EML4551-2

Team 504: Automated Pallet Topper

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Abstract

The abstract is a concise statement of the significant contents of your project. The abstract should be one paragraph of between 150 and 500 words. The abstract is not indents.

Keywords: list 3 to 5 keywords that describe your project.

Disclaimer

Your sponsor may require a disclaimer on the report. Especially if it is a government sponsored project or confidential project. If a disclaimer is not required delete this section.

Acknowledgement

These remarks thanks those that helped you complete your senior design project. Especially those who have sponsored the project, provided mentorship advice, and materials. 4

- Paragraph 1 thank sponsor!
- Paragraph 2 thank advisors.
- Paragraph 3 thank those that provided you materials and resources.
- Paragraph 4 thank anyone else who helped you.

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Notation

A17	Steering Column Angle
A27	Pan Angle
A40	Back Angle
A42	Hip Angle
AAA	American Automobile Association
AARP	American Association of Retired Persons
AHP	Accelerator Heel Point
ANOVA	Analysis of Variance
AOTA	American Occupational Therapy Association
ASA	American Society on Aging
BA	Back Angle
BOF	Ball of Foot
BOFRP	Ball of Foot Reference Point
CAD	Computer Aided Design
CDC	Centers for Disease Control and Prevention
CU-ICAR	Clemson University - International Center for Automotive Research
DDI	Driver Death per Involvement Ratio
DIT	Driver Involvement per Vehicle Mile Traveled
Difference	Difference between the calculated and measured BOFRP to H-point

DRR	Death Rate Ratio
DRS	Driving Rehabilitation Specialist
EMM	Estimated Marginal Means
FARS	Fatality Analysis Reporting System
FMVSS	Federal Motor Vehicle Safety Standard
GES	General Estimates System
GHS	Greenville Health System
H13	Steering Wheel Thigh Clearance
H17	Wheel Center to Heel Pont
H30	H-point to accelerator heel point
HPD	H-point Design Tool
HPM	H-point Machine
HPM-II	H-point Machine II
HT	H-point Travel
HX	H-point to Accelerator Heel Point
HZ	H-point to Accelerator Heel Point
IIHS	Insurance Institute for Highway Safety
L6	BFRP to Steering Wheel Center

Chapter One: EML 4551C

1.1 Project Scope

1.1.1 Project Description

The objective of this project is to design an automated device to assist in Corning's current palletization and depalletization process through placement and removal of pallet toppers and embedded foam layer. Corning has begun using automation within their manufacturing processes, and a successful completion of this project would convert a strenuous portion of that manufacturing process into an automatic one. Current systems require Corning employees to physically place and remove these burdensome pallets throughout the course of the day. This project aims to automate this task, increasing the efficiency of the system, as well as allowing Corning employees to focus on other pressing tasks. There are also key goals for the project that Team 504 will focus on, leading them towards a design that will accomplish all these important aspects.

1.1.2 Key Goals

An important goal for this project is to move both the plastic pallet topper and foam layer off the pallet in the depalletization cell, as well as onto the pallet in the palletization cell. The plastic pallet topper is the finalizing piece of a pallet in Corning's system. The foam layer is used as a protective layer for ceramic cylinders. These pallets are used for storage of ceramic cylinders, until it is time for them to be used in the manufacturing of diesel particulate filters. The ability to place both layers when a pallet is being built, as well as remove them while a pallet is being disassembled is the ultimate key goal of this project.

Another key goal of the project is to minimize human interaction, so a reliable, self-sufficient design is an important aspect of the project. Minimizing human interaction will allow

Corning to use this human interaction elsewhere in their manufacturing process as well as alleviate the physical strain that the workers are put through. Employees will be able to interact in valuable tasks which in return will create a more efficient work environment, as well as save Corning money. In addition, the device should not require a great deal of maintenance and should work without causing issues for the employees of Corning. The device requiring maintenance leads to inability to operate, slowing the manufacturing process. Creating a reliable device ensures continued operation and an efficient manufacturing process.

In addition to minimizing human interaction, one key goal is to be able to design a device that can fit within Corning's specified spatial constraints and to incorporate the company's current robot with the team's device. Corning has spent a considerate amount of money on their palletizing and depalletizing robots. Making sure Team 504's design supports and works in unison with their robots is vital to the success of the project. These robots operate within a warehouse that includes many employees and moving aspects. Taking up limited space allows for efficient operation to take place around it, creating a smooth, and synchronous process.

Lastly, the device should also include fail-safes, to ensure the safety of employees working in the area. Regulations are in place for work done with heavy machinery, so the project must adhere to those rules and regulations. Corning has stressed the importance of fail-safes within their manufacturing process, and as this device creates an addition to that process, it must meet those safety requirements set in place. Failure to design a safe device will result in Corning's inability to use said device, meaning Team 504's project would be a failure. The fail-safes will mitigate injury to Corning employees as well as potential lawsuits to responsible parties.

These key goals were made with Corning's manufacturing process in mind. They were set to assist in creating a more efficient, more effective, and safer system of automation. Ultimately, Corning is Team 504's primary market behind this project.

1.1.3 Primary Market

The primary market for this project is the company Corning. This project will be made to their specifications and built with their current pallet packaging process in mind. A successful project will result in a much more efficient packaging process for them specifically.

1.1.4 Secondary Market

Ultimately, this specific project is to assist Corning in creating a more efficient storage process of these filtration parts, as these parts end up in storage for an extended period before use. So, any secondary market is one that has a longer, and more extensive manufacturing process, as well as involving a great number of parts.

John Deere is a company that fits these characteristics. With their larger products needing to be pre-ordered before being assembled, this means that their corresponding parts are stacked and stored, waiting for assembly. With some of John Deere's tractors being tens of thousands of individual parts, an efficient process of packaging and unpackaging of these parts is important. A successful design for Corning could be adjusted to the specifications of John Deere's process as well.

Another company that fits this characteristic could be Kroger. Kroger is always storing away, packaging, and processing groceries/goods to be shipped. Once they receive the goods from outside sources, they are stored away. They then unstack pallets, remove the goods, and place the goods in certain containers depending on where they are being delivered to in a certain neighborhood. This would make Kroger a good secondary market because a successful design for Corning could change or adjust to the specific needs of Kroger.

A pallet topper manufacturer is the company SSI SCHAEFER. SSI SCHAEFER produces a design that is advertised as a “nestable pallet design”. Corning has implemented a different design but falls around the range of SSI SCHAEFER where the pallets can be stackable and nested onto each other, except Corning has introduced a foam padding inside their pallet toppers that ensures the materials being stacked onto of each other can be stored and shipped safely. Introducing this new concept to the company's current nestable pallet topper can allow the shipments of products on the pallet to be safer than it ever was before.

Lastly, Ford Automotive can also be included in the secondary market. Corning informed Team 504 that they manufacture parts for automakers, including Ford, pack them on a pallet, and then ship them out. Since Corning will use Team 504’s device to place the topper in their palletizing process, they can anticipate the device can also be used by any of Corning’s customers in their depalletizing process.

1.1.5 Assumptions

To ensure team 504 stays within the scope of the project, a few things must be assumed. The team will assume that there will be a power supply that is within reach for the device, this means that the Corning facilities will have any needed power available. The team will assume that the pallet stacking surface will be stable and uniform for the device. Another assumption is that the warehouse has a controlled environment, so the device does not need to withstand certain weather conditions. The team will also assume that pallet stacks are removed from the conveyer system in a timely manner for efficiency. Another assumption to be made is that each foam piece and pallet topper are mostly uniform in size and weight and do not vary too much.

1.1.6 Stakeholders

The stakeholders for this project include Team 504, Dr. McConomy, as well as the Senior Design T.A.'s Eliase Haase, Tripp Lappalainen, and Jacob Schmitt. The list of stakeholders also includes the sponsoring company, Corning, and their corresponding representatives; Jeffery Stott, Trent Brush, and Billy Terry. Any secondary market interested in the device is also included in the list of stakeholders. Dr. Hubicki is also a stakeholder in the project as the team's appointed advisor. Additionally, Occupational Safety and Health Administration (OSHA) are stakeholders as Team 504 must adhere to their rules and regulations.

Table 1

Stakeholder Matrix

Stakeholder	**Investors**	**Decision-Makers**	**Advisors**	**Receivers**
Dr. McConomy			x	x
T.A.'s			x	
Dr. Hubicki			x	x
Corning	x	x	x	x
Team 504		x		
OSHA				x
Secondary Market				x

1.2 Customer Needs

1.2.1 Introduction

Team 504's initial meeting with Corning provided much background information on the project but left the team with a broad and unspecified scope. There were a few different directions in which the team could go with the project, such as working around different robotic cells Corning had been using or focusing on the pallet toppers and foam separators specifically. Corning's initial thoughts seemed to be that any help the team could give in their palletizing/depalletizing process would be great. Corning also felt that giving directional freedom would allow the team to find the issue and solve it effectively.

Over the following week, Corning decided that providing more direction would benefit the project, as during the next meeting they gave the team a specific area of their process to focus on and try to optimize.

Table 2

Customer Needs Question, Response, and Interpretation

Question	**Customer Statement**	**Interpreted Need**
What are the key goals Team 504 should have for the project?	"The goal of this project is to make the employee's lives better, the process more efficient, and improves the job that we do."	The device needs to improve the current palletization and depalletization process.
What would you consider a successful project?	"If the pallet topper can be removed from the depalletization cell, and placed in the palletization cell, that would be a successful project. If the foam layer can also be removed/placed that would be great."	The device needs to remove pallet toppers from stacks in the depalletization cell, and place pallet toppers on stacks in the palletization cell.
Are there spatial constraints due to the current cell setups?	"The safety fences can be adjusted to where you would need, the gate can be moved for more space, and the conveyer belts can be extended out further if needed. You should be creative with the space."	The device needs to fit within a current or adjusted assembly cell.

Should pallets removed from the Depalletization cells be used directly in the Palletization cell?	"That could be an option, but since the two robots are not operating in unison necessarily, this may not be realistic."	The pallet toppers need to have a stagnation place, as the palletization and depalletization cells are not working in unison, so the toppers will not be transitioned automatically from one to the other.
Can the Design of the Automated Pallet Topper be inside the Cell where the robot is inside?	"Yes, it can be placed inside or outside the cell, if they must turn off the robot first for our design to operate and finish the task."	The device needs to be placed anywhere in or near the cells, cannot interfere with the current robots.
How long does it take for an employee to stack the pallets manually?	"It takes roughly two minutes."	The device needs to match the amount of time of human interaction.
How heavy is the pallet topper?	"The pallet is about 30 lbs. and the foam inside of it is between 4 and 5 lbs."	The device needs to lift over the expected amount of weight of the pallet topper.
How does the conveyer belt work? Is it automated?	"The conveyor belt communicates with the robots through the PLC, which acts as a bridge between the two systems letting them know when the next step is able to be taken."	The device needs to communicate with Corning's current system to have a synchronous operation system between the three stages.
What is the exact material of the pallets and foam?	"The pallet toppers are made from polystyrene, and the foam layers are made from polyethylene."	The device needs to move the pallet topper and foam layer without damaging or affecting those pieces.
Are the pallet stacks uniform in height?	"No, the stacks are not of uniform height. The heights are measured using sensors within the machine's safety curtains, and the cylinders are placed at a certain height based on those readings."	The device needs to be able to detect certain heights of pallet stacks.
How much vertical and horizontal space would you say we are able to work with?	"The building that these cells have about 30-foot ceilings and a wide area of space on the ground. There has to be room for the forklifts to operate, and space for the completed pallets, but 2 dimensional drawings will be	The device needs to be able to fit within the spatial constraints provided by Corning.

	provided to the team to display the estimated amount of space in the warehouse."	

1.2.2 Explanation of Results

Over three meetings between Team 504 and the sponsors at Corning, Team 504 gathered a lot of information about the project and specifications as to what the project's goals will be. The goal is to create a device that works in unison with Corning's current systems to automate the placement and removal of the pallet topper, based on whether the palletization cell or depalletization cell is operating. This device needs to fit within Corning's spatial constraints but cannot interfere with or disrupt Corning's current robot processes. To effectively complete these goals, the device needs to be able to understand the heights and location of the pallet stacks and have ongoing communication with Corning's current system.

1.3 Functional Decomposition

1.3.1 Introduction

Functional decomposition is the breakdown of a system's overall procedure into smaller sub-systems all the way down to basic functions. This is where all system processes are broken down into smaller parts to be fully analyzed. Using a horizontal hierarchy chart, Team 504 broke down the project into the main sub-systems, and most basic functions. This hierarchy chart was formed by considering the customer needs, project objectives, and key goals. The project was divided into sub-systems: Movement, Communication, Sensors, Support, and User Interface. Functional Decompositions creates a visible link and a deeper understanding of how a system's most basic functions lead to a project's success.

1.3.2 Discussion of Data Generation

The data and information gathered for the functional decomposition was created by questioning the sponsors at Corning. Three meetings were held to determine the exact goals and needs for the overall project. While meetings are still being held with Corning, some needs and goals will be adjusted. With the current information, though, Team 504 was able to break the project down into systems, sub-systems, and functions. These systems, sub-systems, and functions allow Team 504 to understand how the device will need to operate. This also helps the team in understanding what functions will create success and help guide in the process of decision-making and concept generation.

