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Team 504: Aftermarket Workflow and Project Creation and Implementation

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Abstract

Danfoss Turbocor wishes to improve the process of replacing parts for damaged compressors returning from the field. The current job of a planner is to find the appropriate replacement parts. Our goal is to help the planner by streamlining and automating this process. We are implementing a MATLAB script that produces a bill of materials of suitable replacement parts for a damaged compressor.

There are three reasons that parts need replacement: failure, compatibility, and obsolescence. Planners filter through these factors to determine the proper replacement parts. There is no standard procedure for this process which has led to organizational problems within Danfoss production. Therefore, we are creating a system that determines part replacements based on the criterion for replacement. Our system identifies the most recent revision of a failed part. If a replacement depends on other parts, the other parts must be added to the bill of materials as well. Furthermore, our system determines whether a part is obsolete. This prevents outdated parts from entering the bill of materials.

Our team is designing a MATLAB script to organize the part replacement process. The script automates the logic for part replacement. Certain scenarios are dependent on the intuition of the planner. We discussed this issue with Danfoss personnel and developed a way of addressing these problems. Therefore, the script is used with a standard which handles the manual side of planning. Together, the script and standard produce a final bill of materials. While we have designed our system to handle Danfoss's TT/TG model compressors, our system is formatted to be replicated for all Danfoss compressor models.



Disclaimer



Acknowledgement



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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
	Clemson University - International Center for
CU-ICAR	Automotive Research
DDI	Driver Death per Involvement Ratio
DIT	Driver Involvement per Vehicle Mile Traveled



Difference between the calculated and measured

Difference 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

Danfoss expanded its business several years ago to include the refurbishment of its compressors. These compressors have been in field service for many years. Such a service requires diligent management of hardware throughout the process. There can be no integration of new compressors and refurbished parts. Therefore, a separate logistics and product flow had to be created that was distinct to those compressors coming back from the field. The system evolved into a series of subsystems. Each subsystem is functional on its own, however, it requires technician diligence to keep the records organized. Danfoss wishes to integrate the various subsystems and develop a system that is far more user friendly, automated, and robust. This integrated system is to generate a bill of materials for a given aftermarket compressor using records provided by Danfoss's aftermarket investigation team.

Project Description

The objective of this project is to design an integrated system that generates a bill of materials for a given aftermarket compressor using records provided by Danfoss's investigation and planning team



Key Goals

There are a few key goals surrounding the DTC Aftermarket Workflow and Process Creation and Implementation Project. The system is easy to use as it will be handled by technicians and operators who have little to no prior knowledge as to which parts need replacement in aftermarket compressors. The system is to organize a list of parts that need to be fixed for any given aftermarket compressor and print out a bill of materials for refurbishment. The display is aesthetically pleasing with a favorable graphic user interface. The system is capable of handling TT/TG compressors and accommodates for backwards compatibility. Danfoss will then be capable of duplicating the system for various models of compressors. The system accounts for human error by automating Danfoss's subsystems ensuring the right parts are replaced. The system also does not allow duplicate items or items to be listed on the report that do not need to be replaced. This system will be tested and validated using fictitious compressors. Once the process has been validated, it will be tested on the aftermarket production line. Danfoss hopes to implement this system by the end of spring in 2021.

Primary Market

The primary market for the project is aftermarket compressor manufacturers. More specifically, compressor manufacturers that have organization issues within their aftermarket production line.

Secondary Markets

Another potential market for the product is recalls in the auto-manufacturing industry. The product can assist in determining replacements for mandatory callbacks. The



system could also be used in inventory management to automate the record keeping process eliminating human error. The product could be used in supply chains and logistic firms by using existing data to culminate solutions decreasing the time it takes to make accurate decisions. Finally, the solution could be implemented in laboratories to increase organization of incoming data and assist with post-processing.

Assumptions

For this project, there are few necessary assumptions to be made. First, the product is functional on a PC platform. The technician can operate the digital interface. The product will be used at Danfoss in their aftermarket manufacturing facility. The operator will be inputting valid data. Another assumption is the compressors are not being redesigned. The results from the solution are based on the data provided by Danfoss. The system does not simulate or test the conditions of failure in the compressor, but gives feedback based on the compressor failure reports which have been provided by Danfoss's testing facility. Finally, the system excludes the processes which occur prior to testing and after production.

Stakeholders

Stakeholders are those who will use, benefit, are interested, or have a concern about this project. The primary users of the system will be operators and technicians at Danfoss Turbocor. The primary benefactors are the customers that receive the refurbished compressor from Danfoss.



Other users of this system comprise those listed in the secondary markets section mentioned above. They include but are not limited to companies that have compressors as one of their assets and plan on using Danfoss's aftermarket compressor repair services.

Businesses like Ryder and EY, logistics and supply chain companies, will benefit from the system. These are potential stakeholders in this product.

Our point of contact Stephen Seymore, the operations engineering director, as well as other members of Danfoss's upper management benefit from a faster aftermarket repair program and positive image produced by satisfied customers.

Our professor and advisor for this project is Dr. Shayne McConomy. Other interested faculty include Dr. Mohd Ali, the project's faculty advisor. Finally, the FAMU/FSU College of Engineering supports the project.

1.2 Customer Needs

For any manufacturing facility, the use of cataloging and organizing parts is essential for efficient operation. Danfoss is revamping their aftermarket production process and are looking for a solution to address their current cataloging system. Our group was first introduced to Stephen Seymore, the Operations Engineering Director. He was prompted with questions about the aftermarket process, the current system in place for cataloging, and expectations from our team. From the questions, we were able to generate a chart that shows our customers' questions, customers needs and the interpreted needs.



Background

Aftermarket production at Danfoss deals with repairing clients' malfunctioning compressors. The current method that Danfoss uses to implement aftermarket production consists of three main departments: aftermarket testing, material handling, and production. The job of a material handler is to assess the data received from aftermarket testing and determine what components are malfunctioning on a compressor. The material handler is then to determine what parts need to be replaced and then create a bill of materials to be sent to production. The material handlers at Danfoss are currently using a material requirement planning program (MRP) to catalog data. The MRP program is currently supplied by Systems Applications and Products in Data Processing (SAP).

Customer Needs and Interpretations

Customer Needs and Interpretation:

Question/Prompt	Customer Statement	Interpreted Need
Interview		
What kind of project is this: mechanical engineering or logistics?	This project will be mostly a logistical problem. There is a possibility of a mechanical component being added to the project. But as of now it is entirely logistical.	A system that does not involve mechanical components or moving parts.



<p>What is the current system Danfoss has in place for aftermarket production?</p>	<p>Danfoss is currently using an MRP supplied by SAP as well as Cool inspector. Cataloging is done mainly by experienced material handlers.</p>	<p>A system that an inexperienced material handler is capable of operating</p>
<p>Is there a specific kind of program you would like us to use in order to do the record keeping?</p>	<p>Danfoss uses Creo, Matlab, SAP, and Cool Inspector, but are open to all programs and solutions.</p>	<p>Danfoss is open to all possible solutions</p>
<p>How in depth are we going to need to understand which parts need to be replaced for a given aftermarket compressor?</p>	<p>Ordinarily, supervisors make those decisions, so I don't believe you will need to make those decisions yourself. We simply need a more formal method of making those decisions based on cataloged data .</p>	<p>An organized solution that reflects all the decision making of the supervisors.</p>
<p>If a part breaks, do we need to come up with a solution to which parts need to be fixed or will that information be given to us?</p>	<p>That information will be provided. Getting access to these reports shouldn't be an issue. Reports are recorded in a system called CoolingInspector. Your system will make decisions based on the information we supply.</p>	<p>Able to identify replacements based on prior data from material handlers.</p>



<p>Does our solution need to be robust enough to include any possible compressor model from any possible year?</p>	<p>Ideally, at some point Danfoss wishes to include all potential models from any potential year. However, it is likely that this is outside the scope of what can be accomplished within the timeframe allotted for the project.</p>	<p>Danfoss needs a system that can be replicated for any possible compressor model.</p>
<p>Is it possible for us to limit the scope of the project to a single compressor model until we arrive at a solution which meets the project goals.</p>	<p>Do work on the MiniTT compressor as we have the most cataloged data for this model. If the project is fully operational with the MiniTT compressor then it should be easy to replicate for other models of compressors.</p>	<p>The scope can be limited to the MiniTT compressor</p>
<p>What improvements would you make to the technology you use currently?</p>	<p>I want any Joe Schmoe off the street to be able to look at this process and be able to follow it to the T.</p>	<p>Easily understood by people with no formal knowledge of manufacturing engineering.</p>



<p>Do all compressors need to be upgraded or can the compressor efficiency remain the same?</p>	<p>The goal is to have the same level of performance. The two goals are to give a list of mandatory replacements in the form of a bill of materials, and the replaced parts need to be functional so as to fix the issues within the compressor. It is always favorable if the efficiency is greater.</p>	<p>Outputs parts that maintain the same level of performance or higher for the compressor.</p>
<p>Are there known parts that frequently break or does this solution need to be general enough to encapsulate all the part failures within a compressor?</p>	<p>It needs to be able to handle all possible part failures and list the failed parts in a formal bill of materials.</p>	<p>Solution is general enough to include all possible part failures.</p>
<p>Is there a specific format needed to be given to the material handlers?</p>	<p>No, SAP is an enterprise resource system used by the material handling department for MRP, but it is not imperative that the solution outputs to SAP's specific format.</p>	<p>An output naming convention that is understood by the material handlers.</p>



<p>Are there well known solutions to this problem used in industry that you propose we use to solve the problem at hand?</p>	<p>There is no one specific way to solve the problem at hand, however solutions in the past have included scripts, MRP software, and catalogs to organize the data.</p>	<p>Software, scripts and catalogs may be used.</p>
<p>Would you like to have a system that is easily updatable?</p>	<p>Yes it would be beneficial for employees at Danfoss to input new data that comes from aftermarket testing.</p>	<p>Updates with ease and complies with future products.</p>

Analysis

Based on the meeting with Mr. Seymore, we've concluded that the solution that Danfoss is looking for is a "compendium system that is far more automated and robust" The current process has the material handlers and technicians making decisions based on experience. Danfoss would rather have a system in place that expedites the decision making process and does not rely on the potential human error of material handlers.



In addition to being accurate and faster, our system will also be compatible and easily integrated with their preexisting aftermarket compressor repair process shown below.



Figure 1: Compressor Aftermarket Process Flow Chart

The interpreted need for Danfoss is a system that can transition the analysis and investigation phase (red blocks), to the portion of the process responsible for repair (grey blocks). The current blue blocks (logistics) are what our system will replace. For this to happen our design will need to be compatible with the data collected in the analysis phase. Being compatible with the analysis phase includes, having a naming convention that can be understood by the material handlers.

As well as being compatible, our design will be updatable and replicable for any compressor model. Compressor models and versions are always updating, so our design will also need change accordingly.

Being that Danfoss has many versions and types of compressors, there was discussion during the meeting to limit the scope of the project to just the MiniTT compressor model. This compressor has the most cataloged data out of all compressors. Completing the project with this model first will make translating to other compressors models easier.



Conclusion

In conclusion, the meeting with Stephen Seymore highlighted the demands that our design needs to meet. He pointed out that the aftermarket process has current issues that our design should counter. Now that we have the interpreted and customer needs we can proceed to look at the functionality of our design.

1.3 Functional Decomposition

Functional Decomposition is used to break a complex system down into simpler parts. This engineering design method was used to break down the logistical system into four primary functions: retrieve, process, store, and output. From this, a cross reference table and hierarchical flow chart were made to depict the functions themselves and their sub-functions. The components of our system were then discussed in more detail and justified.



Discussion

System				
Function	Retrieve	Process	Store	Output
Collect data from compressor failure reports	+			
Collect a list of mandatory replacements	+			
Collect list of obsolete parts	+			
Determine relevant vs negligible parts to include in this analysis		+		
Determine how failed and obsolete parts are replaced	+	+		
Determine what conforming parts need to be replaced	+	+		
Determine what additional parts need replacing due to obsolete part changes		+		
Determine the age of the compressor and each individual part	+			
Record the experience and expertise of the engineers into the solution	+	+	+	+
Create a database to catalog the chronology of compressor repair		+	+	+
Adapt for future products	+	+	+	+
Memoize data		+	+	
Display Bill of Materials			+	+
Display list of recommended replacements based on historical data		+		+
Output all of the data to an executive summary		+	+	+
Organize and streamline the process such that it is replicable	+	+	+	+
Track part and serial numbers throughout each manufacturing stage	+	+	+	+

Figure 1: Functional Decomposition Cross Reference Table

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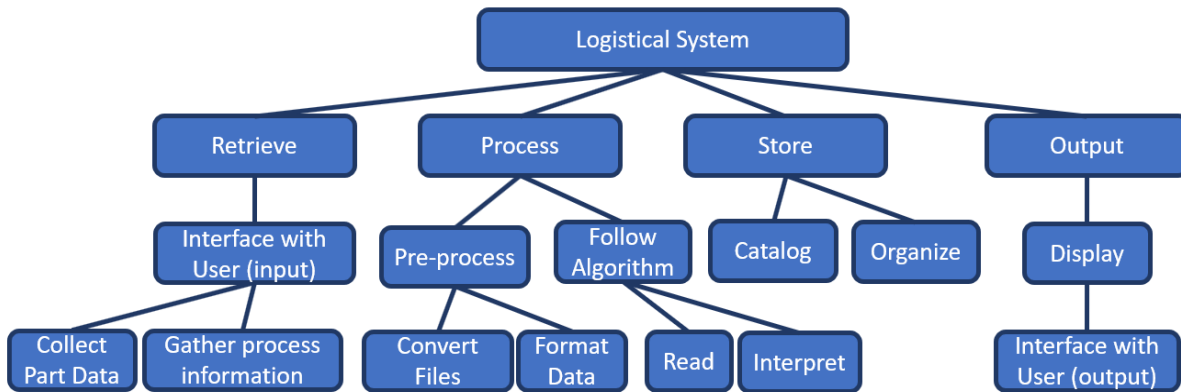


Figure 2: Functional Decomposition Flow Cart

From the information gathered in the customer needs, we concluded that the main four functions of the system are to retrieve, process, store and output the data coming in from failure analysis of the compressor. These four main functions will allow Danfoss to catalogue these parts. Further breakdown and analysis of tasks lead to the cross-reference table shown in Figure 1.

The first main function is retrieving the data. This function is responsible for all the inputs of our system and will be at the highest priority in the ranks of our system. The list of mandatory inputs for the system include mandatory replacement parts for the compressor, a list of obsolete parts, and the failure report data. All this information is necessary before entering the processing function of our system.

The processing portion of our system will be responsible for decision making. Ultimately, our system needs to be able to reflect the decisions made by the Danfoss supervisors. The supervisors want our system to be able to determine parts that have passed inspection, failed, and/or are obsolete. Since the system is iterative, there needs to be a storing function within the system.



Storage of data is required in the retrieval stage all the way down to the output of our system. The storing function is responsible for storing data to a database with all the information needed to catalogue these compressors. This includes, but is not limited to, serial numbers, age of the compressors, and other relevant information desired by the user.

The last main function that our system must execute is outputting the processed data. This data will be brought to technicians so that they have the information needed to repair the compressors. Therefore, the data should be user friendly and easy to use.

