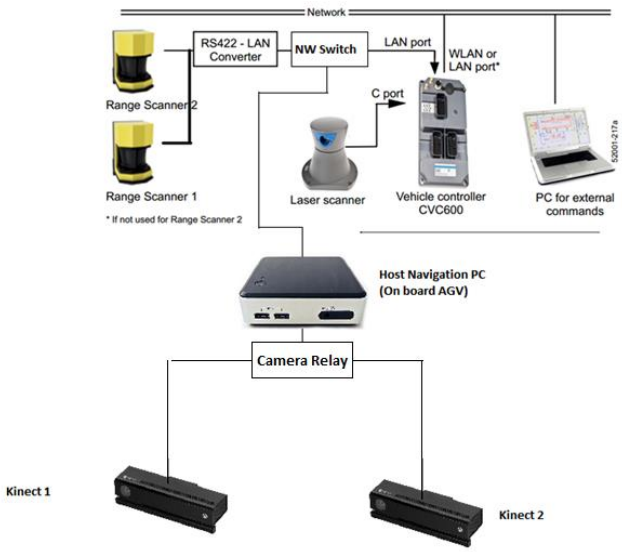


Figure 9: AGV Control Cabinet Hardware Architecture

5.2 Process Design and Implementation

The following steps depict the container loading process, in terms of what was designed and then implemented.

Navigation Procedure - New Container Procedure

Setup

1. Create the container walls with the layout design tool where the estimated trailer position will be.

2. Create the path into the container as two external flexible segments
3. Setup the Nav PC to talk to the NMC over Ethernet

Running System

1. A new container arrives
2. PLC triggers a new container over OPC to System Manager
3. When the vehicle reaches the outside container it scans where the actual container walls are located. This is achieved by using the rear facing, waist height S300 scanner.

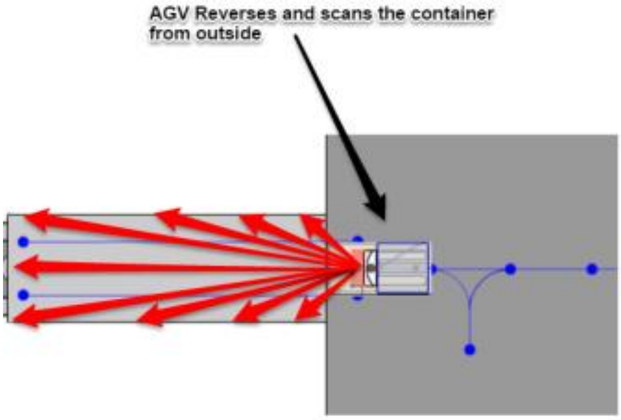


Figure 10 - Initial Container Scan

4. The scanned walls are used together with the walls in the layout map to update the path.
5. The calculated path is used by all vehicles that will load the container.
6. Vehicle will fill the container with the goods from the infeed conveyor.
7. When the vehicle navigates in the container, it uses the range sensors together with the map. This means that no other navigation types are used at this point.

Initial Container Scan Interface

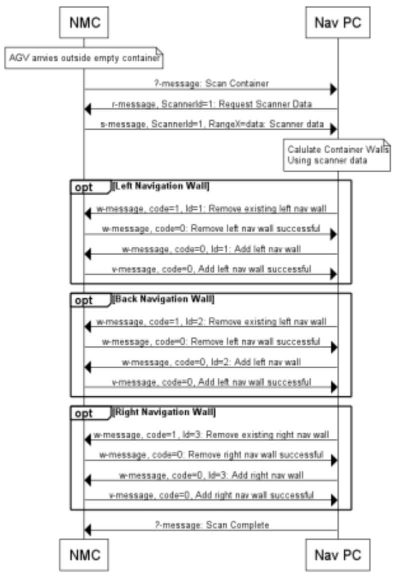


Figure 11 - New Container Scan Sequence Diagram

Enter Container Procedure

1. AGV approaches the external flexible segment of the container.
2. The Nav PC updates the segment spline into the container based on the initial container scan.
3. The AGV continues to the "Unload Procedure"