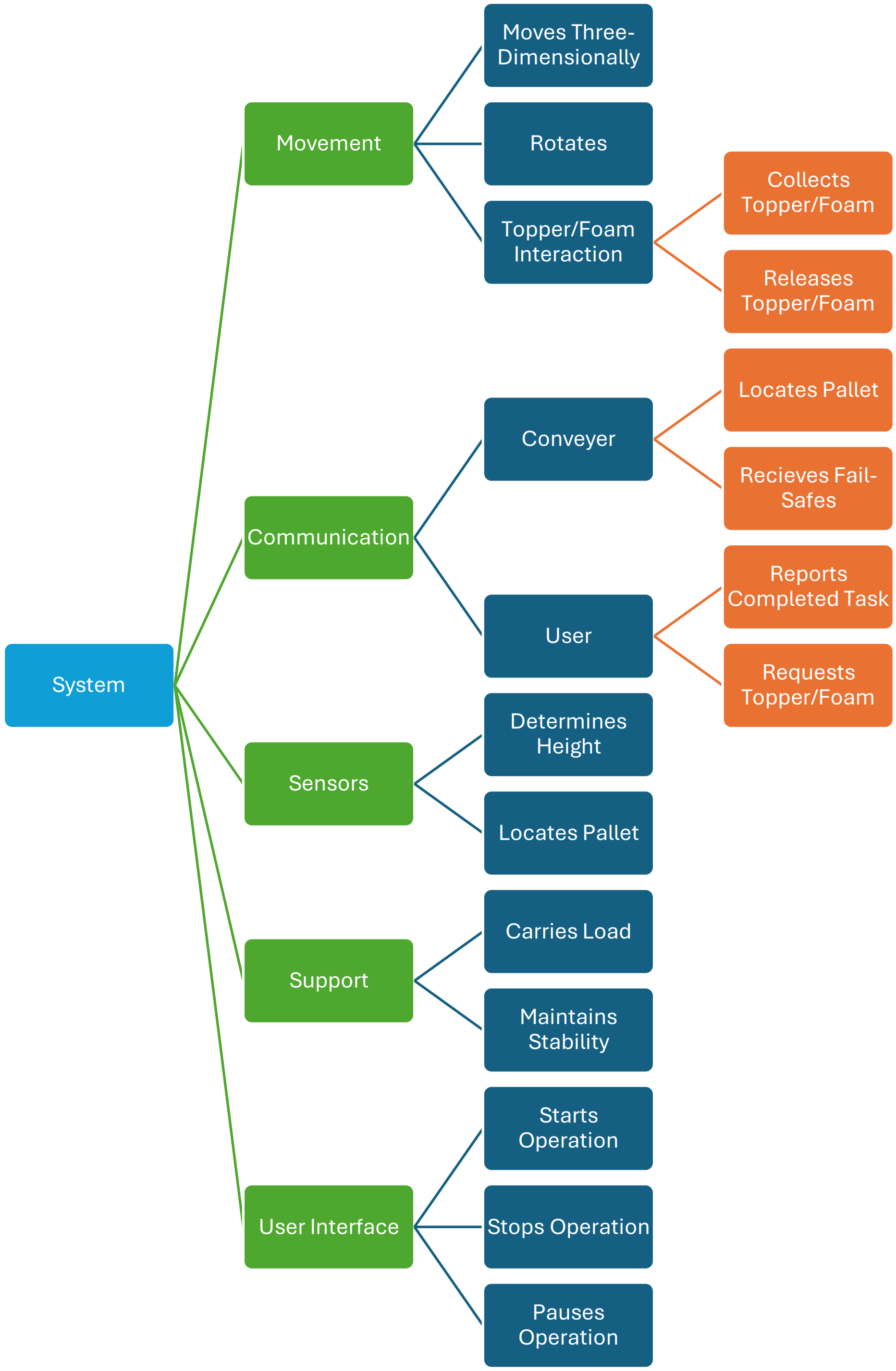

Figure 1. Hierarchy chart for Functional Decomposition.

Table 3

Cross Reference Chart

System					
Function	**Movement**	**Communication**	**Sensors**	**Support**	**User Interface**
Moves Three-Dimensionally	**X**				
Rotates	**X**				
Collects Topper/Foam	**X**			**X**	
Releases Topper/Foam	**X**			**X**	
Locates Pallet		**X**	**X**		
Receives Fail-Safes		**X**			
Reports Completed Tasks		**X**			**X**
Requests Topper/Foam		**X**	**X**		**X**
Determines Height			**X**		
Carries Load	**X**			**X**	
Maintains Stability	**X**			**X**	
Stops Operations					**X**
Pauses Operations					**X**

1.3.3 Introduction of Graphics

The hierarchical diagram above shows how the system is organized into constituent parts and how they react with each other based on the desired outcome. All the functions and sub-systems branch out of the "System" node. Each function and sub-system were created with the actions and consequences of the customer's needs. Movement, communication, sensors, support, and user interface are the five sub-systems the "System" has been divided into. Those five sub-systems are then divided into twelve functions, which categorize seven tasks the device must complete.

1.3.4 Connection to Systems

The Cross Reference Display Table reveals the relationships between the devices' most basic functions and the sub-systems of the project. This provides direction and clarity on why quality work done on the most basic functions of the project relates back to high quality and efficiency throughout the sub-systems of the project. In addition, both the Hierarchy Chart and Cross Reference Display Table show which sub-systems have the most basic functions, which correlates to the importance of those sub-systems. For example, many of the basic functions are involved in the Movement sub-system. This makes sense as movement is crucial to the success of the project, as the movement of the pallet topper and foam layer from one place to another is essentially the goal of the project.

1.3.5 Smart Integration

When looking at the Cross Reference Display Table, it may be noticed that some of the basic functions of operation fit within multiple sub-systems. This is to be expected, and these situations are known as cross sub-system relationships. While each sub-system separates things to complete the project's objective, it is important to understand that a level of cross sub-system relationship is needed to achieve success. To get a better understanding, let's look at the basic function of "Maintain Stability". Maintaining stability is crucial for anything to operate successfully, as it relates to the device's ability to support itself, and the objects it moves, which is why the function "Maintain Stability" fits under the sub-system "Support". However, maintaining stability plays a role in more than just that sub-system, as without stability, it would not be possible for the device to move in its intended way. This is why the basic function "Maintain Stability" applies to both the "Support" and "Movement" sub-systems.

1.3.6 Discussion on how F.D. was Gathered

To start the functional decomposition the system must initially be broken down into its most important sub-systems. These sub-systems are the general things that the system must contain to be able to complete the project objective. In the case of Team 504, these sub-systems are Movement, Communication, Sensors, Support, and User Interface. Movement is essential to the success of the project, as movement is simply a requirement to get the topper and foam pieces from point A to point B. Communication is also crucial for the success of this project, as this device must be integrated into Corning's current manufacturing process. Communication is needed to ensure synchronous operation within the entire manufacturing system. Sensors are necessary within the device, as it must be able to understand the height and location of the pallets to ensure accurate placement and removal of the topper and foam pieces. Like most devices, Team 504's project must withstand its own weight and the weight of what it is moving to be successful, making support a main sub-system. Like any manufacturing machinery, Team 504's device requires a user interface to allow human interaction to take place when needed. This allows for the device to start, stop, and pause based on employee input.

1.3.7 Function Relation

The system is broken down into five different sub-systems that contribute to the palletization and depalletization of stacks that will be dealt with. If performed correctly the system will be able to do these tasks with efficiency while requiring very little user interference, which in terms alleviates the need for human labor greatly.

The movement sub-system ensures that the system can move freely within any plane of a three-dimensional field. The combination of movement along with the function to interact with the pallet topper and foam will allow the device to grab the topper and the foam together, lift them, and then rotate them down to a stack or off a stack.

The communication sub-system will allow the system to be able to accurately place and remove the pallets and enable a fail-safe through the conveyor belt that Corning already uses. The conveyor belt has a master plate that never leaves and will be the main thing to assist with the accuracy of placing and removing the pallet. It also has a light curtain as a failsafe that will be active when a person gets too close to the operating system. By taking these and incorporating them into the system it will allow the tasks to be performed in a similar way. This sub-system will also be able to interact with the user to request more pallets if they run out and communicate when the task of palletization or depalletization is complete.

The sensor sub-system will allow the system to determine how high the stack of filters is and where the filters are so that it is able to properly place the top pallet on or remove it. This sub-system works closely with the communication sub-system as they help each other complete the task. Although it is not listed in the functional hierarchy, there is a possibility that the sensors sub-system will also be used as another failsafe apart from the one that Corning has installed. This depends on where the system will be installed relative to corning's current system.

The support sub-system is concerned with the system's operational safety and physical capacity. The system must be able to support the weight of itself as well as the weight of the parts it must move. It includes the system's capacity to carry the topper with foam inside while maintaining stability throughout use. This is essential for the task's productivity as well as to guarantee that safety regulations are followed, preventing mishaps and material failure while in use.

To enable user engagement with the system, user interface is essential. Operators can start, stop, or pause operations via the user interface. Starting an operation, either palletizing or depalletizing starts the system's workflow. Stopping the system might be required for a safety concern or a mistake. For safety reasons, Corning already has a sensor curtain on both sides of the conveyor belt. If any movement is detected, the sensor stops all operations on the side where the robot is operating. This illustrates the need for a halt function in the system. Pausing an action allows flexibility during the workflow. Adding more pallets or removing a complete pallet might be an example of why this is needed.

1.3.8 Action and Outcome

Ultimately, the project's objective is to assist in Corning's current manufacturing process, specifically in the removal and placement of the pallet toppers with foam layers. When looking at the physical technical actions that must take place, it can be well summarized by the sub-systems of movement, communication, sensors, support, and user interface. Each of these sub-systems plays a crucial role in achieving the project objective, and without each sub-system, Team 504's project would not have found success.

1.4 Target Summary

The most basic functions are taken from the function decomposition hierarchy chart. The explanation and clarity behind these functions become the metrics of this project. The targets are the quantitative values that are hoped to be reached. Below is the summary table which contains the most crucial targets and metrics for the operation of a successful project. Successfully reaching these targets and metrics will lead to a successful project that will possibly be incorporated into Corning's current system.

Table 4

Critical Targets

Functions	Metrics	Targets	Units
Move Three-Dimensionally	Moves with width, depth, and height	x-y-z	Planes
Rotates	Fully Spins	360	Degrees
Collects Topper/Foam	Picks up and holds Topper/Foam	≤ 30	Seconds
Moves Between Two Set Points	Moves from one location to another	≤ 30	Seconds
Releases Topper/Foam	Drops Topper/Foam	≤ 30	Seconds
Communicates Pallet Location	The device receives information from the conveyor belt about pallet location	1	Boolean
Determines Height	Read stack height	$32.75 < x < 42.5$	Inches
Carries Load	Lifts and moves pallet topper/foam	≥30	Pounds
N/A	Cycle Time	120	Seconds
	Grip Reliability	90	Percent
	Robustness of Positional Error	6	Inches
	Max Payload	210	Kilograms

1.4.1 Validation and Derivation of Targets and Metrics

Having the ability to move within a three-dimensional field opens a wide range of possibilities for solutions to the problem. It also allows for efficient and accurate placement and removal of the pallet toppers, which again is a key goal of the project. The target of this metric would be the planes on which it can move, being the x, y, and z planes. Based on Corning's current layout the device needs to be able to freely move in any direction for accurate placement and removal of pallet toppers. To validate this movement, we can run CAD simulations within Corning's current assembly cells. These CAD simulations can also be used for other movement functions that are listed below. Any design we make can be implemented into Corning's current CAD designs and simulated to get an idea of how it will function.

The "Rotates" function is similar to the three-dimensional movement function, as it also allows for efficient movement and operation of the device. Full rotation allows for the ability to position the device and pallet topper in ideal position for removal and placement. Based on Corning's cell setup, a centralized device that rotates seems the most ideal. So, having a target of 360 degrees gives the system the widest range of options and abilities that may not be available with a condensed rotational range. This also allows for closer reaching distances to the device.

"Collects Topper/Foam" is a crucial function of the system as the transition of pallet toppers from one place to another is reliant on the ability to pick up those materials. The collection of the topper and foam piece are the first physical step in the system's ability to complete its task. The target of 30 seconds or less is based on the customer's needs, and the cycle time that is expected of the system.

The "Moves Between Two Set Points" function refers to the system's ability to move between the specified locations within the cell. There are set locations where the system will have to collect or release materials, but efficient movement in between these locations allow for effective cycle times. Ultimately, a target of less than or equal to 30 seconds was decided based on the project needs, as well as how the timing of the cycle is planned on operating. If the system can move between the set points in 30 seconds or less, it will likely be able to finish a complete cycle in less than the 120 second goal. To return to the start position and complete the cycle, it is important to remember that the system must move between two set points twice per cycle.

The "Release Topper/Foam" function is a crucial step in the palletization and depalletization process, making it a crucial function within the system. Effectively releasing the topper onto the intended location is one of the final physical steps of the system's cycle. An accurate and effective release of pallet toppers are a crucial aspect of the system. The target of 30 seconds relates back to the customer needs, and the cycle time goal. Ultimately, if the system reaches the targets of less than or equal to 30 seconds for collects topper, moves between two set points, and releases topper, it will also reach the cycle time target of 120 seconds.