With all functions defined we analyzed how each function relates to one another. While the main functions start with retrieval and end with output, they step into one another with the defined minor functions. A good example is how in Figure 1 the minor function where the system is to record the expertise of the engineer is active throughout each major function. Moreover, the system provided is to be updated constantly. This results in the adaptation function, which also runs within each major function. While most minor functions can be traced down to more than one major function. Some of the minor functions can only be achieved while one major function is active. For example, all the collection of data from existing parts are to be retrieved in the first step as per the user's input request.

Justification

When coming up with the functions for the project we revisited our key goals and the customer needs to define what the system has to do. The main functions were defined as retrieve, process, store, and output. The major functions were then split into minor functions. Figure 2 illustrates how these functions were broken down into sections starting with the system as whole. The



system was labeled "Logistical System", as its goal is to automate and streamline the aftermarket compressor repair process, taking the input from the users and giving them the desired output.

These four functions were chosen because they represent the needs of the customer in the most precise way. The system will retrieve the relevant failure data, process this data to determine what parts should be fixed, store this data in a local database, and output this data to the user. The system is designed to output data in a way that is easy to recognize for the user. The system also allows for a very seamless user interface whereby the user can input the relevant information in order to get the desired output. Since the system is designed to reflect the experience and expertise of the engineers, it delivers on storing and outputting this data in an organized way. Danfoss's primary problem with their current system was data management and lack of organization. This system would help to organize and catalog all relevant information related to the aftermarket repair process. This information can be retrieved and called upon at a later date in an automated way to significantly reduce the time required by the production planners. In order to satisfy the need of the system being able to adapt to future updates, the system is made with a user manual explaining all of the details of the operation of the system. The system is also made in a way that allows for changes to the input files and covers a wide range of potential part failures. This ensures that the system is functional and easily updatable as technology progresses and more failure data is added to the database. The functions take care of solving the intricate problem of keeping track of multiple part failures. It also determines what to replace each of those parts with while maintaining simplicity in the way it interfaces with the user. It is general enough to include all of the potential part failures, but limited in scope enough



to know which parts are relevant to the compressor repair program. It is able to track the changes throughout the chronology of the compressor repair process and catalogs this information systematically. By performing these tasks, the system satisfies all of the customer needs.

Conclusion

Functional decomposition serves as a method to break down a complex system into smaller simpler parts. For this project we were able to break down the functionality into four main functions. The function in question became retrieve, process, store, and output. Based on the project's description, goal, and customer needs the four functions were then subdivided into the simplest task the logistical system is to achieve. With the functions defined, Figure 1 and 2 were created to better illustrate and represent what the logistical system has to do. To be clear, none of the defined functions specify a solution or a component. The functions are all tasks for the logistical system. Discussion of data serves as an explanation of each main and minor function, having Figure 2 represent a simplified connection of all functions to the main system. Figure 1 goes a step further by showing how minor functions associate with more than one major function. Justification of data references as to how the functions were defined and overall serve the goal of the project.

1.4 Target Summary

Targets Metrics and Functions

Now that the fundamental functions of our system have been broken down, metrics can be used to validate and quantify the functions specified. For example, the function of software



will usually be given metrics like speed, storage, and accuracy. To accompany these metrics, targets are used to give specific values to the metrics. Looking at Figure 1 below, the functions of the system have been broken down. With this information we are to relate each function with a target and a metric.

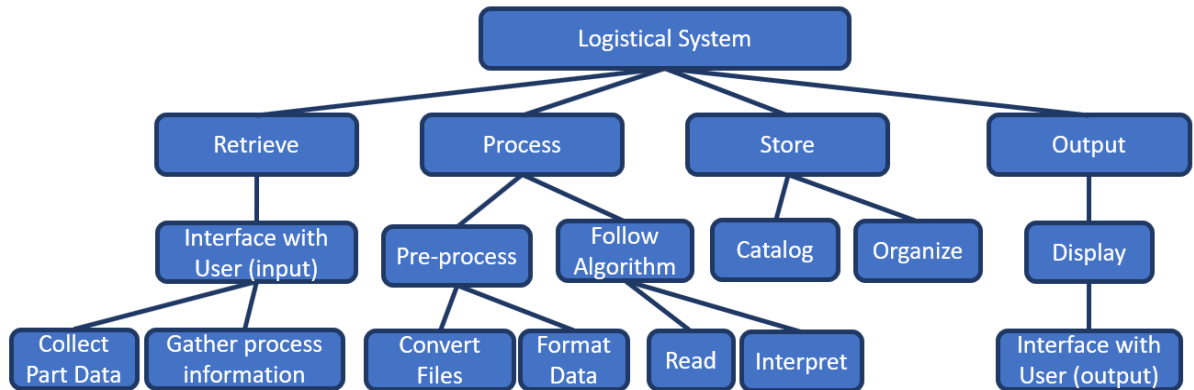


Figure 1: Functional Decomposition Flow Chart

Derivation and Validation of Targets and Metrics:

Functions and subfunctions were broken up into targets and metrics in order to assess how each of the functions will be validated.

Retrieve:

The first function, retrieve, was broken up into 4 sub functions: collect part data, interface with the user, gather part information, and gather process information. In order to properly collect part data, the metric of storage capacity was assigned. The target is to achieve a total file input size of $0 < x < 10\text{MB}$, where x is the size of the input file(s). This metric ensures two things. First, if the file is non-zero, that ensures that there is some part data that has been obtained. Second, this ensures that the operating system used by Danfoss is able to handle the file size. A target of 10MB ensures that the computational speed will not be too long and



prevents the system from crashing due to overflow. This target was derived by taking the largest file we may be expected to work with (2MB) and multiplying that by a safety factor of 5. This gives us 5 times the assurance that our solution will be able to run effectively and be able to handle unconventionally large file sizes if needed.

Next, is the sub function “interface with user.” This function was broken down into two metrics: ease of use, and aesthetic appeal. Ease of use will be measured by the number of clicks required upon opening the system on the user's operating system. This was derived with a view to reducing the amount of effort required by the user. The second metric, “aesthetic appeal” is measured using a customer satisfaction survey (see Appendix D). This survey will have a 1-5 scale where 5 represents an excellent user interface and 1 represents a poor one. The customer survey will also include a survey with comments to give Team 504 feedback on what can be improved for future versions. This metric was written with a view to achieving a 5 on the customer satisfaction survey with positive feedback in the comments. This target was derived to gauge whether the customer needs have been satisfied to their standard.

The final sub functions include gathering information in the form of part data and process data. Both of these functions can be validated using the same metric by employing a kind of ratio, that is the ratio of information obtained to the ratio of information needed. The information obtained can be found by using a simple count function in excel. The information needed will be obtained by coordinating with Danfoss to ensure the correct amount of information needed is represented in the system. This also can be found using the count function in excel to ensure no human error in counting. This target associated with this metric is 1 as ideally the system should have all the information it needs to make decisions on part



data. However, in the world of manufacturing, all of this data is not always readily available and is dependent on the information given to the planners from testing. A separate process will need to be implemented in order to ensure that this information is obtained correctly and will be validated by a separate metric discussed later in the document. This metric was designed with a view to quantifying how much data the system has at its disposal to make accurate decisions. However, the system should still function even if the ratio is not equal to 1.

Process:

The second function process was broken down into 6 subfunctions: convert files, format data, follow the algorithm, interpret, read, and organize code. In order to accomplish the global function of processing, the system needs to be able to process at a certain speed. This was broken down into two targets. Based on research of optimum processing speed for typical software and program files, the target of 3.0 GHz was assigned. Coupled with the processing speed target is the amount of time the system actually takes in order to run the script. Knowing these two pieces of information will provide information on how long the system takes to run on different CPUs with different processor performance specifications. The system processing time target was assigned a value of 2 min. This was designed in an effort to increase the ease of use so the customer would not need to wait for a long time to get the information they need to continue. A conservative value of 2 min was chosen to account for the possibility of large file sizes.

The first subfunction, convert files, was assigned the metric “file conversion accuracy.” This metric will be checked manually by a member of team 504 to ensure that the converted file



contains the same information and ordering system as the original file. This target is binary, either 1 or 0, where 1 represents success and 0 represents failure. Upon completion of this task for every possible input file given to the system, this metric would be considered satisfied as file conversion has been standardized and is considered a mature field in the software community.

The second sub function, format data, was assigned the metric “data format accuracy.” This metric will also be defined by a manual check using the same methodology as that of “file conversion accuracy” by checking to see if all the files and rows have been moved to their correct locations. This metric will also need to ensure that upon re-arrangement of the information, the data is still the same and representative of the file from which it came. Like file conversion accuracy this target will be binary, either a 1 or a 0 where 1 represents success and 0 represents failure. Upon completion of this task for every possible case the system may encounter this task will be considered complete. This is because once the file has been organized correctly once and has been checked for each possible case, the system will follow the same logic every time and there is no need to continuously check this. The assumption that we are making with this metric is that places from which we draw this data are static, not changing with time. If the file types, or file ordering scheme change, then the system will need to be reconfigured to account for these changes. This will be part of the process creation step of this project and this assumption has been confirmed to be within the liberty of what Team 504 is allowed to impose on the testing team.

The third and fourth subfunctions, follow algorithm and interpret, are both satisfied by the metric of part conversion efficiency. Part exchange efficiency is defined as the ratio of parts exchanged correctly to the total number of parts exchanged. The target will be set to 1 as ideally,



the system will be able to successfully exchange parts 100% of the time. This target is governed by the ratio of information obtained to the information needed from the previous section. This is due to the fact that if not all the information needed is present, the system will not be able to accurately predict all of the part replacements. This target (part exchange efficiency) was designed to account for the need of quantifying how good the system is at exchanging parts correctly. This target will be validated by comparing the bill of materials produced by the system with the final bill of materials produced at the end of the production phase of the manufacturing process. This information is contained in the catalogs given to us by Danfoss.

The fifth subfunction, read, is measured by the metric “reliability.” This metric is defined as the ratio of system failures to the number of system successes. This data will begin to be obtained from the moment the product is released to the customer indefinitely. This information will be stored internally and will be displayed upon request from the user. This metric will be assessed by using a simple count function within the processing function of the system. The system will count the number of times the system has been run and compare it to the number of times it has successfully run. A successful run is defined as a run with no error messages or bugs. The target for this metric is 93% success rate which will be discussed in more detail in the store section of the document.

The final subfunction, organization of code is represented by the metric code complexity. Code complexity will be defined by the customer satisfaction survey and will be measured on a 1-5 scale the same way as the aesthetic appeal is measured (see Appendix D). This metric was derived with a view to quantifying how readable, organized, and reproducible the systems code is. This satisfies the customer's need for adaptability.



Store:

The third main function “store” has two subsections: catalog and organize. In order for our system to operate our system needs a way to store the data. With the function store, the metric used to measure this function is storage capacity. The target associated with this is $0 < x < 10\text{MB}$. Since this is the size of the input file given to our system, the system should also be capable of storing this amount of data. Per information given to us from Danfoss, it is known that their computing resources are not limited and there is not a realistic ceiling for how much data storage will be available to the system. However, this metric was established with a view to processing speed and reliability. This target was derived the same way that “storage capacity” was defined and can be considered to be cross-functional with collect part data.

The sub function “catalog” needs to be able to store these files in the correct location. The metric that validates this function is reliability and is measured by the target of a 93% average success rate. This average success rate was measured by benchmarking an Apple iPhone7 which has the same average success rate of 93%. This is also dependent on the accuracy of the algorithms in the system. The iPhone 7 is considered to be a good standard. This reliability measurement can be considered to be the same as the reliability metric in the process section of the document. In other words, the sub function “read” can be considered cross-functional with “store.”

Output:



The final main function output was broken into two primary subfunctions: display and interface with user. Both of these subfunctions are satisfied by targets previously specified in the document. Display is satisfied by the customer satisfaction survey corresponding to the metric of aesthetic appeal. To ensure that the information is displayed accurately, all of the previous metrics will be outputted to the system display. Since the accuracy of the display is contingent on the accuracy of the underlying metrics, this metric is already quantified by the underlying metrics and can be considered obsolete. Also this metric can be implicitly defined by the system reliability. The system reliability can be considered to be cross functional with the read, catalog, and display functions. The interface with user function can be defined by the previously stated metric “number of clicks.” This is to say that the input and output of the system can be considered cross-functional: one and the same in terms of metrics.

Discussion of Measurements:

In order to verify the systems' metrics and validate the targets, a mix of data and resources will be used as tools to serve as indicators. For measuring storage capacity, processing speed, file conversion, and file location accuracy a Danfoss operating computer or a computer that matches the system's specs will be the primary tool to validate such metrics, while task manager, MATLAB, and data centers will be the main sources to check if the targets match their respective metric. Other metrics such as data format accuracy, part conversion efficiency, and reliability will also be measured within a computer but will be rated to match their target by the program Danfoss computers have for the inspection, planner, and material handler teams. Finally, metrics that deal with ease of use, aesthetic appeal, ratio of obtain to needed information,



code complexity, and organization difference will be measured based on feedback of Danfoss' planning team, making surveys as the main tool to measure such metrics.

Critical Targets and Metrics:

All the metrics in our system can be boiled down to storage, accuracy, and speed. However, the critical metrics in our system will be storage and reliability. Being that our solution will involve software, storage and reliability are imperative so that the system can work. If the data files are too big to enter the system, it will fail at that instant. If the algorithm we run has bugs, then the systems will stop running. The assumption is that the data going into the system will be around a 2 MB, so the target was made 10MB. This was done with a factor of safety of 5 to ensure that our system will be able to compute that amount of data. The target of the reliability metric is going to be 7% percent. This target was generated as a benchmark from Apple's iPhone 7 which had a failure rate of %7. (cite). The iPhone 7 is a good standard for a system to follow.

Summary and Catalog:

After defining the functions, the logistical system was broadened to include an understanding of what it is the system has to do. The targets and metrics defined how these functions are to perform these tasks and outlined a path to completing them successfully. Metrics were assigned to each function and each metric was assigned a given target. Our main functions retrieve, process, store, and output were synthesized into three critical metrics: storage, reliability, and speed. The targets associated with these metrics are $0 < x < 10\text{MB}$, the ratio of system successes to system failures 93%, and 2 min respectively.



1.5 Concept Generation

Concept Generation Tools

Concept generation and selection are easily the most important steps in the design process as decisions that are made in this step affect the rest of the project. Coming up with 100 concepts is no easy task so a few different methods were employed to assist in this task. These methods are biomimicry, crap shoot, and morphological chart.

Biomimicry involves taking inspiration from nature to come up with design ideas. Crap shoot is making up a design that may seem entirely improbable but could possibly yield valuable insights into the design at hand. An example of this was the design named robotic planner. This doesn't seem feasible because building a robot whose soul task it is to plan compressor rebuilds for Danfoss seems ridiculous. However, it satisfies multiple customer needs: organization, automation, and adaptability. The robotic planner helps visualize what an automated solution may look like on its ability to satisfy the customer needs.

A morphological chart can be used to generate multiple designs by using the power of combinations. An example can be seen in Figure 1 below.

Morphological Chart			
Coding Language	Python	MATLAB	C
Quality Control Method	Pareto Analysis	Stratification	Statistical Sampling



Inventory Control Method	Six Sigma	Drop shipping	Lean Manufacturing
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This chart can produce 27 different concepts by finding every possibility of coding language, quality control method, and inventory control method. An example of one concept may be Python – Pareto Analysis – Six Sigma. Another may be MATLAB – Statistical Sampling – Six Sigma. This method helps to generate multiple concepts helping create a larger pool of ideas to decide between.

