8/28/2017

Team 509: Corning

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Abstract

Corning Inc. is a ceramics company that makes diesel particulate filters. These filters are very brittle throughout the manufacturing process. These filters are picked up by a robot tooling and centered on a table, which is called the justification process, before being partially filled with cement. When the robot is completing the centering process, the tooling repeatedly grabs and releases the filter. As it releases, debris from the outer layer of the part falls onto the pattern sticker, a sticker used to create a seal with the robot tooling. This debris creates a problem for the filling process, due to the seal being compromised by the debris. To solve this problem our team created a design to catch the debris before it falls onto the pattern sticker. As the robot encloses the filter, our design covers most of the quarter-inch gap between the robot's tooling and filter. The debris then falls from the filter onto our design, keeping it away from the sealing zone on the pattern sticker. Our design is a simple and effective solution within a complicated manufacturing process. This design is simple because it has no moving parts and utilizes a minimum amount of materials, lowering the cost of the entire design. The effectiveness of our design is proven by its ability at catching debris and ensuring a proper seal between the tooling and the sticker.

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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

DPF	Diesel Particulate Filter

Chapter One: EML 4551C

1.1 Project Scope

1.1.1 Project Description

The objective of this project is to prevent damage to the filter during the manufacturing process. This objective was determined from our meeting with the Corning Sponsor team. During the meeting, we discussed how the ceramic filter was damaged during the manufacturing process.

1.1.2 Key Goals

The first key goal of this project is to prevent damage to the ceramic diesel particulate filter. The second key goal is to reduce the material waste that occurs during the manufacturing process. The third key goal is to stay within the budget given to us for the project. The last goal for this project is to provide a working and successful product to Corning Inc. for them to implement into their manufacturing process.

1.1.3 Market

The primary market for this project is Corning's factory. Corning will use this project to maximize their factory process for making ceramic diesel particulate filters. This project will benefit the company directly. The secondary market for this project will be any other company or factory that uses a similar manufacturing process for ceramic diesel particulate.

1.1.4 Assumptions

To complete the project, the team had to make multiple assumptions. Assume the robotic programming will remain constant throughout the project. The solution needs to allow the robot to effectively handle parts.

1.1.5 Stakeholders

The stakeholders for this project include the sponsors from Corning, Jeffery Roche, Trent Brush, and Justin Barber. In addition to the Corning sponsors, Dr. McConomy is also a stakeholder in this project as the senior design instructor. Each stakeholder has an invested interest in this project and will benefit from the successful completion of the project. Other stakeholders can include companies and factories that are invested in the secondary market.

1.2 Customer Needs

The needs of the customer are the most important part in determining the project's success. The questions that we asked our sponsors are not related to specific designs but are essential to understand the specific constraints for this project. During our meeting with the Corning sponsors, we asked several questions to get a better understanding of this project. Based on their responses we interpreted their needs and began the project. The questions are listed below along with Corning's responses and the interpreted needs.

Table 1
Interpreted Customer Needs

Our Questions	Answer	Interpreted Need
Where on the surface is damage consistently observed?	"Where the upper grippers touch the DPF."	The solution prevents the debris from falling onto the mylar sticker.
At what point in the manufacturing process is damage occurring?	"All throughout the manufacturing process from extrusion, moving the DPF, etc."	The solution handles the part with care to prevent further damage.
Are there any mechanical constraints for the project?	"The upper gripper needs to hold the DPF."	The DPF requires support through the justification process.
Are there any weight constraints for the robot arm?	"The tooling needs lift assistance and the robots can handle a lot of extra weight."	The weight of the design is not heavily restricted by the robot.
Are there any power constraints for the project?	"The factory has plenty of available power."	The solution does not require an internal power source.
What is the state of the part just prior to the justification process?	"The DPF's skin is already damaged before the justification process."	The solution handles the part with care to prevent further damage.
Is there a specific surface dedicated for handling the parts?	"The DPF is placed on a table during the justification process."	The solution can utilize the justification table throughout the process.
What is the most important thing you want out of this project?	"Center the DPF on the justification table and ensure no debris gets on the mylar sticker to create a proper seal where the DPF, lower tooling	The solution allows for centering of the DPF while preventing debris from reaching the mylar sticker.

Our Questions	Answer	Interpreted Need
	and mylar sticker are on the same plane.”	
How would you define success for this project?	“Forming a proper seal between the DPF and the mylar sticker.”	The solution involves the sticker successfully sealing to the lower tooling.
What impact do you want the project to have on the manufacturing process?	“Be able to plug the DPF properly, make it easier for the sticker to be peeled off, and have overall less repair and down time.”	During the justification process, other processes are not hindered or delayed.
Can you elaborate on the need for this solution?	“The solution would allow us to save millions of dollars.”	The solution reduces the amount of material and time waste.
How is the problem being handled currently?	“Never changed from how it has always been done. There is nothing being done to mitigate the problem.”	The project presents a feasible, first-time solution for the company
Are we providing a mechanism or material?	“A mechanism is what we have in mind.”	Physical prevention of debris.
Does the solution need to be automated?	“It is preferred for the solution to be automatic.”	An automated solution provides a wide range of applications.

1.2.1 Explanation of Results

During the process of asking our Customer Needs questions, we determined that three of our interpreted needs were of higher importance. Out of the interpreted needs we determined, we found that three of them were of higher importance. The first one was that the solution prevents the debris from falling onto the mylar sticker. This is of higher importance because this is the foundational problem for our project. Another one is the solution handles the part with care to prevent further damage. This is because the DPF creates more debris when damaged which can cause more issues throughout the justification process. Lastly, we found that the solution can utilize the justification table throughout the process. This would allow us to not constrain ourselves in how we manipulate the debris.

1.3 Functional Decomposition

Team 509 utilized a functional decomposition to categorize the different systems identified for our project. The systems were identified as major components of the project that are essential for mission accomplishment. These systems were identified to be Support, Compatibility, Prevention, and Safety, with each being selected after consideration to the data generated via meetings with the Corning sponsors. A hierarchy chart and cross-reference table are provided that depict the major systems and their various functions. Once the systems were selected, the team ideated to create important functions for each system. The hierarchy chart displays the functions and which system they pertain to. The cross-reference table displays the functions and contains an ‘X’ for each system the function can be applied to. This is to show any overlapping between functions and systems.

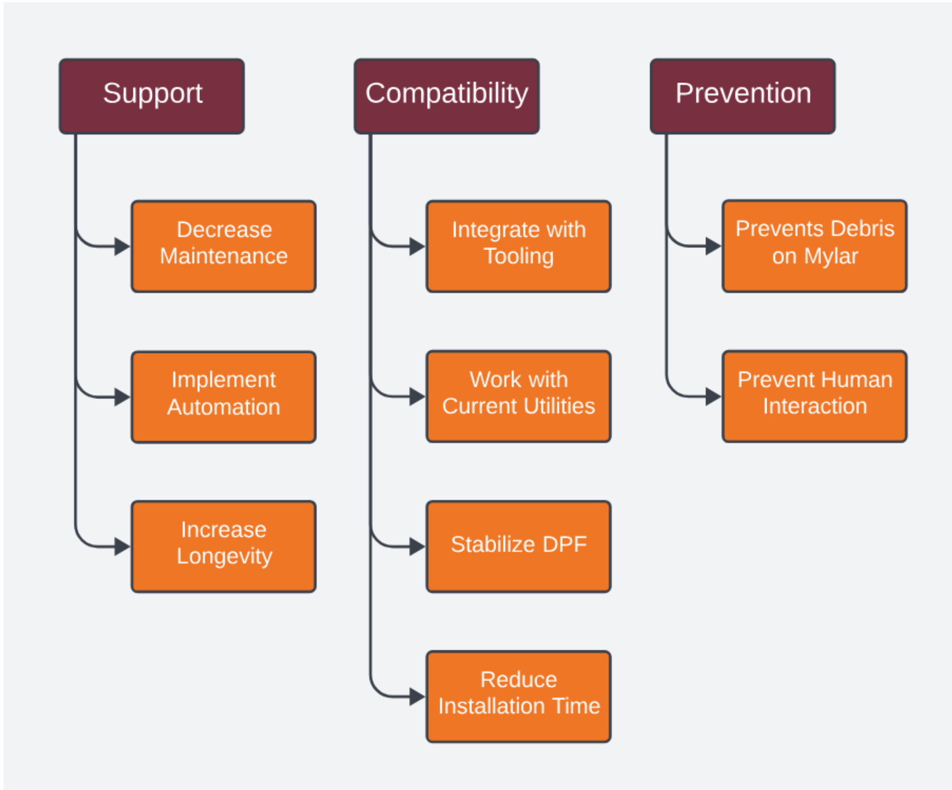

Figure 1. Hierarchy chart for Functional Decomposition.

