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Automated Container loading Proof of Concept

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Abstract

The majority of Australian meat is exported in cartons and packed in refrigerated shipping containers. This shipping method produces a number of challenges including:

- Product loss and rejection due to carton damage
- OH&S issues resulting from manual handling cartons
- Proof of load and traceability issues.
- Cost and efficiencies of manual loading vs. an automated solution.

The objectives of this project were to

- Design a proof of concept Automated Container Loading System to overcome these issues and produce 2D and 3D concepts for industry discussion.
- Manufacture and integrate this concept design for trials at MAR.
- Perform container loading POC trials at MAR facility for industry viewing and discussion.

Trials of the POC system were conducted at MAR's workshop in March 2014 and feedback from those in attendance highlighted areas where improvements can be made. MAR believe these improvements can be achieved in the next phase of development.

Executive Summary

The majority of Australian meat is exported in cartons and packed in refrigerated shipping containers. This shipping method produces a number of challenges including:

- Product loss and rejection due to carton damage.
- OH&S issues resulting from manual handling cartons.
- Proof of load and traceability issues.
- Cost and efficiencies of manual loading vs. an automated solution.

The objectives of this project are to

- Design a proof of concept Automated Container Loading System to overcome these issues and produce 2D and 3D concepts for industry discussion.
- Manufacture and integrate this concept design for trials at MAR
- Perform container loading POC trials at MAR facility for industry viewing and discussion

MAR have consulted and made site visits as part of this project to the following processors:

- Kilcoy pastoral Company
- JBS Beef City
- Oakey Abattoir
- Teys Bros Beenleigh
- John Dee

With the feedback and information gathered from these processors MAR has developed a Proof of Concept automated container loading system that is able to load cartons into a container in a comparable time to that achieved by 2 - 3 units of labour. This proof of concept system was demonstrated to Industry representatives in May 2014 and following feedback from the representatives MAR can see a need to develop the system further to:

- Reduce the real estate needed for the system
- Improve the ability of the recover from fault situations
- Improve the ability of the system to deal with inconsistency in carton dimensions due to bulge
- Further use of active vision to maintain accurate positioning of system within the container
- Modifications need to be made to the gripper design to allow it to be more flexible, with possible use of a multiple box pick up gripper

- Review of the options with regards to dunnage/packing of cartons.

MAR proposes resolving these in the next stage of development in the following ways:

- Use of a more compact buggy/vehicle and a single robot to reduce the footprint.

- Further use of active vision and addition of more sensing to:

    - allow accurate positioning of the vehicle in the container
    - ‘live’ assessment of the stacks to overcome issue with bulging cartons
    - For proof of load purposes

- Modifications to gripper to allow picking of multiple cartons and the inclusion of a carton stacker to allow this to take place.

- Possibilities remain for:

    - Use of foam dunnage
    - Use of air bag dunnage
    - No dunnage
    - Application of glue to the outside of the cartons to provide stability when stacked

  Further trials are required to determine the best solution for and automated system.

- Port marking of cartons as they enter the system.

Contents

1 Background

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.
Although some semi-automated or load assistance devices exist for container packing of frozen cartons, there is a need to develop alternative solutions especially where chilled meat cartons are being packed in containers for shipping.
The purpose of this project is for MAR to study the problem in detail, working with processors, to develop an automated container loading solution. It is intended that this be for chilled cartons and be developed as a proof of concept with trials and a demonstration at MAR which would enable the next stage of development via processor plant implementation of a fully Automated Container Loading System potentially as a PIP project to proceed.
The project is based upon a concept solution utilising automated guided vehicles "AGV's" and robotics, however early stage design reviews, examination of existing and other possible methods best suited to produce an outcome may influence the current thinking and produce a solution utilising other concepts.

An automated container loading solution would address the following issues faced by processors exporting red meat cartons:

- Product loss and rejection due to carton damage
- OH&S issues resulting from manual handling cartons
- Proof of load and traceability of loaded carton products
- Cost and efficiencies manual loading vs. an automated solution.

The current AGV/Robot concept in principle:

- Cartons are conveyed via traversable conveyor fixed to an AGV system
- All barcodes on cartons will be scanned for tractability and confirmation
- All cartons will be 3D profiled to detect carton bulge
- Cartons will be unloaded from conveyor via robot mounted on AGV and stacked in container in required stacking pattern
- AGV, Robot and conveyor traverses in and out of container as required
- Cycle repeats until container is full.

Some Challenges to be addressed within project are;

- Identifying correct concept to produce and suitable automated container loading system
- Integrating a suitable automated system combination that has the capability to meet all requirements
- Physical restrictions (concept design vs container and space available in plants)
- Automated system transition from dock to container (eg. floor levels)
- Variations in stacking patterns and methods including packing materials used to avoid carton movement during shipping

2 Project Objectives

The project will provide the following outputs/outcomes:

- Progress reports upon completion of each milestone to detail work to date and any findings
- Progress reports for any Go/No Go decision points identified and agreed with AMPC during the project
- Produce 2D & 3D automated container loading concept designs for discussion and industry input
- Integration and manufacture of an automated container loading concept for trials at MAR
- Perform container loading POC trials at MAR facility for industry viewing and discussion
- Power Point presentation and videos summarising the project and key outcomes
- A comprehensive final report (following approval of a draft by AMPC and MLA) detailing all aspects of the research conducted (methodology, data, analysis and conclusions);

3 Methodology

The above objectives will be achieved by completing the following Milestones:

Milestone 1. **<u>Industry Consultation</u>**

- Consult with industry representatives and processing plants to identify and confirm container loading challenges, system requirements and specifications to include current and expected container loading rates, dimensions, carton loading patterns, etc.
- Consult with MAR international client, supplier and solution provider networks to identify and examine existing technologies that may influence the project concept and outcome.
- Host and attend meetings and site visits where required to obtain information for developing automated container loading concept
- Identify potential industry cost benefits (OH&S, Labour, Quality, Loss, Yield, etc.)
- Produce Milestone report that identifies findings outlining challenges, requirements and possible concept solutions

Milestone 2. **<u>Concept Design & Reviews</u>**

- Produce 2D and 3D automated container loading concept designs for review
- Produce potential cost benefit and payback scenarios based upon estimated equipment costs and findings from milestone 1.
- Industry consultation to obtain feedback on design concepts and options produced by MAR as potential solutions
- Produce Milestone report that identifies preferred solution and reasoning to progress development

Milestone 3. **<u>Project Progress Reviews & Go/No Go Decision</u>**

- Present to AMPC and MLA findings from related project "MAR / MLA partnership project "P.PSH.0634" Mobile robots on AGV's" "dependent upon preferred concept solution identified in milestone 2 this may not have any influence on project"
- Host and attend meetings with AMPC, MLA and industry representatives where necessary to present findings to date and discuss path to completion of project.
- Produce progress report for Go/No Go decision with AMPC

Go/No Go Decision

Milestone 4. **<u>Design build & test automated container loading system</u>**

- Finalise design for automated container loading concept. (POC design)
- Procurement of components and materials to perform POC trials at MAR
- Manufacture and assembly auto container loading to concept design
- Test and debug auto container loading components in preparation for POC trials
- Produce Milestone report that identifies progress to date and details schedules for trials and industry demonstrations

Milestone 5. <u>Perform POC trials at MAR</u>

- Setup auto container loading at MAR to simulate production conditions
- Perform operational trials, testing and debugging of auto container loading in preparation for industry demonstrations
- Produce Milestone report that identifies progress to date and details schedules for industry demonstrations

Milestone 6. <u>Demonstrate working concept to industry</u>

- Power Point presentation summarising the project and key outcomes
- Present automated potential container loading design options for installation in plants
- Produce potential cost benefit and payback scenarios based upon estimated equipment costs and findings to date
- Perform operational demonstrations of auto container loading system at MAR

Milestone 7. <u>Detailed Project Report & Videos</u>

- Power Point presentation and videos summarising the project and key outcomes

Produce a comprehensive final report (following approval of a draft by AMPC and MLA) detailing all aspects of the research conducted (methodology, data, analysis and conclusions)

4 Results – Milestone 1

As a starting point and to get feedback/ involvement from processors a survey was sent to the following processors:

- JBS Beef City
- Oakey abattoir
- Kilcoy Pastoral Company
- Teys Bros Beenleigh

Responses were received from three of these processors and their responses are documented in the table below.

Information Requested	JBS Beef City	Oakey	Kilcoy
How many labour units are used to load containers: • Number used for Scanning/Marking • Number used for loading • Number used for Forklift • Number used for other activities	3 – 4 per shift 1 for frozen 3 for chilled 4 9 people to stack down chilled and frozen cartons	2 2 1 4	1 2 1
How many shifts are run loading containers?	2	2	2 x 7days
What size containers are filled 20Ft / 40Ft / Both?	Both	Both	Both 90% 40ft
How long does it take to fill a • 20Ft container • 40Ftcontainer	1hr 1hr 30min	30 – 60 min 60 – 90 min	50min 90min
How many containers are loaded per day?	Five 40ft and one 2ft max per shift	15 - 20	12
How many loading docks does your load out area have?	3	4	3
What size are your cartons?	Chilled: 585 L x 345 W x 135 / 185 / 210 H Frozen: 540 L x 360 W x 160 H Frozen Offal : 540 L x 345 W x 115 H Frozen Offal : 410 L x 270 W x 115 H	Chilled 9” 515 x 370 x 220 Chilled 6” 515 x 370 x 150 Chilled 4” 340 x 360 x 100 Frozen 6” 540 x 365 x 150 Frozen 540 x 360 x 100	

What is the maximum weight of your filled cartons?	35 kilos	30kg	30kg
Do different sized cartons get loaded into the same container?	Yes	Yes	Yes

What Stacking patterns do you use?
• Column/interlocked
• How many cartons high and how many cartons wide do you stack
• Is there space left above the cartons in the container when fully stacked? If so how much?
• How many cartons do you load into
  ○ A 40Ft container
  ○ A 20Ft container
  ○
	Frozen cartons 6 in a row, chilled 5 in a row (3 wide and 2 long), frozen 13 cartons high,
	Chilled 12 cartons (mixed) high.
	20 to 30 mm space left above cartons at times
	
	Average
	1300 ctns chilled, 1000 ctns frozen
	750 chilled & 750 frozen
		Column and interlocked
		14 high , 6 wide
		
		50mm left above cartons in container
		
		840 in a 20 Ft container
		1200 – 1400 in a 40ft container
			Both
			
			Variable
			
			Yes
			
			40ft – 1170 up to 4800
			20ft 500 up to 2400

Do you use dunnage? If so what is it? And where do you use it? Could you provide a plan view sketch of the container to show dunnage location?	Yes, Polystyrene strips. Photos attached	Yes Foam sticks at end of container	Yes only on US loads
Are there any issues relating to Traceability of cartons (eg identifying what cartons are loaded in each container shipped?	No	No	Yes
What is the available footprint of your loading dock area ie how many meters by how many meters. Could you supply a CAD drawing of	Photos		

the area including all obstacles if possible?			
What is the ceiling height in the load out area?	6300mm	5500mm	
How are cartons currently delivered to the load out area (eg, pallet and forklift/ conveyor)?	Pallet and forklift	On pallets on forklift By conveyor	By pallet using electric forklift
What is the estimate % of cartons that are damaged during the process of container loading?	Nil	Less than 1 %	Less than 1%
Could you please supply images the following: • Loading dock area • Loading patterns • All Cartons used			
Are there any other comments/points you wish to make that you feel would assist us?			

Following the responses to this survey site visits were conducted and the following is a summary of the further information gathered and images obtained.