Selected Concepts

The following eight concepts were chosen from over 100 generated concepts. These eight differ in design but seemed like the most probable out of the designs generated. For all of these concepts it was decided that neither coding language preference, quality control method, nor inventory control method should be an axis of scrutiny. This was decided because these adaptations could be form fitted to any of the designs in theory. Rather than studying what makes the designs similar, variant characteristics were chosen as the focus in these design choices. Using a better coding language or control method could give one design an unfair advantage. Eliminating this as a focus point helps reduce bias.

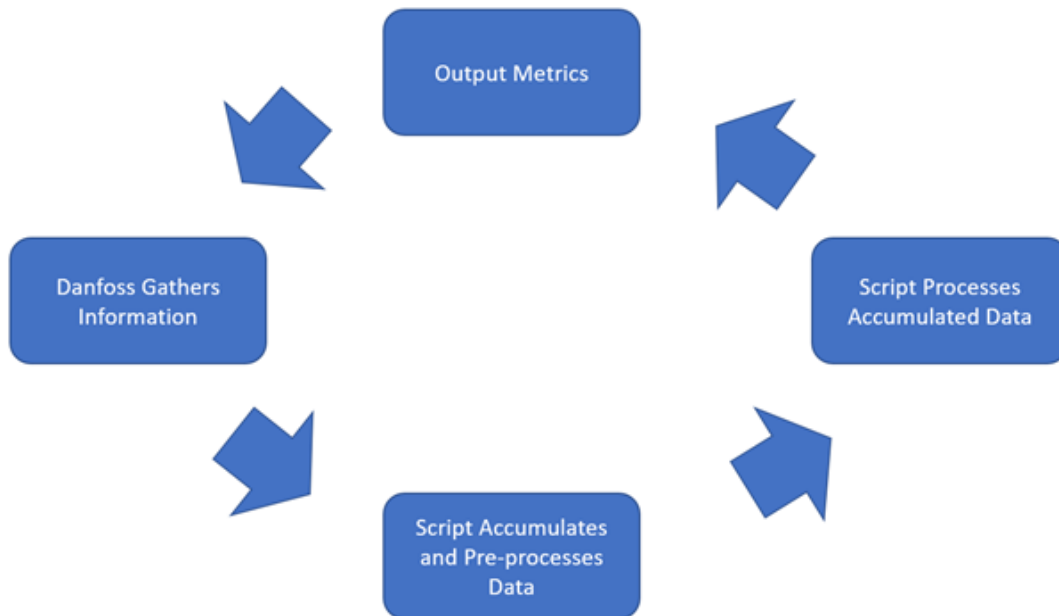


High Fidelity

Concept 1.

Script and Database Design

The main idea of this design is to design a script that can draw from a database of information already gathered by Danfoss to make decisions about how to replace parts. The database would be created by the script drawing from files directories Danfoss currently uses to store information. The script would preprocess multiple files and accumulate the data into one master excel file for a given aftermarket compressor repair. The script would then use all of the information in this file to make decisions about what replacements are needed for a given compressor model. As the script runs it will also gather statistical data about how often certain parts fail compared to previous cases for quality assurance purposes. It will also create a metric for quantifying how accurate it is at making part change decisions.





This process is iterative as once Danfoss has all the information they need to plan the compressor build; they will use these outputs to replace these parts on the manufacturing line. If these parts have been chosen correctly then this process gets repeated for the next compressor. However, if this information is chosen incorrectly the script will be given the data that is collected from the failed part replacement to recalibrate its selection algorithm. This is done until, by the script's internal metrics, it is 100% accurate for a given aftermarket compressor model. It will generate report logs that will be stored for Danfoss's quality department.

Concept 2.

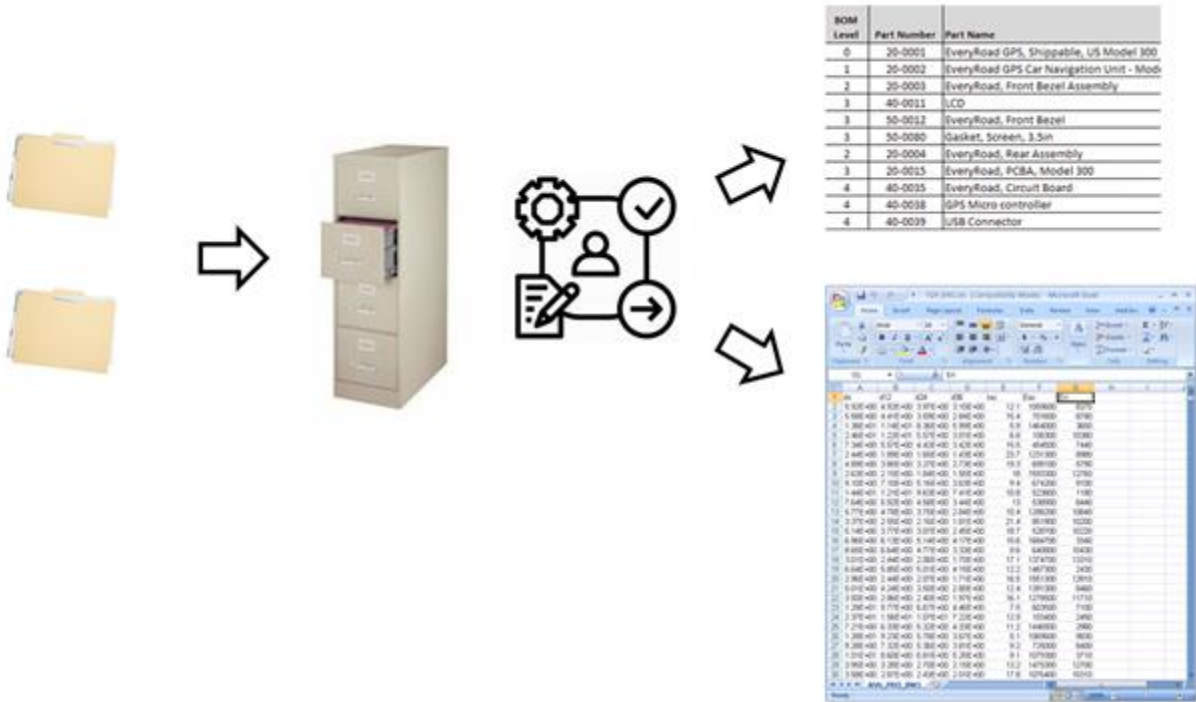
Filing System

The idea behind this design is to create a more organized workflow for Danfoss's employees by centralizing a filing system. This filing system would contain all the files necessary for the planners to decide what parts to replace. In this new workflow, the investigation team would be required to gather specific information about failing parts, documenting these details in folders. It would then be the job of the planner to compile all this data into one master file. From this file they will make decisions about which parts to replace. The planner will also be required to document the part changes that were made once the compressor is repaired successfully. This itemized part list will be an excel file containing the protocol for how to replace any given part from any given year. After all the parts have been cataloged, this will no longer be the planner's job as the file has now been generated with the procedure for how to replace any part given its part number.

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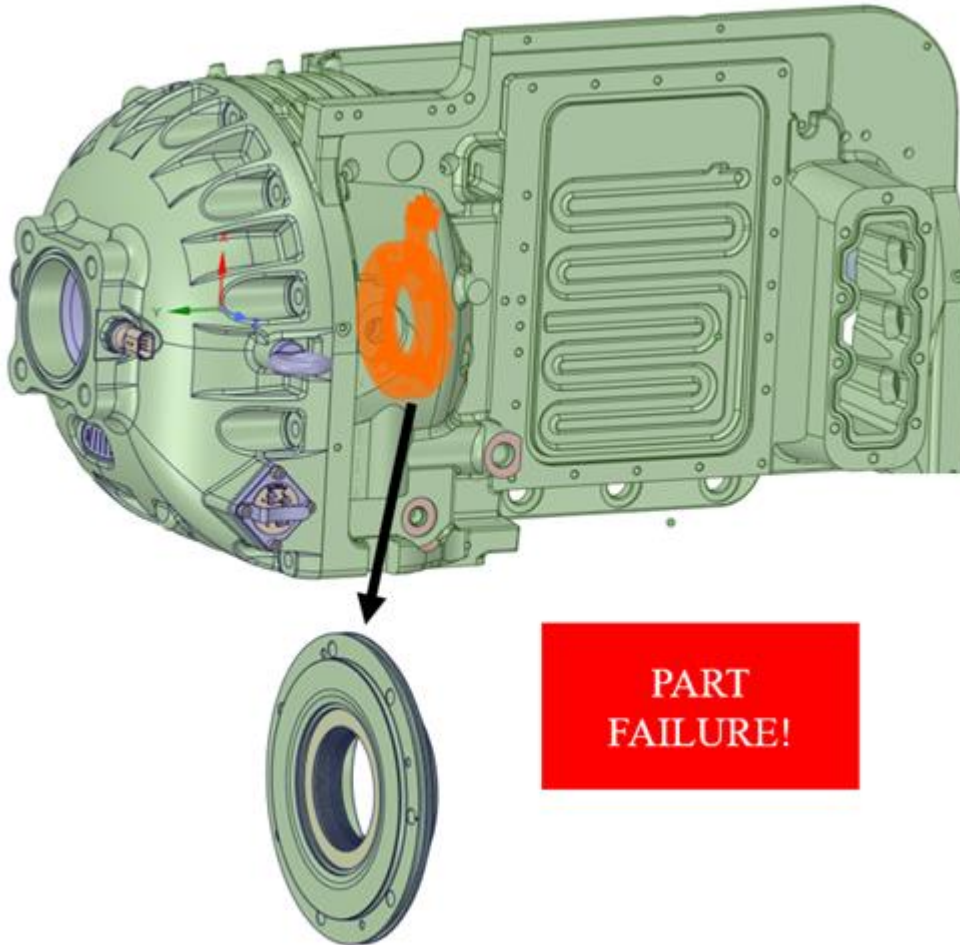


Concept 3.

Part Failure Graphic User Interface

This concept came out of trying to maximize user experience and usability of the system. This system would have a full CAD model of the compressor as a visual display of part failure. It would highlight all the parts that have failed giving the planner a visual display of what parts need to be replaced. The program will have access to all the CAD models of compressors as well as a list of parts that are still used in circulation on the manufacturing line. Once it knows a particular part has failed, it will cross check that part with other compressor models to see if that part can be replaced with a future model. It will also ensure that the new part will fit the geometry of the old compressor, mating with the other parts with no overlap. If it satisfies these

criteria it will add that part to the bill of materials. This gives the planner assurance beforehand that the part will not fail on the line when it goes to assembly.



Medium Fidelity

Concept 4.

Six Sigma

Six Sigma is a method that gives organizations such as Danfoss tools to improve the capability of business processes. Implementing this process often leads to an increase in performance and decrease in process variation. This can yield reductions in defects and improvements in



employee morale, profits, and quality. This method relies primarily on using quality management methods such as empirical and statistical methods. Experts of these methods are placed on projects and specific targets are set to improve the overall process at hand. For example, in the case of Danfoss, part replacement quality is the metric of interest. These experts work with Danfoss's team to improve their workforce making them more efficient at their job. The goal of this concept would be to research these methods and provide an updated procedure as to how the current process should be run to improve the process performance. This may result in the emergence of new roles or responsibilities of Danfoss employees to carry out the aftermarket repair process more efficiently.





Concept 5.

Virtual Compressor Logs

This concept involves creating a virtual workspace and user environment where employees from different departments can interact during the investigation and repair process to streamline information gathering. This platform will allow the planners to post what information they need in modules that the investigations team can fill out. The platform will act like a live script, updating real time to give the teams all the information they need in one place accessible to all. The investigation will not be considered complete until all the action items in the information gathering stage have been completed by the investigations team. This will help enforce better record keeping during the investigation phase as well as help the investigations team know what information the planners need to make their decisions. A report will only be submitted by manager approval of all the action items listed within the modules keeping both departments accountable. This is both a management solution as well as a technological solution.





Concept 6

Artificial Intelligence (AI)

The purpose of this concept is to use the capabilities of AI to gather and store relevant data that normally may be hard to retrieve. This is especially useful in the aftermarket compressor repair process as there is information needed that is not easily accessible in Danfoss's file directories. An example of this is written reports provided by the investigation team. These written reports could be read using AI algorithms and the information is synthesized and stored. This information could then be called upon by a script to exchange parts within the compressor. After a database is accumulated this data could then be fed into the AI algorithm. This will help to train the AI, helping it to make future predictions. Once it has seen thousands of compressor repairs, it will get more accurate about making future part replacements. By storing all the information regarding its failures as well as its successes, it will know how to improve its own performance.



Concept 7

Material Resource Planning System (MRP)

The idea behind this system is to assist in production planning, inventory control, and manufacturing process management. MRP ensures that parts are available for production. It also assists in maintaining the lowest possible material and product levels in the facility. It is especially useful when planning manufacturing processes. Since Danfoss already uses this software there would be no transition to a different technology. The tools within this software could be utilized to gather information needed to make decisions about part replacements. MRP's internal database could be called upon to get real time metrics into which parts are available, and which part needs to be replaced. Creating a process within this resource

would provide Danfoss with a solution that will not cost a significant amount in upgrades or other technologies. It will also save time since the information will be stored internally in the MRP database requiring no transfer of data from outside files into MRP. The combination of real time inventory control, material planning tools, and reporting software make MRP a valuable resource and potential solution for Danfoss's aftermarket repair process.

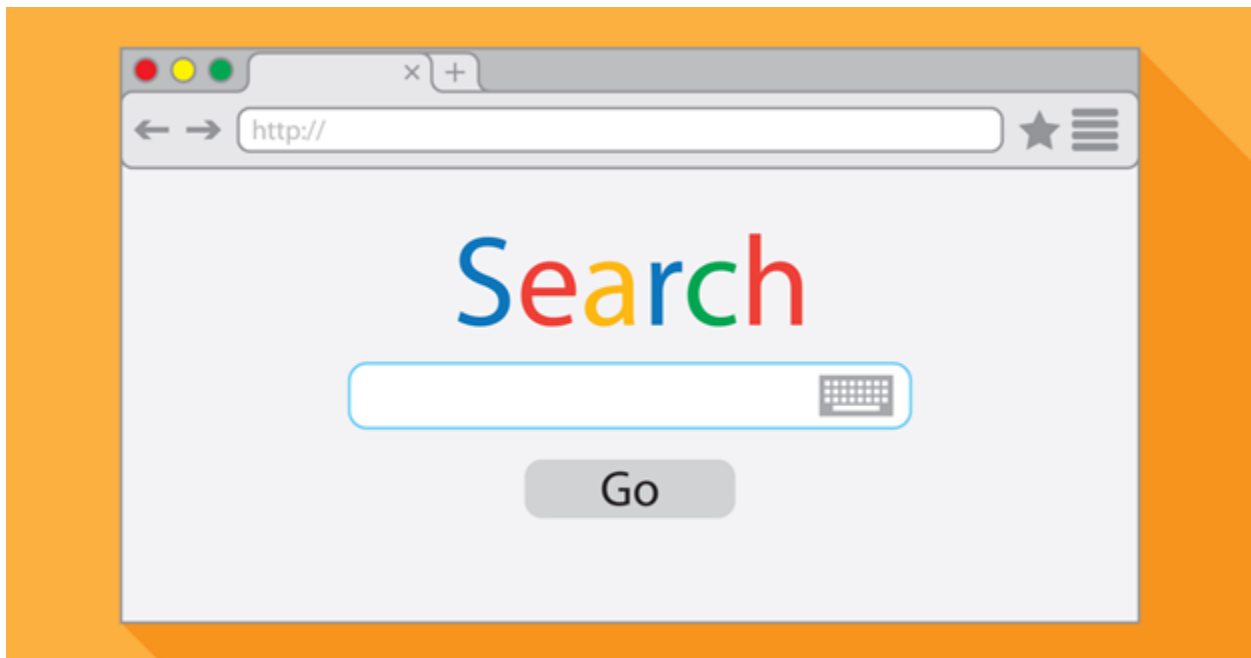




Concept 8

Digital Part library

The digital part library is a system designed to be like a search engine. The user will have a search bar at the top of the program and can search any part from any compressor model. The library will then take the user to a webpage where all the information about that part as well as its known replacements will be stored. As new discoveries are made about which part replacements work for which compressor, that information will be updated by Danfoss's staff with easy to use features. After searching a certain part number, alternative search bars will be available within that to refine the search further such as is the display features in craigslist or google shopping. This database will help Danfoss to make informed decisions about how to replace a given part. It also helps reduce the workload on the other teams to explain to the planners what parts need to be replaced for a given compressor.