Unload Procedure

1. AGV enters the container along a flexible segment and uses the warning field of the S300 to detect the boxes.

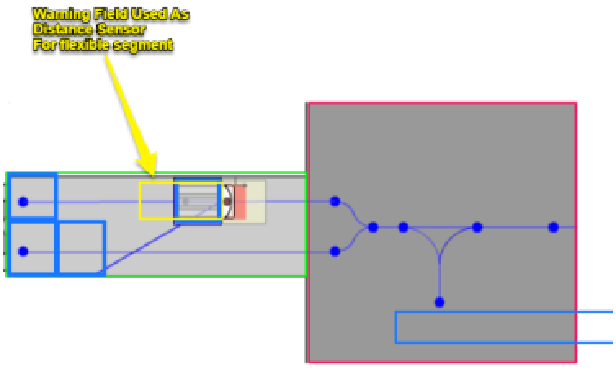


Figure 12 - AGV Enters Container

2. The warning field on the front scanner trips which stops the flexible segment.

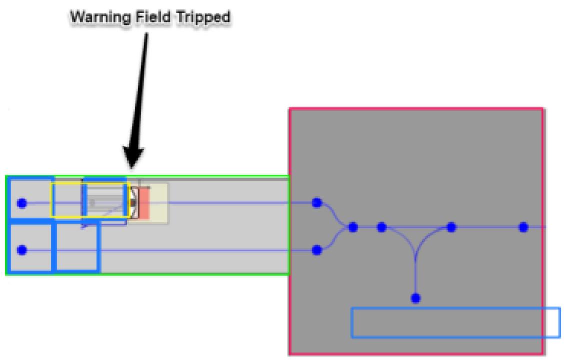


Figure 13 - AGV Senses Boxes

3. The Kinect cameras scan the boxes and set the height of the unload position as well as the side shift position. The cameras also detect if any boxes have fallen or are misaligned.

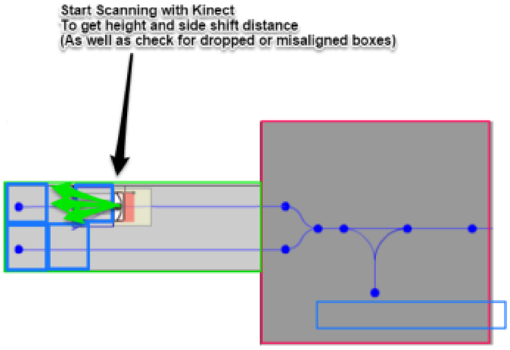


Figure 14 - Kinect 3D cameras scan boxes for unload position

4. The AGV unloads the boxes and continues to the "Exit Procedure".

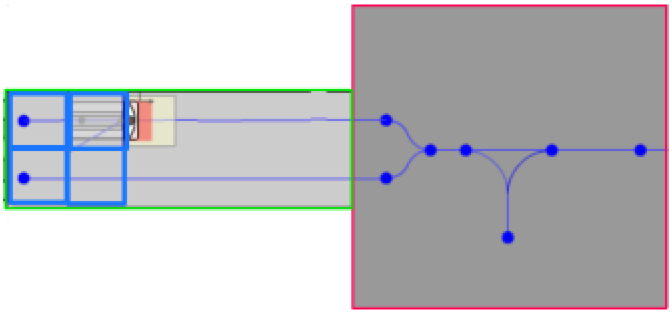


Figure 15 - AGV unloads boxes

Exit procedure

5. The Nav PC updates the reverse segment spline into the container based on the initial container scan.
6. The AGV exits the container on the new external reverse segment.

6.0 FACTORY ACCEPTANCE TESTING

Once the system was designed, built and implemented, Factory Acceptance Testing at Scott was carried out. This was done in order to ensure the most success when the system was taken to site. FAT was carried out over the course of a few days, and the images below depict a cycle of normal operation.

Figure 16 - AGV FAT Cycle

7.0 INSTALLATION AND COMMISIONING AT PRODUCTION TRIAL SITE

The milestone objective as worded in the research agreement was 'Installation and commissioning of AGV container load pilot system on-site. Go/No Go decision point'.

This milestone includes the commissioning and installation schedule, tasks undertaken, results and key learnings from on-site commissioning.

The loading bay and stacking requirements were reviewed, and observations such as the lateral gap between the ramp and container doors and significantly bulging boxes were noted.

The scanner was calibrated and the conveyor table pick-up location was programmed. Reflectors were installed throughout the loading docks. The system was configured and reflector surveys carried out. Parts of the code were optimized, algorithms tuned, muting zones created and numerous scans and container loading dry runs performed.

A video showing movement into and out of the container using the vision guidance system was issued to AMPC along with the Milestone report.

The following sections detail the work undertaken in installing and commissioning the AGV container loading system at the Kilcoy site.

navigation. The container scan routine was tested and adjusted for the 40ft container length.