The function "Communicate Pallet Location" is essential since it guarantees the system can precisely find the pallet topper/foam through communication with Corning's conveyor belt and the mother plate. This is necessary for the accurate handling of both the collection and release of the foam/topper. The target is set to 1, indicating whether the pallet has been located. The measure for this function is successfully identifying the pallet's position. The unit of measurement, Boolean (true or false), indicates whether the system finds the object.

The "Determines Height" function is important to make sure that the device can properly place the pallet topper on top of the stack of cylinders. Based on the information Corning gave, there are multiple ceramic cylinders with different heights, and this will cause different final heights when completing a stack. For the product to do its job accurately it must assess how high the pallet topper needs to go, otherwise, the product will think that all the stacks are the same. This will result in either the stack being hit and knocked over or the top being dropped from too high. Being able to read these varying heights will reduce the risk of damage. The target of this function is based on information from Corning, with the possible height extremes ranging from 32.75 to 42.5 inches. 32.75 inches is the height of the shortest pallet, without the topper, so the system will have to read its height before placing the topper. 42.5 inches is the tallest pallet height, including the topper, which will have to be read and removed to begin depalletization.

“Carries Load” is a crucial function as it is necessary for all movement functions to operate. Without the ability to carry the intended load, the goal of the project will not be able to be met. The target of carrying at least 30 pounds was established based on how much Corning’s pallet toppers weighs and to factor in some safety when considering this. This load does not consider the tooling that is used to grip the pallet topper but is specifically referring to just the load of the pallet topper, which is the heaviest piece in the process. If the system can carry the weight of the pallet topper, the weight of the foam pieces or ceramic cylinders should not be an issue, weight wise. The load applied to the system can continuously increase, seeing how the system will move with a lighter load, and eventually a heavy load. Ideally, the system will operate at a load greater than that of 30 pounds, but that is the target for this function.

With the goal of creating an efficient process, completing the task of placement or removal of the pallet topper in the expected time is important. This correlates with the “Cycle Time” metric with a target of 120 seconds. To specify, cycle time is the time it will take to complete a stack or disassemble a stack. For example, if the palletization cell has a completely stacked pallet, and needs a topper placed, the cycle time is the time from when the pallet is in position, until the pallet topper is placed on the completed pallet. Based on Corning’s estimate of human interaction to get the task complete, as well as consideration to what cycle time allows for the system to continue to operate productively and in unison, the target of 120 seconds was found. The complete cycle can be continuously run, and ultimately optimized until a cycle time of 120 seconds is reached and consistently run.

The function of “Grip Reliability” is an important aspect of the project, as the first step of either placing or removing a topper is the gripping of the pallet topper. For the system to be reliable, the gripper must be successful during most of its operation, giving a target of 90% grip reliability. The reliability of the gripper is important, as the ability of the system to collect and release the topper is crucial to the success of the system. In other words, the system will not be successful in transferring pallet toppers from one place to another if the ability to grab and hold these pallet toppers is not reliable. To find the grip reliability, repeated testing of the gripping mechanism is needed. Once a large sample size is taken of the grippers successful and failed attempts are taken, it will be observed what that grip reliability value is.

"Robustness of Positional Error" is referring to the offset that the system should be able to handle, and still complete the expected tasks. More specifically, it is the distance that the pallet toppers can be offset in the gripping area and the device will still be able to pick them up. For example, with a target of 6 inches, if the pallet topper is 6 inches from its expected position, the system should still be able to grip and hold it without any issues. This can be tested by increasing the offset of the system and seeing at what distance the gripping mechanism no longer completes the task. That offset point will be the robustness of positional error, and the hope is that it will be 6 inches or greater.

The "Max Payload" of the system is an extremely important aspect to keep in mind. The current robots that operate in Corning's manufacturing line are FANUC R2000 robots, with the two robots in these systems being 210F models. Basing the system off the R2000iC/210F robots, the total payload cannot extend over 210 kilograms. This includes both the tooling on the robots, as well as the pallet toppers, foam layer, and ceramic cylinder. Keeping the payload below 210 kilograms is crucial to the success of the project, as the robot arms will not be able to operate with a mass greater than 210 kilograms, completely shutting down the entire system. Incrementally increasing the payload on the R2000 robot will test its ability to move and operate.

It will allow for a better understanding of how the robot will move with an increased payload, compared to a lighter payload, as well as confirm if the max payload is 210 kilograms.

1.4.2 Summary

Accurate and quality targets and metrics are crucial for the success of a project. It gives quantitative goals to the basic functions of a system, which leads to its ability to operate successfully. These targets were found based on the information provided by Corning and bench marking. These metrics can be tested to ensure the targets are attained. As the project progresses, the targets and metrics will be a guide to finding success within each sub-system, ultimately leading back to the success of the project.

1.5 Concept Generation

1.5.1 Introduction

With the project scope specified, customer needs recognized, and functional deposition completed, there is enough information and understanding of the project to begin concept ideation to begin working towards a final solution. In terms of the Corning Automated Topper project, there are essentially three streams of ideation for which the direction of the project may go. One branch of concepts would be new tooling dynamics to be integrated into Corning's current R-2000 robots, to give them the capabilities of handling both the ceramic cylinders and the pallet toppers. Another branch of concepts would be to include an additional Fanuc robot into Corning's cell configuration. These robots would be specifically focused on the handling of the pallet toppers and would also require the design of tooling to fit the needs of the robot. Fanuc has a great number of robot options that have different strengths that can be used for a successful project. The final branch of concepts are mechanisms that do not require Fanuc robots or the design of tooling for them to operate. This branch has a much broader scope of concept options and includes concepts that may use aspects of Corning's warehouse, simple mechanisms, and a lot of creativity.

1.5.2 Medium Fidelity

After generating all 100 ideas, the team then made a list of 5 medium fidelity concepts. This was done by everyone in the team picking their favorite ideas, which was then condensed into a list of 21 ideas. After creating the list of 21 ideas, everyone gave each idea a rating between 1 and 10, the ones with the highest ratings were chosen as high or medium fidelity. Even though these 5 concepts for medium fidelity are not of high priority, they are still crucial. These will allow for a broader comparison to the high-fidelity options when selecting a final idea or even to implement other ideas into a high-fidelity concept.

Long Hook Clamp (60):

The Long Hook Clamp concept involves a clamping mechanism to the top and bottom of the pallet topper. On the bottom of the of the pallet topper the tooling wraps out and around the middle footing in a hook fashion for added support and equal distribution. This tooling will be able to lift and move both the pallet topper and embedded foam layer. It will not be able to complete the actions of Corning's current tooling, so it will have to be added to their current system and be able to operate synchronously with their current tooling. This concept can perform all necessary movements required of it, while have good support of the large, heavy topper.

Spider Claw on R-2000iB/200T (2):

This concept consists of creating a whole new tooling that can be incorporated onto a different robot. This device will then be placed into Corning's current assembly cell or nearby to complete the final stacking or removal of a topper. The robot that will be used for this concept is a Fanuc R-2000iB/200T. This robot can be used as a gantry device, this will allow it to be mounted outside and overhead the assembly cells. It will be able to move overhead between each cell to place or remove the pallet topper. The gripper will look kind of like the legs of a spider. This will allow for it to expand and then close on multiple sides of the topper to secure it.

Vacuum on M-710iC/70T (45):

This idea consists of using a vacuum gripper as the tooling. The tooling will essentially use air to grip the pallet topper. This gripper will be placed on the Fanuc M-710iC/70T. The robot has a lighter payload of 70 kg as it will only be handling the pallet topper. To successfully stack and remove toppers, it can be used as a gantry device since it is a top loader robot. Ultimately, it will act very similar to the idea above (2) and be mounted overhead so that it can easily move between the palletizing and depalletizing cells.

Pinch Stacker (54):

It is assumed in this design that the pallets are stacked with the top deck facing down, and that the foam layer is either glued or zip-tied to the pallet. To grasp the cylinder, it would add an extension to Corning's existing tooling. Assuming, per Corning, the foam could be stuck in the pallet topper, this extension will be able to pinch the pallet on two opposites sides. The motion will consist of the robot arm extending, pinching the pallet, elevate the arm as it moves in with the now secured pallet, rotate in the direction of the stacked pallet, and then place it atop the finished stack.

Hexagonal Cell Tooling (55):

Hexagonal Cell Tooling uses a webbing of hexagonal cells, like that of a beehive. These cells can collapse around an object that is forced within it, and form around that shape. So, this tooling could be added to Corning’s current R-2000 robots and be able to handle both the ceramic cylinders and the pallet toppers. The ceramic cylinders would only need one gripper to operate, but the pallet topper would need two grippers to handle. This tooling could be able to perform all the movement functions required of it.

1.5.3 High Fidelity

Below are the three concepts that were identified as high fidelity. These three concepts seem to fit the customers' needs the best as well as the key goals of the project. Since these three concepts seem to fit the overall goals and needs of the project, one of them will most likely be selected as the final idea and prototyping will begin.

Rack and Pinion Retractable Clamp (67):

The rack and pinion retractable clamp is essentially like the side clamp tooling. It will be able to open and close pneumatically. This design will allow for easy integration with Corning's current system as it will be able to slide in or out with a rack and pinion setup. The ability for this tooling to slide in and out is important because it cannot interfere with how Corning currently stacks the ceramic cylinders. When the clamp is needed to place or remove a topper it can be activated and slide out. However, when it is not needed, it can slide back in and stay out of the way for the cylinder stacking process. This design idea also incorporates the current robots that Corning uses. So, it is important to make sure the max payload of the robot is not exceeded.

Piston Retractable Side Clamp (64):

The piston retractable side clamp acts almost the same as idea 67 mentioned above. It will be used on Corning's current robots, but instead of sliding in and out with a rack and pinion setup, it will slide in and out with a pneumatic piston. This will allow for the clamp to be deployed when needed in the stacking process. When it is not needed it will be sucked back in and tucked away by the piston. Again, it is important to make sure that this tooling will not exceed the maximum payload of 210 kg.

Vacuum on R-2000iC/165R (17):

This design idea consists of a vacuum gripper attached to a different robot. The robot that will be utilized for this design is the Fanuc R-2000iC/165R. Since this robot will only be dealing with the pallet and utilizing only one tooling, the maximum payload can be lower. Essentially, this design will work by using vacuum suction cups that stick to the pallet and then move the pallets around to the desired locations or stacks. This robot is also a rack mount meaning that it will not have to be mounted to the floor. The rack mount robot saves floor space within the assembly cell and could be a better way of implementing another robot into their current stacking process.

1.5.4 Concept Generation Tools

Concept generation tools are crucial when ideation includes reaching such a high number of concepts. A morphological chart was used for concepts 1-49 for this branch of concepts, having seven different tooling options for seven different Fanuc robots with different strengths and capabilities. This proved to be extremely useful, as the tooling options were focused on the action of handling the pallet toppers and were not dependent on what robot they were a part of. So, this allows for each option from the morphological chart to be a viable concept as each tooling option could operate with each Fanuc robot option. Biomimicry was another tool used for concept generation. By looking at processes that occur in nature, concepts could be generated and confirmed to be viable. Brainstorming was also useful and allowed the team to spit ball many ideas.

Table 5

Morphological Chart

Concept Generation		Tooling Options						
		Flat Clamp (FC)	Spider Claw (SC)	Vacuum (Vac)	Side Clamp	Fork Lift (FL)	Pinch (P)	Elastic Rollers (ER)
Robot Options	R-2000iB/200T Toploader Robot	FC on R-2000iB/200T	SC on R-2000iB/200T	Vac on R-2000iB/200T	Side Clamp on R-2000iB/200T	FL on R-2000iB/200T	Pinch on R-2000iB/200T	ER on R-2000iB/200T
	R-2000iC/210F	FC on R-2000iC/210F	SC on R-2000iC/210F	Vac on R-2000iC/210F	Side Clamp on R-2000iC/210F	FL on R-2000iC/210F	Pinch on R-2000iC/210F	ER on R-2000iC/210F
	R-2000iC/165R	FC on R-2000iC/165R	SC on R-2000iC/165R	Vac on R-2000iC/165R	Side Clamp on R-2000iC/165R	FL on R-2000iC/165R	Pinch on R-2000iC/165R	ER on R-2000iC/165R
	M-410iC/185	FC on M-410iC/185	SC on M-410iC/185	Vac on M-410iC/185	Side Clamp on M-410iC/185	FL on M-410iC/185	Pinch on M-410iC/185	ER on M-410iC/185
	M-900iB/280L	FC on M-900iB/280L	SC on M-900iB/280L	Vac on M-900iB/280L	Side Clamp on M-900iB/280L	FL on M-900iB/280L	Pinch on M-900iB/280L	ER on M-900iB/280L
	R-1000iA/130F	FC on R-1000iA/130F	SC on R-1000iA/130F	Vac on R-1000iA/130F	Side Clamp on R-1000iA/130F	FL on R-1000iA/130F	Pinch on R-1000iA/130F	ER on R-1000iA/130F
	M-710iC/70T Toploader Robot	FC on M-710iC/70T	SC on M-710iC/70T	Vac on M-710iC/70T	Side Clamp on M-710iC/70T	FL on M-710iC/70T	Pinch on M-710iC/70T	ER on M-710iC/70T

1.6 Concept Selection

After conceptualizing one hundred ideas and determining the high and medium fidelity concepts, it is important to then decide on a final concept for design. Rather than picking based off judgement, it is important to do so through the analysis of the high and medium fidelity concepts. The analysis was done through the processes of Binary Pairwise Comparison, House of Quality, Pugh Charts, Analytical Hierarchy Process, Pairwise Comparison for Selection Criteria, and the Final Rating Matrix. To make sure that the customers voice was heard, Quality Function Deployment was used. Below, each step of the process of concept selection will be described and explain how a final concept was decided upon in an analytical fashion.