1.6 Concept Selection

House of Quality

With the information about our customer requirements (CR) we can begin to translate the customer requirements into quantifiable design variables or engineering characteristics (EC). This requires the use of Quality Function Deployment (QFD) tools to “infuse the voice of the customer into the design process”.

The first step in figuring out the importance of each customer requirement is the Binary Pairwise graph below.

Binary Pairwise Graph

	1	2	3	4	5	Total
1. Organization	-	1	1	1	1	4
2. Automate	0	-	1	1	1	3
3. Quality Control	0	0	-	1	1	2
4. User Experience	0	0	0	-	0	0
5. Adaptability	0	0	0	1	-	1
Total	0	1	2	4	3	10

This binary pairwise chart shows all the main customer requirements in the leftmost column and numbers one through five in the topmost row. This row represents the same customer requirements in the leftmost column. To fill in the rest of the data, the customer requirements on the top row are compared to the customer requirements in the leftmost



column. For example, the “organization”, customer requirement, is more valuable than making the system user friendly. To indicate this, a one is added to the “organize” row and the “automate” column, and a zero for its counterpart (row “automation” and column “organize”). The binary pairwise is essentially a comparison of customers’ requirements in matrix form.

Next, the collection of the binary data is tallied under both the total row and column. The customer requirements with the most tallies are ranked and now can be used in the House of Quality (HOQ) as “importance weight factors”.

The next important component of the House of Quality is the engineering characteristics. The engineering characteristics and the customer requirements are thrown in the HOQ as a relationship matrix with customer requirements as the row and engineering characteristics as the columns. The engineering characteristics we use to quantify the customer requirements are: speed, storage capacity, accuracy, usability, aesthetics, maintainability, simplicity, and reliability.

Speed is defined as the time it takes for our system to run and is quantified in seconds. Storage capacity is defined as the amount of space for data and is quantified with bytes. Accuracy is defined as the ratio of parts correctly replaced, over the total number of parts that need to be replaced. This will be quantified with a percentage and it will ideally be 100%. Usability of our system is defined as how easy it is for our customers to use. This is a psychological metric so it can’t be quantified, however, we can use quantifiable metrics like “number of clicks” to help quantify usability. Aesthetics is defined as how well it looks to the



customer and this is also a psychological measurement. Maintainability in our context is defined as the ease of which our system can make modifications and extend functionality. This also an EC that cannot be quantified. Simplicity is defined as how compacted our solution will be, or how many components are in our system. Finally, the reliability characteristic is how our system will perform. This is quantified with a failure rate with whether our system can run without bugs.

Based on the ECs above, the exponential range will be used to quantify how much the EC will contribute to satisfying the CR. This is done with the exponential range below.

Rank	Meaning
0	Not at all
1	Slightly
3	Moderately
9	Significantly

For example, speed (engineering characteristic) has no contribution to filling the customer requirement of “adaptable”. Therefore, the column “speed” and the row “adaptable” will receive a 0. If the EC and the CR are closely related they will receive a high number in the exponential range like 9.

EC and CR are related and can now be used as weighted importance factors. This was all done in excel and these are the findings: reliability, accuracy, and usability were respectively the top three EC. These high ranked EC that come out of the HOQ are now design parameters that



can be used to make decisions in the design process. The EC, speed, is the lowest ranked and can be considered not as critical to the success of the design.

House of Quality		Engineering Characteristics							
Improvement Direction		↑	↑	↑	↑	↑	↑	↑	↓
	Units	sec	byte	%	n/a	n/a	n/a	n/a	%
Customer Requirements	Importance Weight Factor	Speed	Storage Capacity	Accuracy	Usability	Aesthetic	Maintainability	Simplicity	Reliability
Organizes	5	1	3	9	1	1	3	1	9
Automate	4	1	0	1	9	0	9	1	3
Controls Quality	3	0	1	9	1	0	3	3	9
Interacts with User	2	0	1	1	9	9	0	3	1
Adaptable	1	0	3	1	9	1	9	3	3
Raw Score (391)		9	23	79	71	24	69	27	89
Relative Weight %		2.30%	5.88%	20.20%	18.16%	6.14%	17.65%	6.91%	22.76%
Rank Order		8	7	2	3	5	4	6	1

Pugh chart

Going into the selection process, a Pugh chart was made to compare the 8 concepts selected. Those concepts were labeled in numerical order and were compared to the current method used at Danfoss to access the aftermarket repair program, which involves word of mouth, an extensive yet incomplete bill of materials, and expertise from employees to identify and replace obsolete compressor parts.



Selection Criteria		Concepts							
		1	2	3	4	5	6	7	8
Speed	Datum (Current Method)	+	+	+	+	+	+	+	+
Storage Capacity		+	-	-	S	S	-	+	+
Accuracy		+	+	+	+	+	+	+	+
Usability		+	+	+	+	+	+	+	+
Aesthetic		+	+	+	S	+	+	+	+
Maintainability		+	+	+	+	+	+	+	+
Simplicity		+	-	-	+	+	+	+	+
Reliability		+	+	+	+	+	+	+	+
Pluses		8	6	6	6	7	7	8	8
Minuses		0	2	2	0	0	1	0	0

The Pugh chart above shows all the concepts generated and compares them to the engineering characteristics. Essentially, the Pugh chart is deciding which concepts match and satisfy the engineering characteristics. For example, the concepts 2 and 3, compared to the other concepts, underperformed with 2 minuses and 6 pluses. Due to their result, concepts 2 and 3 were eliminated. Concepts 1, 7, and 8 were the best concepts compared to the datum with all pluses and no minuses. Concepts 4 through 6 were in the middle of the results. Concept 5 was



chosen as the next datum to be compared to the rest of the concepts for its balance result and comparable design.

Selection Criteria		Concepts				
		1	4	6	7	8
Speed	Datum (Concept 5)	+	S	+	+	+
Storage Capacity		+	-	-	+	S
Accuracy		+	-	+	+	+
Usability		+	-	+	+	+
Aesthetic		+	-	+	+	+
Maintainability		+	-	+	+	+
Simplicity		+	-	+	+	+
Reliability		+	-	+	+	+
Pluses		8	0	7	8	7
Minuses		0	7	1	0	0

Looking at the second Pugh chart, concept 4 is eliminated with 7 minuses and zero pluses. Having both concept 1 and 7 with the same result while concepts 6 and 8 not too far apart, a third matrix was created with concept 7 as its datum for being the most balanced result.



Selection Criteria		Concepts		
		1	6	8
Speed	Datum (Concept 7)	S	+	-
Storage Capacity		S	-	S
Accuracy		+	+	S
Usability		-	+	S
Aesthetic		S	S	S
Maintainability		-	+	+
Simplicity		+	-	+
Reliability		+	+	S
Pluses		3	5	2
Minuses		1	2	1

Finally, the third Pugh chart compares concept 1, 6, and 8 against concept 7. Concept 6 resulted with the most pluses. Concepts 1 and 8 both had one minus and more pluses, having concept 7 eliminated. Therefore, the concepts that will be evaluated using the Analytical



Hierarchy Process (AHP) are Concepts 1, 6 and 8.

Analytical Hierarchy Process (AHP)

Normalized Criteria Comparison Matrix									
	Speed	Storage Capacity	Accuracy	Usability	Aesthetic	Maintainability	Compactness	Reliability	Criteria Weight (W)
Speed	0.179	0.216	0.192	0.321	0.125	0.234	0.25	0.227	0.218
Storage Capacity	0.06	0.072	0.192	0.036	0.075	0.141	0.083	0.136	0.099
Accuracy	0.036	0.014	0.038	0.036	0.075	0.016	0.028	0.045	0.036
Usability	0.06	0.216	0.115	0.107	0.125	0.141	0.083	0.136	0.123
Aesthetic	0.536	0.361	0.192	0.321	0.375	0.234	0.417	0.227	0.333
Maintainability	0.036	0.024	0.115	0.036	0.075	0.047	0.028	0.045	0.051
Compactness	0.06	0.072	0.115	0.107	0.075	0.141	0.083	0.136	0.099
Reliability	0.036	0.024	0.038	0.036	0.075	0.047	0.028	0.045	0.041
Sum	1	1	1	1	1	1	1	1	1

Consistency Check		
$\{W_s\} = [C]\{W\}$ Weighted Sum Factor	$\{W\}$ Criteria Weights	$Cons = \{W_s\} ./ \{W\}$ Consistency Vector
1.932	0.218	8.854
0.834	0.099	8.393
0.298	0.036	8.274
1.087	0.123	8.841
2.986	0.333	8.969
0.417	0.051	8.221
0.844	0.099	8.553
0.345	0.041	8.391



$$\lambda=8.562$$

$$CI= (\lambda-n)/(n-1) = (8.562-8)/(8-1)=.0803$$

$$CR= CI/RI=.0803/1.4=.0574$$

$$CR < 0.1$$

The first step in the Analytical Hierarchy Process is using a pairwise comparison. This pairwise comparison measures the importance of each engineering characteristic in each column to each row on a scale of 1,3, or 5. If the comparison value is a 1, then the characteristic in the column is equally as important as the characteristic in the row. If the value is a 3, then the column is slightly more important than the row. If the value is a 5, then the column is much more important than the row. The sum of each column is then used to normalize the matrix. To normalize the matrix, each element in a column is divided by the sum. The sum of each column in the normalized matrix is equivalent to 1. To get the criteria weight factors, each row in the normalized matrix is summed. The criteria weight factors were then multiplied by the original criteria comparison matrix to obtain the weighted sum factors. The consistency vector was found by dividing the weighted sum vectors by the criteria weights. To determine if the engineering characteristics were unbiased, the average of the consistency vectors was found to be 8.562. The steps shown above are used to determine the consistency ratio. The consistency ratio was found to be 0.0574, which is less than 0.1. This means the analytical hierarchy process for these engineering characteristics were unbiased and fairly assessed.



Speed Comparison Norm				
	Script and Database	A.I.	Digital Library	Design Alternative Priorities
Script and Database	0.091	0.130	0.048	0.090
A.I.	0.455	0.652	0.714	0.607
Digital Library	0.455	0.217	0.238	0.303
Sum	1	1	1	1

Consistency Check		
$\{W_s\} = [C]\{W\}$ Weighted Sum Factor	$\{W\}$ Criteria Weights	Cons= $\{WS\}./\{W\}$ Consistency Vector
0.272	0.090	3.031
1.965	0.607	3.238
0.954	0.303	3.145

$\lambda=3.138$

$CI = (\lambda - n) / (n - 1) = (8.562 - 3) / (3 - 1) = .069$

$CR = CI / RI = .0803 / 0.52 = 0.132$



Storage Capacity Comparison Norm				
	Script and Database	A.I.	Digital Library	Design Alternative Priorities
Script and Database	0.143	0.143	0.143	0.143
A.I.	0.714	0.714	0.714	0.714
Digital Library	0.143	0.143	0.143	0.143
Sum	1.000	1.000	1.000	1.000

Consistency Check		
{Ws}=[C]{W} Weighted Sum Factor	{W} Criteria Weights	Cons={WS}./{W} Consistency Vector
0.429	0.143	3
2.143	0.714	3
0.429	0.143	3

$$\lambda=3$$

$$CI = (\lambda - n) / (n - 1) = (3 - 3) / (3 - 1) = 0$$

$$CR = CI / RI = 0 / 0.52 = 0$$

Usability Comparison Norm				
	Script and Database	A.I.	Digital Library	Design Alternative Priorities
Script and Database	0.231	0.217	0.333	0.260
A.I.	0.692	0.652	0.556	0.633
Digital Library	0.077	0.130	0.111	0.106
Sum	1	1	1	1



Consistency Check		
$\{W_s\}=[C]\{W\}$ Weighted Sum Factor	$\{W\}$ Criteria Weights	Cons= $\{WS\}./\{W\}$ Consistency Vector
0.790	0.260	3.033
1.946	0.633	3.072
0.320	0.106	3.011

$\lambda=3.137$

$CI= (\lambda-n)/(n-1) = (3.137-3)/(3-1)=0.069$

$CR= CI/RI=0.069/0.52=0.132$

Accuracy Comparison Norm				
	Script and Database	A.I.	Digital Library	Design Alternative Priorities
Script and Database	0.143	0.2	0.077	0.140
A.I.	0.429	0.6	0.692	0.574
Digital Library	0.429	0.2	0.231	0.286
Sum	1	1	1	1

Consistency Check		
$\{W_s\}=[C]\{W\}$ Weighted Sum Factor	$\{W\}$ Criteria Weights	Cons= $\{WS\}./\{W\}$ Consistency Vector
0.427	0.140	3.049
1.853	0.574	3.230
0.897	0.286	3.133



$$\lambda=3.039$$

$$CI= (\lambda-n)/(n-1) = (3.039-3)/(3-1)=0.019$$

$$CR= CI/RI=0.019/0.52=0.037$$

Aesthetic Comparison Norm				
	Script and Database	A.I.	Digital Library	Design Alternative Priorities
Script and Database	0.2	0.2	0.2	0.2
A.I.	0.6	0.6	0.6	0.6
Digital Library	0.2	0.2	0.2	0.2
Sum	1	1	1	1

Consistency Check		
{Ws}=[C]{W} Weighted Sum Factor	{W} Criteria Weights	Cons={WS}./{W} Consistency Vector
0.6	0.2	3
1.8	0.6	3
0.6	0.2	3

$$\lambda=3$$

$$CI= (\lambda-n)/(n-1) = (3-3)/(3-1)=0$$

$$CR= CI/RI=0/0.52=0$$

Maintainability Comparison Norm				
	Script and Database	A.I.	Digital Library	Design Alternative Priorities



Scripts and Database	0.2	0.2	0.2	0.2
A.I.	0.6	0.6	0.6	0.6
Digital Library	0.2	0.2	0.2	0.2
Sum	1	1	1	1

Consistency Check		
$\{Ws\}=[C]\{W\}$ Weighted Sum Factor	$\{W\}$ Criteria Weights	$Cons=\{WS\}./\{W\}$ Consistency Vector
0.6	0.2	3
1.8	0.6	3
0.6	0.2	3

$$\lambda=3$$

$$CI = (\lambda - n) / (n - 1) = (3 - 3) / (3 - 1) = 0$$

$$CR = CI / RI = 0 / 0.52 = 0$$

Compactness Comparison Norm				
	Script and Database	A.I.	Digital Library	Design Alternative Priorities
Script and Database	0.231	0.429	0.2	0.286
A.I.	0.077	0.143	0.2	0.140
Digital Library	0.692	0.429	0.6	0.574
Sum	1	1	1	1



Consistency Check		
$\{W_s\}=[C]\{W\}$ Weighted Sum Factor	$\{W\}$ Criteria Weights	$Cons=\{WS\}./\{W\}$ Consistency Vector
0.897	0.286	3.133
0.427	0.140	3.049
1.853	0.574	3.230

$\lambda=3.137$

$CI = (\lambda - n)/(n - 1) = (3.137 - 3)/(3 - 1) = 0.069$

$CR = CI/RI = 0.069/0.52 = 0.132$

Reliability Comparison Norm				
	Script and Database	A.I.	Digital Library	Design Alternative Priorities
Script and Database	0.2	0.2	0.2	0.2
A.I.	0.6	0.6	0.6	0.6
Digital Library	0.2	0.2	0.2	0.2
Sum	1	1	1	1

Consistency Check		
$\{W_s\}=[C]\{W\}$ Weighted Sum Factor	$\{W\}$ Criteria Weights	$Cons=\{WS\}./\{W\}$ Consistency Vector
0.6	0.2	3
1.8	0.6	3
0.6	0.2	3



$$\lambda=3$$

$$CI = (\lambda - n) / (n - 1) = (3 - 3) / (3 - 1) = 0$$

$$CR = CI / RI = 0 / 0.52 = 0$$

Final Rating Matrix

Speed	Storage Capacity	Accuracy	Usability	Aesthetic	Maintainability	Compact
0.090	0.143	0.140	0.260	0.2	0.2	0.0
0.607	0.714	0.574	0.633	0.6	0.6	0.0
0.303	0.143	0.286	0.106	0.2	0.2	0.0

{W} Criteria Weights
0.218
0.099
0.036
0.123
0.333
0.051
0.099
0.041

Concept	Alternative Value
Script and Database	0.184
A.I.	0.571
Digital Library	0.245



The alternative value is used to determine which concept is superior. In the case of our AHP, the concept with the lowest alternative value will be the best fit concept. A final rating matrix was found by taking the design alternative priorities from each of the characteristic comparison matrices. To obtain the alternative values, the final rating matrix was multiplied by the criteria weights from the original normalized comparison matrix. Of the three final concepts that went through the analytical hierarchy process, the script and database concept was determined to be the best concept.