Teys Bros
Met with: John Coughlan and John Lewis

- 5 docks all being used for loading of frozen product, higher demand for frozen product at this point in time, 1 dock for Pantech's - domestic only
- The two docks that were usually used for chilled product are at a different level to frozen product docks.
- All docks
- All frozen docks being loaded at once.
- All chilled docks are loaded at once depending on staff and demand.
- Barcodes on chilled need to be facing out.
- Frozen pallets delivered on pallet un-shrink wrapped, Port marked then re-shrink wrapped before being loaded into the container.
- Cartons packed the way they are for stability
- Damaged cartons need to be repacked
- Entry dimensions to suit container entrance dimensions

No photography permitted

Beef City
Met with: Justin McCormick, Clinton Gascone, Ray

- Stacking pattern due to stability
- Do pack to roof of containers, sometimes above line, 70mm from roof, line 200 mm from roof, container we saw packed to 270mm from roof
- Stack carton size as it comes will be mixed (photo)
- Fork lift pallet to to container entrance, then pallet jack into container to unload, unloaded with 2 guys
- 3 docks, 2x chilled , 1 x frozen, pack all at once when needed, 60- 70 % chilled
- Ribbed floor in container for air flow
- Foam strips used as dunnage, open to idea of pre-sticking foam to side of container, could be difficult due to damp wall, could wedge up against roof if longer?
- Hydraulic ramp adjusts to height of container
- Entry size see notebook, 2403 wide, 2630 high
- Barcodes visible at ends
- Auto Port marking would be a big advantage, 6 – 10 degrees c
- Chilled Carton bulge not really a problem
- Code 128 barcodes used
- Stack height determined by number in order

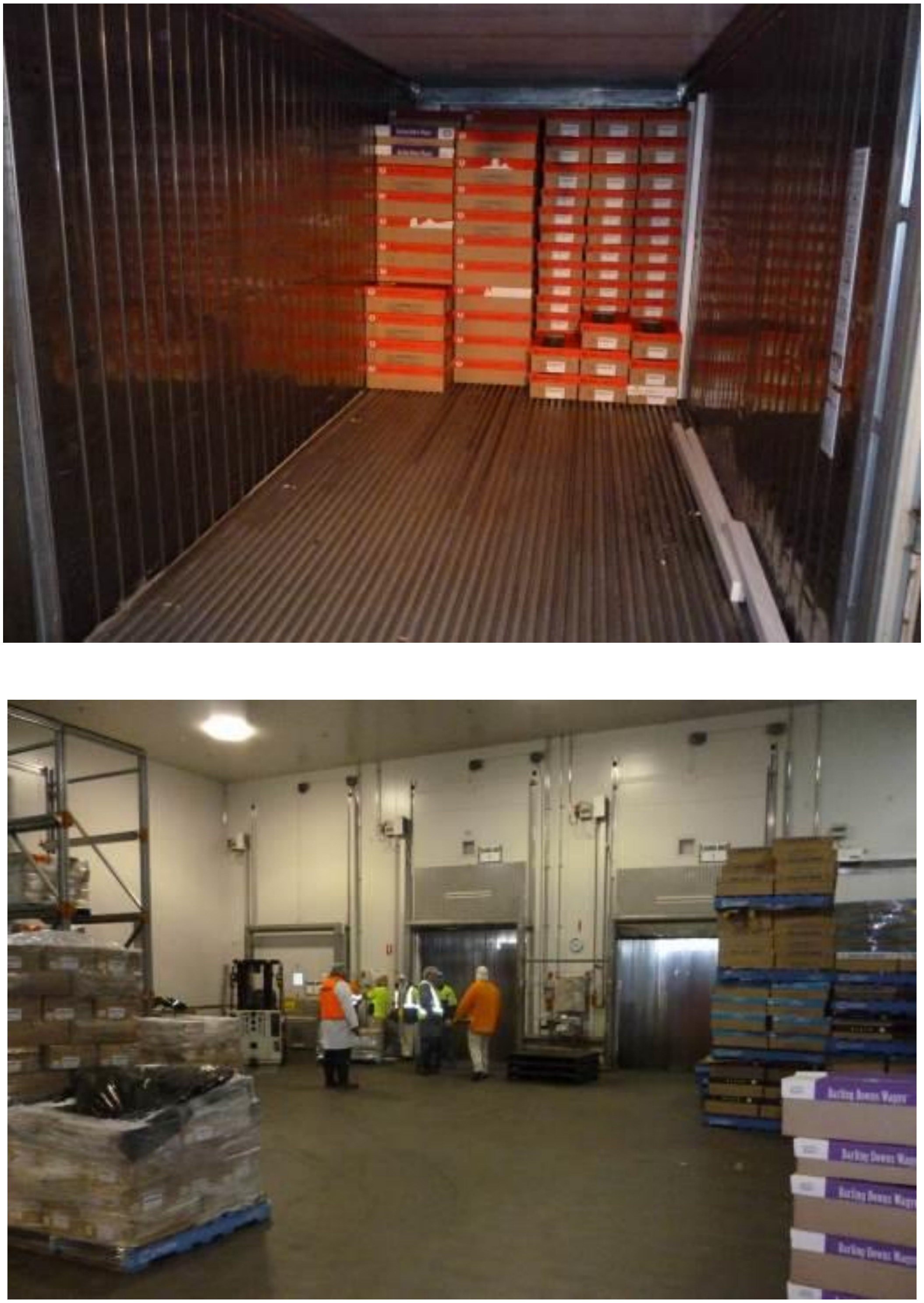


Fig. 1 Load out area at JBS Beef City

Oakey
Met with: Pat Gleeson

Container loading

- Current form enough space
- 2 off 4 loadouts already serviced by OH conveyor, loaded from a whole order coming from palletising area. Vision is to separate loadout building to be all frozen and the area below the hayloft to be all chilled to minimise up to triple handling, like the idea of circular loop around load out area with chilled cartons to supply conveyors down to containers.

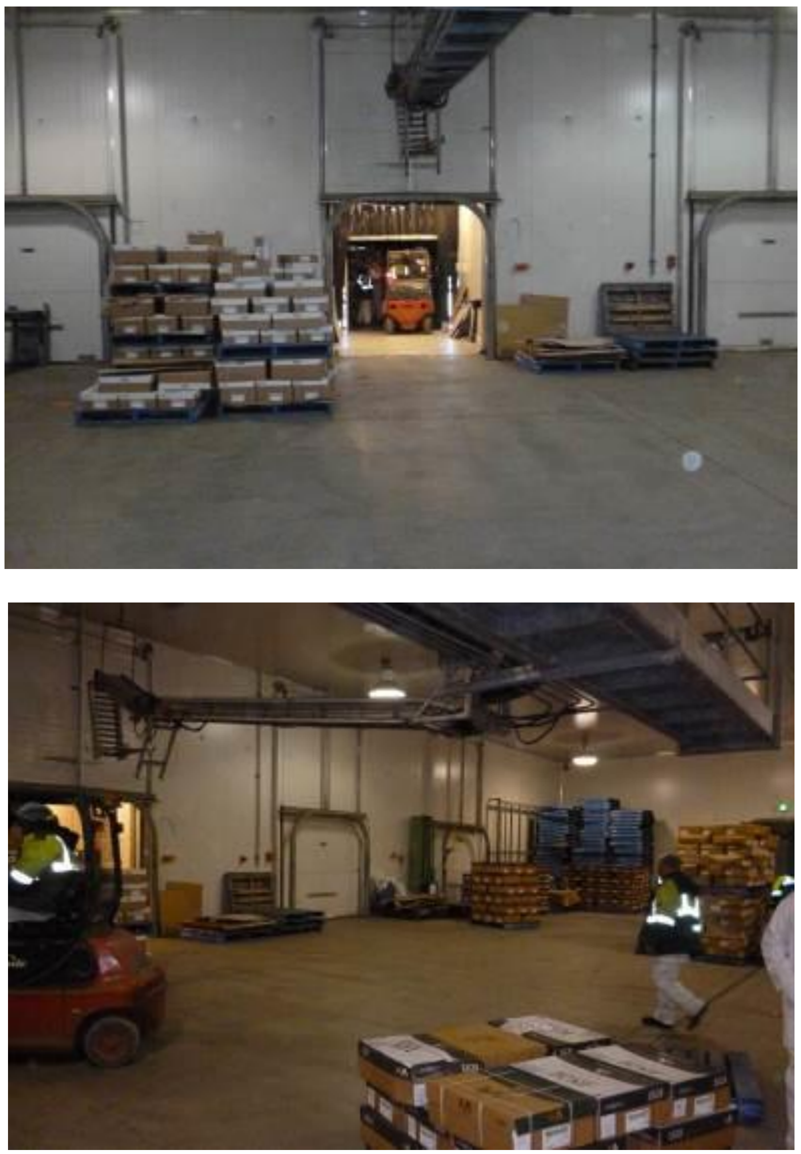


Fig. 2 Load out area at Oakey

Kilcoy

Met with: Shane Clancy, Ian Woods

- New area to be built, would all be conveyor fed
- 3 docks, 2 leveliing, one used for vans
- Generally load frozen during day and chilled at night due to cycle of IBEC
- Head space in container a concern
- Stacked interlocked for stability, however customers specify that they don't want codes mixed and customs require one carton of each code at the doors of the container for inspection
- The cartons need to be scanned, port marked and a secondary label placed on some orders
- Some chilled loads are required to be all column stacked with labels facing doors
- Suggestion that possibly a full row be stacked to full height then then whole row pushed into position (? Not really practical ?)
- Possible trial area at back of existing loading docks

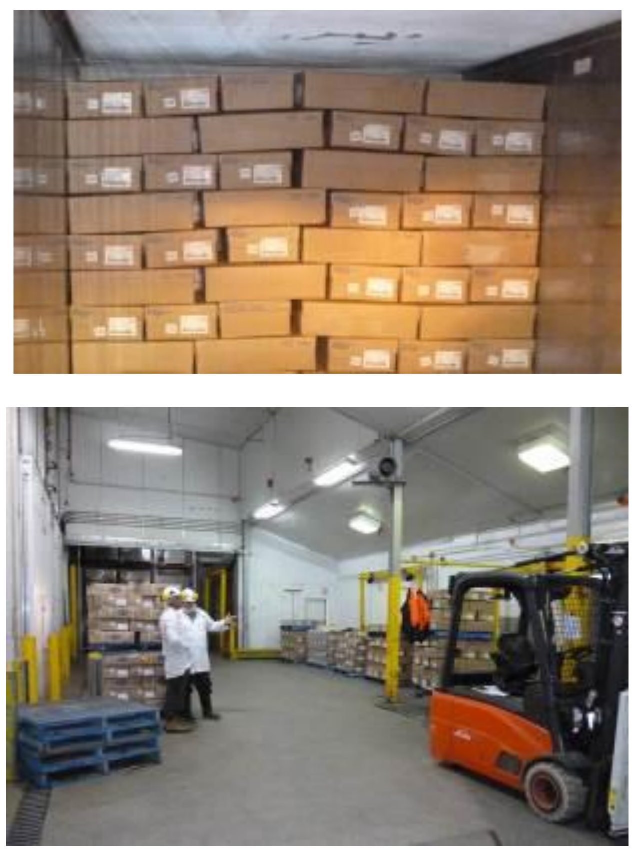


Fig. 3 Load out area at Kilcoy

With the above data and comments in mind the table below summarises potential cost savings that could be achieved by developing an automated container loading system.

Benefits	Detail	Est. Saving/Year
Labour	4 x labourers & 2 x scanners per shift, (x 2 shift operations)	$600,000
OH&S	Hard to quantify but on history manual container loading injuries costs above, but could be substantial if a long term injury accrued	$20,000
Improved efficiencies	Could be substantial if eventual developed container loading system can operate at higher than 10/min rates.	?
Traceability	Traceability is a major selling point, removing the human component from the final point of loading the container is a huge plus not only pertaining to cartons loaded as per customer order criteria but also knowing exactly where each carton is placed in the container would be helpful.	$50,000
Quality	For Manual Loading on average 4-8 cartons per container load require reworking due to carton damage.	$10,000

MAR consulted with our client, supplier and solution provider networks, including our sister partner in the United States, JLS Automation with regards to solutions for automated container loading. Solutions for:

- Semi-automated container loading, especially in the area of loading aircraft baggage containers. The images below so two of the solutions identified,