Table 2
Cross-Reference Chart

	System			
Functions	*Support*	*Compatibility*	*Prevention*	*Safety*
Increase Longevity	X			X
Decrease Maintenance Time	X			X
Implement Automation	X	X		
Integrate with Tooling		X		
Work with Current Utilities		X		
Reduce Installation Time		X		

	System			
Functions	*Support*	*Compatibility*	*Prevention*	*Safety*
Stabilize DPF	X	X		
Prevent Debris on Mylar			X	
Prevent Human Interaction				X

The design must support the DPF in the justification process. With the system of support three functions of Decrease Maintenance Time, Implement Automation, and Increase Longevity were created. To decrease maintenance time, our project is intended to work with minimal support from external personnel. To implement automation, our project will not require human intervention to have it complete its function. Finally, to increase longevity, the product should be built to have long lasting life cycle.

Yet another goal is to ensure that our design can be implemented with the hardware already in use during the justification process. Thus, the system of Compatibility with functions of Integrate with Tooling, Work with Current Utilities, Reduce Installation Time, and Stabilize DPF. Our design needs to not interfere with the tooling used during the justification process, which are the upper gripper, lower tooling, robot arm, and justification table. The factory has a plethora of available utilities that our device will be able to utilize. Our design must also ensure that the DPF is stable on the justification table and doesn't change the inherent stability of the justification process. Lastly, we will have our design be easily added to the justification process.

Our team's main design goal is to prevent debris from getting on the mylar sticker. Using Prevention as a main system we created three functions to accomplish the system. These functions are Prevents Debris on Mylar, Prevent Further Damage on DPF, and Prevent

Downtime. The DPF filter is made of a brittle ceramic, which sheds ceramic debris on contact with the grippers. The debris falls on the Mylar sticker during the justification process. This prevents the mylar sticker from creating a seal with the lower tooling, which then leads to the cement batch leaking out. As the cement batch leaks, it causes issues in the automation process by adding weight to the mylar sticker as well as requiring each part to be handled manually by a specialist to remove the excess batch. This increases the downtime of the system as well as increases damage to the DPF. Our goal is to prevent additional damage to the DPF which will prevent debris falling onto the mylar sticker which will allow the automated process to continue without interruption.

Safety is a major factor in the function of our design. The solution will reduce human interaction, have an ergonomic design, and have an ergonomic installation. To reduce human interaction, the solution will be able to be self-sufficient and require minimal maintenance. To have an ergonomic design, the solution will be able to be safely handled and will work within the space restraints. Lastly, to have an ergonomic installation, the solution itself should be able to be installed easily with minimal to no changes in the functions throughout the justification process.

1.4 Target Summary

The targets for our project establish numerical values for what our project must accomplish to be deemed successful. We derived the targets based on the interpreted customer needs as well as our functional decomposition. Additionally, we discussed various metrics and targets with our sponsors over multiple meetings to dial in on the specifics. Each function outlined in the functional decomposition provides the tasks that the device needs to perform to achieve success. Starting with these functions the team was able to define metrics and numerical values that must be met by the various systems.

1.4.1 Critical Targets

Shown in *Table 3* are the critical targets determined by the team. After discussion with our customer, we chose the targets based on the needs to determine the success of our product. The corresponding metrics and targets are the ideal values to hit for the project. To determine the success of this project, these targets and metrics must be accomplished based on the device's ability to mitigate problems created by the debris.

Table 3
Critical Targets

Systems	Function	Metric	Target
Support	Implement Automation	N/A	True
Support	Decrease Maintenance	Parts per Day	50 parts
Compatibility	Integrate with Tooling	Degrees of Freedom	2
Prevention	Prevent Debris on Mylar	Weight (g)	0.4 g
Prevention	Prevent Human Interaction	Time (hrs/month)	9 hrs/month

1.4.2 Validation and Discussion of Measurement

To validate the critical target of implementing automation, we can test it by running a simulation of the justification process and seeing how our device interacts throughout the process. To validate the critical target of decreasing the maintenance to 50 parts a day, we can test it by counting the number of parts that need maintenance per day before and after we add our device. The difference between the two will validate our target of 50 parts a day requiring maintenance. To validate the critical target of having two degrees of freedom to integrate with the tooling, we can test it by running a cad simulation of the part and the forces that will be applied to it to see how it interacts. In addition, we can do linkage math to theoretically confirm its degrees of freedom. To validate the critical target of preventing .4 grams of debris on the mylar, we can test it by taking stickers of multiple parts and averaging the weight of the debris on the stickers. To validate the critical target of limiting human interaction to 9 hours a month, we can test it by using a time sheet to determine if the hours a month between the three current employees that go in and fix the product is reduced to 9 hours a month.

1.4.3 Arrival of Targets and Metrics

The first and most important mission critical target is to prevent debris on the mylar. As the grippers contact the DPF and then release, debris from the ceramic DPF fall off the filter and settle on the mylar sticker. When debris gets on the sticker, this prevents a poor seal with the lower tooling leading to a failure in the process. After discussing with our sponsor, we determined that the current mass of debris on the mylar sticker is .4 grams. We want to reduce that mass by 50% to .4 grams. We believe that this number of debris will be enough to prevent an improper seal and achieve our objective.

The next critical target determined within the support system is that the product needs to be automated. The reason this function is a critical function is the current system that Corning uses for their production process of their ceramic filters is completely automated, so the sponsors require our solution be automated as well. This will prevent down time.

The following critical target in the support system is to decrease the maintenance on the ceramic parts per day. Currently the factory goes through approximately 150 parts per day which require maintenance to repair the parts after they are damaged. The parts must be repaired by a ceramic specialist, and each part can take hours of incredibly precise work to be fully repaired. Our solution must be able to greatly decrease the number of parts down to a third, 50 parts repaired per day, to decrease overall production cost.

The critical target for the compatibility system is that our solution must integrate with the tooling currently available at the factory. The current tooling apparatus which is used to move the ceramic filters around the factory floor has 3 degrees of freedom. However, during the justification process, the tooling only uses two degrees of freedom to move the part in the x-direction and y-direction. We have determined that our solution must match the degrees of freedom during the justification to match the current tooling used to be integrated properly.

The last critical target defined in the table is a part of the prevention system. The device needs to reduce the human interaction within the DPF process. Currently if the mylar sticker gets weighed down by the debris, the process must temporarily stop so a worker can enter the facility and physically peel the sticker off the defective part before the process can continue. On average the human interaction time of peeling defective stickers is 18 hours per month. With 3 people tasked to peel stickers, the total human cost comes to about hundred thousand a year per person. With our device, we intend to reduce that number to 9 hours per month. We chose this number because we want to reduce this interaction by 50%. According to our sponsor, these 18 hours per month equates to $300,000 per year dedicated to peel stickers. With a 50% reduction in interaction time, that will lead to a new cost of $150,000 per year to peel stickers.