1.6.1 Binary Pairwise Comparison

The binary pairwise comparison is a tool used to give the customer needs relative weights by comparing them to themselves. In this process, a table is set up with a list of the customer needs going down the side and the same customer needs going across the top in the same order. To compare the customer needs and give them a relative weight they will be looked at going across and comparing one need to the rest of them. If the need in the row is more significant to the project than the need in the column then it is given a 1 and if it is less important, then it will be given a 0. When looking at the diagonal of the table, every cell will be filled in with a dash because it will compare a customer need against itself and there is no comparison there. At the end of the process, all the sums of the rows will be added up on the far-right side and those will be the relative weights that will be used in the House of Quality. Table 1 shows the binary pairwise comparison of the customer needs for this project and the column on the far right will show their relative weights based on the process that was taken, the higher the number, the more important that costumer need is for the success of this project. The Binary Pairwise Comparison charts are used to get an understanding about which customer needs are most critical to the success of the project. Throughout concept selection, the more crucial customer needs will have a heavier importance for concepts to successfully meet those needs. Concepts that can efficiently complete the most important customer needs will have a greater chance of being the selected concept.

Table 6

Binary Pairwise Comparison

Customer Requirements	1	2	3	4	5	6	7	8	9	Total
1. Remove and place pallet toppers in corresponding cells	-	1	1	1	1	1	1	1	1	8
2. Fit within current cells	0	-	0	0	0	0	0	0	1	1
3. Match the time of human interaction	0	1	-	0	1	0	1	0	1	4
4. Lifts over the weight of the pallet topper	0	1	1	-	1	1	1	0	1	6
5. Communicates with Corning's current system	0	1	0	0	-	1	1	1	1	5
6. Operates without damaging pieces	0	1	1	0	0	-	1	0	1	4
7. Detects certain heights of pallets	0	1	0	0	0	0	-	0	1	2
8. Does not interfere with the current robots	0	1	1	1	0	1	1	-	1	6
9. Includes stagging area	0	0	0	0	0	0	0	0	-	0
Total	0	7	4	2	3	4	6	2	8	36

1.6.2 House of Quality

The House of Quality is a strategic planning tool that assists design teams in concentrating on customer needs and converting them into product specifications. It is a matrix with a house-like shape, where various facets of product development are represented by "rooms." Customer needs are listed on the left, and engineering qualities are listed on the top. This helps determine how effectively each engineering quality satisfies customer needs by establishing a correlation between them. In contrast, the significance of each feature according to customer objectives is ranked at the bottom.

The table below reflects the house of quality for an automated pallet topper. On the left, customer requirements, such as "Remove and place toppers, fit within current cells, Does not interfere with current robots…" and other safety and compatibility needs are included. An

“Importance Weight Factor” ranging from 1 to 8 is applied to each customer requirement. This indicates the priority level for fulfilling each criterion in accordance with customer requirements.

The engineering qualities, which are the features that the design team can control to meet the client’s needs, are represented on the top, including “rotates, locates pallets, carries load, collects foam/topper, etc.” To meet the customer's needs, the improvement direction shown by arrows recommends whether each engineering attribute should increase, decrease, or stay at the same level.

1, 3, or 9 were used to determine whether the customer need has a weak, medium, or strong relationship with the Engineering Characteristics. For example, it shows a strong relationship between the customer’s need to “remove and place pallet toppers in corresponding cells” and the engineering characteristics “Move three-dimensionally, rotate, locate pallet, etc.” This implies that these characteristics are essential to fulfill this specific need successfully.

Raw scores display the cumulative influence of each engineering characteristic across all customer needs and are computed at the bottom of each column. The relative weight percentage shows how important each engineering characteristic is in relation to achieving customer needs. “Collects Topper/foam” and “Release topper/foam,” for example, which have a higher relative weight percentage (28.47%), can be interpreted as being more important than “Stop Operation”, and “Pause Operation” for the customer.

This helps determine which engineering characteristic should be focused on more to achieve better customer satisfaction by using the rank order in the last row, which gives each engineering characteristic a priority based on its relative value.

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Table 7

House of Quality

		Engineering Characteristics													
Improvement Direction		↑	↑	↓	↓	↓				↑↓	↑	↑	↓	↓	↓
Units		m^3	degrees	seconds	seconds	seconds	boolean	boolean	boolean	cm	kg	N	seconds	seconds	seconds
Customer Requirements	**Importance Weight Factor**	Moves Three-Dimensionally	Rotates	Collects Topper/Foam	Releases Topper/Foam	Locates Pallet	Recieves Fail-Safes	Reports Completed Task	Requests Topper/Foam	Determines Height	Carries Load	Maintain Stability	Starts Operation	Stops Operation	Pauses Operation
1. Remove and place pallet toppers in corresponding cells	8	9	9	9	9	9			3	9	9	3	1		
2. Fit within current cells	1						3								
3. Match the time of human interaction	4	3	3	9	9	3		3	3	3	9	3			
4. Lifts over the weight of the pallet topper	6	1	1	9	9						9	9			
5. Communicates with Corning's current system	5					9	9	9	9	3			9	9	9
6. Operates without damaging pieces	4	3	3	9	9	3	1			3	9	9		1	1
7. Detects certain heights of pallets	2									9					
8. Does not interfere with the current robots	6	3	3	9	9		9				9	9			
9. Includes stagging area	0								9						
Raw Score	885	120	120	252	252	141	106	57	81	129	252	180	53	49	49
Relative Weight %		13.56	13.56	28.47	28.47	15.93	11.98	6.44	9.15	14.58	28.47	20.34	5.99	5.54	5.54
Rank Order		7	8	1	2	5	9	11	10	6	3	4	12	13	14

1.6.3 Pugh Charts

The first Pugh Chart below compares all high and medium fidelity concepts to the Optimate Robotic Palletizer. This is another type of robot that palletizes in the manufacturing industry. The engineering characteristics were then used to compare the Optimate device to each of the eight concepts. If it was believed that either the Optimate Device or a concept compared best to a characteristic, it received a plus. If it did not compare well, it received a minus and if it was about the same it received “satisfactory”. After doing so, three of the concepts were able to be thrown away and five were kept to perform another Pugh Chart with. The Table below shows the first Pugh chart.

Table 8

Pugh Chart 1

Engineering Characteristics	Optamate Robotoic Palletizer	Concepts 1	2	3	4	5	6	7	8
Collects Topper/Foam	Datum	-	S	+	S	-	-	-	+
Releases Topper/Foam		-	S	+	S	-	+	+	+
Carries Load		S	S	-	+	-	-	-	-
Maintains Stability		-	S	S	S	S	S	S	-
Locates Pallet		S	S	S	S	S	S	S	S
Pluses		0	0	2	1	0	1	1	2
Minuses		3	0	1	0	3	2	2	2
Satisfactory		2	5	2	4	2	2	2	1
	Ranking	-4	5	4	6	-4	0	0	1

The second Pugh Chart was then used to compare the top five concepts from the first chart to one of the three concepts that got thrown away. From this it was then determined what three of the five concepts would be selected to continue the process of concept selection. These three compared better to the datum and were deemed more efficient.

Table 9

Pugh Chart 2

Engineering Characteristics	Concepts 8	2	3	4	6	7
Collects Topper/Foam	Datum	+	S	+	S	S
Releases Topper/Foam		-	S	-	-	-
Carries Load		+	S	+	S	S
Maintains Stability		S	-	S	S	S
Locates Pallet		S	+	S	S	S
Pluses		2	1	2	0	0
Minuses		2	3	2	4	4
Satisfactory		1	1	1	1	1
	Ranking	4	3	4	2	2

1.6.4 Analytical Hierarchy Process

The criteria comparison matrix was the first step in the analytical hierarchy process. This matrix was used to determine a more distinct weight among the customer needs by comparing them against each other. A more distinct scale of 1,3,5,7,9 is used in this process to accomplish the task of discerning which need is more crucial to the success of this project; the higher the value, the more important one need is over the other.

Table 10

Criteria Comparison Matrix

Criteria Comparison Matrix [C]					
	1	2	3	4	5
1. Collects Topper/Foam	1.0	1.0	0.3	5.0	5.0
2. Releases Topper/Foam	1.0	1.0	0.3	3.0	5.0
3. Carries Load	3.0	3.0	1.0	5.0	7.0
4. Maintains Stability	0.2	0.3	0.2	1.0	5.0
5. Locates Pallet	0.2	0.2	0.1	0.2	1.0
Sum	5.40	5.53	2.01	14.20	23.00

The next table in the Analytical Hierarchy Process is used to normalize the values that were gathered from the criteria comparison matrix. This is done by taking each individual cell and dividing it by the average of that column. The criteria weight for each customer need is then gathered by taking the average of the normalized values in that row.

Table 11

Normalized Criteria Comparison Matrix

Normalized Criteria Comparison Matrix [NormC]						
						Criteria Weights {W}
1. Collects Topper/Foam	0.19	0.18	0.17	0.35	0.22	0.22
2. Releases Topper/Foam	0.19	0.18	0.17	0.21	0.22	0.19
3. Carries Load	0.56	0.54	0.50	0.35	0.30	0.45
4. Maintains Stability	0.04	0.06	0.10	0.07	0.22	0.10
5. Locates Pallet	0.04	0.04	0.07	0.01	0.04	0.04
Sum	1	1	1	1	1	1

These criteria weights are then transferred to a consistency check table where they are transformed into a weighted sum vector. The weighted sum vector is then divided by the criteria weights to find the consistency vectors, if all of the consistency vectors are within the same range then it shows the numbers to be accurate and unbiased. The table below shows that all the vectors are within the range of 5 which means that the numbers are consistent.

Table 12

Consistency Check

Consistency Check		
Weighted Sum Vector {Ws} = [C]{W}	Criteria Weights {W}	Consistency Vector {Cons} = {Ws}./{W}
1.25	0.22	5.67
1.06	0.19	5.49
2.45	0.45	5.45
0.50	0.10	5.13
0.21	0.04	5.12
Average Consistency		5.37

For the final part of the analytical hierarchy process, a consistency index and consistency ratio will be taken, for the consistency index is calculated by taking the average consistency, subtracting it by the number of customer needs and then dividing it by one less than the number of customer needs that is had. The consistency ratio is gathered by taking the consistency index and dividing it by 1.11. For both numbers it is ideal to have them as close to zero as possible to show that everything for the process has been accurate and unbiased. The table below shows that the consistency index and ratio are 0.09 and 0,08 respectively. This shows a strong correlation of consistency when gathering the weight of the customer needs.

Table 13

Consistency

Consistency Index	0.09
Consistency Ratio	0.08
Consistent?	Yes

1.6.5 Final Selection

In the final selection process, the three concepts with the highest ratings from the Pugh charts are further compared and analyzed to make a final decision for which concept will be used going forward. The three concepts are compared against each other for each individual customer need using a scale of 1, 3, 5, 7, and 9. With this scale, 1 represents the two concepts that complete the customer need at the same effectiveness, while 9 represents that one is much better than the other at effectively completing the customer need. These charts are set up in the same manner that the Binary Pairwise Comparison chart is. If the concept in the row is better than the concept in the column in the specific customer need, then it will be given a whole number based on how much better it may be, if it is worse than the other concept then it will be given the inverse of that number. With calculations the charts can confirm if the ratings have been consistent throughout the concept selection process, leading the team towards the final concept. Once all comparisons have been made between the three final concepts, the final rating matrix will display the concept that is deemed the most effective in completing the most important customer needs. Ultimately, this concept selection process is an analytical way of arriving at the concept that will be most efficient in completing the goals of the project.

Table 14

Final Rating Matrix

[Final Rating Matrix]^T					
	Collects Topper/Foam	Releases Topper/Foam	Carries Load	Maintain Stability	Locates Pallet
2	0.49	0.09	0.64	0.19	0.20
3	0.11	0.82	0.07	0.08	0.20
4	0.41	0.09	0.28	0.72	0.60

Concept	Alternative Value
2	0.44
3	0.23
4	0.33

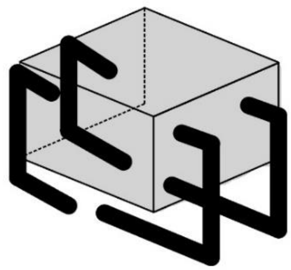


Figure 2. Spider Claw Rough Concept

1.8 Spring Project Plan

Chapter Two: EML 4552C

2.1 Spring Plan

Project Plan.

Build Plan.