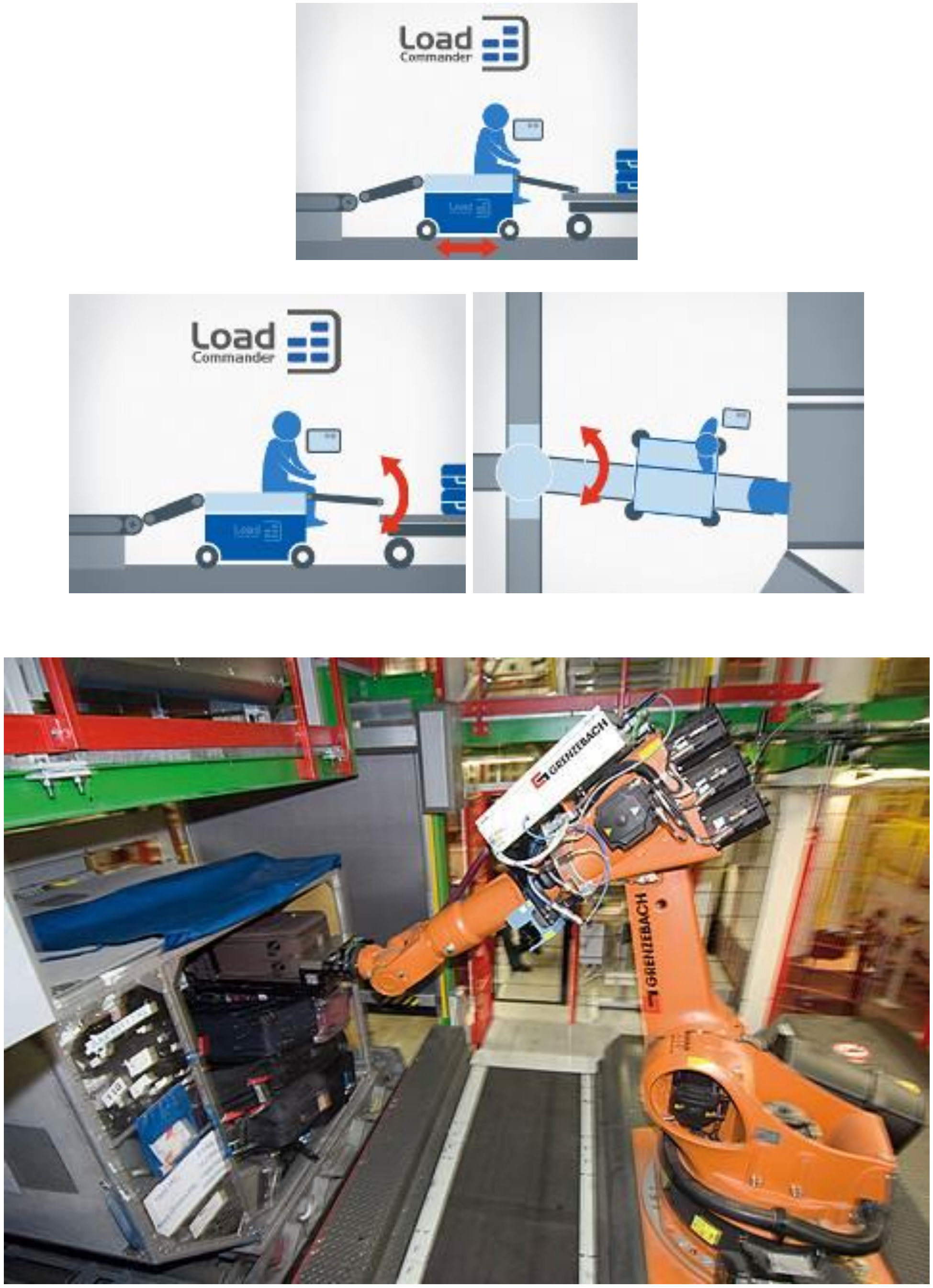


Fig. 4 Semi Automated Container Loading

Both these solutions require manual intervention and would not be suitable for the larger shipping containers that meat processors are dealing with.

- Bulk loading of pallets or large crates as depicted below. Here whole pallets are retrieved from storage and loaded onto a medium which slides/guides them into the container. This process would not be suitable for the loading or chilled cartons where the pallets need to be removed and carton damage would occur.

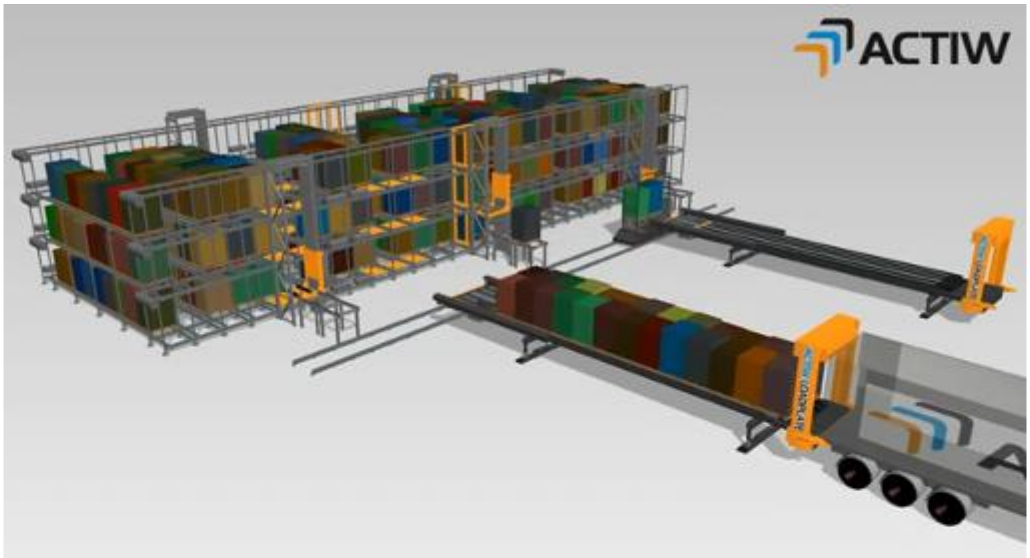


Fig. 5 Bulk unloading of pallets

- Container unloading, the below shows an automated container unloading system, the concepts developed in this may influence the direction taken when developing concepts in the next milestone.

Fig. 6 Container Unloading

Outcomes from Survey and Site Visits

It can be derived from the survey and site visits that the major factors influencing processors interest in automated container loading are:

- Reduction in labour, in both loading the containers and scanning and port marking areas
- Reduction in OH&S issues
- Improvements in traceability and quality
- Possible improvements in efficiencies.

The major challenges that are seen are

- Developing a system that can meet the required loading rate
- The ability of the developed system to stack the required pattern
- The handling of dunnage used
- The ability to fit the system in the required load out space.

The image below shows the current container loading concept, where a robot is mounted on an AGV that works its way into and then out of a container along with a telescopic conveyor as the container fills up. Along with the development of further concepts, additional work on this concept will be conducted in the next milestone to confirm that this setup can meet the rate, weight, space restrictions of working inside a container.

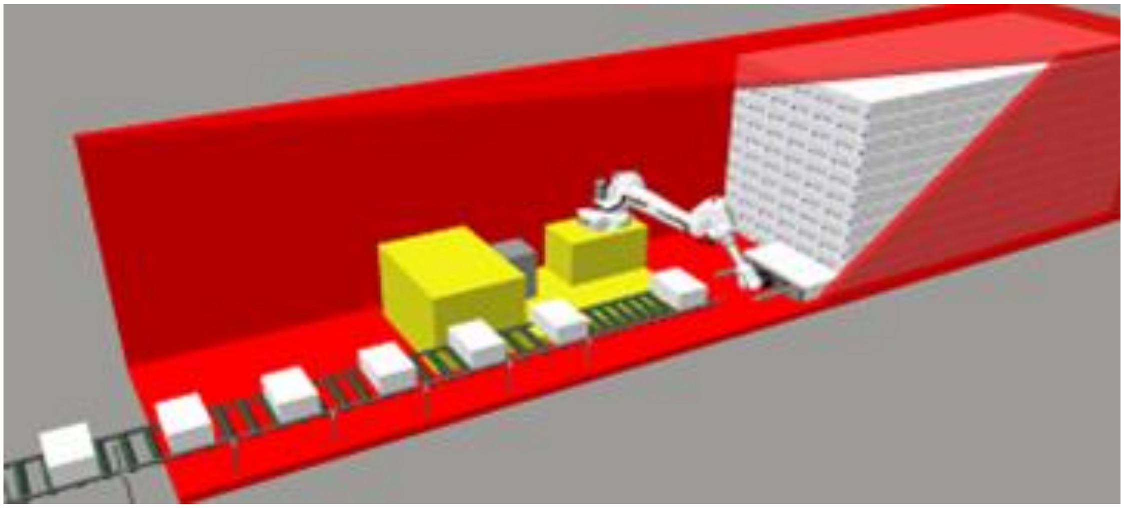


Fig. 7 Container Loading Concept

5 Results – Milestone 2

From the feedback achieved in Milestone 1 it can be seen that the major factors influencing processors interest in automated container loading are:

- Reduction in labour, in both loading the containers and scanning and port marking areas
- Reduction in OH&S issues
- Improvements in traceability and quality
- Possible improvements in efficiencies.

The major challenges that are seen are

- Developing a system that can meet the required loading rate
- The ability of the developed system to stack the required pattern
- The handling of dunnage used
- The ability to fit the system in the required load out space.

Parameters on which concepts are to be based:

- Carton weight up to 35kg
- Average cartons loaded into 40ft container in 90 min equals 1350 – one carton every 4 seconds
- Column and interlocked stacking patterns to be considered

Concept development

Initial concept brainstorming considered a number of possible options with regards to automating container loading, and these are listed below along reasons why they were discounted:

- Full pallet build external to the conveyor then auto transport into container and push into position. Perceived issues with this included:
    - Carton damage
    - Size mechanics required to transport the full pallet into the conveyor.

- Positioning conveyor that transported the cartons to the stacking point then stacked using a mechanical guiding mechanism to place the cartons in the correct location, conveyor end to rotate and pivot to allow change in height and angle across conveyor. Perceived issues included:
    - Inability to account for different sized cartons
    - Difficultly in manoeuvring conveyor to all locations required.

- Convey cartons into container, form a full row using a mechanical mechanism on a conveyor/platform at right angles to the flow of cartons then push off full row. Perceived issues include:
    - Carton damage
    - Inability to handle different carton sizes

Options incorporating robots and a form of vehicle to transport the robots were also considered. The image above in Section 4 shows a preliminary concept where a robot is mounted on an AGV that works its way into and then out of a container along with a telescopic conveyor as the container fills up. This preliminary concept was presented as a possible option in the MS1 Report for this project (copied for reference in email) and was based on using an ABB IRB 4600 robot with 60kg payload.

This initial concept was reviewed internally at MAR and concerns were raised with:

- The ability of the single robot to achieve the desired cycle time of 4.5 sec/carton
- The payload capacity if attempting pick up of multiple cartons to achieve the cycle time

With these points in mind further investigation was carried out and the following robot options were investigated:

- A larger ABB robot, an IRB 6640 and 6620 were considered, these both have higher payload, which would have allowed multiple cartons to be picked up at once solving potential cycle time issues, and longer reach. Simulations using the ABB simulation software were conducted with each of these robots. From the simulations it was seen that while these two robots provide a higher payload and longer reach they are larger in size. This caused flexibility issues with regards to their ability to reach to their full extent and their ability to manoeuver inside the container as well as issues with regards to the size of the vehicle required to transport them.
- Robots from the manufacturers below were also considered in the investigation carried out. Along with ABB the following had options that were comparable to the ABB IRB 6620
    - Nachi
    - Kuka
    - Fanuc

  The following were discounted due to the fact they had no models of suitable size/capacity or offered no advantages over the 4 preferred brands:

Adept	Comau
Denso	Epson
Kawasaki	Mitsubishi
Motoman	Panasonic
Staubli	

As described in the point above there were issues with the physical size of the larger ABB robots and the comparable options from their competitors. In subsequent design reviews the option of mounting two IRB 4600's on a moving platform was raised. The thinking behind this was that with two robots the cartons could be picked individually, eliminating the payload issue, and at twice the rate of a single robot, overcoming the cycle time issue. The progression below shows the development of this concept.