1.4.4 Summary

The targets of our project are as follows in these three systems. For the support system there are three functions increase longevity to one year, decrease maintenance to only 50 DPF parts a day and implementation automation. In the compatibility system the four functions are to integrate with the tooling by having a target of 2 degree of freedom, work with current utilities, reduce installation time to 8 hours and stabilize the part to 90°. The last system is prevention, and the two functions are preventing debris on mylar sheet to 0.4 grams, and this is 50% of the current debris weight, and prevent human interaction by limiting it to 9 hours per month. Lastly there are three targets that do not correspond to any functions, they are to have a max weight of 100 pounds, a max volume occupied of 7 ft^3, and a temperature resistance of 90 ºF.

1.5 Concept Generation

During the concept generation phase, the team collaborated to brainstorm different solutions to our problem. With a goal of 100 ideas, the team was able to generate concepts that could be potential solutions to mitigate debris on the mylar sheet. The intent with this method is to account for a wide variety of solutions and approaches so that there was no idea that was excluded. To come up with our concepts we utilized methods like brainstorming, crapshoot, and anti-problem.

For brainstorming, our team looked at the objective and tried to focus our efforts to prevent the ceramic debris from falling onto the mylar sheet. We reduced our ideas down to a couple of subsections. Generally, the ideas ranged from blowing or sucking the debris before it reaches the mylar adhesive sheet, covering the adhesive sheet with a ramp or object, and lastly wrapping the DPF in a material to prevent the debris from falling at all.

For crapshoot, the team began to spurt ideas out at random to spark a new wave of ideation. Although unsuccessful, the team was able to come up with ideas such as a drone that constantly circles the DPF and grabs debris or lasers which blast the ceramic particulates out of the air. Lastly, for anti-problem the team decided to move forward with the counter-objective of getting as much debris onto the mylar as possible. This allowed us to come up concepts such as making grippers grip with more pressure, having the mylar sheet adhesive be stickier, and making the part out of a more brittle material to increase the amount of debris that is generated. With the concepts in mind, the ideas we came up with to counter the problems were decrease gripper pressure or make the grippers softer, decreasing the adhesive properties or changing them to be activated by pressure, or making the part softer so there is less debris generated.

1.5.1 High Fidelity

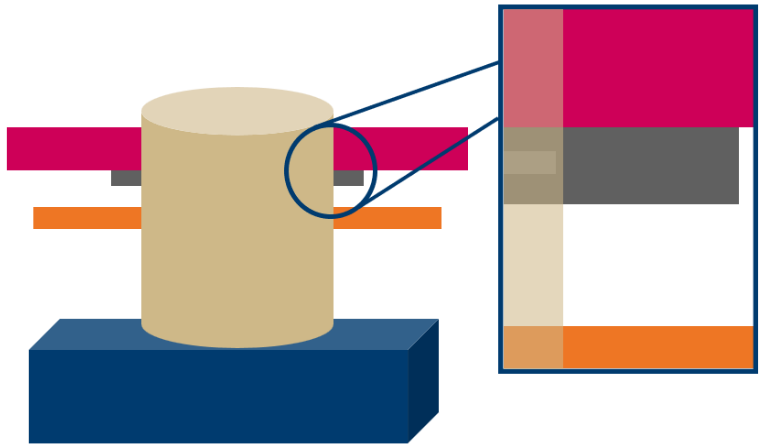

Figure 2. Vacuum Channel concept.

1. Concept #25 “Vacuum Channel”: This concept utilizes a device like a vacuum extension piece placed right below the upper gripper. For this design to work, the team will redesign the tooling to move the upper grippers further up to allow enough room for the device. Once enough room is available, the device will be placed directly underneath the upper grippers and will be attached to the grippers so that the device moves in and out with the grippers. The device will be shaped in such a way to match the profile of the grippers and will create a channel connected to a vacuum tube. The tube will be connected to the factory’s vacuum lines. As the grippers contact the filter and move away from it, the device will vacuum up the debris that falls before it falls onto the mylar sheet.

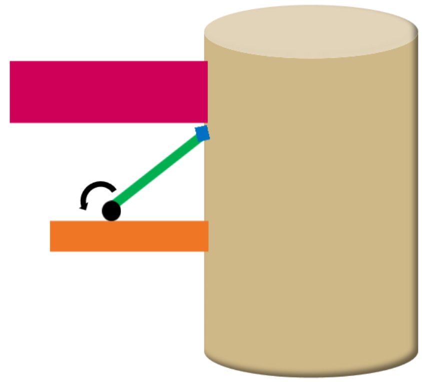

Figure 3. Spring Ramp concept.

2. Concept #85 “Spring Ramp”: The spring ramp is a ramp that attaches to the lower tooling of the end effector with a spring connected to the joint. The ramp itself will cover the gap that exists between the lower tooling and the DPF to prevent debris from falling on the Mylar sticker. The tip of the ramp will be touching the DPF so a soft material will be utilized at the top to prevent the further creation of debris due to that contact. To make sure that there is no gap between the tip of the ramp and the DPF, the inner diameter is a half inch smaller than the DPF’s diameter. The spring is then utilized to push the ramp back just enough to have the tip of the ramp to be resting on the DPF. With this closed gap the debris that falls from the upper grippers will be blocked from the Mylar sticker and will slide off the side of the justification table or be on the ramp.

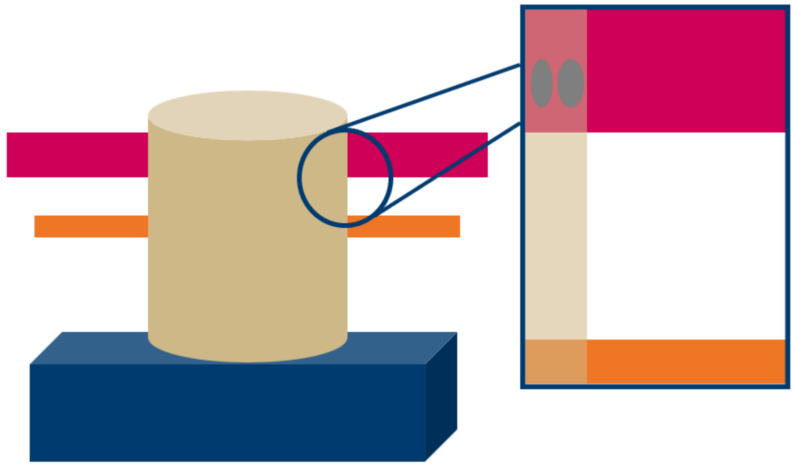

Figure 4. Suction Gripper concept.

3. Concept #43 “Suction Gripper”: The suction gripper is a design that will require minimum change to the current factory floor while possibly producing a maximum result. Currently the grippers are a solid piece and apply pressure to the ceramic filter (DPF) along its sides. Our problem arises when the grippers release the DPF, and ceramic particulates fall off the filter from the friction caused during contact. However, if the grippers are designed to have holes all throughout the plate which grips the DPF, and a vacuum is attached to the grippers, the particulates are sucked up immediately before they can reach the mylar.

1.5.2 Medium Fidelity

Figure 5. Plastic Wrapper concept.

1. Concept #3 “Plastic Wrapper”: This concept utilizes a plastic sheet wrapped around the DPF filter so that when the gripper grabs it, the debris is contained within the plastic wrap. This allows the debris to not be a problem during the justification process. Once it's done a knife system would be used to cut the plastic wrap off. This process of removing the plastic wrap can be implemented later down the DPF creation process so that it may be useful for other steps.

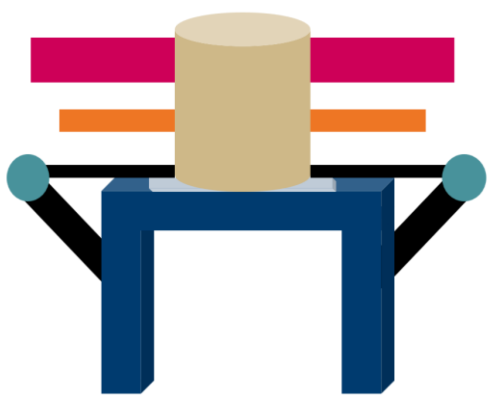

Figure 6. Mylar Defender concept.