1.8 Spring Project Plan



Chapter Two: EML 4552C

2.1 Restated Project Definition and Scope

Project Scope

Danfoss expanded its business several years ago to include the refurbishment of its compressors. These compressors have been in field service for many years. Such a service requires diligent management of hardware throughout the process. There can be no integration of new compressors and refurbished parts. Therefore, a separate logistics and product flow had to be created that was distinct to those compressors coming back from the field. The system evolved into a series of subsystems. Each subsystem is functional on its own, however, it requires technician diligence to keep the records organized. Danfoss wishes to integrate the various subsystems and develop a system that is far more user friendly, automated, and robust. This integrated system is to generate a bill of materials for a given aftermarket compressor using records provided by Danfoss's aftermarket investigation team.

Project Description

The objective of this project is to design an integrated system that generates a bill of materials for a given aftermarket compressor using records provided by Danfoss's investigation and planning team

Key Goals



There are a few key goals surrounding the DTC Aftermarket Workflow and Process Creation and Implementation Project. The system is easy to use as it will be handled by technicians and operators who have little to no prior knowledge as to which parts need replacement in aftermarket compressors. The system is to organize a list of parts that need to be fixed for any given aftermarket compressor and print out a bill of materials for refurbishment. The display is aesthetically pleasing with a favorable graphic user interface. The system is capable of handling TT/TG compressors and accommodates for backwards compatibility. Danfoss will then be capable of duplicating the system for various models of compressors. The system accounts for human error by automating Danfoss's subsystems ensuring the right parts are replaced. The system also does not allow duplicate items or items to be listed on the report that do not need to be replaced. This system will be tested and validated using fictitious compressors. Once the process has been validated, it will be tested on the aftermarket production line. Danfoss hopes to implement this system by the end of spring in 2021.

Primary Market

The primary market for the project is aftermarket compressor manufacturers. More specifically, compressor manufacturers that have organization issues within their aftermarket production line.

Secondary Markets

Another potential market for the product is recalls in the auto-manufacturing industry. The product can assist in determining replacements for mandatory callbacks. The system could also be used in inventory management to automate the record keeping process



eliminating human error. The product could be used in supply chains and logistic firms by using existing data to culminate solutions decreasing the time it takes to make accurate decisions. Finally, the solution could be implemented in laboratories to increase organization of incoming data and assist with post-processing.

Assumptions

For this project, there are few necessary assumptions to be made. First, the product is functional on a PC platform. The technician can operate the digital interface. The product will be used at Danfoss in their aftermarket manufacturing facility. The operator will be inputting valid data. Another assumption is the compressors are not being redesigned. The results from the solution are based on the data provided by Danfoss. The system does not simulate or test the conditions of failure in the compressor, but gives feedback based on the compressor failure reports which have been provided by Danfoss's testing facility. Finally, the system excludes the processes which occur prior to testing and after production.

Stakeholders

Stakeholders are those who will use, benefit, are interested, or have a concern about this project. The primary users of the system will be operators and technicians at Danfoss Turbocor. The primary benefactors are the customers that receive the refurbished compressor from Danfoss.

Other users of this system comprise those listed in the secondary markets section mentioned above. They include but are not limited to companies that have compressors as one of their assets and plan on using Danfoss's aftermarket compressor repair services.



Businesses like Ryder and EY, logistics and supply chain companies, will benefit from the system. These are potential stakeholders in this product.

Our point of contact Stephen Seymore, the operations engineering director, as well as other members of Danfoss's upper management benefit from a faster aftermarket repair program and positive image produced by satisfied customers.

Our professor and advisor for this project is Dr. Shayne McConomy. Other interested faculty include Dr. Mohd Ali, the project's faculty advisor. Finally, the FAMU/FSU College of Engineering supports the project.

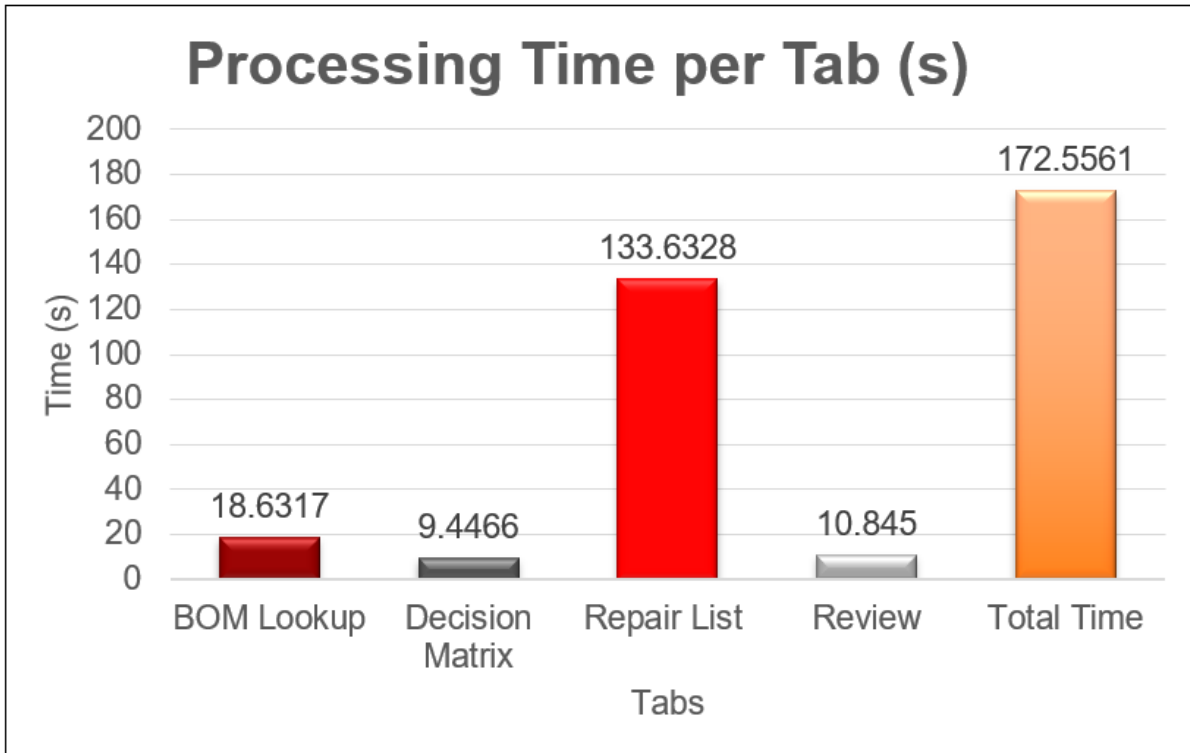
2.2 Results and Discussion

Our design for our project slightly altered over the course of the spring semester. The final result of our system was using the MATLAB App Designer. This was used to create an app that consolidates all the files and information needed to create a bill of materials for an aftermarket compressor. The critical targets we needed to validate consisted of time, processing time, number of clicks, and a customer satisfaction survey value. After completion of our app, we went through the process of creating a bill of materials for a repair order on a TT300 model compressor. From this test, we found the total time to run this process took 8 minutes and 13 seconds. This met our target of being faster than the current method. The current method took approximately 30 minutes to complete. Our system was just over 3x faster.

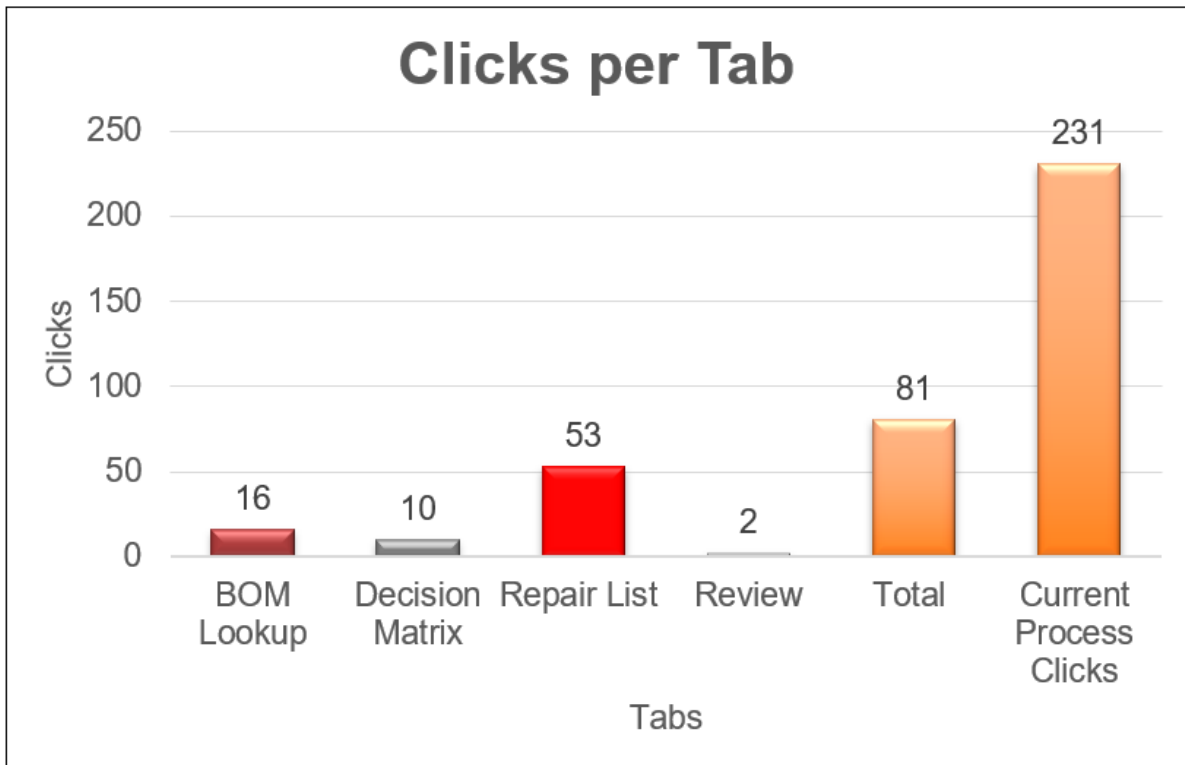
The total processing time was 2 minutes and 52 seconds. The bar chart below displays how long each section took to process. A majority of the total processing time came from the repair list tab. This accounted for inputting individual repair list items manually. The planner will have the option of uploading an excel file that contains the entire repair list. This will cut down



the processing time for this tab drastically. Anyhow, we still met our target of having the processing time be less than 3 minutes.



We used number of clicks as a method of validation to measure how many steps it takes to accomplish the process. Our goal was to have less clicks than the current process. This would signify that our process would have less error and be simpler to use. The total number of clicks it took to complete the process using the current method was 231 clicks. We reached our target since our system required only 81 clicks.



Most of the feedback we wanted to receive on our project consisted of qualitative measures. We decided to use a customer satisfaction survey that related to certain aspects of our project we felt were important in satisfying the customer needs. The survey addressed needs of usability, aesthetic appeal, organization, adaptability, comfortability, functionality, and overall satisfaction. The user rated the attribute on a scale of 1-5, with 5 representing that our system performed exceptionally in this feature. Our target was an average score of 4.1, meaning that our system would work as a beneficial replacement to the current method. We presented our product to Danfoss and asked the Danfoss personnel to complete the survey. The survey below shows the average score in each of the attributes. We achieved our target with having an overall average score of 4.3.



Quality	Scale (1-5)
Usability (did you find it easy to navigate?)	3.5
Aesthetic Appeal (did it look well put together?)	5
Organization (do you think this is more organized?)	4.5
Adaptability (do you think this could be adapted to more of Danfoss's needs?)	4.5
Comfortability (do you think a planner would be comfortable using this?)	3.5
Overall satisfaction (how did you like this method?)	4.5
Functionality (does it perform all the necessary functions?)	4.5
Average Score	4.3
Comments:	

2.3 Conclusions

The overall objective of this project was to design an integrated system that would generate a bill of materials for a Danfoss aftermarket compressor. We set out to automate and streamline the current process. We designed a MATLAB App that consolidates all the resources needed to complete the planning process. It then makes decisions for appropriate part replacements. We reached our critical targets of reducing the time it takes to complete the process, the number of clicks, and a satisfied customer survey. Our system successfully streamlined the process and can serve as an appropriate replacement to the current process. Danfoss was satisfied with our product.

2.4 Future Work

Following the presentation of our project to Danfoss personnel, our team still has some work to do. Danfoss was satisfied with the functionality of our system, however, there were



some specific details that the planner would like to have adjusted. We need to adjust the final bill of materials to display parts that were not used to have a quantity of zero. We also need to make formatting changes to the final BOM to notify the planner where the static BOM and the repair list differentiate. We also would like to create a detailed manual of how to operate the system and how the script functions. This will help Danfoss make changes to our app in the future.

2.5 References

- [1] Seymore, Stephen. (2020). Aftermarket Services Danfoss Turbocor[®] Compressors. [PowerPoint slides]. Retrieved from <https://3.basecamp.com/3939307/buckets/18515621/uploads/3119943154>
- [2] McConomy, Shayne. (2020). Aftermarket Workflow Project 2020. [Word document]. Retrieved from <https://3.basecamp.com/3939307/buckets/18515621/uploads/3078752695>
- [3] Bishop et al. (2020). SD T504 201106 Concept Generation and Selection. [Word document]. Retrieved from <https://famu-fsu-eng.instructure.com/courses/4476/assignments/18861/submissions/102840000000061346>
- [4] Seymore, Stephen. (2020). Special Compressor Process. Danfoss Turbocor[®]. [PDF file]. Retrieved from <https://3.basecamp.com/3939307/buckets/18515621/uploads/3119943196>



Appendices



Appendix A: Code of Conduct

Mission Statement

This senior design team seeks to provide clients with innovative, cost-effective, aftermarket workflow and process creation and implementation. Our concern for excellence will show in our design and your satisfaction.