Concept V1 – Dual Robots with traverse pick up conveyor

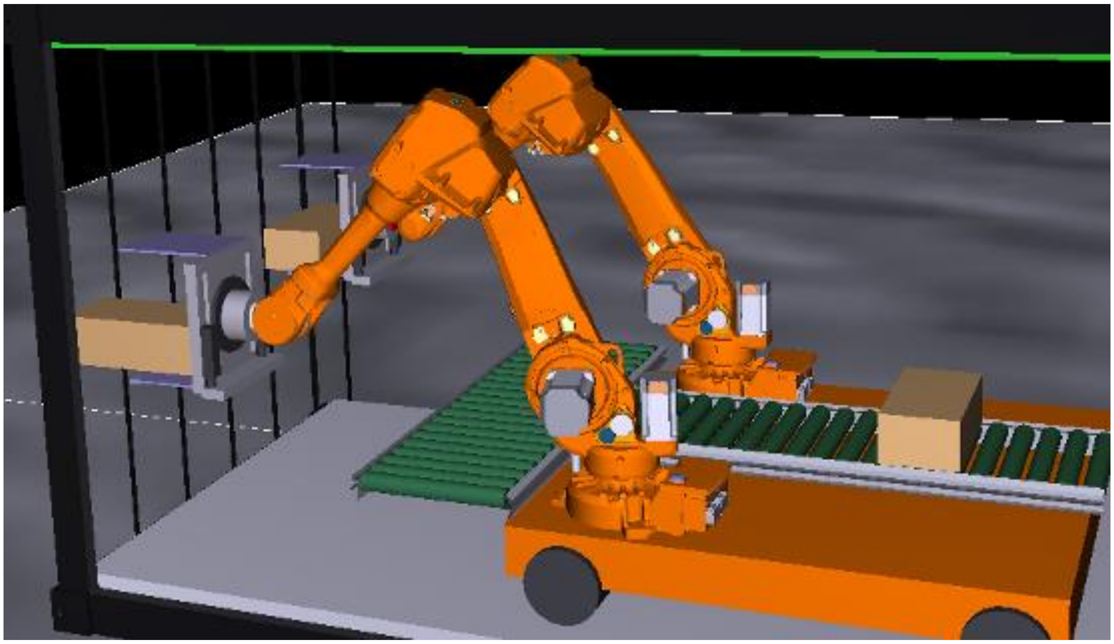


Fig. 8 Concept V1 Dual Robots with Traverse pick up conveyor

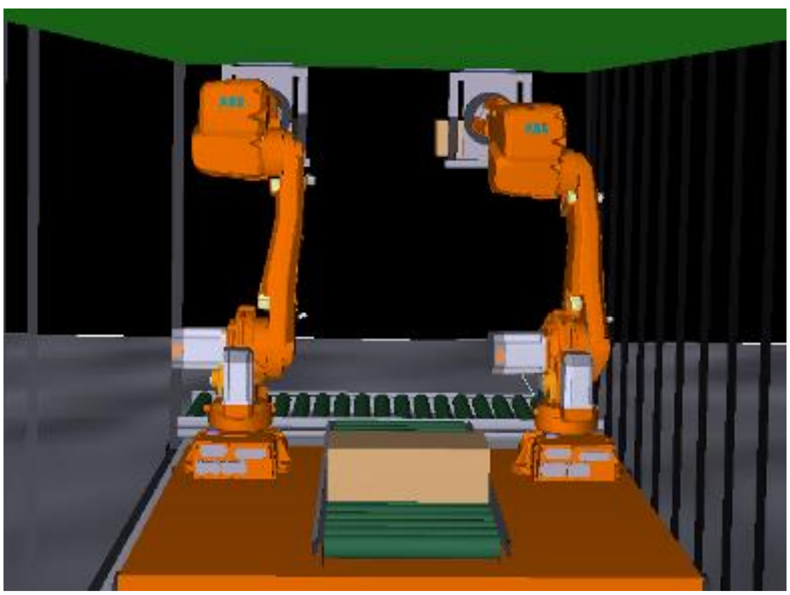


Fig. 9 Concept V1 Dual Robots with Traverse pick up conveyor

Perceived issues/concerns

- Issue with sequencing on box pick up, both need to rotate through same space leading to sequencing and cycle time issues.
- A lot of Axis 4 rotation, involving interim moves which could affect cycle time.
- Robots set 350mm of deck
- In feed needs to be keep low to ensure robot can reach over the top leading to possible pneumatic transfer and squaring issues.

Concept V2 – Dual Robots with side pickup platform for pickup of cartons on short and long face

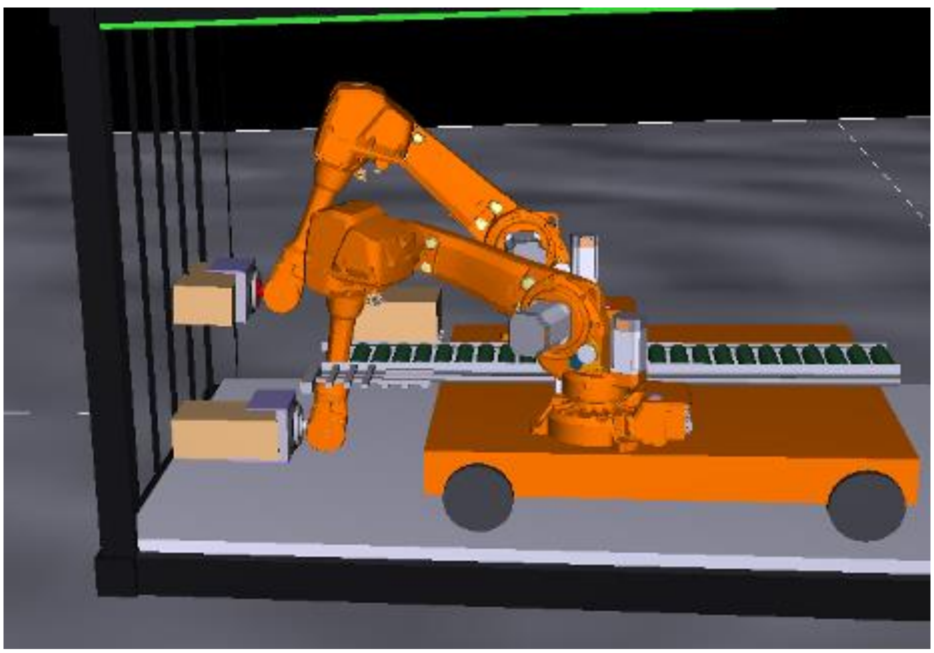


Fig.10 Concept V2 – Dual Robots with side pickup platform for pickup of cartons on short and long face

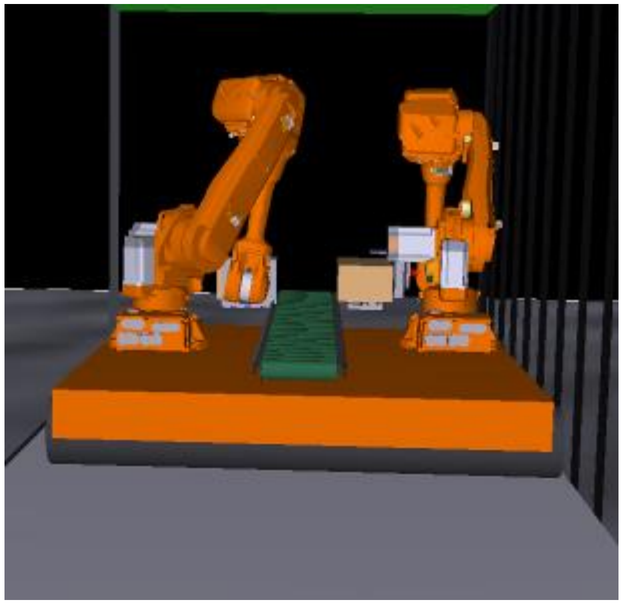


Fig.11 Concept V2 – Dual Robots with side pickup platform for pickup of cartons on short and long face

Perceived issues/concerns

- Robot reach
- Interference issues with pick up platforms

Concept V3 – Dual Robots with pneumatic pop up for carton pickup

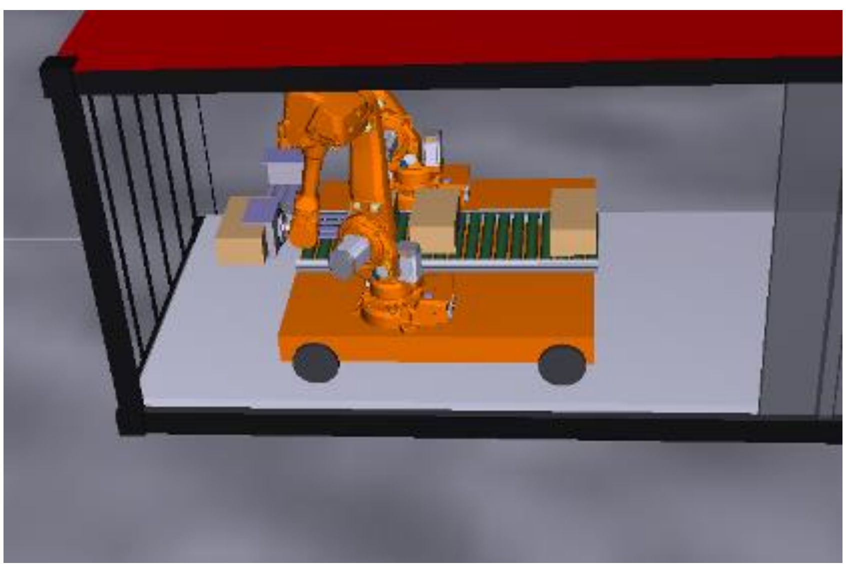


Fig.12 Concept V3 – Dual Robots with pneumatic pop up for carton pickup

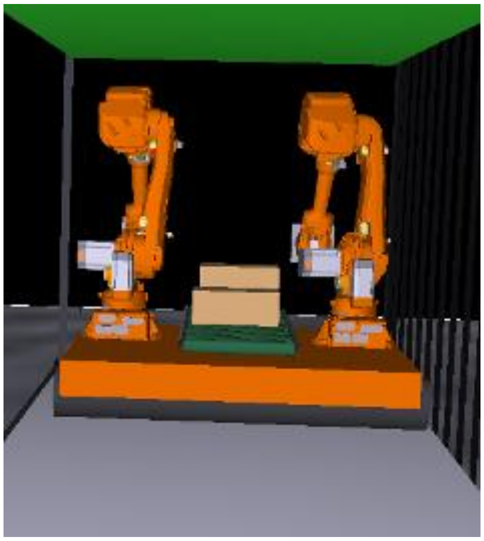


Fig.13 Concept V3 – Dual Robots with pneumatic pop up for carton pickup

Resolutions, perceived issues/concerns

- Pick up and interference issues between robots resolved
- Robot collides with side of container when placing lowest cartons

Concept V4 – Dual Robots with pneumatic pop up for carton pickup and MAR patented translating grippers for carton placement

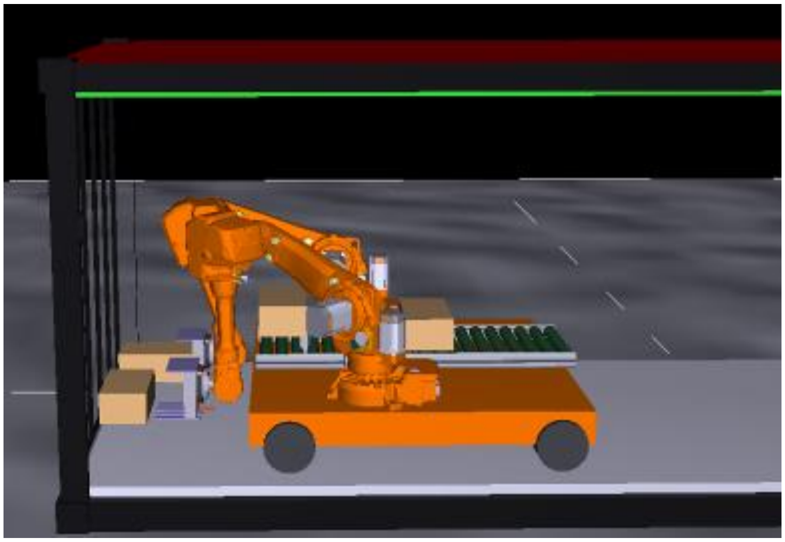


Fig.14 Concept V4 – Dual Robots with pneumatic pop up for carton pickup and MAR patented translating grippers for carton placement

Fig.15 Concept V4 – Dual Robots with pneumatic pop up for carton pickup and MAR patented translating grippers for carton placement

Resolutions, perceived issues/concerns

- MAR patented translating grippers allows pick up and drop off of cartons to all locations
- Tyne style gripper required

Concept V5 – Dual Robots, with pneumatic pop up, MAR Patented translating grippers, MARBOT and retractable conveyor

With the concept of the pickup and drop off of cartons with dual robots developed attention turned to the vehicle to be used to transport the robots into and out of the container and the method of transporting the cartons to the robots.

A number of auto guided vehicles were considered, however for the purpose of container loading complex guidance systems are unnecessary. When considering alternatives we moved away from the idea of using a vehicle that consisted of individual wheels or rollers due to possible issues with point loading the container floor. For access to the container up ramps at docks the pre-existing patented MARBOT (which MAR have designed and fabricated in house) track vehicle was considered a better option. For conveying the cartons to the robots an extendable/retractable conveyor would be utilised.

Operation of the system would consist of:

- The MARBOT, with robots mounted on it, being manually driven into the conveyor to the appropriate position (determined by sensing). Once in position the MARBOT would extend locators to 'clamp' it in position against the floor and container walls.
- The conveyor extended and coupled to the MARBOT.

- The system put into auto and cartons loaded onto the conveyor
- The robots building a row at a time, once a complete vertical layer is built the locators would retract and the MARBOT and conveyor index back.
- This would be repeated until the container was full.