2. Concept #8 “Mylar Defender”: This concept utilizes a sheet that is automatically moved above the justification table after the filter has been set down. This sheet covers right above the mylar sticker and moves out of the way when the final justification step is done to make the deal between the mylar and the lower tooling. When the sheet moves out of the way the debris falls onto the floor below the table.

Figure 7. Mylar Vacuum Seal concept.

3. Concept #20 “Mylar vacuum seal”: This concept will utilize vacuum pressure to create the seal with the mylar sheet rather than relying solely on adhesive. Once the filter is justified, the lower tooling will move down and contact the mylar sheet. Once it makes contact there will be various small vacuum lines connected to the lower tooling. Those lines will activate and suction the mylar sheet to the lower tooling to create a better seal. This increased seal will reduce the amount of batch material that spills out, removing the need to mitigate debris.

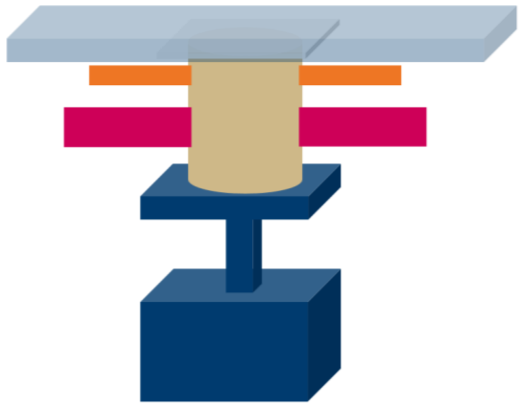

Figure 8. Inverted Justification concept.

4. Concept #30 “Inverted Justification”: This concept intends to flip the justification process upside-down to eliminate the effect of gravity on the debris. In order for this to work, the filter will be placed on a hydraulic piston table. The mylar sheet will be suspended above the filter vacuum suctioned to a platform. As the robot tooling centers the filter the piston will move up and down to allow for centering. Once the filter is justified underneath the mylar sheet the suction on the mylar sheet will release and the robot arm will continue to move the filter and sheet to the next step in the process. Every part of this process will essentially be the same however, when the gripper make debris on the filter they will fall and not make any contact with the mylar.

Figure 9. Ring on DPF concept.

5. Concept #84 “Ring on DPF”: This concept utilizes a ring that is placed on the filter before the justification process. The ring has a tight tolerance with the DPF to prevent slipping but not too tight to cause damage when putting it on and taking it off. With this concept the upper grippers will grab the ring rather than the DPF, and doing this will prevent debris from falling onto the Mylar sticker when the upper grippers leave the surface of the DPF. If there is debris still being created by the force exerted on the DPF through the ring by the upper grippers, the ring will be able to hold all of it in place until it is taken off. The ring will have an outer surface made of a hard metal material, while the inside is made of a soft rubber material. The hard outer surface will take the brunt of the force exerted by the upper grippers while the inner surface will create a cushion like lock on the DPF to prevent the creation of debris or lock in the created debris.

1.6 Concept Selection

In the process of determining our final selection we put our engineering characteristics, which were derived from our targets and metrics, and our customer requirements through a House of Quality chart, Table 4. From the House of Quality, we got a ranking order of our engineering characteristics which is: Debris on Mylar, Maintenance, Stabilize DPF, Longevity, Integrate with Tooling, Automation, Size of Device, Human Interaction, Installation Time, Temperature Resistance, Weight of Device, and Work with Current Utilities.

Table 4
House of Quality

	Engineering Characteristics												
Improvement Direction		↑	↓		↓		↓	↑	↓	↓	↓	↓	↑
Units		yrs	parts/day	N/A	DoF	N/A	hrs	°	g	hrs/month	lbs	ft³	°F
Customer Requirements	**Importance Weight Factor**	**Longevity**	**Maintenance**	**Automation**	**Integrate with Tooling**	**Work with Current Utilities**	**Installation Time**	**Stabilize DPF**	**Debris on Mylar**	**Human Interaction**	**Weight of Device**	**Size of Device**	**Temperature Resistance**
1. Prevent Debris on Mylar	**10**	1	3					1	9				
2. DPF is Supported	**4**			1	9			9					
3. DPF is Centered	**3**			1	9			3					
4. Reduces Wasted Time and Material	**5**	3	9		1		3		9	3			3
5. Automated	**6**	9	1	9	1						1	1	
6. Physically Prevent Debris	**9**	1	3						9				
7. Handles DPF with Care	**7**	1	3		3			9	3				
8. Weight Requirement	**0**	1	1		1		1				9	3	
9. Power Source	**1**	3				9	3						
10. Mylar Seals to Lower Tooling	**8**		9						9		1	3	
11. Other Processes Unhindered	**2**	3	3	3	3	1	1		3	3		9	
Raw Score	978	104	207	67	101	11	20	118	315	21	14	48	15
Relative Weight %	100	10.634	21.166	6.851	10.327	1.125	2.045	12.065	32.209	2.147	1.431	4.908	1.534
Rank Order		4	2	6	5	12	9	3	1	8	11	7	10

From this we determined our top 6 engineering characteristics to be Debris on Mylar, Maintenance, Stabilize DPF, Longevity, Integrate with Tooling, and Automation. Taking the top six engineering characteristics and our fidelity concepts we compared the concepts against a datum, what Corning has tried to do in the past to solve the problem, in a Pugh chart, Table 5.

Table 5
Market Comparison

		Concepts							
Selection Criteria	Soft Grippers	Vaccum Channel	Spring Ramp	Suction Gripper	Inverted Justification	Ring on DPF	Mylar Vacuum Seal	Plastic Wrapper	Mylar Defender
Debris on Mylar	Datum	+	+	+	+	+	-	+	+
Maintenance		+	+	+	+	+	+	+	+
Stabilize DPF		S	S	S	-	S	S	S	S
Longevity		-	-	-	-	-	-	-	-
Integrate with Tooling		S	-	S	-	-	S	-	-
Automation		S	S	S	S	S	S	S	S
Number of pluses		2	2	2	2	2	1	2	2
Number of minuses		1	2	1	3	2	2	2	2
Plus/Minus Ratio		2.000	1.000	2.00	0.67	1.000	0.50	1.000	1.000

From the first Pugh chart we took the four higher plus/minus ratio concepts, the Plastic Wrapper, the Vacuum Channel, the Spring Ramp, and the Suction Gripper, and put them into another Pugh Chart, Table 6. In the second Pugh Chart we chose the Plastic Wrapper as a new datum and compared them again.

Table 6
Concept Comparison

		Concepts		
Selection Criteria	Plastic Wrapper	Vaccum Channel	Spring Ramp	Suction Gripper
Debris on Mylar	Datum	+	+	-
Maintenance		-	+	-
Stabilize DPF		S	+	-
Longevity		-	S	-
Integrate with Tooling		S	-	S
Automation		S	S	S
Number of pluses		1	3	0
Number of minuses		2	1	4

From this chart we selected the Plastic Wrapper, Vacuum Channel, and Spring Ramp as concepts to move on in the selection process. We then took our top six engineering characteristics as determined before and weighed them against each other in an AHP chart (Table 7), next we normalized the weight (Table 8) and checked the consistency (Table 9).