Appendices

Appendix A: Code of Conduct

Mission Statement

Team 504's mission statement is to complete a successful project for the Corning Automated Pallet Topper. Assignments will be completed efficiently and in a timely fashion, keeping the team ahead of schedule, allowing the team to have freedom to adjust and make improvements without the threat of due dates. Communication with sponsors and team members will be consistent and clear, ensuring that all expectations are met.

Outside Obligations

Brightson is enlisted in ROTC as well as the Army, while Ahmari is on the FSU Track and Field team as well as working part time at the FSU Bowling and Billiards center. Their obligations outside of this project will not be affected by the teams meeting dates and times. If Brightson is required by the Army, the team will communicate virtually, and he will assist as much as he can in that instance.

Team Roles

Computational Engineer – Ahmari Avin

Design Engineer – Daniel Mack

Systems Engineer – Brightson Bazile

Materials Engineer – Craig Yox

Manufacturing Engineer – Michael Rodriguez Capera

The team will have assignment coordinators for each major assignment. This means each team member will review and understand the assignment at least a week before its due date and distribute work throughout the team to complete it. The assignment coordinator will have final revision over that assignment and will be looked to lead the team through completion of that assignment. The assignment coordinator will change with every important assignment, which will allow the team to have strong understanding under every assignment.

Every member of the team will be involved and contribute to every assignment. Every suggestion and idea offered to the team from a team member will be discussed and decided upon by the team.

<u>Methods of Communication</u>

The team will meet at least twice per week in person to talk about upcoming assignments, plan of completion, and preparation of future work. Team meetings will occur after Tuesday's and Thursday class, and Friday morning if need be. Tuesday meetings are for communication about assignments due that Friday, and how they will be completed. Thursday meetings are for final adjustments of said assignments and preparation for next week's assignments. Any form of communication will be responded to by the team within 24 hours.

Communication will be continuous throughout the year. Basic communication or urgent information will be done through text, including.

- Team Meeting Times
- Team Meeting Dates
- Schedule Changes
- Late arrival to a meeting

Microsoft Teams will be the team's main source of communication, being used to communicate project information.

- Assignment information
- Adviser/Sponsor Meeting Information

- Documents

Dress Code

Team 504 will wear a solid color polo shirt and khaki pants for all team meetings with sponsors and advisors.

Team 504 will wear a solid color button down shirt and slacks for all virtual design reviews and presentations.

Attendance Policy

The entire team is required to be present at all Advisor and Sponsor meetings. An 80% attendance rate is expected by team members for team meetings throughout the course of the year. Team meetings will be held at a time available for all team members. If a team meeting is missed by a team member, an agenda and summary will be provided and communicated to that person, to keep the entire team on the same page and working in unison. There will be a mandatory team meeting every Thursday after class.

If a member of the team does not meet the required attendance rate, or fails to communicate with the group, external support will be included.

Notify Group

Any last-minute adjustments or changes will be notified through text, while other important information will be sent through Microsoft Teams and Microsoft Outlook. Each member must respond within 24 hours.

Professional Communication

Any email or message to a Sponsor, Advisor, or Professor will be written professionally and checked by team members prior to being sent.

The project will be treated in a professional manner, and any communication from the team will reflect that.

Code of Conduct Amendments

If a team member wants to make an amendment to the team's code of conduct document, it must be agreed upon by at least 4 out of 5 of the team members.

Before Contacting Dr. McConomy or TA's

When the team finds issues within their project, they will seek assistance from professors with experience in that field.

Any issues that may arise within Team 504 about possible team members' effort will first be worked through with strong communication to that individual, and open dialog about issues caused by that person.

Contact McConomy

If a team members conduct reaches a point of hindering the project, or the quality of work for other classes of the other team members, and multiple conversations have occurred concerning this team member conduct without change, Dr. McConomy will be reached out to for support.

McConomy To Do

We would like Dr. McConomy to give us advice on how we can solve a specific issue and potentially help us fix it.

How to Amend

The team will continue to move forward with the project and set expectations within the team about how everyone's conduct will be.

Statement of Understanding

By signing this document, the members of Team 504 agree that they have read and agree to follow the terms listed in this document.

Confidentiality

By signing this document, Team 504 has agreed to respect the confidentiality of team discussions and sensitive information. Do not share or disclose confidential details outside of the team unless required by the Project Sponsors (Corning Inc.), Project Advisor (Dr. Hubicki), or Project Supervisor (Dr. Shayne McConomy).

X Ahmari Avin ____________________

Ahmari Avin

X ____________________

Brightson Belius Vilnor Bazile

X ______________________________

Craig Yox

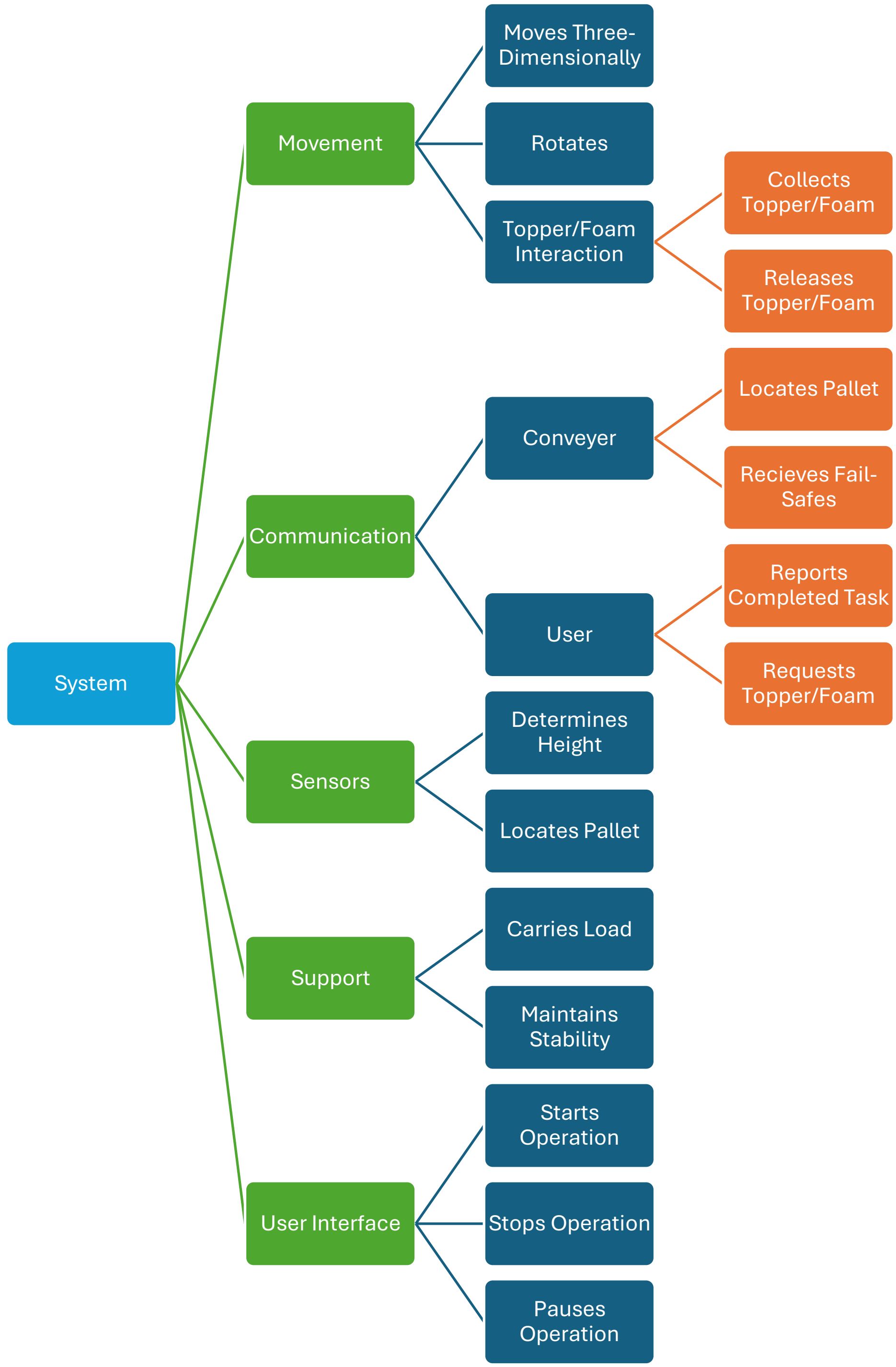
X ______________________________

Daniel Mack

X ______________________________

Michael Rodriguez Capera

Appendix B: Functional Decomposition



Appendix C: Target Catalog

Target Catalog				
Sub-System	**Functions**	**Metrics**	**Targets**	**Units**
Movement	Move Three-Dimensionally	Moves with width, depth, and height	x-y-z	Planes
	Rotates	Fully Spins	360	Degrees
	Collects Topper/Foam	Picks up and holds Topper/Foam	≤ 30	Seconds
	Moves Between Two Set Points	Moves from one location to another	≤ 30	Seconds
	Releases Topper/Foam	Drops Topper/Foam	≤ 30	Seconds
Communication	Communicates Pallet Location	The device receives information from the conveyor belt about pallet location	1	Boolean
	Receives Fail-Safe	The device receives the system's fail-safes	1	Boolean
	Reports Completed Task	Communicates completed pallet	1	Boolean
	Requests Topper/Foam	Requests needed materials	1	Boolean
Sensors	Determines Height	Read stack height	32.75 < x < 42.5	Inches
	Locates Pallet	Sensors the position of the pallet on conveyor belt	1	Boolean
Support	Carries Load	Lifts and moves pallet topper/foam	≥30	Pounds
	Maintains Stability	Structures are at equilibrium	0	N
User Interface	Starts Operation	Begins systems	1	Boolean
	Stops Operation	Shuts down system	1	Boolean

	Pauses Operation	Momentarily stops, then resumes the system	1	Boolean
N/A	N/A	Cycle Time	120	Seconds
		Grip Reliability	90	%
		Robustness of Positional Error	6	Inches
		Max Payload	210	Kilograms

Receives fail-safe: This is an important function for the system's dependability and safety. It can recognize problems and halt or modify operations to avoid damage or failure. The ability to receive a fail-safe signal serves as the function's metric, and since the target is set at 1, the system either receives the signal or doesn't. When the fail-safe is triggered, the system will react appropriately because the unit of measurement is Boolean(true/false).

Reports completed tasks: This function guarantees that the system can convey that a task has been successfully completed, which is necessary for process monitoring and system effectiveness. The target set to 1 indicates that the report has been made. The statistic for this function is whether the system reports the task as done. To ensure appropriate system feedback, the unit of measurement is Boolean, meaning that the system either properly reports the completed task or does not.

Requests topper/foam: This function enables the system to ask for new foam/topper as needed, which is critical for efficiency and preventing disruptions. The system's capacity to submit a request for the topper or foam is the function's metric, and a request with a goal of 1 indicates that the request has been made. The determination of whether a new pallet is needed can be done by setting up a height. If the device goes below that height and doesn't sense a pallet, it will convey that a new stack of pallets is needed for operation continuation. Boolean measurement ensures that the system can efficiently manage its own supply demands.

Maintains stability: In any event of what ends up being the final solution to the problem, a key aspect of it must be its stability. The product must always be able to hold itself together with no faults, and it must also be able to correct unforeseen movements when dealing with the pallet toppers.

Starts, Stops, and Pauses Operation: These three functions are all under the user interface sub-section, meaning that they are all concurrent on human input. As one of the needs of the system is automation, the device should be able to operate and complete the tasks without human interaction. These functions give the employees working around the system the ability to have control over the system and when it will be working.