Images of the simulation built for this concept are shown below:

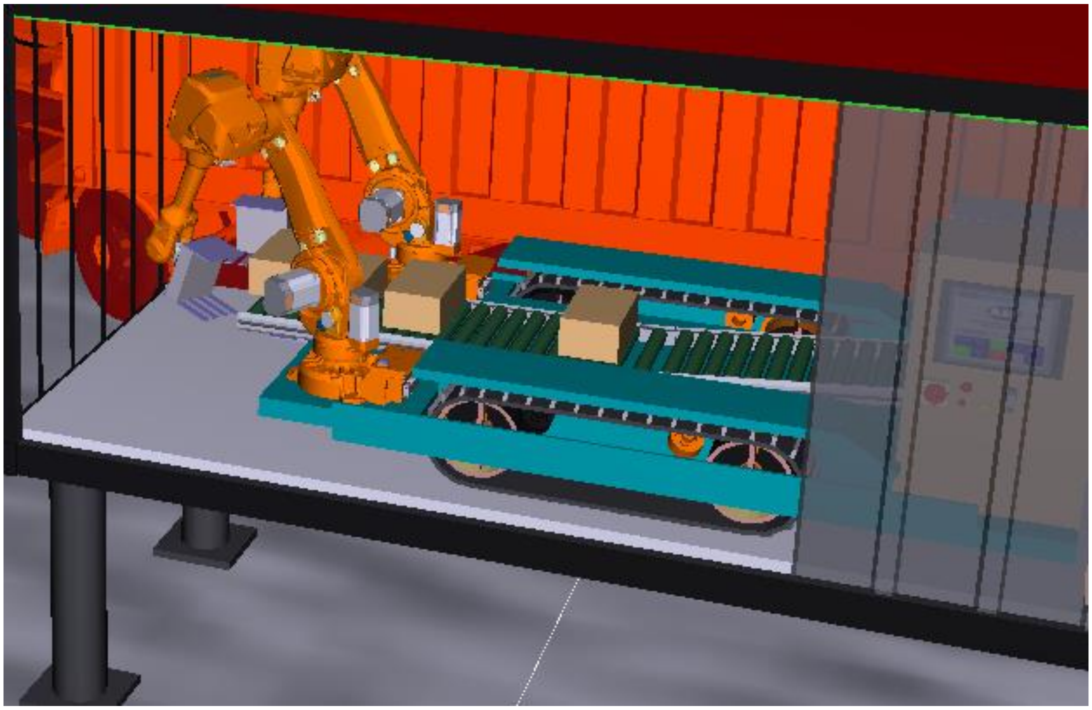


Fig.16 Concept V5 – Dual Robots, with pneumatic pop up, MAR Patented translating grippers, MARBOT and retractable conveyor

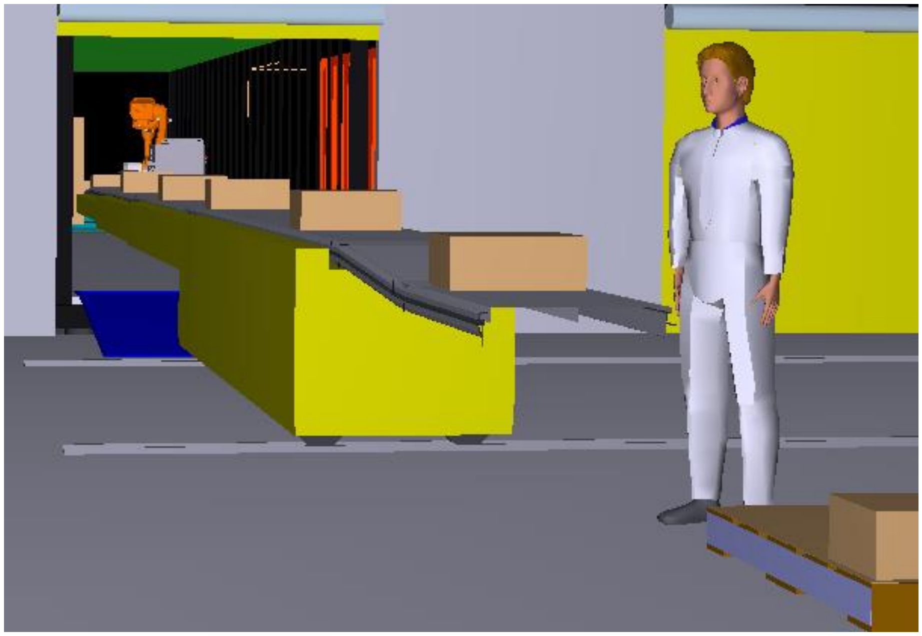


Fig.17 Concept V5 – Retractable conveyor

Fig.18 Concept V5 – Track vehicle with robots mounted on the front and electrical panel and robot controller at the rear

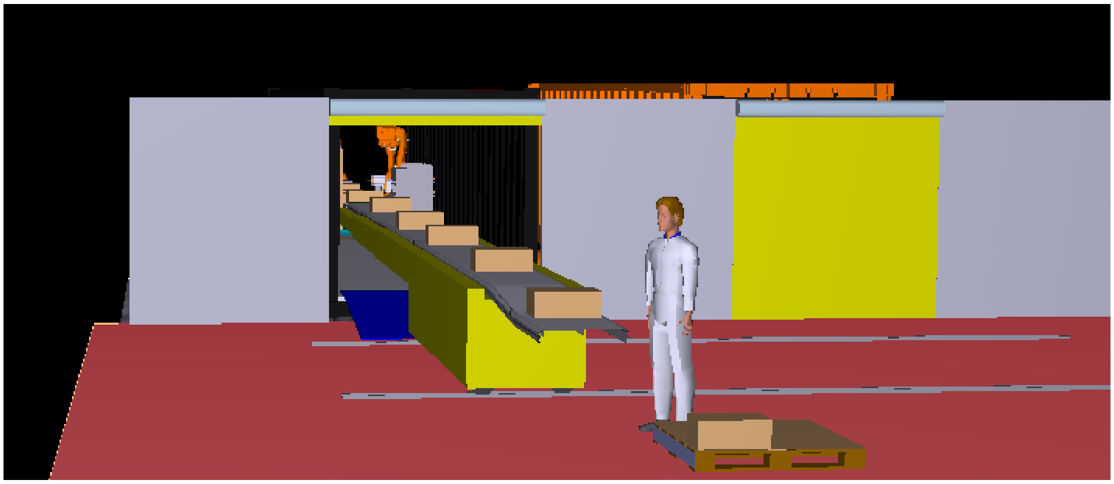


Fig.19 Concept V5 – View from dock area

Methods of loading the retractable container in the dock area include:

- manually as depicted above
- robotic de-palletiser
- direct feed of sorted cartons from chillers

Stacking patterns

Design reviews with regards to the different stacking patterns used, show that the robot can easily cope with both the interlocking pattern as well as column stacking pattern. The issue that has been found is with the design of a system to automatically place the dunnage where required for column stacking. Preliminary concepts have shown that this is cumbersome and that it could be difficult to achieve a cost effective solution. The images below show the initial concepts for a dunnage 'magazine' which would require a spreader mechanism to allow insertion of the dunnage between wall of the conveyor and the last carton n the row.

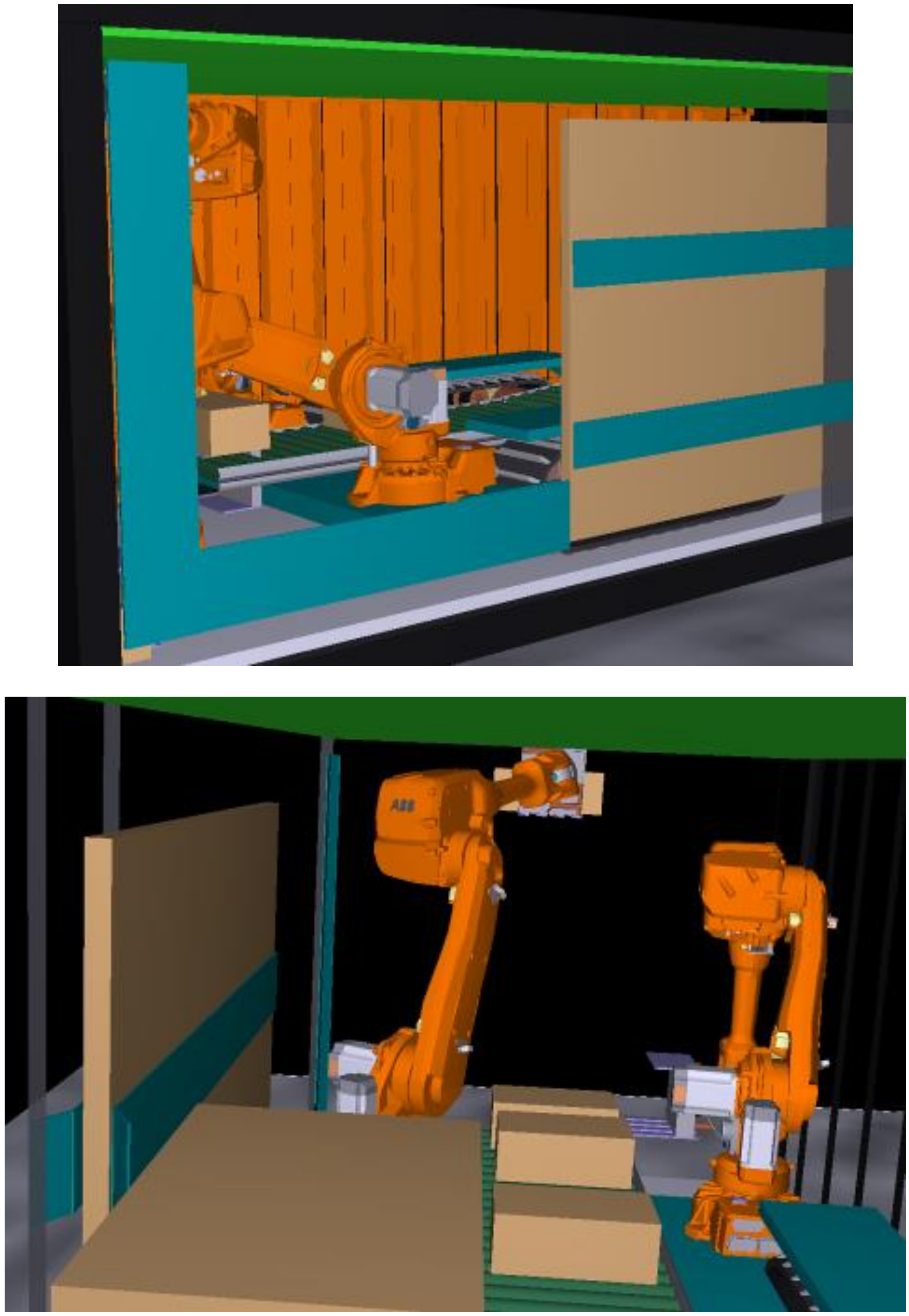


Fig.20 Concept V5 – Concept for Dunnage magazine

Below are possible alternatives for discussion during the teleconference

- Optimise carton sizes so no gaps and hence no need for dunnage

- Column stack as is currently done with the gap down one side (shown below) with an air bag attached to the side of the container prior to loading which is inflated once the container is full.

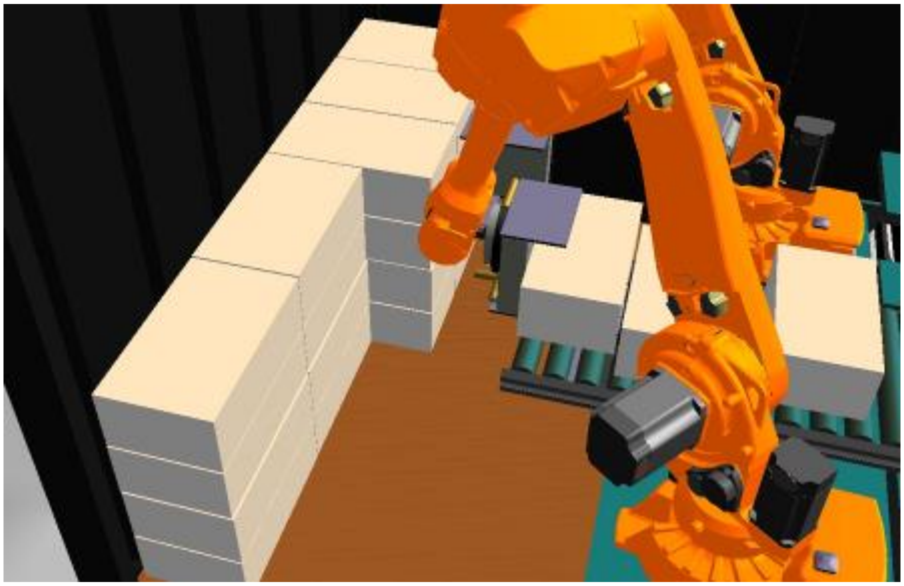


Fig.21 Concept V5 – Column Stack using airbag.