Table 7
Criteria Comparison

Criteria Comparison Matrix [C]						
	Debris on Mylar	Maintenance	Stabilize DPF	Longevity	Integrate with Tooling	Automation
Debris on Mylar	1.000	3.000	3.000	5.000	3.000	7.000
Maintenance	0.333	1.000	1.000	5.000	0.333	3.000
Stabilize DPF	0.333	1.000	1.000	5.000	1.000	3.000
Longevity	0.200	0.200	0.200	1.000	0.333	0.200
Integrate with Tooling	0.333	3.000	1.000	3.000	1.000	3.000
Automation	0.143	0.333	0.333	5.000	0.333	1.000
Sum	2.343	8.533	6.533	24.000	6.000	17.200

Table 8

Normalized Criteria Comparison

Normalized Criteria Comparison Matrix [NormC]							
	Debris on Mylar	Maintenance	Stabilize DPF	Longevity	Integrate with Tooling	Automation	Critical Weights {W}
Debris on Mylar	0.427	0.352	0.459	0.208	0.500	0.407	0.392
Maintenance	0.142	0.117	0.153	0.208	0.056	0.174	0.142
Stabilize DPF	0.142	0.117	0.153	0.208	0.167	0.174	0.160
Longevity	0.085	0.023	0.031	0.042	0.056	0.012	0.041
Integrate with Tooling	0.142	0.352	0.153	0.125	0.167	0.174	0.185
Automation	0.061	0.039	0.051	0.208	0.056	0.058	0.079
Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 9

Criteria Consistency Check

Consistency Check					
{Ws}=[C]{W} Weighted Sum Vector	{W} Criteria Weights	Cons={Ws}./{W} Consistency Vector			
2.614	0.392	6.665		λ	6.556
0.938	0.142	6.615		RI	1.250
1.062	0.160	6.623		CI	0.111
0.258	0.041	6.231		CR	0.089
1.263	0.185	6.807			
0.504	0.079	6.396			

We then compared the three concepts against each other with how well they can meet the engineering characteristics criteria with an example in Table 10. We then normalized it and checked the consistency of our decisions, with examples in Table 11 and Table 12.

Table 10

Debris on Mylar Comparison

Debris on Mylar Comparison [C]			
	Plastic Wrapper	Vaccum Channel	Spring Ramp
Plastic Wrapper	1.000	3.000	1.000
Vaccum Channel	0.333	1.000	0.333
Spring Ramp	1.000	3.000	1.000
Sum	2.333	7.000	2.333

Table 11
Normalized Debris on Mylar Comparison

Normalized Debris on Mylar Comparsion [NormC]				
	Plastic Wrapper	Vaccum Channel	Spring Ramp	Design Alternative Priorities {Pi}
Plastic Wrapper	0.429	0.429	0.429	0.429
Vaccum Channel	0.143	0.143	0.143	0.143
Spring Ramp	0.429	0.429	0.429	0.429
Sum	1.000	1.000	1.000	1.000

Table 12
Consistency Check for Debris on Mylar Comparison

Debris on Mylar Consistency Check					
{Ws}=[C]{Pi} Weighted Sum Vector	{Pi} Criteria Weights	Cons={Ws}./{Pi} Consistency Vector			
1.286	0.429	3.000		λ	3.000
0.429	0.143	3.000		RI	0.520
1.286	0.429	3.000		CI	0.000
				CR	0.000

Finally, we took our data and put it through the AHP's Final Rating Matrix, Table 13, and got our selected concept: the Spring Ramp.

Table 13

Final Rating Matrix

Selection Criteria	Plastic Wrapper	Vaccum Channel	Spring Ramp
Debris on Mylar	0.429	0.143	0.429
Maintenance	0.429	0.143	0.429
Stabilize DPF	0.106	0.260	0.633
Longevity	0.106	0.633	0.260
Integrate with Tooling	0.429	0.429	0.143
Automation	0.480	0.115	0.405

	Alternative Value					
Selection Criteria	Debris on Mylar	Maintenance	Stabilize DPF	Longevity	Integrate with Tooling	Automation
Plastic Wrapper	0.429	0.429	0.106	0.106	0.429	0.480
Vaccum Channel	0.143	0.143	0.260	0.633	0.429	0.115
Spring Ramp	0.429	0.429	0.633	0.260	0.143	0.405

Concept	Alternative Value
Plastic Wrapper	0.368
Vaccum Channel	0.233
Spring Ramp	0.400

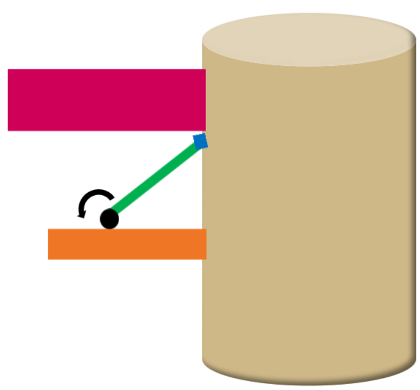

Figure 10. Final selected concept.

The spring ramp once again is a curved ramp that is slightly bigger than the upper grippers that are causing the debris to form. This curved ramp is supported by a spring-like hinge to create tension when the lower grippers come in towards the filter by pressing against the filter.

Thus, pushing the ramp back a little causing a firm seal around the filter. The debris that was going to fall onto the mylar below now falls onto the ramp and the ground. The purpose of the spring-like hinge is so that when the upper gripper and lower tooling leave the part, the debris that is falling doesn't fall through the gap that would be created by the lower tooling and evidently the ramp, because the ramp is still pushing against the filter as the tooling leaves the part.

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 509's mission is to pursue a successful project for the Corning Mylar Stick End Effector. Through consistent and clear communication with group members, our cooperation will be a top priority with sponsors and team members in order to meet project expectations.

Outside Obligations

- Anthony Arroyo
    - ROTC Physical Training MWF 05:45 AM to 7:00 AM
    - ROTC Laboratory TH 05:45 AM to 7:30 AM
    - ROTC Meeting Tu 07:00 AM to 8:00 AM
    - Starts working at a new job soon hours will be determined weekly for about 20 hours a week.
- Austin Cramer
    - Work every Wednesday from 12:00 PM to 5:00 PM
- Khanh Nguyen
    - Work every Monday from 2:00 PM to 5:00 PM
    - Work every Wednesday from 7:00
    - Work every Friday from 10:00 AM to 5:00PM
- William Shuman
    - Starts working at a new job soon hours will be determined weekly for about 20 hours a week.
- Nathan Thompson
    - Every Saturday I reserve the day for social life and football games. Exceptions can be made on a case-by-case basis.
    - Sundays from 9-11 I have church.

Team Roles

Material Specialist – Kahn Nguyen

Design Engineer – Nathan Thompson

Manufacturing Engineer – Anthony Arroyo

Control Systems Engineer – Austin Cramer

Testing Specialist – William Shuman

Communication

The team will primarily communicate through Microsoft Teams. Secondary forms of communication will include but are not limited to FSU email and text messages. All team members will be copied on all emails between the sponsor, advisors, and/or Dr. McConomy. All team members have committed to responding to communications within 24 hours. A professional and inclusive tone will be used throughout all communications. Stakeholders will be addressed to by their proper titles. All team members will always treat each other with dignity and respect.

Dress Code

Class and team meetings will have a dress code of casual or athleisure wear. The dress code for meetings or presentations with stakeholders will be business casual including a polo or button-down shirt, dress pants, belt, and dress shoes. Shirts will be tucked in, and team members will appear presentable.

Attendance Policy

All team meetings will never exceed past 9 PM. Meetings will either be in person at the FAMU-FSU College of Engineering or another specified location or on Zoom if an in-person meeting is not available. Meetings will be mandatory unless an excusal is approved by all other team members 24 hours in advance. If an emergency occurs, then excusal will be approved accordingly. If a team member does not show up to a meeting and they are unexcused, they must put $5 in the social jar. If a group member misses 3 consecutive meetings with no excusal, then Dr. McConomy will be notified, and steps will be taken at his discretion. If an excused member is able to attend an in-person meeting on Zoom, they will be accommodated.

How to Notify Group

The group will be notified by each other through text, or teams chat. Each team member will be copied on all emails going to Dr. McConomy or the sponsor.