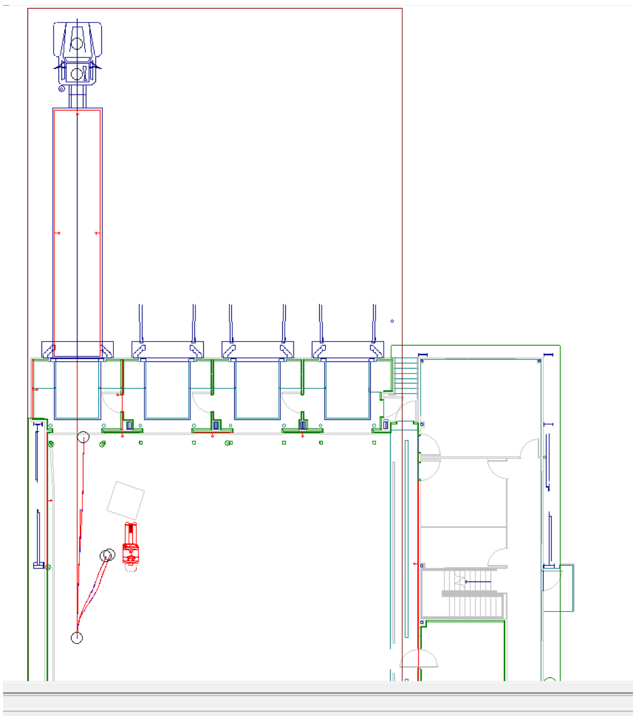


Figure 17: Layout Configuration for use with loading dock 4

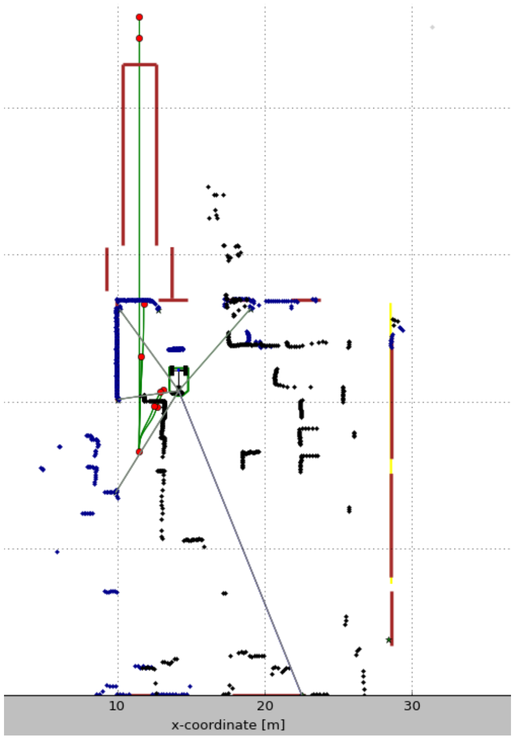


Figure 18: Initial scan of loading dock 4

7.1 Reflector Installation

For the ability of the AGV to navigate on the loading dock, the reflectors had to be installed around the loading dock. The installation positions can be seen in the figure below.

Figure 19: Location of reflectors thoughout the loading docks

7.2 Conveyor and MCC Installation

After the installation of the reflectors, the conveyor and electrical control cabinet were installed and commissioned for the use with the Container Loading System.

Figure 20: Location of Installation of Conveyor and Control Cabinet

The laser reflector positons were configured and surveyed. A number of bugs in the layout code were resolved and the reflector positions were resurveyed. The resulting accuracy was significantly improved. The container scan code was tested, and although working, was not sufficiently accurate.

A full day access to a container allowed testing of the container scan accuracy and container navigation accuracy. The scanner muting zones were tuned and the algorithm for the container scan was further tuned. We were able to perform dry runs into the container and check accuracy.

The next step was loading the container. Kilcoy management hired help to stack loads. The aim was to load one full 40ft container, making adjustments as we go.

8.0 EXTENDED PRODUCTION TRIALS

The milestone objective as worded in the research agreement was 'Completion of extended production trials at participating site (expected duration 3-4 weeks). Operational personnel as well as cartons and pallets to be provided by participating site for trials'.

This milestone details the extended production trials at the participating site. Stakeholders were invited to the site for a demonstration of the system and discussion regarding the next steps. The stakeholders included AMPC and processors who during the initial milestones expressed an interest in applying the technology at their facilities and were keen to host the trial.

The system design was presented, including the automatic guidance system and how the concept operates, before a trial of the current AGV system was observed. The next project concept was presented and a Q&A session held. The demonstration and presentation were successful and following the meeting to discuss pros/cons of current concept and future concept, both the Kilcoy and Oakey were supportive of next steps to move forward.

Automation of the container loading process has potential benefits in relation to OH&S issues, traceability and quality, and loading efficiency.

The following section details the extended production trial of the AGV container loading system at the Kilcoy site.

The following photographs show the Kilcoy loading bay, and the operating area within which the trial was performed. With Dock 4 chosen as the trial area, reflectors were installed and the AGV path programmed.