Appendix D: Work Break Down Structure

Fall 2024 Senior Design Work Break Down

Milestone	Task	Notes	Assignee	Status	Date Completed
Code of Conduct					
	Mission Statement	Statement that the team lives by	Ahmari	Complete	9/12/2024
	Outside Obligations	Any conflict that a group member may have	Brightson	Complete	9/12/2024
	Team Roles	Assigning members to certain roles	Craig	Complete	9/12/2024
	Method of Communication	How the team will discuss anything about the project	Daniel	Complete	9/12/2024
	Dress Code	How each team member will dress for meetings and presentations	Michael	Complete	9/12/2024
	Attendance Policy	Shows who needs to be present and when	Ahmari	Complete	9/12/2024
	Notify Group	How to get into contact with one another	Brightson	Complete	9/12/2024
	Professional Communication	How to handle profesional meetings	Craig	Complete	9/12/2024
	Code of Conduct Ammendment	How will something in the code of conduct be changed if need be	Daniel	Complete	9/12/2024
	Before Contacting Dr. McConomy or TA's	What will be done before contacting help	Michael	Complete	9/12/2024
	Contact Dr. McConomy	How will Dr. McConomy be contacted	Ahmari	Complete	9/12/2024
	Dr. McConomy To Do	How McConomy can hopefully help	Brightson	Complete	9/12/2024
	How to Amend	Explain how to fix an issue	Craig	Complete	9/12/2024
	Statement of Understanding	Make a statement that shows everyoe agrees	Daniel	Complete	9/12/2024
	Confidentiality	NDA	Michael	Complete	9/12/2024
	Submit Report	Review and double check report before submission	Ahmari	Complete	9/12/2024
Project Scope					
	Project Description	The objective of the project	Brightson		
	Key Goals	What will be achieved during the project	Craig		
	Market	Justifications are given for the target market	Daniel		
	Assumptions	System and environmental barriers are defined.	Michael		
	Stakeholders	Those who have investment, interest or concern	Ahmari		
	Objective Statement	The objective of this project is...	Brightson		
	Submit Report	Review and double check report before submission	Craig		
Customer Needs					
	Interpreted Need	Needs of customer will be interpreted to engineering terminology. Explains what must be done not how. 50% of phrasing need to be positive and avoid using definitives	Daniel		
	Explanation of Results	Discusses how to the customer statements were gathered	Michael		
	Customer Statements	Customer statements are given	Ahmari		
	Submit Report	Review and double check report before submission	Brightson		
VDR1					
	Project Brief Summary	Summary of Goals, Scope, and Deliverables	Craig		
	Project Scope	Outlines Boundaries of the Project	Daniel		
	Customer Background	Who they are and what they are looking for	Michael		
	Customer Needs	Factors to motivate customer to buying product or service	Ahmari		
	Future Work	What plans/work are ahead for the project	Brightson		
	Submit Report	Review and double check report before submission	Craig		
Functional Decomposition					
	Graphics	Provide graphics of charts, used to reach results	Daniel		
	Explanation of Results	Explain the results.	Michael		
	Connection to Systems	What systems is the compenent comprised of	Ahmari		
	Smart Integration	Break down each system into subsystems	Brightson		
	Fuction Resolution	How each system and subsystem will work together to accomplish functionality	Craig		
	Action and Outcome	Describe the physical action of the outcome.	Daniel		
	Submit Report	Review and double check report before submission	Michael		
VDR1 Corrections					
	VDR1 Corrections	Make any corrections to first submission of VDR1	Ahmari		
	Function Decomposition	Include information regarding the work done in the functional decomposition.	Craig		
	Submit Report	Review and double check report before submission	Brightson		
Targets					
	Targets and Metrics	Identify and determine the metrics	Craig		
	Method of Validation	What tests will be used or how will we confirm our metrics	Daniel		
	Derivation of Targets and Metrics	How we determined our metrics/research	Michael		
	Critical Target/Metrics	What is critical to the project	Ahmari		
	Summary and Catalog	Overview of targets and metrics	Brightson		
	Submit Report	Review and double check report before submission	Craig		
Concept Generation					
	100 Concepts	Create 100 concepts of design for the project.	Michael		
	5 Medium Fidelity Concepts	Select 5 concepts that broaden ideation	Ahmari		
	3 High Fidelity Concpets	Concepts that closeley encompass the customers needs and key goals	Brightson		
	Concept Generation Tools	What tools were used to come up for 100 concepts.	Craig		
	Submit Report	Review and double check report before submission	Daniel		
Concept Selection					
	House of Quality	Use the House of Quality with the top concepts	Michael		
	Pugh Chart	Use the Pugh Chart with the top concepts.	Ahmari		
	Analytical Hierarchy Process	Use analytical hierarchy process to narrow down concepts	Brightson		
	Final Selection	Decide on a final concept selection for the project.	Craig		
	Submit Report	Review and double check report before submission	Daniel		
Risk Assessment					
	Potential Issues	Where possible risks could arise.	Michael		
	Safety Measures	What is put in place to avoid future accidents.	Ahmari		
	Emergency Contact	Emergency protocal and emergency contacts for employees.	Brightson		
	Submit Report	Review and double check report before submission	Craig		
VDR2					

	Project Brief Summary	Summary of Goals, Scope, and Deliverables	Michael		
	Project Scope	Outlines Boundaries of the Project	Ahmari		
	Customer Background	Who they are and what they are looking for	Brightson		
	Customer Needs	Factors to motivate customer to buying product or service	Craig		
	Future Work	What is next to be completed in the project.	Daniel		
	Function Decomposition	Breaking Down System into smaller indivual parts to manage better	Michael		
	Targets	What the system needs to be able to handle	Ahmari		
	Concept Generation	Generating ideas and solutions to a problem	Brightson		
	Concept Selection	Comparing different design options to select the best one for a project	Craig		
	Submit Report	Review and double check report before submission	Daniel		
Bill of Materials					
	Line Items	Items in order.	Michael		
	Order Names	Name of each item	Ahmari		
	Throughness of Project	Ability to list each item used, including smaller, insignificant items.	Brightson		
	Vender Identification	Where the pieces are from.	Craig		
	Line Items Maturity	New item of an existing one.	Daniel		
	Project Maturity	Changes to the project over time.	Michael		
	Cost	Cost of the pieces.	Ahmari		
	Submit Report	Review and double check report before submission	Craig		
Spring Project Plan					
	Project Progress Timeline	Timeline of future deliverables, and how they will be completed.	Daniel		
	Final Design	How the final design is looking at this point, and why that has been the decision.	Michael		
	Submit Report	Review and double check report before submission	Ahmari		
VDR3 Prototype					
	Current State	The point of the project at this time.	Brightson		
	Project Forecast	Next steps of the project.	Craig		
	Problem Areas within Project	Issues within the project at this point. How they were resolved?	Daniel		
	Complete Prototype	Idea brought into testing form	Ahmari		
	Submit Report	Review and double check report before submission	Michael		
Poster					
	Poster Design	The presentation of the proster.	Ahmari		
	Project Timeline	Plans for the project in the spring semester.	Brightson		
	Current State	The state of the project is at at this point in time. What is completed?	Craig		
	Mission Statement	The goals of the project, what should be accomplished.	Daniel		
	Prototype/CAD Design	Physic prototype of CAD model to display the plans for the project.	Michael		
	Submit Report	Review and double check report before submission	Ahmari		

Appendix E: List of 100 Concept Ideas

Idea #	Idea: Automated Pallet Topper
1. Flat Clamp on R-2000iB/200T	A device that uses an R-2000iB/200T robot with a flat clamp gripper (top and bottom of pallet). The robot will grip the topper and use a gantry to move from one stack to another. (Top Loader Robot)
2. Spider Claw on R-2000iB/200T	A device that uses a R-2000iB/200T robot with a spider claw type gripper. The robot will grip the topper and use a gantry to move from one stack to another. (Top Loader Robot)
3. Vacuum on R-2000iB/200T	A device that uses a R-2000iB/200T robot with a vacuum gripper (suction on top of pallet). The robot will grip the topper and use a gantry to move from one stack to another. (Top Loader Robot)
4. Side Clamp on R-2000iB/200T	A device that uses a R-2000iB/200T robot with a Side clamp (grips sides of pallet). The robot will grip the topper and use a gantry to move from one stack to another. (Top Loader Robot)
5. Forklift on R-2000iB/200T	A device that uses a R-2000iB/200T robot with a Forklift (Slides under pallet). The robot will lift the topper and use a gantry to move from one stack to another. (Top Loader Robot)
6. Pinch on R-2000iB/200T	A device that uses a R-2000iB/200T robot with a Pinch Gripper (grips center mold of topper). The robot will grip the topper and use a gantry to move from one stack to another. (Top Loader Robot)
7. Elastic Rollers on R-2000iB/200T	A device that uses a R-2000iB/200T robot with Elastic rollers (Rollers use elastic tension to grip). The robot will grip the topper and use a gantry to move from one stack to another. (Top Loader Robot)
8. Flat Clamp on R-2000iC/210F	A device that uses R-2000iC/210F robot with a flat clamp gripper (top and bottom of pallet). The robot will grip the topper, rotate, move the arm up and down while floor mounted and move toppers from one stack to another.
9. Spider Claw on R-2000iC/210F	A device that uses R-2000iC/210F robot with a spider claw type gripper. The robot will grip the topper, rotate, move the arm up and down while floor mounted and move toppers from one stack to another.
10. Vacuum on R-2000iC/210F	A device that uses R-2000iC/210F robot with a vacuum gripper (Suction on top of pallet). The robot will grip the topper, rotate, move the arm up and down while floor mounted and move toppers from one stack to another.
11. Side Clamp on R-2000iC/210F	A device that uses R-2000iC/210F robot with a flat clamp gripper (top and bottom of pallet). The robot will grip the topper, rotate, move the arm up and down while floor mounted and move toppers from one stack to another.

12. Forklift on R-2000iC/210F	A device that uses R-2000iC/210F robot with a Forklift (slides under pallet). The robot will grip the topper, rotate, move the arm up and down while floor mounted and move toppers from one stack to another.
13. Pinch on R-2000iC/210F	A device that uses R-2000iC/210F robot with a pinch gripper (grips center mold of topper). The robot will grip the topper, rotate, move the arm up and down while floor mounted and move toppers from one stack to another.
14. Elastic Rollers on R-2000iC/210F	A device that uses R-2000iC/210F robot with elastic roller gripper (Rollers use elastic tension to grip). The robot will grip the topper, rotate, move the arm up and down while floor mounted and move toppers from one stack to another.
15. Flat Clamp on R-2000iC/165R	A device that uses R-2000iC/165R robot with a flat clamp gripper (Top and Bottom of pallet). The robot will grip the topper, rotate, move the arm up and down while rack mounted and move toppers from one stack to another. (Saves Floor Space)
16. Spider Claw on R-2000iC/165R	A device that uses R-2000iC/165R robot with a spider claw type gripper. The robot will grip the topper, rotate, move the arm up and down while rack mounted and move toppers from one stack to another. (Saves Floor Space)
17. Vacuum on R-2000iC/165R	A device that uses R-2000iC/165R robot with a vacuum gripper (Suction on top of pallet). The robot will grip the topper, rotate, move the arm up and down while rack mounted and move toppers from one stack to another. (Saves Floor Space)
18. Side Clamp on R-2000iC/165R	A device that uses R-2000iC/165R robot with a flat clamp gripper (top and bottom of pallet). The robot will grip the topper, rotate, move the arm up and down while rack mounted and move toppers from one stack to another. (Saves Floor Space)
19. Forklift on R-2000iC/165R	A device that uses R-2000iC/165R robot with a Forklift (slides under pallet). The robot will grip the topper, rotate, move the arm up and down while rack mounted and move toppers from one stack to another. (Saves Floor Space)
20. Pinch on R-2000iC/165R	A device that uses R-2000iC/165R robot with a pinch gripper (grips center mold of topper). The robot will grip the topper, rotate, move the arm up and down while rack mounted and move toppers from one stack to another. (Saves Floor Space)
21. Elastic Rollers on R-2000iC/165R	A device that uses R-2000iC/165R robot with elastic roller gripper (Rollers use elastic tension to grip). The robot will grip the topper, rotate, move the arm up and down while rack mounted and move toppers from one stack to another. (Saves Floor Space)
22. Flat Clamp on M-410iC/185	A device that uses M-410iC/185 robot with a flat clamp gripper (top and bottom of pallet). The robot will grip the topper, rotate,

	move the arm up and down while floor mounted and move toppers from one stack to another (High speed).
23. Spider Claw on M-410iC/185	A device that uses M-410iC/185 robot with a spider claw type gripper. The robot will grip the topper, rotate, move the arm up and down while floor mounted and move toppers from one stack to another (High speed).
24. Vacuum on M-410iC/185	A device that uses M-410iC/185 robot with a vacuum gripper (Suction on top of pallet). The robot will grip the topper, rotate, move the arm up and down while floor mounted and move toppers from one stack to another (High speed).
25. Side Clamp on M-410iC/185	A device that uses M-410iC/185 robot with a flat clamp gripper (top and bottom of pallet). The robot will grip the topper, rotate, move the arm up and down while floor mounted and move toppers from one stack to another (High speed).
26. Forklift on M-410iC/185	A device that uses M-410iC/185 robot with a Forklift (slides under pallet). The robot will grip the topper, rotate, move the arm up and down while floor mounted and move toppers from one stack to another (High speed).
27. Pinch on M-410iC/185	A device that uses M-410iC/185 robot with a pinch gripper (grips center mold of topper). The robot will grip the topper, rotate, move the arm up and down while floor mounted and move toppers from one stack to another (High speed).
28. Elastic Rollers on M-410iC/185	A device that uses M-410iC/185 robot with elastic roller gripper (Rollers use elastic tension to grip). The robot will grip the topper, rotate, move the arm up and down while floor mounted and move toppers from one stack to another (High speed).
29. Flat Clamp on M-900iB/280L	A device that uses M-900iB/280L robot with a flat clamp gripper (top and bottom of pallet). The robot will grip the topper, rotate, move the arm up and down while floor mounted and move toppers from one stack to another (Stiff, Strong robot).
30. Spider Claw on M-900iB/280L	A device that uses M-900iB/280L robot with a spider claw type gripper. The robot will grip the topper, rotate, move the arm up and down while floor mounted and move toppers from one stack to another (Stiff, Strong robot).
31. Vacuum on M-900iB/280L	A device that uses M-900iB/280L robot with a vacuum gripper (Suction on top of pallet). The robot will grip the topper, rotate, move the arm up and down while floor mounted and move toppers from one stack to another (Stiff, Strong robot).
32. Side Clamp on M-900iB/280L	A device that uses M-900iB/280L robot with a flat clamp gripper (top and bottom of pallet). The robot will grip the topper, rotate, move the arm up and down while floor mounted and move toppers from one stack to another (Stiff, Strong robot).
33. Forklift on M-900iB/280L	A device that uses M-900iB/280L robot with a Forklift (slides under pallet). The robot will grip the topper, rotate, move the