How to Respond to People in Professional Meeting

Responses in a professional meeting will be respectful and constructive. These responses should hold up the overall respectful tone of the meeting. If this rule is broken, then the team member will formally apologize and then put $50 in the aforementioned social jar.

What do we do before McConomy or TAs

Before we go to Dr. McConomy or the TAs, the team members will get together and attempt to resolve the issue professionally and respectfully. They will aim to have all parties in agreement.

At What point do we contact Dr. McConomy

If it comes to the point where team members can not come to an agreement and settle terms, then the team will collectively go to Dr. McConomy for assistance.

What do you want Dr. McConomy to do when you come

When the team comes to Dr. McConomy, we would like Dr. McConomy to give his input on an ideal solution. The team will then take his input to come to a decision. We would also like Dr. McConomy to make the losing party put $10 into the aforementioned social jar. If there is more than 1 person in the losing party, then each will put in $10.

How to amend

The team will amend these rules by holding a vote. In order to amend the rule the vote must be 5/5. If there is a majority vote but not 5/5 then the majority party will each put $5 in to the social jar and then the rule will be amended.

Statement of Understanding

As a member of team 509, I have read this code of conduct in its entirety, and I agree to all the conditions listed. I acknowledge that I have had the opportunity to ask questions and voice my opinion on any changes that I wanted to be made.

x. Anthony Arroyo

x. Austin Cramer

x. Khanh Nguyen

x. William Shuman

x. Nathan Thompson

Appendix C: Target Catalog

Systems	Function	Metric	Target
Support	Increase Longevity	Time (Years)	1 Year
Support	Decrease Maintenance	Parts per Day	50 parts
Support	Implement Automation	N/A	True
Compatibility	Integrate with Tooling	Degrees of Freedom	2
Compatibility	Work with Current Utilities	N/A	True
Compatibility	Reduce Installation Time	Time (hrs)	8 hours
Compatibility	Stabilize DPF	Orientation of the part (θ)	90 Degrees
Prevention	Prevent Debris on Mylar	Weight (g)	.4 g
Prevention	Prevent Human Interaction	Time (hrs/month)	9 hrs/month
N/A		Max Weight of Device	100 lbs
N/A		Max Volume Occupied	7 ft^3
N/A		Temperature Resistance	90 °F

Appendix D: Concepts List

Concept Number	Concept Idea
1	A device that attaches to the lower tooling and clamps onto the part so as the gripper drops down it catches all the debris that falls off from the upper grippers.
2	A device that sweeps the sticker very finely and softly.
3	A product that wraps ceramic in a type of plastic wrap.
4	The justification process is done in a liquid that doesn't short circuit the devices and remove the stickiness of the sticker causing the debris to fall.
5	Use a ceramic magnet that will pull the ceramic debris towards it.
6	Use air blowing across the sticker to blow off all the debris on the sticker.
7	Shake the filter so much that most of the debris falls off.
8	Put a protector on top of the sticker and remove it right before the seal is about to be made.
9	Make sticker thicker so that the debris doesn't mess with the seal as much.
10	Make the lower tooling wider so that the tooling has more surface area to seal onto the sticker.

Concept Number	Concept Idea
11	On the lower tooling input a device that can catch the debris but does not have it fall off the tooling.
12	A Lazer that shoots the debris as it falls.
13	A device that grabs the debris as it falls.
14	Add an extra set of upper grippers so less force is required to move it decreasing the likelihood of debris being created.
15	Covers device in a binding glue-like agent that causes the debris to have trouble falling off.
16	Extrude the walls on the ceramics to be thicker and shave them down later.
17	Justify the part from the top so the debris falls and not onto the sticker. Have catch under it so the other sticker doesn't get it.
18	Shoots water around the ceramic and removes the debris as its falling
19	Justifies the ceramic horizontally.
20	Change the lower tooling so that it suctions onto the sticker as well as sticking to it.
21	A device that goes between the gripper and lower tooling and channels the debris down to the ground.
22	Large fan that blows the debris away from the part.
23	Redesign the mylar to be less sticky so debris won't stay on it.
24	Once centered, lift tooling up and automatically brushes off the mylar sticker, then lower tooling and make seal.
25	Channel places right below gripper with high vacuum.

Concept Number	Concept Idea
26	Make the mylar sticker vacuum sealed to tooling instead of sticking.
27	Channel places right below gripper with high blow pressure.
28	Decrease the surface area of the mylar sheet that has adhesive to only the tooling and filter.
29	Decrease the pressure in the grippers so they create less debris.
30	Flip the justification process upside down, vacuum the mylar to surface and center ceramic upside down.
31	Add a suction channel on top the lower tooling to vacuum the debris
32	Vacuum platform outside the table that sucks the debris from under the grippers.
33	Larger grippers to increase surface area, to lower overall pressure on the part
34	Move the upper tooling up so there is more room between grippers and lower tooling and add in a fan to blow away falling debris
35	Increase distance between grippers and lowering tooling (less of a chance debris falls in gap)
36	Make the 1/4-inch gap 1/8 inch
37	Put a very large fan on high speed while the justification process occurs
38	Make the ceramic filter harder out the outside so it doesn't make debris
39	Have a person in the justification area with a compressed air blowing away debris
40	Center the mylar sheet on the ceramic filter before and eliminate the justification process
41	An air blower which is underneath the grippers and blows particulates away

Concept Number	Concept Idea
42	Battery powered vacuum underneath grippers which immediately sucks all particulates away
43	Grippers are redesigned to have holes in them, and a vacuum is attached to suck the debris directly through the grippers.
44	Grippers are sticky and allow for particulates to stick to the grippers rather than fall on the mylar sheet
45	Grippers are re-designed with a spongy, water absorbent material and are dampened by a hose, allowing the ceramic particulates to be absorbed by the spongy material
46	Grippers are extended in size to fit fully around the ceramic and decrease pressure on the common areas where particulate dust accumulates
47	Grippers have a softer rubber with more “squish” factor, reducing damage on the ceramic filter
48	Below the grippers are a ramp/skirt which seals onto the ceramic allowing particulates that fall from the gripper to slide off the ramp
49	A ramp is attached on top of the lower tooling which moves and forms a near perfect seal on the ceramic, and the ramp is sticky to collect all the particulates
50	A giant fan is placed at the end of the robot cage, and constantly blows a high velocity of air through the cage, pushing all particulates away to the right
51	A battery powered vacuum is attached to the lower tooling, and constantly sucks upwards to prevent the debris from reaching the mylar
52	The mylar adhesive is activated by pressure, so before the lower tooling lowers onto the

Concept Number	Concept Idea
	mylar sticker a fan blows off the debris from the non-sticky mylar
53	The mylar adhesive is stickier, allowing for a seal with the lower tooling even in the presence of debris
54	A giant fan is placed at the end of the robot cage, and constantly blows a high velocity of air through the cage, pushing all particulates away to the left
55	The robot cage is sealed, and has a high amount of water vapor pumped in to turn the particulate dust into a paste, not debris to fall on the mylar
56	There is a constant flame underneath the common areas where debris falls, burning the ceramic dust before it reaches the mylar
57	Nitrogen gas is pumped underneath the grippers, freezing the particulate dust and a fan subsequently blows the frozen particulates away.
58	A drone is activated in the robot cage, and has a sensor to fly underneath the debris and catch it before it lands on the mylar
59	A fan is attached to the baseboard of the floor and moves on a track to rotate around the part and blow debris.
60	There is a sticky spray applied to the outside to the skin.
61	Heat activated plastic shrink wrap around skin to seal in debris.
62	Automatic air blower for mylar sheet.
63	Anti-gravity chamber does not allow debris to fall.
64	Table for the mylar sheet shakes the debris off.