Figure 21: From the starting position the AGV approaches the stack

Figure 22: The AGV lowers the tynes to the height of the powered conveyor table

Figure 23: The powered conveyor table operates moving the stack onto the AGV tynes

Figure 24: The AGV simultaneously raises the stack and reverses

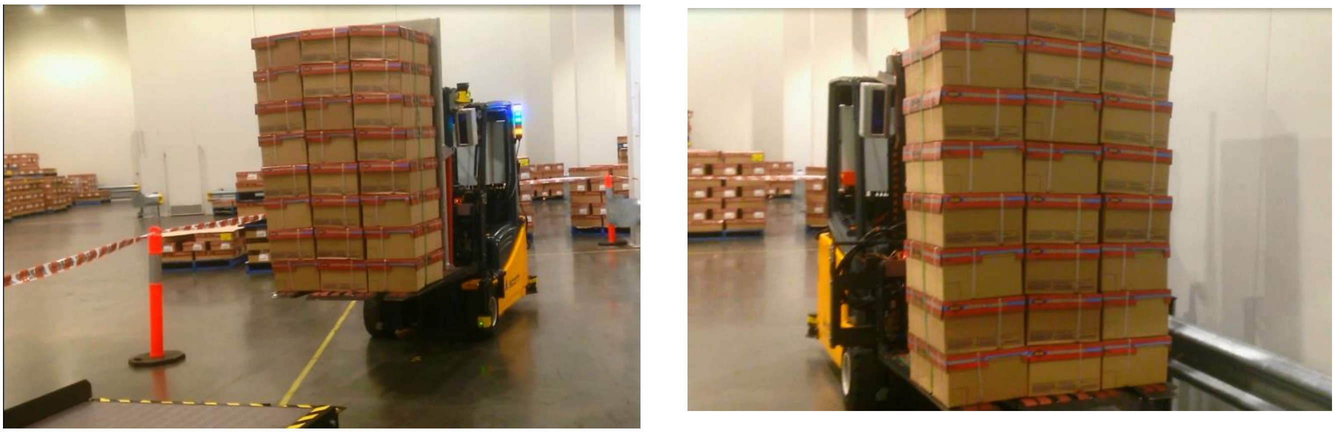


Figure 25: The AGV reverses and lowers the stack before moving towards the designated container

Figure 26: The AGV enters the container and positions the stack, sideshifting to place adjacent to container wall

During the course of install and commissioning, trailing at site, Scott team continuously assessed different elements of system. The loading bay and stacking requirements were reviewed, and observations such as the lateral gap between the ramp and container doors and significantly bulging boxes were noted.

The scanner was calibrated and the conveyor table pick-up location was programmed. Reflectors were installed throughout the loading docks. The system was configured and reflector surveys carried out. Parts of the code were optimized, algorithms tuned, muting zones created and numerous scans and container loading dry runs performed.

At the end of production trials it was shown that:

- Navigation inside and outside of the container was very consistent and reliable
- Lateral and longitudinal positioning inside the container was very repeatable

It was noted that sagging of the stack occurred when loaded onto the AGV forklift tines, with one conveyor tine sagging more than the other two and creating a tilt to the boxes. This sagging improved when the stack is strapped. Kilcoy was happy to strap the carton stacks after observing the unstrapped stacking issues.

Also, one of the center tine belts snapped when unloading, most likely caused by repeated stress, this is something that we will need to monitor going forward.

Figure 27: Within the container the AGV approaches the existing stacks

Figure 28: The AGV side shifts to position the stack close to the container wall to spacer insert

Figure 29: AGV approaches existing stack within container. Stack is side shifted, lowered and placed up against the existing stack

Figure 30: AGV tynes are retracted, pusher plate keeps stack in place, before AGV reverses

Trials at site completed with strapping column of cartons with plastic strap to secure and create stability on stack, although this will bring stability but downside is introduction of extra packaging materials and cost and perhaps extra labour at the other end when container is unloaded.


Figure 31: The AGV reversing out of the container, with pusher plate still in the extend position


Figure 32: As the AGV returns to the home position the tynes and pusher plate reset into the start position

Figure 33: The AGV returning to the container to position the adjacent stack

Figure 34: Placement of an adjacent stack within the container

9.0 CONCLUSIONS/ RECOMMENDATIONS

The main capabilities required of any system to load shipping containers in a red meat processing facility would be as follows:

8. Scan cartons as they enter the shipping container.
9. Reject any product which is out of spec.
10. Port mark the cartons prior to stacking.
11. Hold cartons to load the last for ease of customs checks.
12. Load cartons in any orientation.
13. Allow the container to be loaded to the roof.
14. Photograph every carton or row of stacked product for order of loading proof.

Improvement areas for future concept are:

- A concept that can receive pallets or cartons via a conveyor and convert those to a block of cartons to be moved into container
- Port marking to be added
- Cartons to be scanned and proof of load report to be issued.
- Pictures of cartons to be taken for proof of load
- Rejection stage
- How to address different size of cartons
- How to address different sizes in container, variation in dimensions of container
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- Perhaps new specially pallets to be designed for this operation.
- Using bigger AGV will increase the rate and minimize cycle time.