Team Roles

The team's roles selected all reflect team members aspirations and current interest. Methods for delegating these positions were done as a group and were assessed using personality tests and personal experiences when working with each other.

System Engineer: David Bishop

Focuses on integrating the various subsystems into a working solution. Capable of designing and assembling prototypes.

System Engineer: Julian Villamil

Manages research of various subsystems. Tasked with keeping team on track with specific deadlines for Senior Design as well as Danfoss.

Design Engineer: Kyle Youmans

Focus is on MATLAB related programming as it relates to user interface creation, logic, and widgets within the system.

Design Engineer: Alex Wilson



Serves as the point of contact between the team and Danfoss. Responsible for translating Danfoss's proprietary information about aftermarket compressors into usable code.

Communication

Communication was one of the main points of interest in our team. Multiple group members felt that methods of communication and communicating effectively within the group is the biggest determinant of a successful project. The list below shows how time conflicts are indicated, states how scheduling will be done, and states the primary method of communication.

- A. Scheduling is done through outlook calendar and through basecamp. Class schedules, work schedules, and any time conflicts are synced on the calendar.
- B. Scheduling will be done over zoom meetings or group messages and everyone must come to terms with a date.
- C. Primary communication will happen through group messaging. This is a fast, casual way to communicate among group members.
- D. Communicating to the sponsors will be through email and members will be copied in all emails to the sponsors. All group members need to be in the same loop.
- E. Let group members know when you will be missing a meeting. Zoom videos will be recorded for members that miss sessions. Members who miss need to catch up and watch previous recordings of meetings.
- F. Attendance will be recorded.

Attendance Policy



The purpose of this policy is to set forth this design team's policy and procedures for handling member's absences and tardiness, to promote the efficient operation of the project, and minimize unscheduled absences. Punctual and regular attendance is considered to be essential to keep motivation high and to the satisfactory completion of the required assignments given to each member.

- A. Members are expected to report to each meeting as scheduled, on time and prepared to start working. Members also are expected to remain at the meeting for *[the entire time it was scheduled]*. Late arrival, early departure or other absences from set schedules are disruptive and must be avoided. Offenses labelled as disruptive will be met according to the Alex Wilson Clause.
- B. Absence will be denoted to those who fail to report to meetings, late arrival and early departure to those who did not attend for the entire scheduled meeting. Members who are noted absent, late arrival, and early departure will not be considered disruptive if they met any of the following conditions.
 - I. Members have a schedule conflict due to work, class, or a set up appointment either legal or medical and had inform any other team member 24 hours prior.
 - II. There is an emergency that needs immediate action. The Member needs to let another team member know before the scheduled meeting. If the member is unable to call, he must have someone make the call for them.
 - III. The member is sick or ill, he must let another team member know at least an hour prior to the scheduled meeting.



- C. Due to Covid-19 most meetings will be over zoom, however for face to face meetings team members need to follow social distancing rules.

Alex Wilson Clause

This clause is named after a group member and is proposed to hold all group members accountable and allows the group to have clear rules of engagement when confronting other members. This clause is effective in holding group members accountable and allowing open healthy communication.

- A. After the first offense, the group member will be given the benefit of the doubt, and the group will be warned about the violation.
- B. After the second offense, the group member will be confronted in the presence of the group.
- C. After the third offense, the group will notify McConomy in with hope to peacefully resolve the issue.

Dress Code

This section of the agreement relates to how we dress when meeting with advisors and sponsors. When meeting with sponsors and advisors, all team members should dress professionally in business casual attire. When presenting, team attire should be matching in color and style to reflect the team as a unit.

Vacation Days

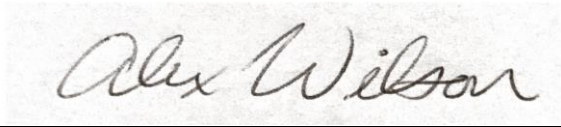
In order to keep proper workflow and proper mental health, two days are awarded every working semester to each member. Vacation days give team members an extra day to turn in an assignment. As a consensus, vacation days will be saved in case of an emergency or class conflict.



Changes to Document

In order to make changes to the document all members must agree unanimously, and new signatures must be issued to the document. A new version number should be associated with the document for revision control.

IN WITNESS WHEREOF, the parties hereto have executed this Code of Conduct Agreement



Signature

Date: 0/12/2021

Name: James Alexander Wilson

Title: Design Engineer



David Bishop

Signature

Date: 04/12/2021

Name: David Bishop

Title: Systems Engineer

Kyle Youmans

Signature

Date: 04/12/2021

Name: Kyle Youmans

Title: Design Engineer

Julian Villamil

Signature

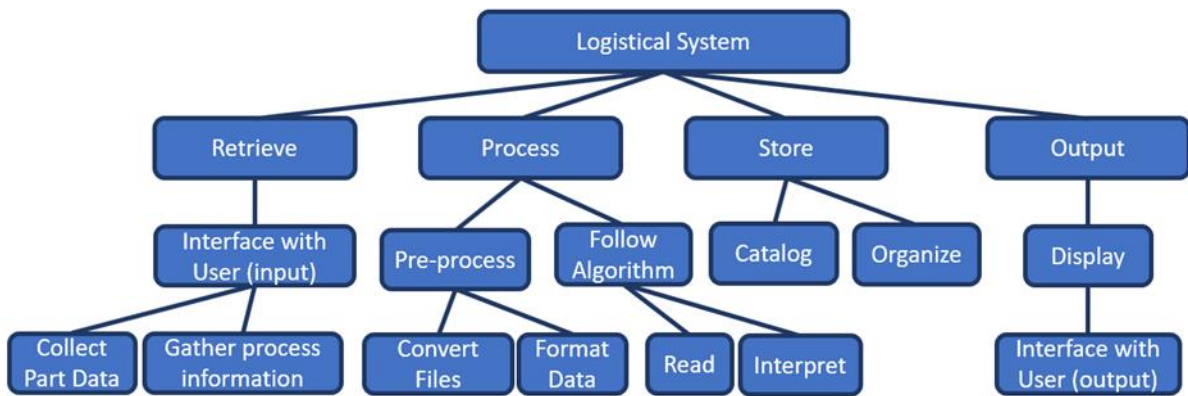
Date: 04/12/2021

Name: Julian Villamil

Title: Systems Engineer



Appendix B: Functional Decomposition





Appendix C: Target Catalog

Metric	Target
Storage Capacity	0 < x < 10 Megabytes
Ease of Use	Number of clicks by user 1
Aesthetic Appeal	1-5 (customer satisfaction survey) 5
Information Obtained to Total Information Needed	100%
Processing Speed	2 GHz to 4.0 GHz
File Conversion Accuracy	Files converted to files requested 100%



Data Format Accuracy	File matches column and row assigned Binary (1-0)
Part Conversion Efficiency	Ratio of parts exchanged correctly to total parts exchanged 100%
Reliability	Below 7% average failure rate
Code Complexity	1-5 (customer satisfaction survey) 5
File Location Accuracy	Files placed in the correct location Binary (1-0)
Organization	1-5 (customer satisfaction survey) 5



Appendix D: Customer Satisfaction Survey

Customer Satisfaction Survey					
Question 1 = unacceptable 2 = poor 3 = satisfactory 4 = good 5 = excellent	Order of Satisfaction				
	1	2	3	4	5
How aesthetically appealing is the display of the product?					
Is the code readable, organized, and reproducible?					
How does the product compare to the previously used method?					

Appendix E: Operations Manual

Terminology

BOM: Bill of Materials

Static BOM: List of mandatory replacements for a compressor

BOM Lookup File: Excel file that contains pages: “BOM List”, “Comments”, and “Phantom Info”

BOM List page: BOM Lookup File page that contains a list of all compressors and their corresponding static BOM



Comments page: BOM Lookup File page that contains a list of specific changes made to replacements and component numbers

Phantom Info page: BOM Lookup File page that contains a list of every part and its corresponding component number

Planner (Material Handler): Responsible for creating BOMs

Investigations (Inspection): Department that determines which parts have failed

Manufacturing Order (MO): Contains all the work orders and bills of materials that go to a specific compressor

Component Number: Specifies a certain part

Revision: An updated part or model with the same component number (i.e. 21097C is component number 21097 revision C)

Project Overview

Danfoss is revamping their aftermarket repair program for failed compressors. Danfoss Turbocor wishes to improve the current process of replacing parts for damaged compressors returning from the field. A damaged compressor returning from the field goes through the customer service department. If the compressor is under warranty, the compressor is fixed for free. If not under warranty, the client can choose to go through a fixed price repair program, the program we are working in. The client has the option of paying a flat rate to repair the compressor or purchasing a new compressor.



The damaged compressor returns from the field and goes through investigations. Technicians in investigations determine which parts have failed and are going to be replaced. They then send a handwritten repair list of the component numbers needed to be replaced to planning. In addition, the investigations team also gives the planners a handwritten list of four main components notorious for causing problems with aftermarket inventory: IGBT, CAP, PWM, and SCR. There are also items that will get replaced for any given aftermarket repair. These components are referred to as the static BOM. Planning then creates a bill of materials of the parts that are being replaced on the compressor. This bill of materials is the sum of the static bill of materials, the four main components, and the repair list given to the planners from investigations. A majority of the current planning process requires manual inputs from a planner who has to cross reference multiple excel files. Error arises with every manual input, so problems can occur throughout the whole aftermarket repair program. Problems include: planners can not read the handwriting of the technicians, duplicate items are placed on the BOM, wrong component numbers are placed on the BOM, component numbers that do not exist are placed on the BOM. Our goal is to help the planner by streamlining and automating this process. We are implementing a MATLAB script that produces a bill of materials of suitable replacement parts for a damaged compressor.

Component Module Description

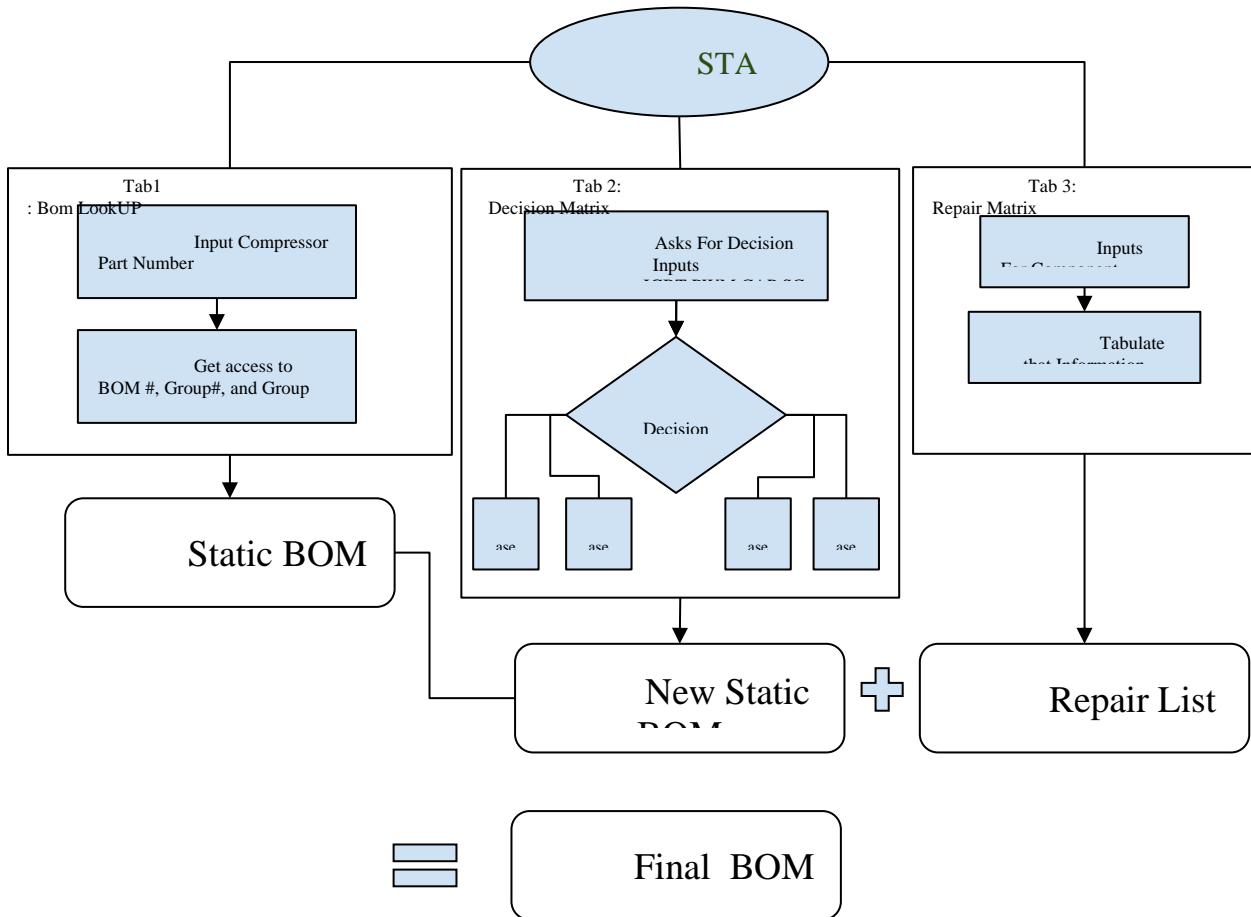


Our system consists of a MATLAB app that requires manual inputs and various input files to produce a bill of materials for a given compressor. The input files include a BOM lookup file, a static BOM, and the list of replacement parts from investigations. The BOM lookup file is an excel file. It contains a page, “BOM List”, that lists all the static BOMs for each compressor. A static BOM is a list of parts that are going to be replaced on the compressor regardless of if they are broken or not. Each compressor is associated with a specific static BOM. The BOM lookup file also contains a “Comments” page. This page lists specific changes that have been made to parts and their component numbers.

The “Phantom Info” page contains a list of all Danfoss parts and their respective component number.

Manual inputs are going to be required for this system. Ideally, we would like to have the technicians scan the replacement part’s ISBN barcode to create the list of replacements. If this is not possible, the technicians will continue to handwrite the replacement part list. The planner will then manually type in the component numbers from the replacement part list.

Pseudocode/State Diagram :



Cases:

- 1) The component number was not on the static BOM but the part was good. Since that part was good, there is no action needed since the part does not need to be added to the final BOM. It does not need to be replaced if it is good.
- 2) The component number was not on the static BOM and the part is bad. In this case, the old component number of this same part needs to be deleted from the static BOM. The new component number which represents the correct replacement is then added to the end of the final BOM.

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- 3) The component number is already on the static BOM but the part is good. Since the part is good the component does not need to be on the final BOM since the BOM needs to contain replacement parts. There is no need to replace something that is not broken, so this part is removed from the final BOM.
- 4) The component number is already on the static BOM and the part is bad. In this case no action is needed because the part is already on the static BOM and the part needs to be replaced. If no action is taken the part will be replaced correctly.