Concept Number	Concept Idea
65	Suction cups for grippers instead of the normal grippers.
66	Gravity beam picks up the DPF filter instead of normal grippers.
67	Aluminum sheet wraps the skin of the DPF filter.
68	Smart Vacuum for the debris that lays on the gripper.
69	Manual sweeping ring for the mylar sheet.
70	Automatic sweeping ring for the mylar sheet.
71	Ceramic Repellent magnetic
72	Small manual vacuum for the gap in the gripper.
73	The grippers are sprayed with a sticky solution for the debris to stick on before falling.
74	Lower the PSI on the gripper with a harder material to reduce the possible chance of debris
75	Change the grippers to a foam memory
76	Manual air blower to blast the debris away from the mylar.
77	Larger gripper with softer surface to reduce pressure on the mylar.
78	Fan underneath the table blowing away the debris.
79	Nonstick spray for the mylar so the debris cannot stick. Add heat to it to remove nonstick.
80	Air compressors that come up on the side of the justification table and blows the debris off
81	Air is blown as a wall around the filter from below to create an invisible wall

Concept Number	Concept Idea
82	Replace the friction grippers with vacuum grippers
83	Harden the ceramic with a solvent
84	Place a ring on the filter and grab the ring instead of the filter
85	Ramp that is attached with a spring to the lower tooling and below the upper gripper to guide the debris off the side
86	Spin the part at high speeds to fling the debris off
87	Flip the part upside down after centering and let the debris fall off
88	Change the grippers to a softer material
89	Use two fans on either side of the filter to blow the debris away
90	Create a high pressure cone under the grippers
91	Add a sticky film to the grippers that holds the debris and can be pulled off
92	Put an indent in the grippers and use a vacuum to suck up the debris
93	The grippers have a design that is like a tree, gripping in multiple organic locations
94	A high pitch speaker blasts the ceramic debris before it reaches the mylar sticker, vaporizing it

Appendix D: House of Quality Charts

Binary Comparison

Customer Needs	1	2	3	4	5	6	7	8	9	10	11	Total
1. Prevent Debris on Mylar	-	1	1	1	1	1	1	1	1	1	1	10
2. DPF is Supported	0	-	1	0	0	0	0	1	1	0	1	4
3. DPF is Centered	0	0	-	0	0	0	0	1	1	0	1	3
4. Reduces Wasted Time and Material	0	1	1	-	0	0	0	1	1	0	1	5
5. Automated	0	1	1	1	-	0	0	1	1	0	1	6
6. Physically Prevent Debris	0	1	1	1	1	-	1	1	1	1	1	9
7. Handles DPF with Care	0	1	1	1	1	0	-	1	1	0	1	7
8. Weight Requirement	0	0	0	0	0	0	0	-	0	0	0	0
9. Power Source	0	0	0	0	0	0	0	1	-	0	0	1
10. Mylar Seals to Lower Tooling	0	1	1	1	1	0	1	1	1	-	1	8
11. Other Processes Unhindered	0	0	0	0	0	0	0	1	1	0	-	2
Total	0	6	7	5	4	1	3	10	9	2	8	
Check: (n-1)	10	10	10	10	10	10	10	10	10	10	10	

House of Quality

	Engineering Characteristics												
Improvement Direction		↑	↓		↓		↓	↑	↓	↓	↓	↓	↑
Units		yrs	parts/day	N/A	DoF	N/A	hrs	°	g	hrs/month	lbs	ft^3	°F
Customer Requirements	**Importance Weight Factor**	**Longevity**	**Maintenance**	**Automation**	**Integrate with Tooling**	**Work with Current Utilities**	**Installation Time**	**Stabilize DPF**	**Debris on Mylar**	**Human Interaction**	**Weight of Device**	**Size of Device**	**Temperature Resistance**
1. Prevent Debris on Mylar	**10**	1	3					1	9				
2. DPF is Supported	**4**			1	9			9					
3. DPF is Centered	**3**			1	9			3					
4. Reduces Wasted Time and Material	**5**	3	9		1		3		9	3			3
5. Automated	**6**	9	1	9	1						1	1	
6. Physically Prevent Debris	**9**	1	3						9				
7. Handles DPF with Care	**7**	1	3		3			9	3				
8. Weight Requirement	**0**	1	1		1		1				9	3	
9. Power Source	**1**	3				9	3						
10. Mylar Seals to Lower Tooling	**8**		9						9		1	3	
11. Other Processes Unhindered	**2**	3	3	3	3	1	1		3	3		9	
Raw Score	978	104	207	67	101	11	20	118	315	21	14	48	15
Relative Weight %	100	10.634	21.166	6.851	10.327	1.125	2.045	12.065	32.209	2.147	1.431	4.908	1.534
Rank Order		4	2	6	5	12	9	3	1	8	11	7	10

Appendix E: Pugh Charts

Market

		Concepts							
Selection Criteria	Soft Grippers	Vaccum Channel	Spring Ramp	Suction Gripper	Inverted Justification	Ring on DPF	Mylar Vacuum Seal	Plastic Wrapper	Mylar Defender
Debris on Mylar	Datum	+	+	+	+	+	-	+	+
Maintenance		+	+	+	+	+	+	+	+
Stabilize DPF		S	S	S	-	S	S	S	S
Longevity		-	-	-	-	-	-	-	-
Integrate with Tooling		S	-	S	-	-	S	-	-
Automation		S	S	S	S	S	S	S	S
Number of pluses		2	2	2	2	2	1	2	2
Number of minuses		1	2	1	3	2	2	2	2
Plus/Minus Ratio		2.000	1.000	2.00	0.67	1.000	0.50	1.000	1.000

Concept

		Concepts		
Selection Criteria	Plastic Wrapper	Vaccum Channel	Spring Ramp	Suction Gripper
Debris on Mylar	Datum	+	+	-
Maintenance		-	+	-
Stabilize DPF		S	+	-
Longevity		-	S	-
Integrate with Tooling		S	-	S
Automation		S	S	S
Number of pluses		1	3	0
Number of minuses		2	1	4

Appendix F: Analytical Hierarchy Process Charts

Criteria C Matrix

Criteria Comparison Matrix [C]						
	Debris on Mylar	Maintenance	Stabilize DPF	Longevity	Integrate with Tooling	Automation
Debris on Mylar	1.000	3.000	3.000	5.000	3.000	7.000
Maintenance	0.333	1.000	1.000	5.000	0.333	3.000
Stabilize DPF	0.333	1.000	1.000	5.000	1.000	3.000
Longevity	0.200	0.200	0.200	1.000	0.333	0.200
Integrate with Tooling	0.333	3.000	1.000	3.000	1.000	3.000
Automation	0.143	0.333	0.333	5.000	0.333	1.000
Sum	2.343	8.533	6.533	24.000	6.000	17.200

Criteria Normalization

Normalized Criteria Comparison Matrix [NormC]							
	Debris on Mylar	Maintenance	Stabilize DPF	Longevity	Integrate with Tooling	Automation	Critical Weights {W}
Debris on Mylar	0.427	0.352	0.459	0.208	0.500	0.407	0.392
Maintenance	0.142	0.117	0.153	0.208	0.056	0.174	0.142
Stabilize DPF	0.142	0.117	0.153	0.208	0.167	0.174	0.160
Longevity	0.085	0.023	0.031	0.042	0.056	0.012	0.041
Integrate with Tooling	0.142	0.352	0.153	0.125	0.167	0.174	0.185
Automation	0.061	0.039	0.051	0.208	0.056	0.058	0.079
Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Criteria Consistency

Consistency Check					
{Ws}=[C]{W} Weighted Sum Vector	{W} Criteria Weights	Cons={Ws}./{W} Consistency Vector			
2.614	0.392	6.665		λ	6.556
0.938	0.142	6.615		RI	1.250
1.062	0.160	6.623		CI	0.111
0.258	0.041	6.231		CR	0.089
1.263	0.185	6.807			
0.504	0.079	6.396			

Comparison for Debris on Mylar Criteria

Debris on Mylar Comparison [C]			
	Plastic Wrapper	Vaccum Channel	Spring Ramp
Plastic Wrapper	1.000	3.000	1.000
Vaccum Channel	0.333	1.000	0.333
Spring Ramp	1.000	3.000	1.000
Sum	2.333	7.000	2.333