	arm up and down while floor mounted and move toppers from one stack to another (Stiff, Strong robot).
34. Pinch on M-900iB/280L	A device that uses M-900iB/280L robot with a pinch gripper (grips center mold of topper). The robot will grip the topper, rotate, move the arm up and down while floor mounted and move toppers from one stack to another (Stiff, Strong robot).
35. Elastic Rollers on M-900iB/280L	A device that uses M-900iB/280L robot with elastic roller gripper (Rollers use elastic tension to grip). The robot will grip the topper, rotate, move the arm up and down while floor mounted and move toppers from one stack to another (Stiff, Strong robot).
36. Flat Clamp on R-1000iA/130F	A device that uses R-1000iA/130F robot with a flat clamp gripper (top and bottom of pallet). The robot will grip the topper, rotate, move the arm up and down while floor mounted and move toppers from one stack to another (Fits within cells).
37. Spider Claw on R-1000iA/130F	A device that uses R-1000iA/130F robot with a spider claw type gripper. The robot will grip the topper, rotate, move the arm up and down while floor mounted and move toppers from one stack to another (Fits within cells).
38. Vacuum on R-1000iA/130F	A device that uses R-1000iA/130F robot with a vacuum gripper (Suction on top of pallet). The robot will grip the topper, rotate, move the arm up and down while floor mounted and move toppers from one stack to another (Fits within cells).
39. Side Clamp on R-1000iA/130F	A device that uses R-1000iA/130F robot with a flat clamp gripper (top and bottom of pallet). The robot will grip the topper, rotate, move the arm up and down while floor mounted and move toppers from one stack to another (Fits within cells).
40. Forklift on R-1000iA/130F	A device that uses R-1000iA/130F robot with a Forklift (slides under pallet). The robot will grip the topper, rotate, move the arm up and down while floor mounted and move toppers from one stack to another (Fits within cells).
41. Pinch on R-1000iA/130F	A device that uses R-1000iA/130F robot with a pinch gripper (grips center mold of topper). The robot will grip the topper, rotate, move the arm up and down while floor mounted and move toppers from one stack to another (Fits within cells).
42. Elastic Rollers on R-1000iA/130F	A device that uses R-1000iA/130F robot with elastic roller gripper (Rollers use elastic tension to grip). The robot will grip the topper, rotate, move the arm up and down while floor mounted and move toppers from one stack to another (Fits within cells).
43. Flat Clamp on M-710iC/70T	A device that uses an M-710iC/70T robot with a flat clamp gripper (top and bottom of pallet). The robot will grip the topper and use a gantry to move from one stack to another (Top Loader Robot). This is a lower payload than the R-2000iB/200T.

44. Spider Claw on M-710iC/70T	A device that uses a M-710iC/70T robot with a spider claw type gripper. The robot will grip the topper and use a gantry to move from one stack to another (Top Loader Robot). This is a lower payload than the R-2000iB/200T.
45. Vacuum on M-710iC/70T	A device that uses a M-710iC/70T robot with a vacuum gripper (suction on top of pallet). The robot will grip the topper and use a gantry to move from one stack to another (Top Loader Robot). This is a lower payload than the R-2000iB/200T.
46. Side Clamp on M-710iC/70T	A device that uses a M-710iC/70T robot with a Side clamp (grips sides of pallet). The robot will grip the topper and use a gantry to move from one stack to another (Top Loader Robot). This is a lower payload than the R-2000iB/200T.
47. Forklift on M-710iC/70T	A device that uses a M-710iC/70T robot with a Forklift (Slides under pallet). The robot will grip the topper and use a gantry to move from one stack to another (Top Loader Robot). This is a lower payload than the R-2000iB/200T.
48. Pinch on M-710iC/70T	A device that uses M-710iC/70T robot with a pinch gripper (grips center mold of topper). The robot will grip the topper and use a gantry to move from one stack to another (Top Loader Robot). This is a lower payload than the R-2000iB/200T.
49. Elastic Rollers on M-710iC/70T	A device that uses a M-710iC/70T robot with Elastic rollers (Rollers use elastic tension to grip). The robot will grip the topper and use a gantry to move from one stack to another (Top Loader Robot). This is a lower payload than the R-2000iB/200T.
50. Two flat clamps on the R-2000 IC 210F	Two clamps, one fixed, one with y-movement attached to a rotating shaft attached on the R-2000 IC 210F robot. The moving one will close on the pallet, once secured, the shaft rotates the pallet and places it on top of the completed stack.
51. Clamps equipped with vacuum suction cups on the R-2000IC 210F	Once the clamps have grasped the pallet, the vacuum suction will aid in holding it in place. The pallet can then be positioned on top of the stack after the shaft has rotated.
52. Swing arm	An arm that takes hold of the pallet at one end and flips it so it can be ready for stacking by swinging it steadily
53. Gripper-Mover	Assuming the pallets are stacked upside down, with the foam zip tied to the pallet, that gripper grabs the pallets, raises it, and place it on top of the stacked cylinders
54. Pincher-Stacker	Assuming the pallets are stacked upside down, with the foam zip tied or glued to the pallet, that tooling pinches the pallet on the outside, booms in, then place the pallet.
55. Hexagonal Cell Tooling	Tooling that uses hexagonal webbing to compress around ceramic cylinder or pallet topper. Hexagonal shapes deform to fit whatever object is being gripped, then compressed to firmly hold.

56. Vertical Conveyer Belt	Lifting tools run along a conveyer belt that moves vertically and horizontally to set locations for placement and removal of pallet toppers.
57. Pressurized Air Tooling	The tooling moves into place around the ceramic cylinder or pallet topper. Pressurized air is pumped into the material of the tooling to form around the object it is lifting. Once enough pressure is placed on the object to secure it, robot movements resume.
58. Overhead Removal/Placement Table	A system of mechanisms sits above the conveyer belts. The mechanisms above the palletization cell conveyer belts have set toppers ready to drop at read heights. The mechanisms above the depalletization cell conveyer belts lift and remove the pallet toppers and move them to the palletization mechanisms.
59. Short Hook Clamp	Tooling that clamps and secures the top and bottom of pallet topper and foam piece and wraps around side center foot on the bottom of the topper.
60. Long Hook Clamp	Tooling that clamps and secures the top and bottom of pallet topper and foam piece and wraps around center foot on the bottom of the topper.
61. Wide Clamp	Tooling that clamps the top and bottom of pallet topper and foam piece by running over the top, runs downside, then down the bottom of topper. Clamp begins wider and taller than that topper, then compresses to fit the pieces.
62. Spider Sensing Gripper	Tooling utilizes tiny sensors on a spider claw type of gripper to sense whether or not the pallet has been collected and can be lifted or removed.
63. Flip out Claw	Tooling that is integrated with Corning's current tooling. It is tucked away while the robot is stacking cylinders and then when it is time to place a topper or remove one, the claw flips out and can grab a topper.
64. Piston retractable side clamp	This tooling can slide in and out to not interfere with Corning's current tooling. It is integrated to work with what they already have. Slides in when not in use, then out when it needs to be used. The motion to get it in and out is air powered.
65. Overhead Stacker	Creating a platform on top of the conveyor belt where the robot is stacking the cylinder that allows you to stack five (5) pallets upside down. Following the completion of the stacking process, the platform moves downward with all the pallets, leaves one pallet behind before moving upward with the remaining ones. Then repeats the process
66. Double-Compartment Overhead Stacker	Creating a platform on top of the conveyor belt where the robot is stacking the cylinder that allows you to stack five (5) pallets upside down. Following the completion of the stacking process, one pallet moves from the top compartment to the bottom one,

	placing it on top of the stacked pallet. Then repeat the process until all five pallets have been placed.
67. Rack and pinion retractable clamp	This tooling works about the same as idea 64, except it is retracted in and out with a rack and pinion.
68. Clamp tooling with its own arm	Tooling that is incorporated into Corning's current tooling. It has its own arm though. This way it can come into the workspace when needed, then leave the workspace when not needed.
69. Cam Mechanism	Mechanism almost works as a rock-climbing cam, drops down to the sides of the pallet topper, and as it lifts, pressure increases to hold the topper, it then moves to placement location where it is lower, drops in pressure, releasing the topper in the intended place.
70. Retractable Claw on the R-2000iB/200T Fanuc	Retractable Claw that will elongate and shorten to reach distance and stack pallets, connected to R-2000iB/200T.
71. Release Drop Motors *(Overhead) Stack	Pallets and Toppers would be stacked over head the palletization cells, allowing for 3 Pallet Stacks to be "Topped" autonomously
72. Conveyor Belt Stack (Overhead)	Pallets from Depalletization cell would be placed on a conveyor belt, and then separated by sensing walls sending each Pallet and its topper over head the stack, for then to be placed
73. Automated Pallet Dispenser (Outside Light Curtain)	When Pallets are rolled out to be finished, Automated Pallet Dispenser will be able to collect and stack pallet at any level by using a sensor to measure the height and number of cylinders used
74. Gyro Ball Joint Claw Tooling	Allows Claw tooling to have equilibrium at all times while R-2000iB/200T Fanuc rotates and moves in directions
75. AI Sensing Automated Pallet Topper	AI controlled sensing and lowering system with claw mechanism
76. Magnetic Lift	A magnetic piece is added to the pallet toppers and the system uses magnetic energy to lift and release the topper in its intended place.
77. Wide Clamp Gantry System	Using the 80-20 Aluminum overhead, a gantry system could be built and operated to drop down and clamp the pallet toppers from the side, lift, and move to specified locations.
78. Drone Carrier Pallet Topper	Creating an Autonomous system for a Drone to Drop Top Pallet Over the 3 cell stacks
79. Claw Mover	A claw looking device that grabs the pallet on both sides using two (2) … at the bottom deck (bottom of the pallet) and one at the top deck. After grabbing and securing the pallet with the foam, the device rotates and moves up to place the pallet topper.
80. Vacuum gripper that goes under	This allows the pallet tooling to be tucked away. When a pallet is ready to be picked up the robot can hover over the pallet and the vacuum will activate causing it to pick up the pallet.

Corning's current tooling	
81. R2000iC/100P mounted on aluminum 8020	Creating a tooling that uses a vacuum sealing to grab the pallet already placed upside down, lifts it up and moves it so it can be placed on top of a stacked pallet.
82. Pinch gripper that goes under the current tooling	This gripper is mounted under the current tooling used and this allows for it to be out of the way while cylinders are being stacked.
83. Elastic roller that flips in and out	This tooling will be motorized so that it will be able to flip in and out of the workspace. This will mitigate interference with their current cylinder stacking
84. Claw machine gripper	Tooling that extends off of existing robot that acts as a claw machine.
85. Hovering rack and pin slider gripper	Sliders with a rack and pin that allow the gripper to have sliding arms. The robot arm will bring the gripper over the pallet and then the gripper will close onto the pallet to grip it. (tooling)
86. Assisted Grab	Devices that hold the pallets at an angle allow the robot to grab them easier while holding the foam piece within the pallet topper.
87. Four-Sided Clamp Tooling	Tooling that drops down and clamps the pallet topper on top and bottom on all four sides by extending out in between the feet.
88. Gripper using tactile sensor	Adding tactile sensor to the gripper, it will sense when the pallet is close, detects the material it made off, and determines how much force is needed to pick it up without causing anu damage to the pallet. Then moves it up and places it on top of the stacked cylinders
89. Piston Raise Lift	Twins-sized Pistons on each side of the palletization cell will lower the pallets together onto of finished pallet stack
90. Rope Line Tension Machine	4 Bars on the Ground will be in a line that will be able to move (left and right) allowing control of location, and precision,
91. Spear Lift	A tooling has four spiked ends that penetrate the pallet topper at an angle and has the capability to lift and move to the intended location, the spiked ends then retract, and the system continues operation.
92. Mounted Robot Extension Arm (Light Curtain)	This Robot will be connected onto the light curtain, that will then be able to extend to the length of the palletization pallet stack and be able to complete the stack by placing the topper, with precision.
93.Pallet moving gantry system	The system will take pallet tops from the depalletization cell and move them to the stacks of the palletization cell in order to avoid flipping the pallet over and unnecessary movements.
94. Momentum Pallet Topping	A device outside of the light curtain that uses the moment of the topper to flip it and put it on top of the stack of cylinders. The side depalletizes will use a flip arm to turn it over to a catching

	system and they will be moved around through a conveyor and elevator system.
95. 4 Point Rubber Claw Tooling	4 Points on the Claw will be able to move in (UP, DOWN, LEFT, RIGHT) that will be able to tighten and compress together to pick the pallet it up, it will account for squeeze using sensors allowing for measurement pressure applied on pallet is universally same for all pallets in cells.
96.Three Finger Tooling	This will be a tool capable of grabbing the pallet from the sides and a thin piece of material that will be able to slide over the top of the pallet so that it can hold the foam layer in place and not interfere with the placement of the pallet.
97. Cage Outside of Light Curtain	There will be a cage outside of the light curtain that surrounds the three lanes on each station. This cage will be equipped with tooling that is able to grab the pallet from the top and bottom, rotate it, and place it where it needs to be.
98. Change Pallet Design	The design of the pallet will change to add an additional piece to the inside that will secure the foam topper. This will allow it to be easier to handle when trying to flip the pallet upside down.
99. Pivot joint Gripper	Gripper will have a top and a bottom piece to hold the pallet and it will pivot at the joint closest to the parts gripping the pallet to flip them easier for palletizing
100. Hooking Tooling	Pallets will be adjusted to have a hook apparatus that the tooling will be able to hook onto, lift, and move to its specified location. Once placed, tooling will unhook and release the pallet.