Integration

Our system uses the MATLAB app to input excel files and then make decisions. The BOM lookup file will be uploaded while using the MATLAB App. The BOM lookup file is then stored as a table in the MATLAB App. All the relevant data is stored as strings so certain characters, such as dashes and commas, are still usable within the script. The static BOM used will also be uploaded as a table. The relevant data from the static BOM is stored as strings as well. The data from these two files are then called on throughout the script.

The BOM List page is used to determine which static BOM should be used based on the corresponding compressor model. The Comments page is embedded within the script to make specific changes on imputed component numbers. For example, if the original component number for a screw was 123 and it had been recently changed to 345, the Comments page would address this issue. The Phantom Info page is used to determine if a part exists. When the user is inputting component numbers from the replacement list, the script will call on the Phantom Info data to determine if the inputted number exists.

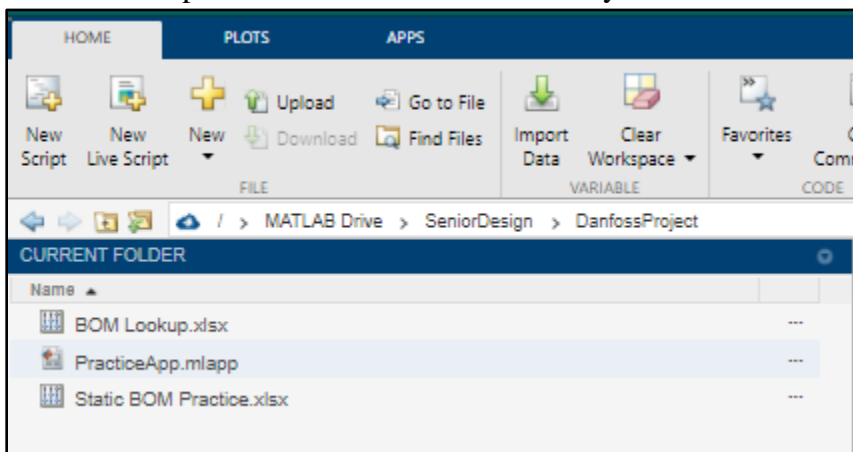


A static BOM is downloaded from SAP, the resource planning software that Danfoss currently uses, and then uploaded to the script. The static BOM is used to add to the final BOM. When the user inputs a component number from the replacement list, the script calls on the static BOM to see if that component number is already on the static BOM. An additional component does not need to be added if the component number is already on the static BOM.

Operation

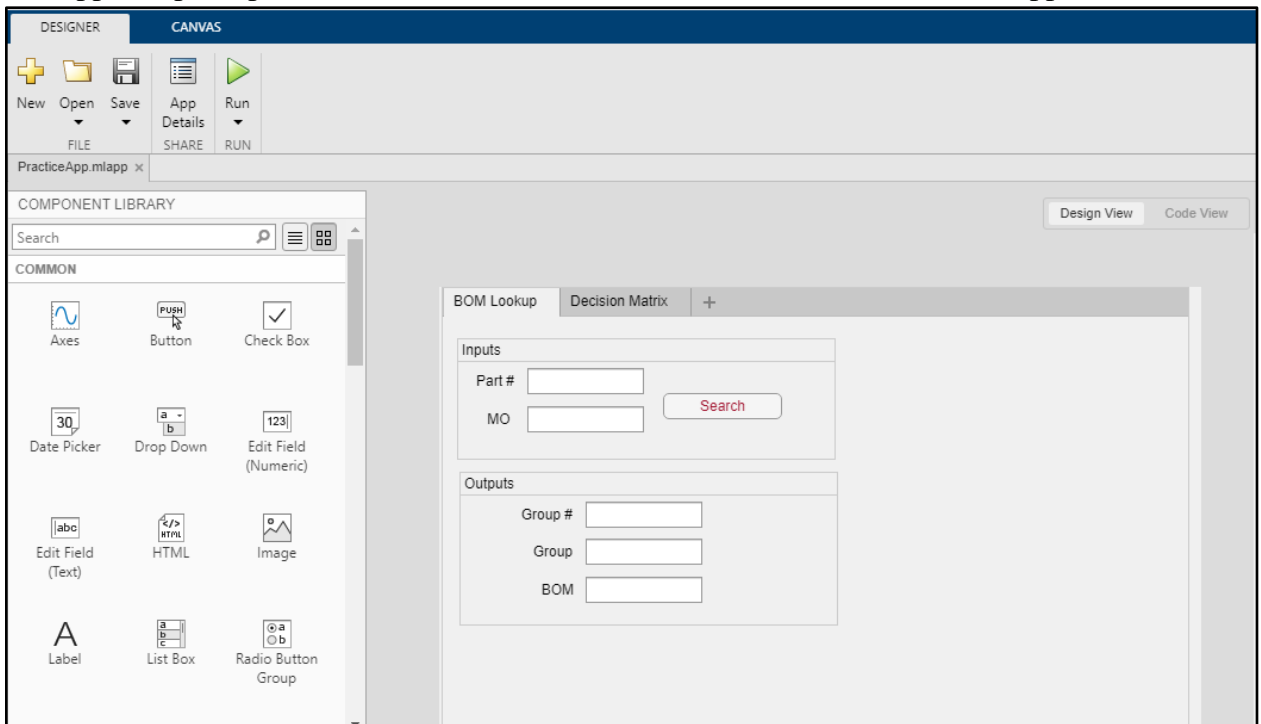
The operation of the MATLAB app is quite simple, however the steps must be implemented in a specific order for the script to run properly.

- 1) First be sure that the most up to date version of the BOM Lookup file has been uploaded to the file directory in which the app is contained. The script will preload this excel file into its workspace in order to create several key variables used in the logic of the code.





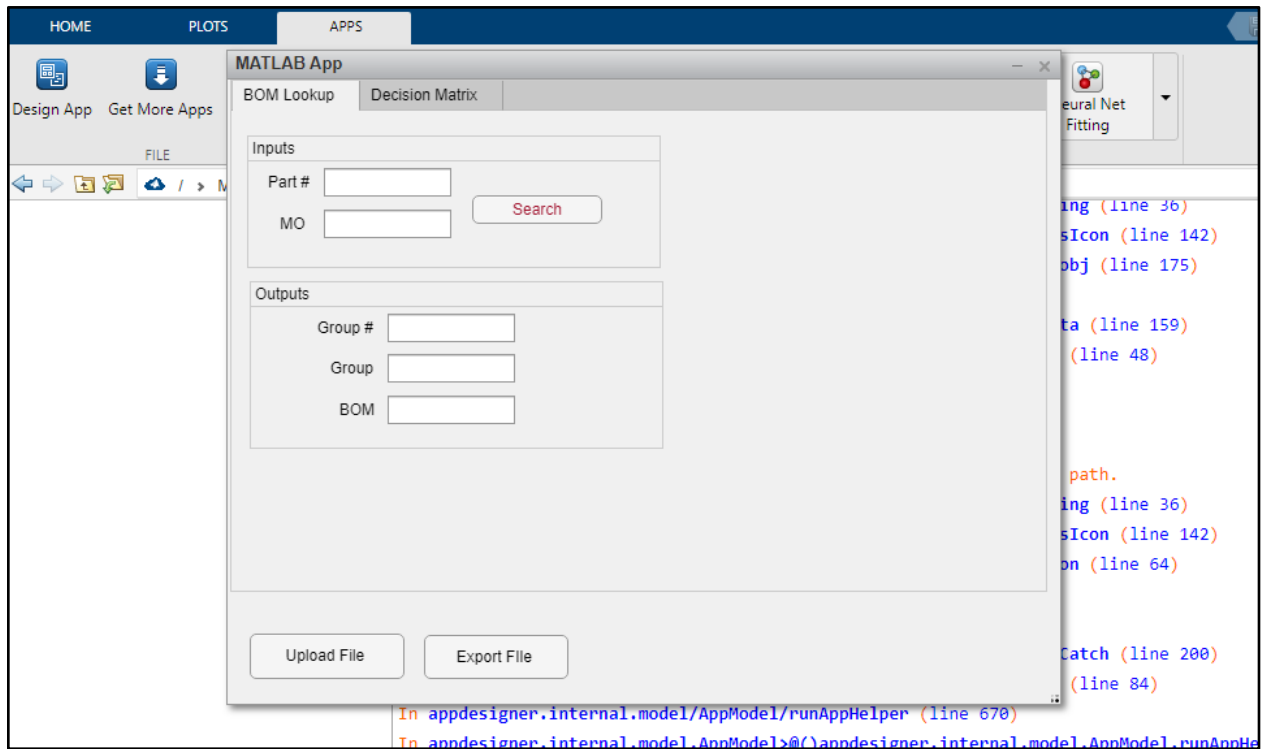
- 2) Within the MATLAB App designer interface, open up the file called PracticeApp.mlapp. The app will pull up with the GUI seen below. Click the run button to start the app.



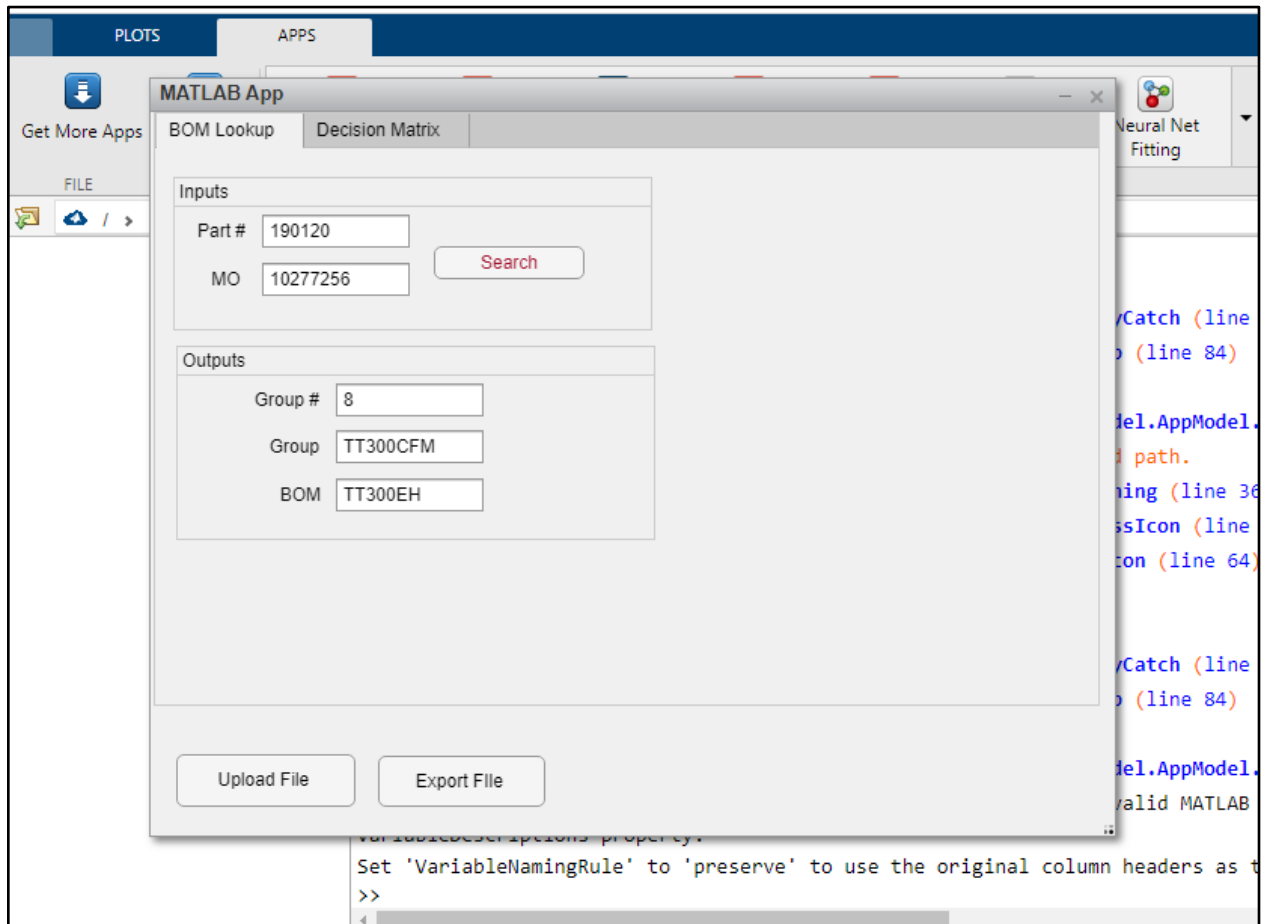
- 3) The GUI interface will appear as an icon where you can type in the Part # for the compressor and the Manufacturing Order number for the repair. After entering this info



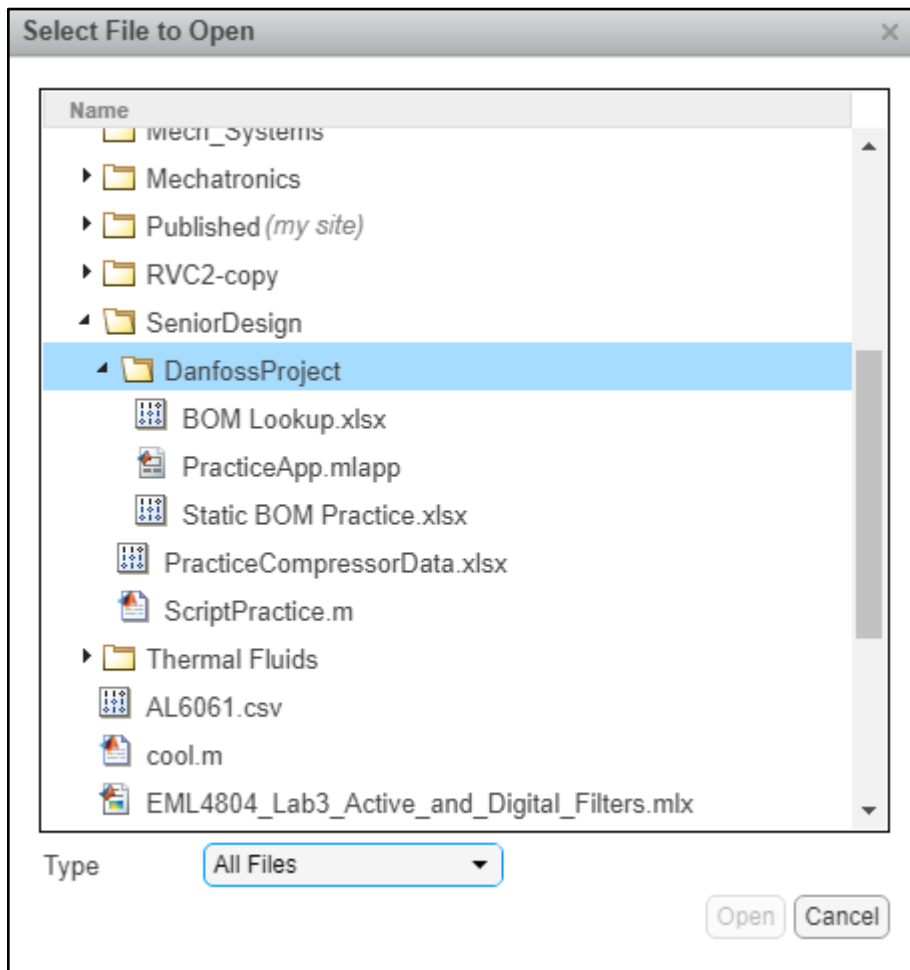
click search.