- Interlock with spaces between cartons

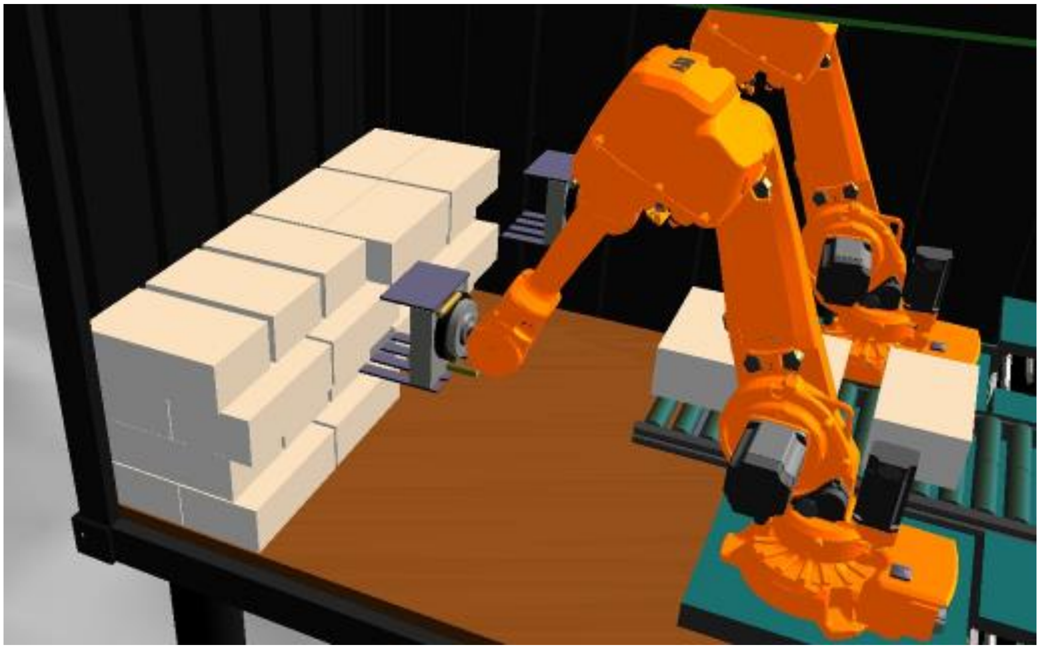


Fig.22 Concept V5 – Interlock with gaps between cartons.

- 'Mini interlock' stack so gap is on one side for one layer and on the other side for the next as shown in the image below

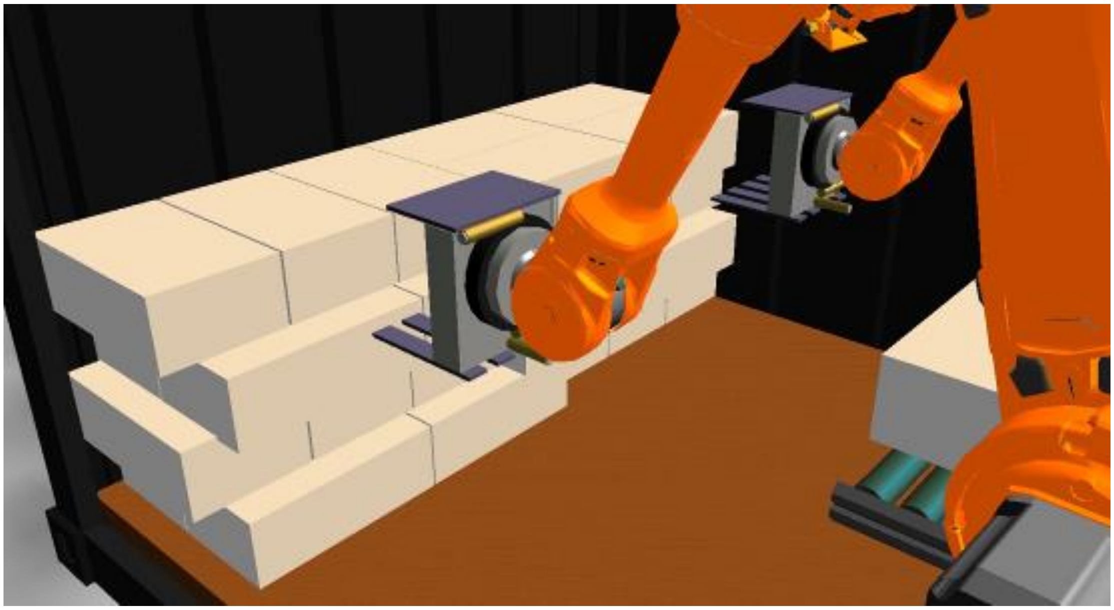


Fig.23 Concept V5 – 'Mini interlock'

Industry Consultation

To gain industry feedback of the concepts developed above an interim version of this report was sent to processors, MLA and AMPC for review. Following this teleconferences were held on the 27/8/13 and 2/9/13 that involved the following people:

Pat Gleeson – Oakey Abattoir
John Hart – John Dee Warwick
Shane Clancy – Kilcoy Pastoral Company
Darryl Heidke – MLA
Christian Ruberg – MLA
John McGuren – AMPC
Stuart Shaw – MAR
Merv Shirazi - MAR
Gavin Inglis – MAR
Kirstian Guard – MAR
Adam Saint - MAR

In addition Justin McCormick from JBS Beef City was spoken to in a separate phone conversation.

General feedback from all who reviewed the interim report was positive and that they would support the project moving forward. All agreed that container loading is an area where use of automation would have a positive effect from a labour, OH&S and product traceability point of view.

The points below were raised as concerns/items for action throughout the phone conversations:

- Dunnage and use of interlocking carton patterns to eliminate use of dunnage,
    - Elimination of dunnage should not be taken as a given. Some plants may still need to use it due to stacking patterns required by customers.
    - All were open to trialling various interlocking carton patterns to see if dunnage could be eliminated
    - Trials would need to be carried out to determine whether cartons could structurally handle being stacked in the configurations proposed.
    - John Hart will do trial stacking patterns proposed and obtain feedback from carton manufacturers.
    - MAR to supply stacking patterns to be trialled.
    - John Hart currently using/has trialled airbags as dunnage, these could be used as a fall back if interlocking patterns are not successful.
    - Trials of stacking patterns/use of dunnage should not affect the Go/No Go decision. Trials can be conducted in parallel with moving forward with the design of the system.

- Use of the MARBOT, robot on a track vehicle was seen as positive

- Traceability of cartons is an important aspect that must be considered in this project. Reading of barcode, port marks, MTC must be addressed in the design phase with carton label reading, reject/retain function and load validation and specific carton locations into the container to be part of actual project proof of concept

- Loading of mixed/random carton sizes is regular current industry practice. Suggest that this project scope assume pre-sorting (noting that automation of this function will likely require a secondary system).

- Need to factor in the impact on labour requirements/CBA of labour required to pre-sort to give realistic assessment of the attractiveness of the value proposition for both development and final commercial cost.

- Imaging of carton as proof of loading to be considered

- Variation in height between dock and truck to be considered in design.

- CBA to consider three options

    - Manual loading of conveyor
    - Robotic De palletising
    - Sortation System – Direct feed.

- CBA to include maintenance costs.

6 Results – Milestone 3

The project P.PSH.0634 'Mobile robots on AGV's' was a project conducted by MAR in collaboration with MLA and AMPC during 2012. It demonstrated the use of mobile robotics (a robot mounted on an AGV) and its potential uses in red meat applications such as:

- Palletising
- De-Palletising
- Mixed Pallet Sortation
- Mixed Pallet Order Picking
- Container Loading

The images below show the AGV and robot in action during the demonstration at MAR in October 2012.

Fig. 24 Image showing AGV, platform, robot and gripper

Fig 25 This image shows the infeed carton conveyor, and the palletising and de palletising conveyors

Fig. 26 Image shows the system palletising from the infeed conveyor

Fig. 27 This image shows the structure used to simulate the container for the container loading demonstration.

Fig 28. This image shows the Pallets and cartons loaded onto the robot platform for the Mixed Pallet and order picking demonstration.

This, Mobile Robots on AGV's, project provided MAR with learning's that were able to be incorporated into the development of the design in the current Automated Container loading POC project. These learnings included:

- Vehicle payload required
- Speed and effect on system cycle time
- Manoeuvrability and space required for AGV to operate
- Interfacing requirements between AGV and Robot

Using the outputs from this AGV project and incorporating them into the concept designs for the Container Loading Project it became evident that for the purpose of container loading a standard AGV would not be suitable. The reasons for this are:

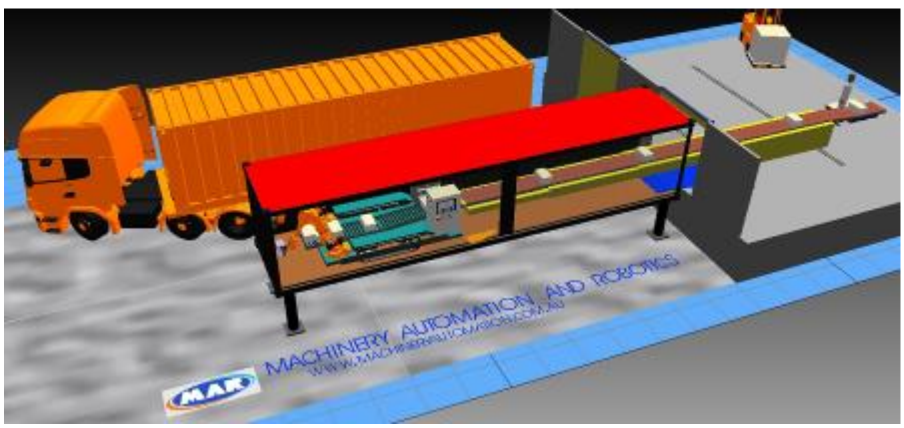
- Production rates suitable for majority of plants now require two robots for container loading increasing payload.
- The load and physical size limitations of AGV's are not suitable for mounting of the two robots required along with their control cabinets, conveyor and related control equipment AGV's with sufficient payload capacity do not have a suitable structure.
- AGV's with sufficient payload capacity are costly items which would make automated container loading non-viable as a commercial product.
- In relation to the above payload and 2 robot structures, the vehicle is now heavier, wider and longer than originally anticipated. This created issues with container entry and exit of vehicle especially where any change in height is present.
- The clearance under AGV's is not suitable for the possible sloping entry to containers, a more 'rugged' solution is required incorporating a vehicle with larger ground clearance and more stability capable of handling the robotic movements that are anticipated

- the complex guidance systems that are inbuilt to expensive AGV's were unnecessary.
- A vehicle with tracked wheels or larger wheels was deemed a requirement to accommodate dimension of vehicle and height changes in loading dock to container.
- Vehicle design had to be very low keeping the centre of gravity suitable and allowing the robots to fit in container and reach all required areas.
- The above required a customised vehicle which will in principle be based upon MAR's MARBOT technology.

7 Results – Milestone 4-5

The images below show the finalised concept for the Automated Container Loading Proof of Concept. The main components of the system are:

- A telescopic conveyor capable of extending into and retracting out of the shipping container.



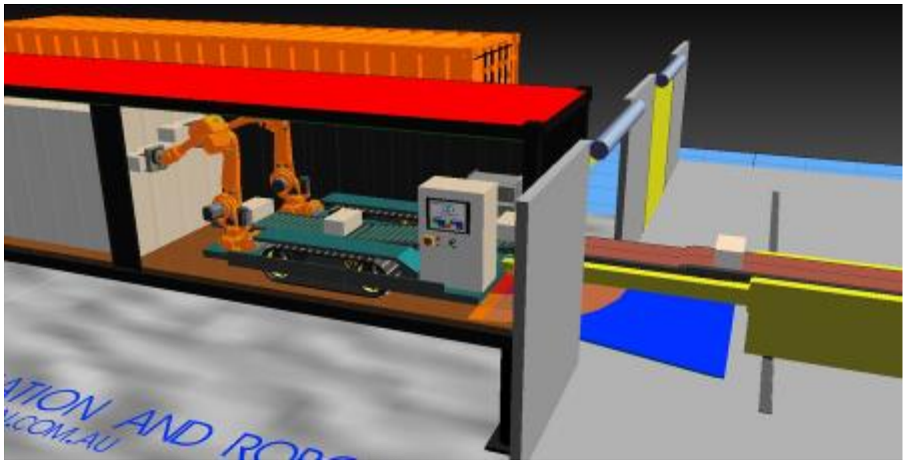


Fig.29 Final concept design featuring telescopic conveyor

- A rugged 4 wheeled MARBOT vehicle. Some of the images below show the MARBOT track vehicle, this was deemed not suitable due to its tendency tip as is imminent in the figure below:

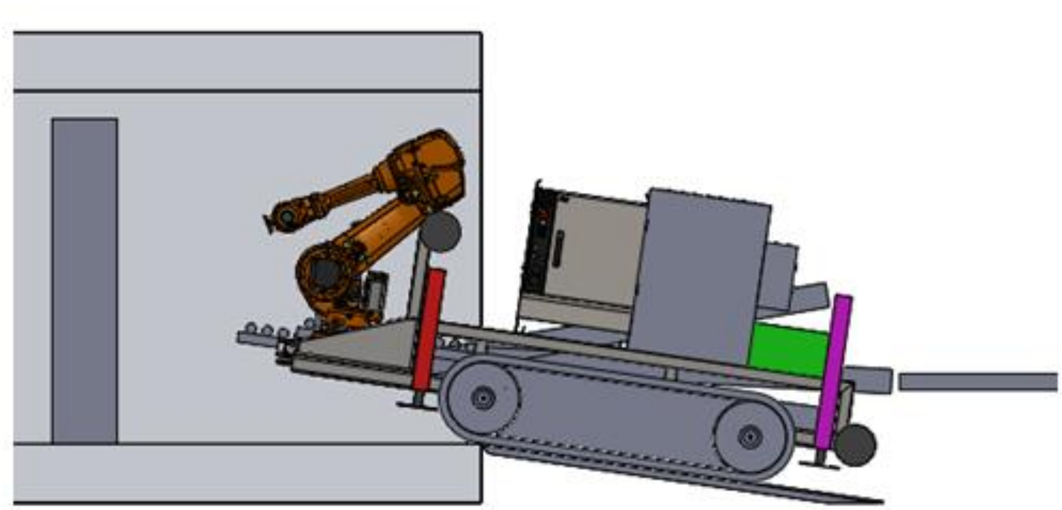


Fig.30 MARBOT Track Vehicle

Instead a rugged 4 wheel MARBOT vehicle will be utilised instead, as shown below:

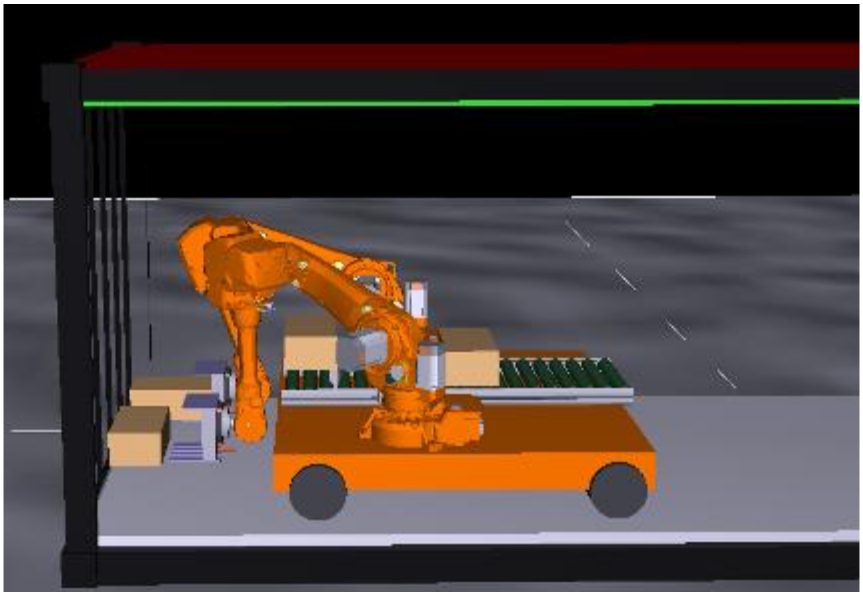
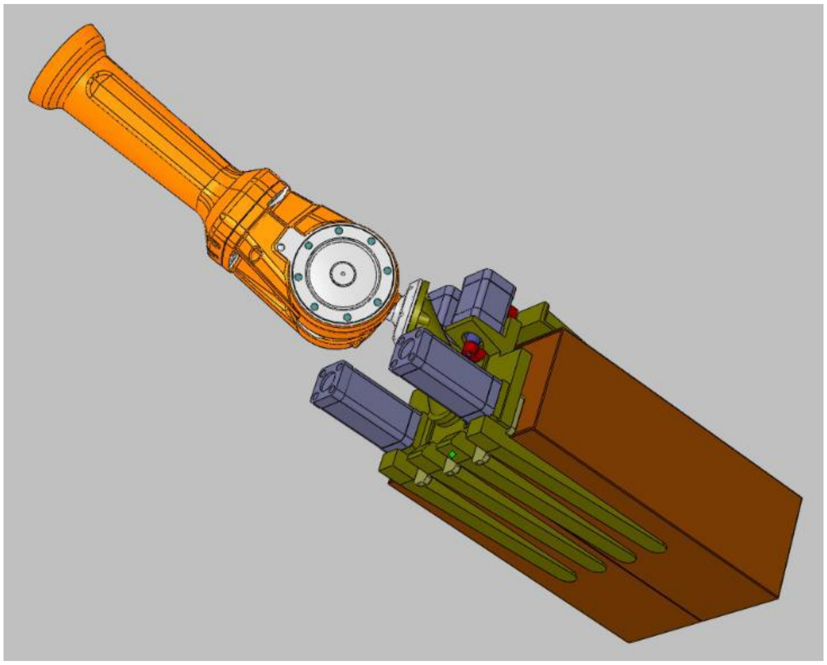


Fig.31 Rugged 4 wheeled MARBOT vehicle

- 2 off (one RH and one LH) grippers with pneumatic telescopic cylinder driven product pushers and top clamps with angled roll face adaptor suitable for ABB IRB 4600 robot



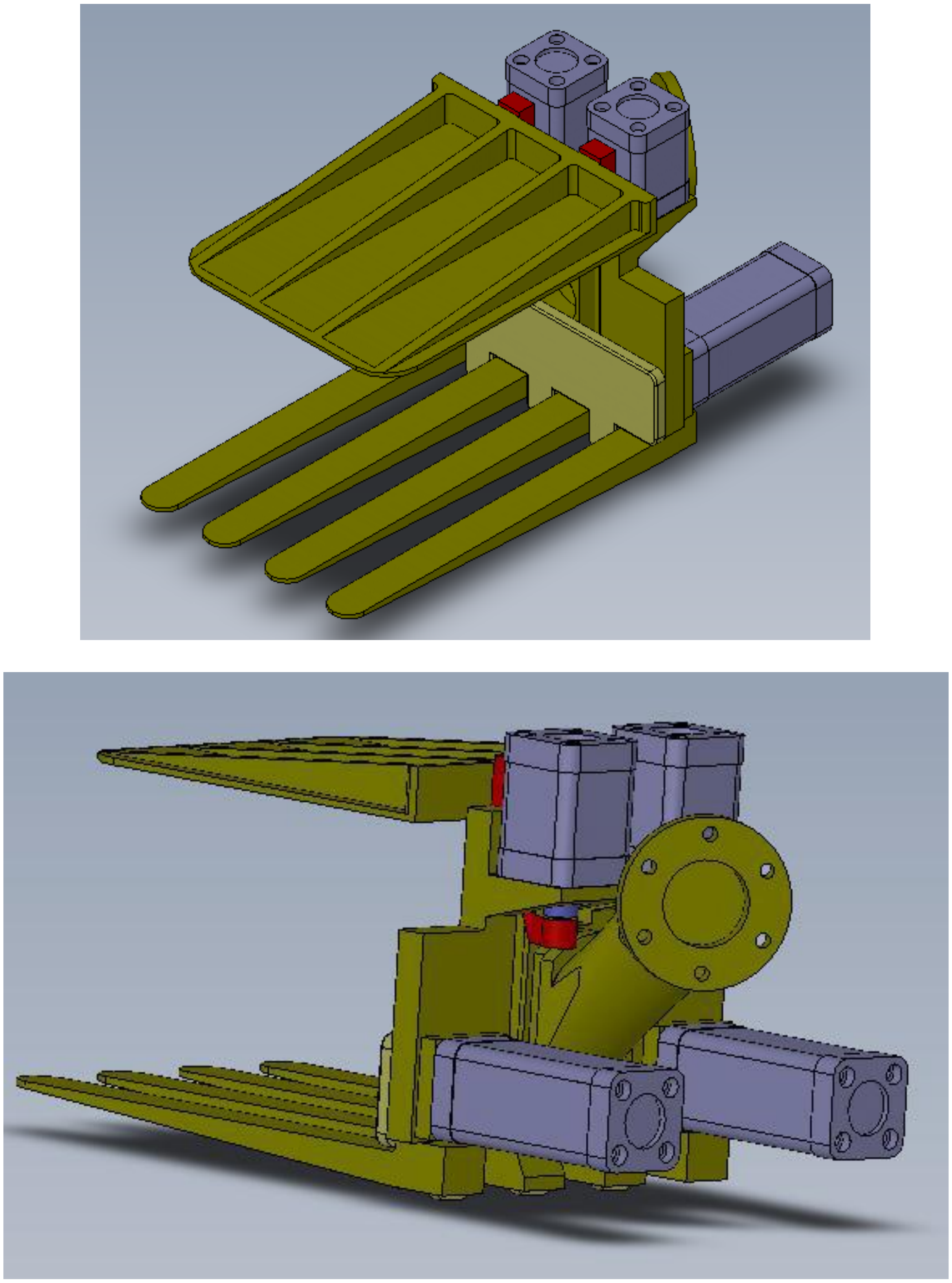


Fig.32 Carton Gripper

- 2 off ABB IRB 4600 robots to be mounted to the front of the 4 wheeled MARBOT vehicle.

Fig.33 ABB IRB 4600 robot

- 1 off carton pick off station mounted on the 4 wheeled MARBOT vehicle.

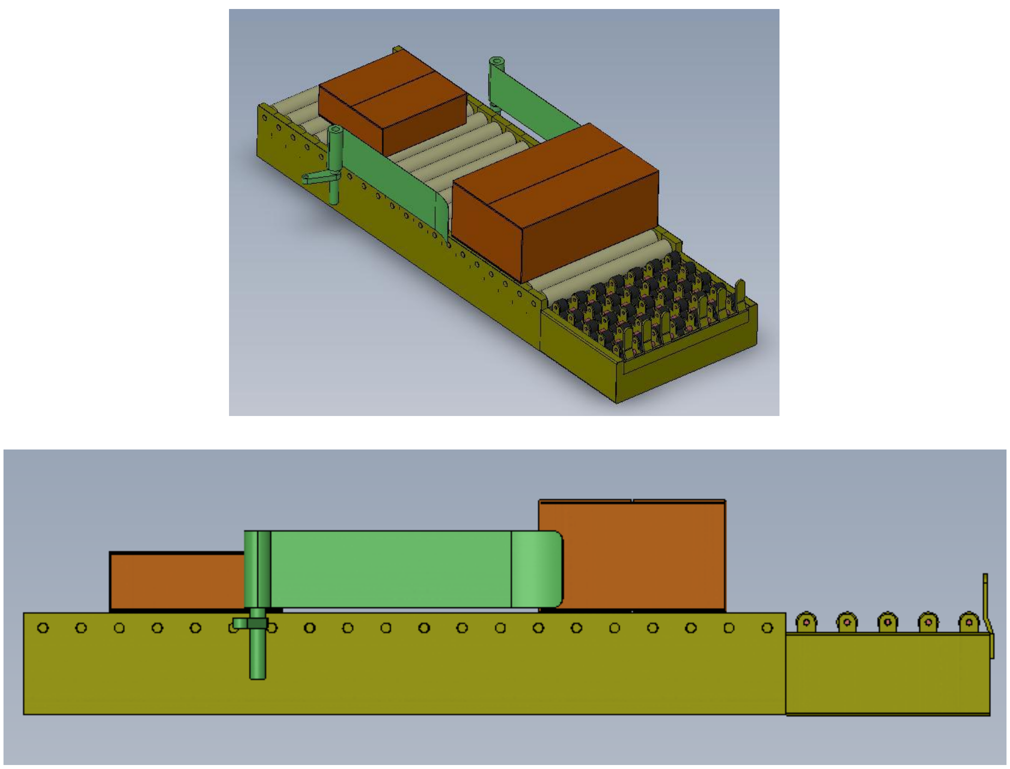


Fig.34 Carton pick off conveyor

With the design complete components of the system were fabricated and procured allowing the:

- Manufacture and assembly of the auto container loader to the concept design
- Test and debug of the auto container loader components in preparation for POC trials
- Setup of the auto container loader at MAR to simulate production conditions
- Perform operational trials, testing and debugging of auto container loading in preparations for industry demonstrations.