Appendix F: Medium and High-Fidelity Determination Chart

Concept Number	Concept Name	Ahmari	Brightson	Craig	Daniel	Michael	Total
55	Hexagonal Cell Tooling	6	5	5	6	5	27
96	Three Finger Tooling	7	7	6	7	8	35
4	Side Clamp on R-2000iB/200T	4	4	5	4	6	23
51	Clamps equipped with vacuum suction cups on the R-2000IC 210F	7	8	6	7	7	35
76	Magnetic Lift	3	2	1	3	4	13
1	Flat Clamp on R-2000iB/200T	5	5	4	5	7	26
36	Flat Clamp on R-1000iA/130F	4	6	4	3	5	22
54	Pincher-Stacker	5	6	6	6	6	29
64	Piston retractable side clamp	6	7	8	6	8	35
17	Vacuum on R-2000iC/165R	7	6	7	8	7	35
67	Rack and pinion retractable clamp	6	8	8	6	8	36
80	Vacuum gripper that goes under Corning's current tooling	4	4	6	5	6	25
45	Vacuum on M-710iC/70T	6	5	7	8	5	31
2	Spider Claw on R-2000iB/200T	6	6	6	7	8	33
58	Overhead Removal/Placement Table	5	4	2	2	4	17
71	Release Drop Motors *(Overhead) Stack	4	4	4	4	4	20
57	Pressurized Air Tooling	3	6	6	6	5	26
60	Long Hook Clamp	6	6	6	7	8	33
65	Overhead Stacker	5	7	7	8	8	35
56	Vertical Conveyer Belt	6	5	6	6	6	29

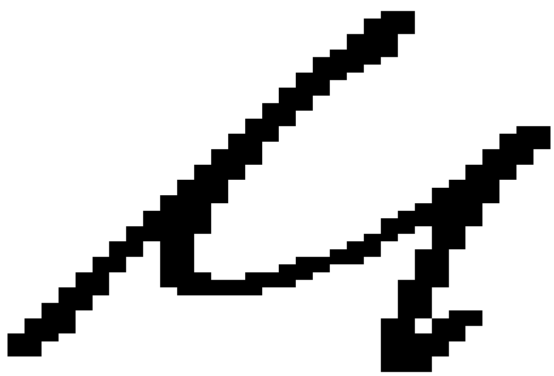
Appendix G: Concept Selection Charts

Customer Requirements	1	2	3	4	5	6	7	8	9	Total
1. Remove and place pallet toppers in corresponding cells	-	1	1	1	1	1	1	1	1	8
2. Fit within current cells	0	-	0	0	0	0	0	0	1	1
3. Match the time of human interaction	0	1	-	0	1	0	1	0	1	4
4. Lifts over the weight of the pallet topper	0	1	1	-	1	1	1	0	1	6
5. Communicates with Corning's current system	0	1	0	0	-	1	1	1	1	5
6. Operates without damaging pieces	0	1	1	0	0	-	1	0	1	4
7. Detects certain heights of pallets	0	1	0	0	0	0	-	0	1	2
8. Does not interfere with the current robots	0	1	1	1	0	1	1	-	1	6
9. Includes stagging area	0	0	0	0	0	0	0	0	-	0
Total	0	7	4	2	3	4	6	2	8	36

		Engineering Characteristics													
Improvement Direction		↑	↑	↓	↓	↓				↑↓	↑	↑	↓	↓	↓
Units		m^3	degrees	seconds	seconds	seconds	boolean	boolean	boolean	cm	kg	N	seconds	seconds	seconds
Customer Requirements	Importance Weight Factor	Moves Three-Dimensionally	Rotates	Collects Topper/Foam	Releases Topper/Foam	Locates Pallet	Recieves Fail-Safes	Reports Completed Task	Requests Topper/Foam	Determines Height	Carries Load	Maintain Stability	Starts Operation	Stops Operation	Pauses Operation
1. Remove and place pallet toppers in corresponding cells	8	9	9	9	9	9			3	9	9	3	1		
2. Fit within current cells	1						3								
3. Match the time of human interaction	4	3	3	9	9	3		3	3	3	9	3			
4. Lifts over the weight of the pallet topper	6	1	1	9	9						9	9			
5. Communicates with Corning's current system	5					9	9	9	9	3			9	9	9
6. Operates without damaging pieces	4	3	3	9	9	3	1			3	9	9		1	1
7. Detects certain heights of pallets	2									9					
8. Does not interfere with the current robots	6	3	3	9	9		9				9	9			
9. Includes stagging area	0								9						
Raw Score	885	120	120	252	252	141	106	57	81	129	252	180	53	49	49
Relative Weight %		13.56	13.56	28.47	28.47	15.93	11.98	6.44	9.15	14.58	28.47	20.34	5.99	5.54	5.54
Rank Order		7	8	1	2	5	9	11	10	6	3	4	12	13	14

	Optamate Robotoic Palletizer	Concepts							
Engineering Characteristics		1	2	3	4	5	6	7	8
Collects Topper/Foam	Datum	-	S	+	S	-	-	-	+
Releases Topper/Foam		-	S	+	S	-	+	+	+
Carries Load		S	S	-	+	-	-	-	-
Maintains Stability		-	S	S	S	S	S	S	-
Locates Pallet		S	S	S	S	S	S	S	S
Pluses		0	0	2	1	0	1	1	2
Minuses		3	0	1	0	3	2	2	2
Satisfactory		2	5	2	4	2	2	2	1
	Ranking	-4	5	4	6	-4	0	0	1

Normalized Criteria Comparison Matrix [NormC]						
						Criteria Weights {W}
1. Collects Topper/Foam	0.19	0.18	0.17	0.35	0.22	0.22
2. Releases Topper/Foam	0.19	0.18	0.17	0.21	0.22	0.19
3. Carries Load	0.56	0.54	0.50	0.35	0.30	0.45
4. Maintains Stability	0.04	0.06	0.10	0.07	0.22	0.10
5. Locates Pallet	0.04	0.04	0.07	0.01	0.04	0.04
Sum	1	1	1	1	1	1



Consistency Index	0.09
Consistency Ratio	0.08
Consistent?	Yes

[Final Rating Matrix]^T					
	Collects Topper/Foam	Releases Topper/Foam	Carries Load	Maintain Stability	Locates Pallet
2	0.49	0.09	0.64	0.19	0.20
3	0.11	0.82	0.07	0.08	0.20
4	0.41	0.09	0.28	0.72	0.60

Concept	Alternative Value
2	0.44
3	0.23
4	0.33

Collects Topper/Foam			
	2	3	4
2	1.00	5.00	1.00
3	0.20	1.00	0.33
4	1.00	3.00	1.00
Sum	2.20	9.00	2.33

Collects Topper/Foam [Normalized]				
	2	3	4	Design Alternative Priorities {Pi}
2		0.56	0.43	0.49
3	0.09	0.11	0.14	0.11
4	0.45	0.33	0.43	0.41
Sum	0.54545455	1	1	1.01250601

Consistency Check		
Weighted Sum Vector {Ws} = [C]{Pi}	Criteria Weights {Pi}	Consistency Vector {Cons} = {Ws}./{Pi}
1.47	0.49	2.99
0.35	0.11	3.03
1.24	0.41	3.06
Average Consistency		3.03

Consistency Index	0.01
Consistency Ratio	0.03
Consistent?	Yes

Release Topper/Foam			
	2	3	4
2	1.00	0.11	1.00
3	9.00	1.00	9.00
4	1.00	0.11	1.00
Sum	11.00	1.22	11.00

Releases Topper/Foam [Normalized]				
	2	3	4	Design Alternative Priorities
2	0.09	0.09	0.09	0.09
3	0.82	0.82	0.82	0.82
4	0.09	0.09	0.09	0.09
Sum	1	1	1	1

Consistency Check		
Weighted Sum Vector {Ws} = [C]{Pi}	Criteria Weights {Pi}	Consistency Vector {Cons} = {Ws}./{Pi}
0.27	0.09	3.00
2.45	0.82	3.00
0.27	0.09	3.00
Average Consistency		3.00

Consistency Inde	0.00
Consistency Rati	0.00
Consistent?	Yes

Carries Load			
	2	3	4
2	1.00	7.00	3.00
3	0.14	1.00	0.20
4	0.33	5.00	1.00
Sum	1.48	13.00	4.20

Carries Load [Normalized]				
	2	3	4	Design Alternative Priorities
2	0.68	0.54	0.71	0.64
3	0.10	0.08	0.05	0.07
4	0.23	0.38	0.24	0.28
Sum	1.00	1.00	1.00	1.00

Consistency Check		
Weighted Sum Vector {Ws} = [C]{Pi}	Criteria Weights {Pi}	Consistency Vector {Cons} = {Ws}./{Pi}
2.01	0.64	3.12
0.22	0.07	3.01
0.87	0.28	3.06
Average Consistency		3.07

Consistency Inde	0.03
Consistency Rati	0.06
Consistent?	Yes

Maintain Stability			
	2	3	4
2	1	3	0.2
3	0.33	1	0.14285714
4	5	7	1
Sum	6.33333333	11	1.34285714

Maintain Stability [Normalized]				
	2	3	4	Design Alternative Priorities
2	0.16	0.27	0.15	0.19
3	0.05	0.09	0.11	0.08
4	0.79	0.64	0.74	0.72
Sum	1.00	1.00	1.00	1.00

Consistency Check		
Weighted Sum Vector {Ws} = [C]{Pi}	Criteria Weights {Pi}	Consistency Vector {Cons} = {Ws}./{Pi}
0.59	0.19	3.04
0.25	0.08	3.01
2.27	0.72	3.14
Average Consistency		3.07

Consistency Inde	0.03
Consistency Rati	0.06
Consistent?	Yes

Locates Pallet			
	2	3	4
2	1.00	1.00	0.33
3	1.00	1.00	0.33
4	3.00	3.00	1.00
Sum	5.00	5.00	1.67

Locates Pallet [Normalized]				
	2	3	4	Design Alternative Priorities
2	0.2	0.2	0.2	0.2
3	0.2	0.2	0.2	0.2
4	0.6	0.6	0.6	0.6
Sum	1	1	1	1

Consistency Check		
Weighted Sum Vector {Ws} = [C]{Pi}	Criteria Weights {Pi}	Consistency Vector {Cons} = {Ws}./{Pi}
0.60	0.20	3.00
0.60	0.20	3.00
1.80	0.60	3.00
Average Consistency		3.00

Consistency Inde	0.00
Consistency Rati	0.00
Consistent?	Yes

Final Rating Matrix			
Selection Criteria	2	3	4
Collects Topper/Foar	0.49	0.11	0.41
Realease Topper/Fo	0.09	0.82	0.09
Carries Load	0.64	0.07	0.28
Maintains Satbility	0.19	0.08	0.72
Locates Pallet	0.20	0.20	0.60

Criteria Weights {W}
0.22
0.19
0.45
0.10
0.04

[Final Rating Matrix]ᵀ					
	Collects Topper/Foar	Releases Topper/Foar	Carries Load	Maintain Stability	Locates Pallet
2	0.49	0.09	0.64	0.19	0.20
3	0.11	0.82	0.07	0.08	0.20
4	0.41	0.09	0.28	0.72	0.60

Concept	Alternative Value
2	0.44
3	0.23
4	0.33

Appendix A: APA Headings (delete)

Heading 1 is Centered, Boldface, Uppercase and Lowercase Heading

Heading 2 is Flush Left, Boldface, Uppercase and Lowercase Heading

Heading 3 is indented, boldface lowercase paragraph heading ending with a period.

Heading 4 is indented, boldface, italicized, lowercase paragraph heading ending with a period.

Heading 5 is indented, italicized, lowercase paragraph heading ending with a period.

See publication manual of the American Psychological Association page 62

Appendix B Figures and Tables (delete)

The text above the cation always introduces the reference material such as a figure or table. You should never show reference material then present the discussion. You can split the discussion around the reference material, but you should always introduce the reference material in your text first then show the information. If you look at the Figure 1 below the caption has a period after the figure number and is left justified whereas the figure itself is centered.

Figure 1. Flush left, normal font settings, sentence case, and ends with a period.

In addition, table captions are placed above the table and have a return after the table number. The second line of the caption provided the description. Note, there is a difference between a return and enter. A return is accomplished with the shortcut key shift + enter. Last, unlike the caption for a figure, a table caption does not end with a period, nor is there a period after the table number.

Table 1

The Word Table and the Table Number are Normal Font and Flush Left. The Caption is Flush Left, Italicized, Uppercase and Lowercase

Level of heading	Format
1	**Centered, Boldface, Uppercase and Lowercase Heading**
2	**Flush Left, Boldface, Uppercase and Lowercase**
3	***Indented, boldface lowercase paragraph heading ending with a period***
4	***Indented, boldface, italicized, lowercase paragraph heading ending with a period.***
5	*Indented, italicized, lowercase paragraph heading ending with a period.*

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