Comparison for Maintenance Criteria

Maintenance Comparison [C]			
	Plastic Wrapper	Vaccum Channel	Spring Ramp
Plastic Wrapper	1.000	3.000	1.000
Vaccum Channel	0.333	1.000	0.333
Spring Ramp	1.000	3.000	1.000
Sum	2.333	7.000	2.333

Comparison for Stabilize DPF Criteria

Stabilize DPF Comparison [C]			
	Plastic Wrapper	Vaccum Channel	Spring Ramp
Plastic Wrapper	1.000	0.333	0.200
Vaccum Channel	3.000	1.000	0.333
Spring Ramp	5.000	3.000	1.000
Sum	9.000	4.333	1.533

Comparison for Longevity Criteria

Longevity Comparison [C]			
	Plastic Wrapper	Vaccum Channel	Spring Ramp
Plastic Wrapper	1.000	0.200	0.333
Vaccum Channel	5.000	1.000	3.000
Spring Ramp	3.000	0.333	1.000
Sum	9.000	1.533	4.333

Comparison for Integrate with Tooling Criteria

Integrate with Tooling Comparison [C]			
	Plastic Wrapper	Vaccum Channel	Spring Ramp
Plastic Wrapper	1.000	1.000	3.000
Vaccum Channel	1.000	1.000	3.000
Spring Ramp	0.333	0.333	1.000
Sum	2.333	2.333	7.000

Comparison for Automation Criteria

Automation Comparison [C]			
	Plastic Wrapper	Vaccum Channel	Spring Ramp
Plastic Wrapper	1.000	5.000	1.000
Vaccum Channel	0.200	1.000	0.333
Spring Ramp	1.000	3.000	1.000
Sum	2.200	9.000	2.333

Normalized Comparison for Debris on Mylar Criteria

Normalized Debris on Mylar Comparsion [NormC]				
	Plastic Wrapper	Vaccum Channel	Spring Ramp	Design Alternative Priorities {Pi}
Plastic Wrapper	0.429	0.429	0.429	0.429
Vaccum Channel	0.143	0.143	0.143	0.143
Spring Ramp	0.429	0.429	0.429	0.429
Sum	1.000	1.000	1.000	1.000

Normalized Comparison for Maintenance Criteria

Normalized Maintenance Comparsion [NormC]				
	Plastic Wrapper	Vaccum Channel	Spring Ramp	Design Alternative Priorities {Pi}
Plastic Wrapper	0.429	0.429	0.429	0.429
Vaccum Channel	0.143	0.143	0.143	0.143
Spring Ramp	0.429	0.429	0.429	0.429
Sum	1.000	1.000	1.000	1.000

Normalized Comparison for Stabilize DPF Criteria

Normalized Stabilize DPF Comparsion [NormC]				
	Plastic Wrapper	Vaccum Channel	Spring Ramp	Design Alternative Priorities {Pi}
Plastic Wrapper	0.111	0.077	0.130	0.106
Vaccum Channel	0.333	0.231	0.217	0.260
Spring Ramp	0.556	0.692	0.652	0.633
Sum	1.000	1.000	1.000	1.000

Normalized Comparison for Longevity Criteria

Normalized Longevity Comparsion [NormC]				
	Plastic Wrapper	Vaccum Channel	Spring Ramp	Design Alternative Priorities {Pi}
Plastic Wrapper	0.111	0.130	0.077	0.106
Vaccum Channel	0.556	0.652	0.692	0.633
Spring Ramp	0.333	0.217	0.231	0.260
Sum	1.000	1.000	1.000	1.000

Normalized Comparison for Integrate with Tooling Criteria

Normalized Integrate with Tooling Comparsion [NormC]				
	Plastic Wrapper	Vaccum Channel	Spring Ramp	Design Alternative Priorities {Pi}
Plastic Wrapper	0.429	0.429	0.429	0.429
Vaccum Channel	0.429	0.429	0.429	0.429
Spring Ramp	0.143	0.143	0.143	0.143
Sum	1.000	1.000	1.000	1.000

Normalized Comparison for Automation Criteria

Normalized Automation Comparsion [NormC]				
	Plastic Wrapper	Vaccum Channel	Spring Ramp	Design Alternative Priorities {Pi}
Plastic Wrapper	0.455	0.556	0.429	0.480
Vaccum Channel	0.091	0.111	0.143	0.115
Spring Ramp	0.455	0.333	0.429	0.405
	1.000	1.000	1.000	1.000

Consistency Check for Debris on Mylar Criteria

Debris on Mylar Consistency Check					
{Ws}=[C]{Pi} Weighted Sum Vector	{Pi} Criteria Weights	Cons={Ws}./{Pi} Consistency Vector			
1.286	0.429	3.000		λ	3.000
0.429	0.143	3.000		RI	0.520
1.286	0.429	3.000		CI	0.000
				CR	0.000

Consistency Check for Maintenance Criteria

Maintenance Consistency Check					
{Ws}=[C]{Pi} Weighted Sum Vector	{Pi} Criteria Weights	Cons={Ws}./{Pi} Consistency Vector			
1.286	0.429	3.000		λ	3.000
0.429	0.143	3.000		RI	0.520
1.286	0.429	3.000		CI	0.000
				CR	0.000

Consistency Check for Stabilize DPF Criteria

Stabilize DPF Consistency Check					
{Ws}=[C]{Pi} Weighted Sum Vector	{Pi} Criteria Weights	Cons={Ws}./{Pi} Consistency Vector			
0.320	0.106	3.011		λ	3.039
0.790	0.260	3.033		RI	0.520
1.946	0.633	3.072		CI	0.019
				CR	0.037

Consistency Check for Longevity Criteria

Longevity Consistency Check					
{Ws}=[C]{Pi} Weighted Sum Vector	{Pi} Criteria Weights	Cons={Ws}./{Pi} Consistency Vector			
0.320	0.106	3.011		λ	3.039
1.946	0.633	3.072		RI	0.520
0.790	0.260	3.033		CI	0.019
				CR	0.037

Consistency Check for Integrate with Tooling Criteria

Integrate with Tooling Consistency Check					
{Ws}=[C]{Pi} Weighted Sum Vector	{Pi} Criteria Weights	Cons={Ws}./{Pi} Consistency Vector			
1.286	0.429	3.000		λ	3.000
1.286	0.429	3.000		RI	0.520
0.429	0.143	3.000		CI	0.000
				CR	0.000

Consistency Check for Automation Criteria

Automation Consistency Check					
{Ws}=[C]{Pi} Weighted Sum Vector	{Pi} Criteria Weights	Cons={Ws}./{Pi} Consistency Vector			
1.460	0.480	3.044		λ	3.029
0.346	0.115	3.010		RI	0.520
1.230	0.405	3.033		CI	0.015
				CR	0.028

Final Rating Matrix

Selection Criteria	Plastic Wrapper	Vaccum Channel	Spring Ramp			
Debris on Mylar	0.429	0.143	0.429			
Maintenance	0.429	0.143	0.429			
Stabilize DPF	0.106	0.260	0.633			
Longevity	0.106	0.633	0.260			
Integrate with Tooling	0.429	0.429	0.143			
Automation	0.480	0.115	0.405			
			Alternative Value			
Selection Criteria	Debris on Mylar	Maintenance	Stabilize DPF	Longevity	Integrate with Tooling	Automation
Plastic Wrapper	0.429	0.429	0.106	0.106	0.429	0.480
Vaccum Channel	0.143	0.143	0.260	0.633	0.429	0.115
Spring Ramp	0.429	0.429	0.633	0.260	0.143	0.405
Concept	Alternative Value					
Plastic Wrapper	0.368					
Vaccum Channel	0.233					
Spring Ramp	0.400					

References

There are no sources in the current document.