The tasks involved included:

- Modifications to the purchased vehicle to fit the specifications of the MARBOT vehicle this involved:
    - Reconditioning of the of the hydraulic system
    - Fabrication of plates for mounting robots
    - Retrofitting a conveyor to the vehicle to take cartons from telescopic conveyor to the pick off station
    - Modifications to the vehicle to allow integration with the telescopic conveyor, retrofitted conveyor and pick off station
    - Addition of Pick off station

- Fabrication of mock container

- Fabrication of carton grippers and robot roll face adaptors including plumbing, wiring and fitting of pneumatics for these

- Procurement and erection of product cartons using sand bags and wooden blocks to simulate weight and maintain form

Fig. 35 Vehicle purchased to be adapted to suit the MARBOT vehicle specifications

Fig.36 Plates fitted to front of vehicle to allow mounting of robots

Fig.37 Vehicle Robots mounted, retrofitted conveyor and pick off station in place

Fig.38 Retrofitted conveyor and pick off station

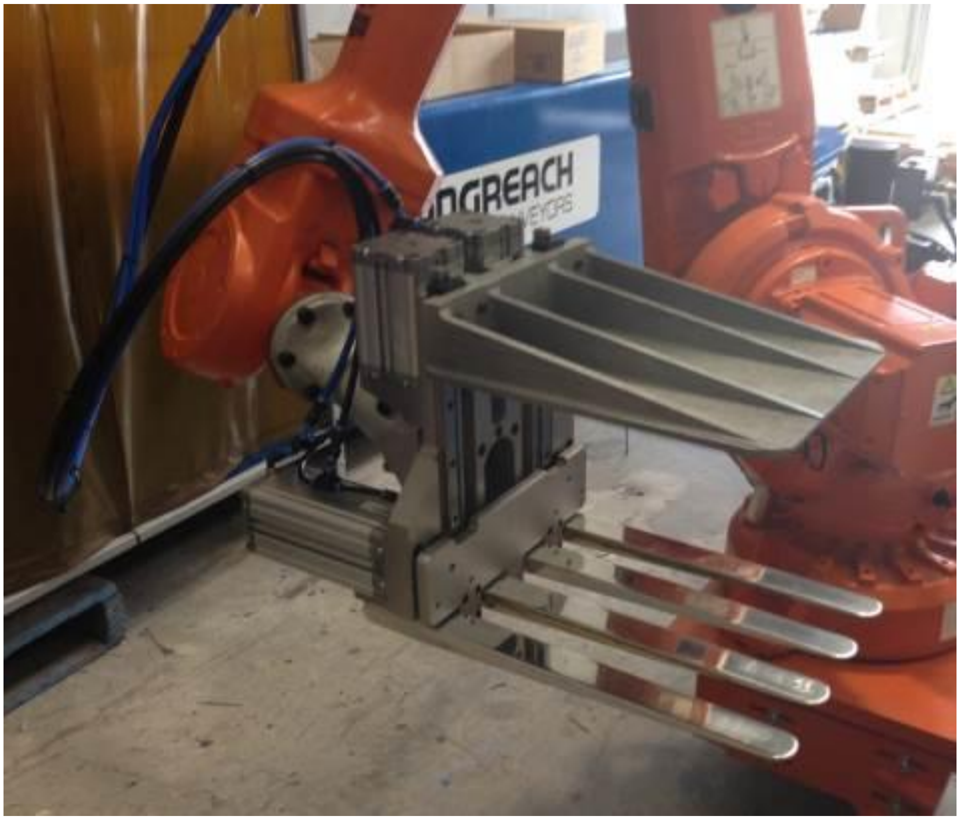


Fig.39 Carton Gripper showing pneumatics plumbed and wired

Fig.40 Robots with Carton Grippers fitted

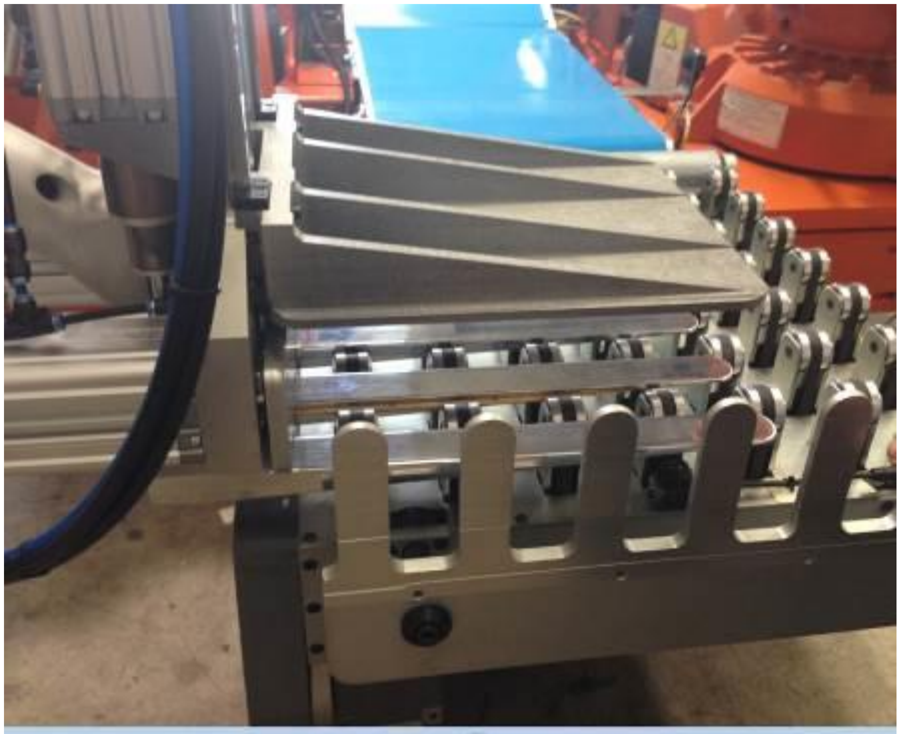


Fig.41 Gripper interfacing with Pick Off Station

Fig.42 Vehicle in front of the Mock Container at MAR's workshop.

Fig.43 Robots picking cartons

Fig.44 Robots picking cartons

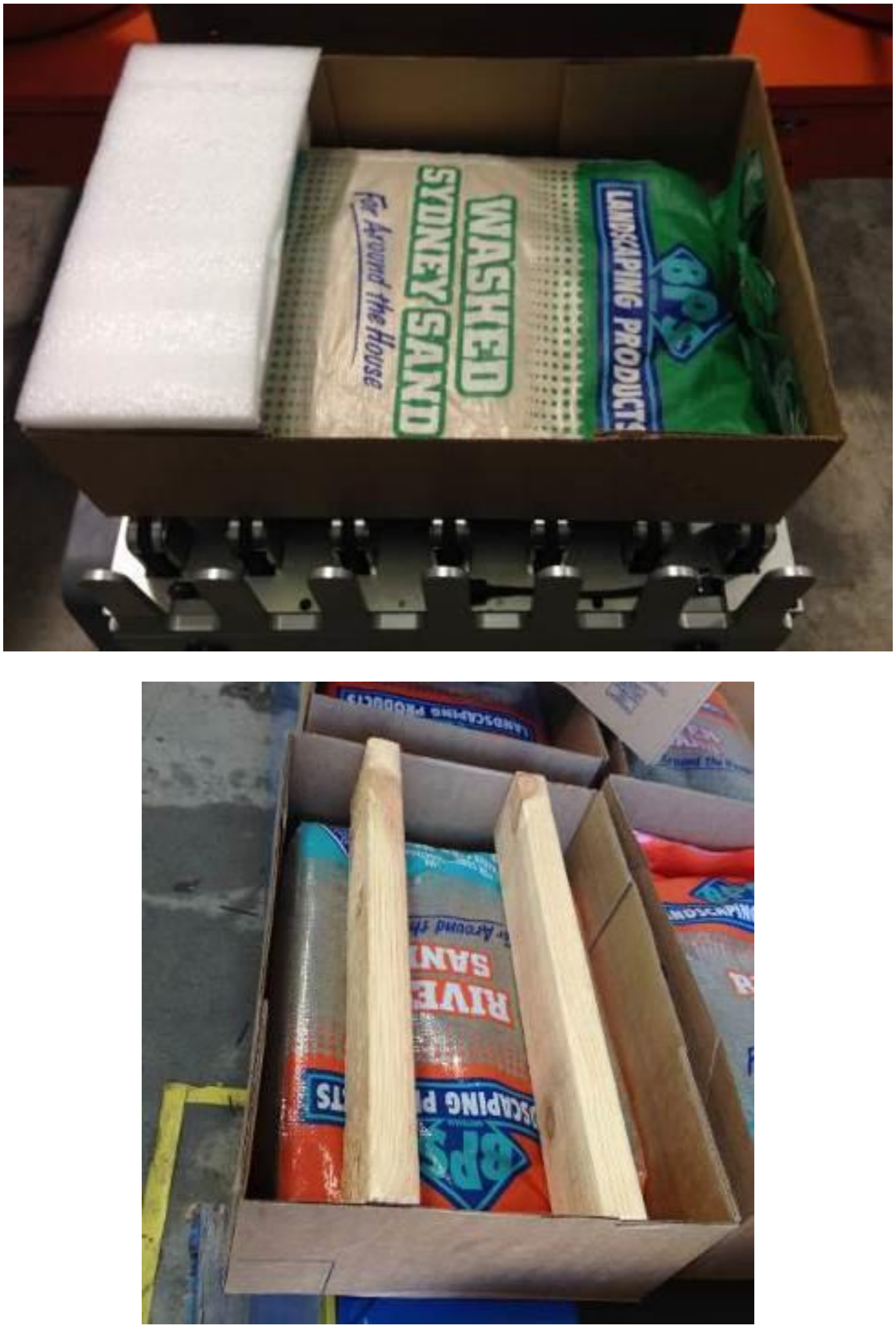


Fig.45 Cartons filled with Sand bags and wooden blocks to simulate weight and maintain form.

Fig. 46 Telescopic conveyor

Fig. 47 Trial work being conducted

Fig. 48 Trial work being conducted

Fig. 49 Stacking patterns trialled

8 Results – Milestone 6-7

The demonstration of the Automated Container Loading Proof of Concept System to industry representatives took place on 29/5/14 at MAR's workshop in Silverwater. Those present were:

- Neil Brereton – JBS
- Graham Treffone – JBS
- Shane Clancy – Kilcoy
- Lee Wright – Kilcoy
- John Hart – John Dee
- Andrew Triance – Nippon
- Darryl Heidke – MLA
- Danielle Bragg – MLA

The images below show the demonstration taking place and the attached PowerPoint Presentation is what was presented prior to the demonstration.

Fig. 50 Demonstration to Processor and MLA

The following email was sent to those that attended to gather their feedback:

From: Merv Shirazi [mailto:MShirazi@machineryautomation.com.au]
Sent: Tuesday, 17 June 2014 2:30 PM
To: Neil Brereton
Subject: Container Loading - Proof of Concept Presentation / Demonstration on Thursday 29/5/14 at MAR - Feedback

Dear ******,

Re: Container Loading - Proof of Concept Presentation / Demonstration on Thursday 29/5/14 at MAR – Feedback

We would like to thank you for your attendance for above presentation at MAR.
To ensure that we have captured feedback and comments of all parties attended and specially how system can be customised to fit to your processing site, I would appreciate if you can share your thoughts with us by return email.

Kind Regards

Merv Shirazi
Project Manager
Machinery Automation & Robotics
T: +61 2 9748 7001 | F: +61 2 9748 7676 | 1/101 Derby Street, Silverwater NSW 2128
mshirazi@machineryautomation.com.au | www.machineryautomation.com.au

9 Conclusions and Recommendations

As can be seen from the attached videos, the POC system developed is able to successfully load cartons into a container at a rate comparable to that done manually by 2 – 3 units of labour.

The system received very positive feedback with a number of processors providing interest for continued development and offering their site for on-site trials.

As part of an R&D process the POC container loading system developed by MAR provided invaluable learnings offering a development path forward. Taking into account what worked, what did not meet expectations and where the system requires improvement to ensure the final solution meets market needs, from the work completed to date MAR is confident a solution can be progressed.

Some of the feedback received showed that some felt that the demonstrated system was too cumbersome and too large in its current format to be suitable for use in existing load out docks. With these issues in mind MAR recognise the following areas as areas where improvements need to be made to the system:

- Real estate – the system needs to be made more compact and be easier to move from one dock to another.

- Recovery – the system needs to be able to recover from fault situations, such as dropped cartons. The impression at this point is that there is not enough access around the system to allow operators to fix such issues should they arise.

- Column Stacking – the system needs to continue to direct development effort towards column stacking of cartons to maintain carton integrity. Chilled cartons are predominately designed to take the load in the 4 corners of the carton.

- Inconsistency in carton dimensions due to bulge – the system needs to be able to take this into account when stacking cartons

- Positioning – the system needs to be able to maintain a centralised position in the container to allow accuracy of carton placement.

- Gripper – the gripper developed was capable of stacking a variety of cartons sizes, with both glued and strapped lids, specified in the data gathered from processors, however modifications need to be made to the gripper design to allow it to be more flexible. Issues were experienced with the current design with regards to head space when loading cartons at the top of the stacks.

- Dunnage/Packing – Options here need to be reviewed as this will be necessary with column stacking being pursued.

- Port marking of cartons as part of the process needs to be incorporated.

To overcome the above issues MAR proposes resolving these in the next stage of development in the following ways:

- Use of a more compact buggy/vehicle and feed conveyor to reduce the footprint, making the system easier to move around and improving access.

- Use of a single robot to reduce footprint. Since the commencement of the project a new robot has come on the market that has the reach to enable cartons to be loaded with a single robot and the payload required to load multiple cartons at once so that cycle time can be achieved.

- Further use of active vision and addition of more sensing to:
    - allow accurate positioning of the vehicle in the container
    - 'live' assessment of the stacks to overcome issue with bulging cartons
    - For proof of load purposes

- Modifications to gripper to allow picking of multiple cartons and the inclusion of a carton stacker to allow this to take place.

- Possibilities remain for :
    - Use of foam dunnage
    - Use of air bag dunnage
    - No dunnage
    - Application of glue to the outside of the cartons to provide stability when stacked

  Further trials are required to determine the best solution for and automated system.

- Port marking of cartons as they enter the system.