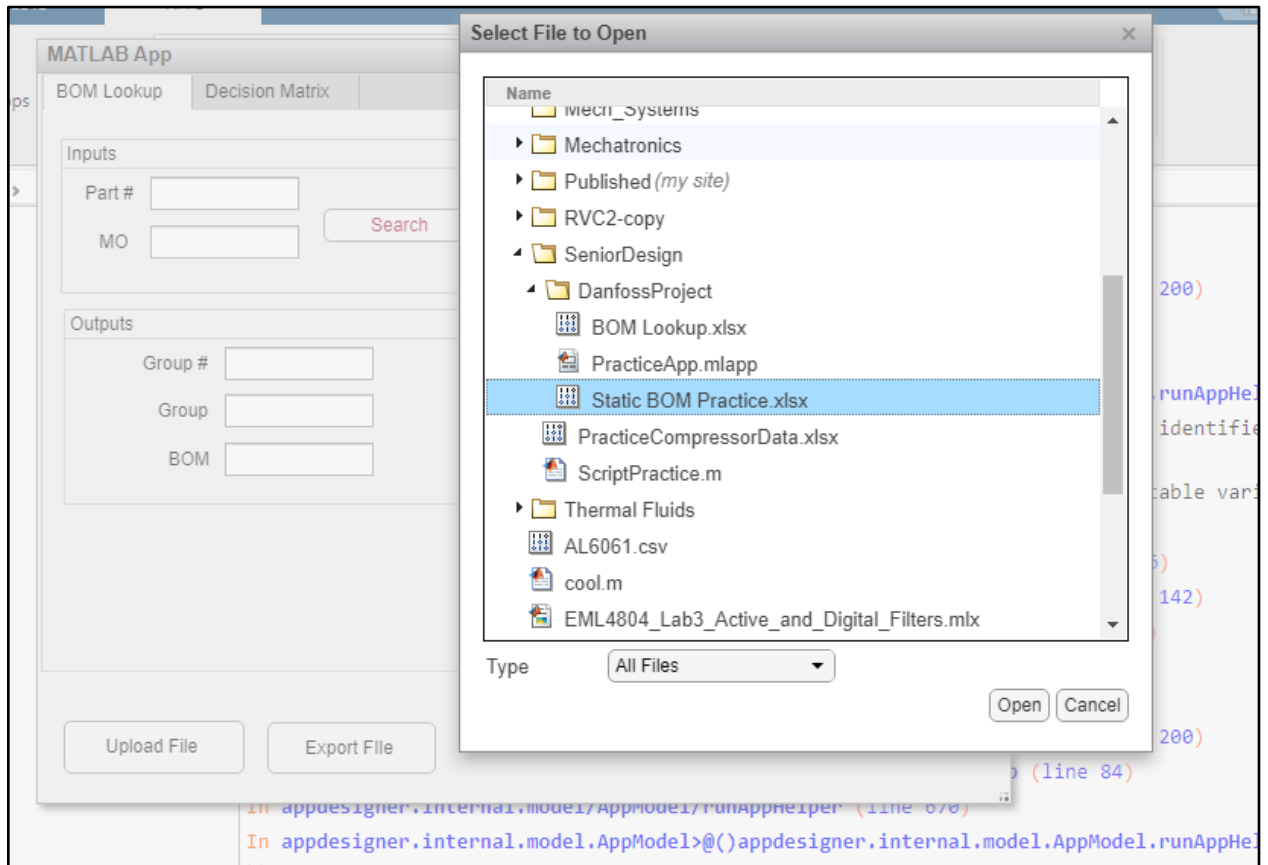
- 4) After this info is typed in, the Group #, Group, and BOM fields will populate as seen in the next image.



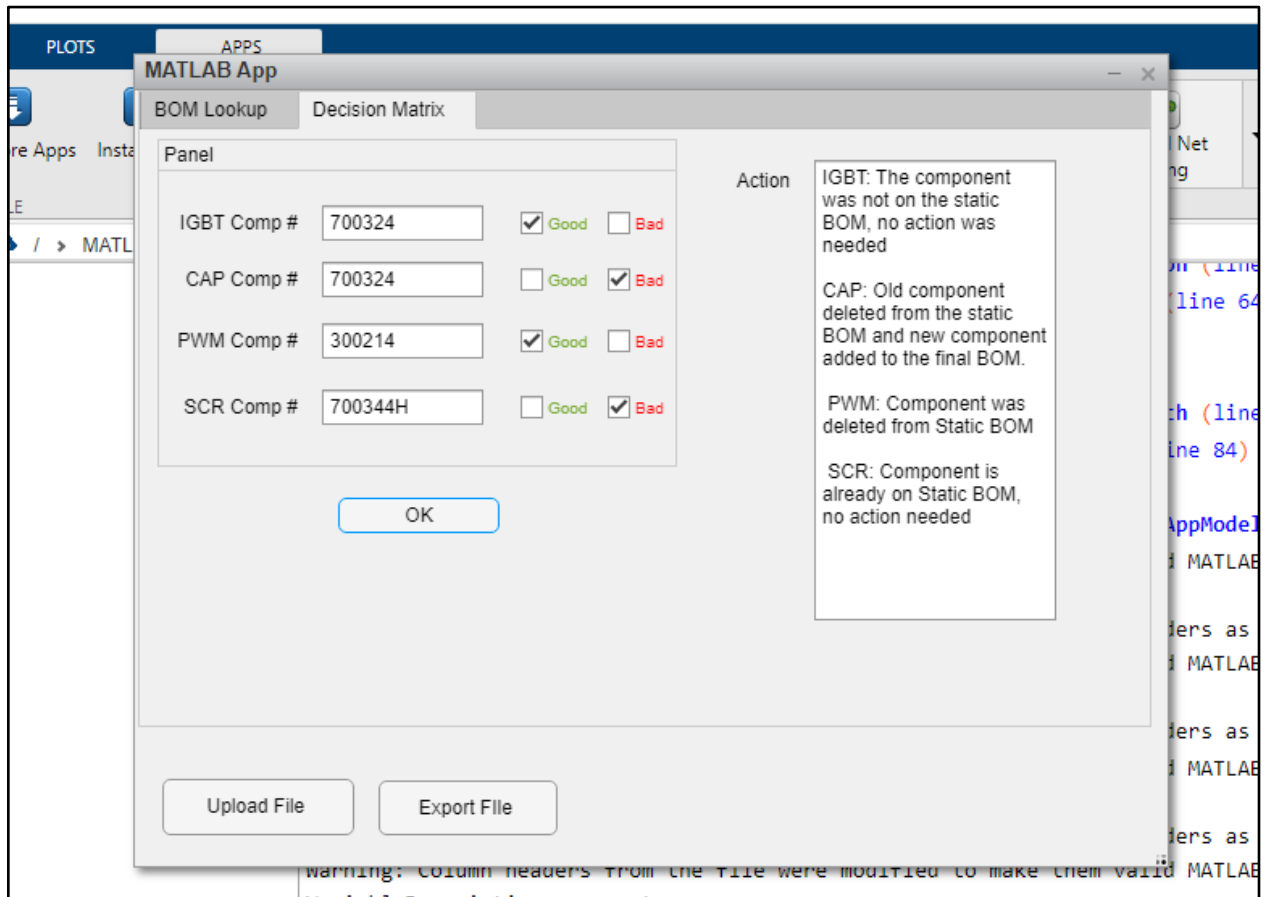
- 5) Now the user knows the correct Static BOM to use, “TT300EH.” This static BOM will need to be downloaded from SAP or whatever ERP program Danfoss is working with in the future in order to begin the next steps of the process.



- 6) Select the upload file button and choose this file you just downloaded from SAP and upload. Remember under type to select “All Files,” otherwise you will not be able to see your excel file within the folder. It is also best practice to save your downloaded static BOM file in the same folder as the working directory of the MATLAB App itself.



- 7) After this file has been uploaded we can now move on to the second panel of the app. This panel has been named the decision matrix, as this panel handles the four main components and the logic surrounding them. At this stage, enter the four main components given to planning from investigations. Also select whether the part provided was good or bad.

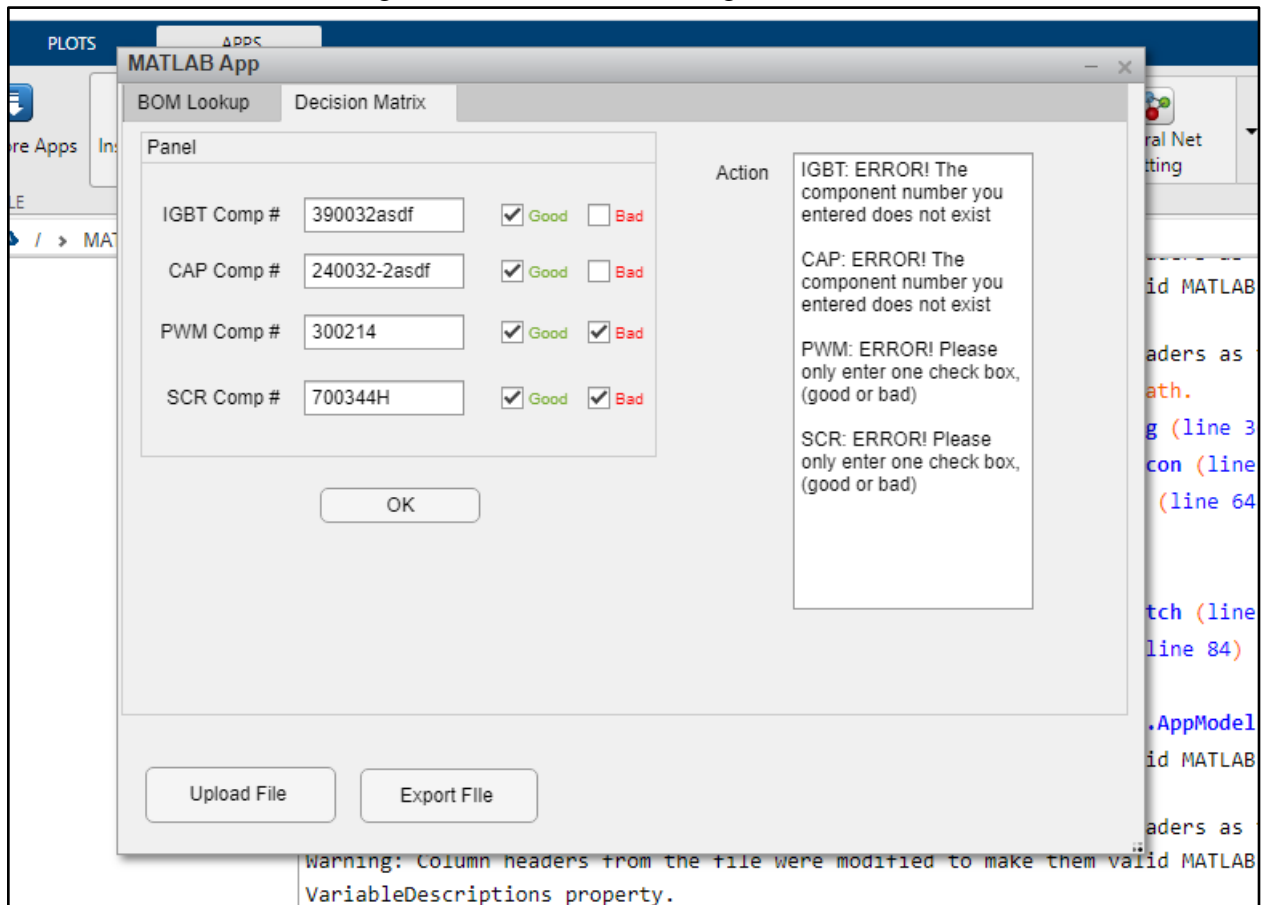


Above outlines the four possible outcomes of actions needed based on the inputs. These four possible outcomes are also explained in the control diagram in the section entitled pseudocode/state diagram.

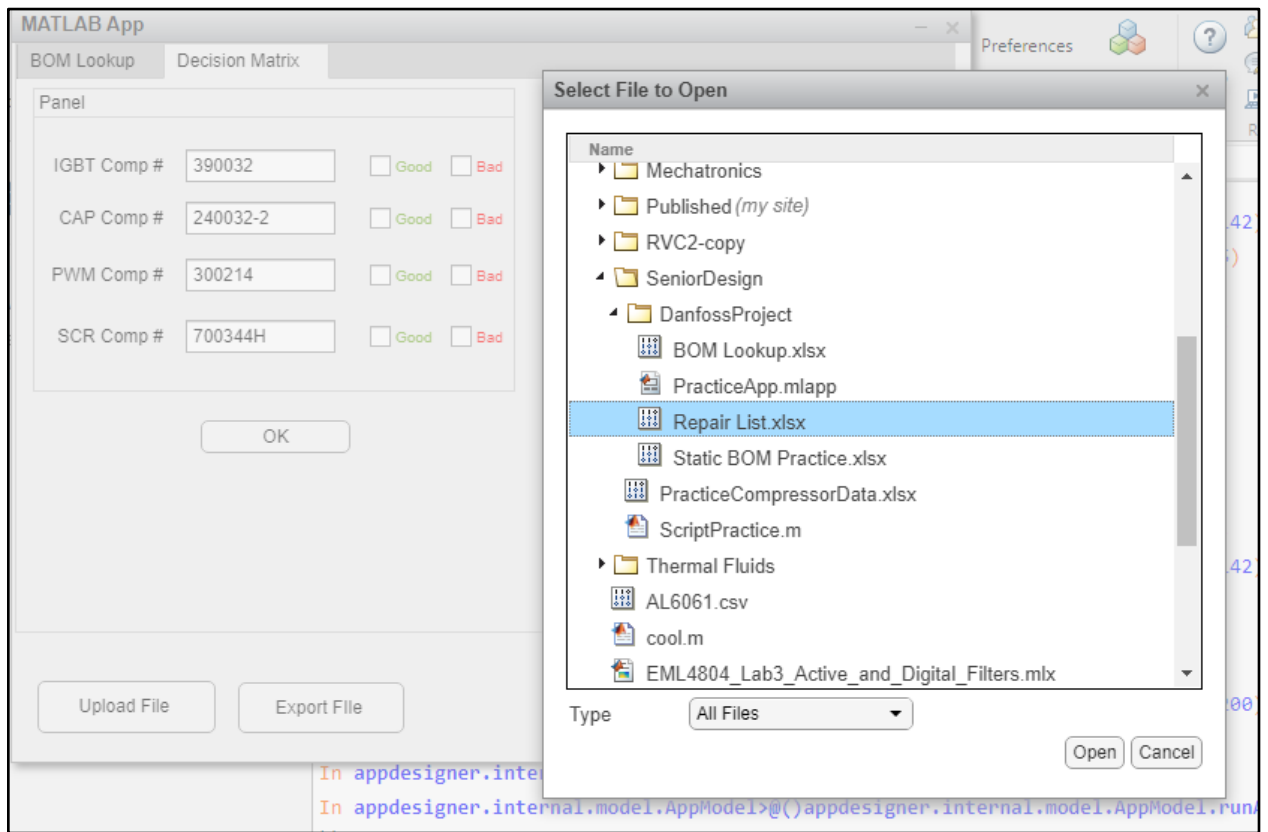
- 5) The component number was not on the static BOM but the part was good. Since that part was good, there is no action needed since the part does not need to be added to the final BOM. It does not need to be replaced if it is good.
- 6) The component number was not on the static BOM and the part is bad. In this case, the old component number of this same part needs to be deleted from the static BOM. The new component number which represents the correct replacement is then added to the end of the final BOM.
- 7) The component number is already on the static BOM but the part is good. Since the part is good the component does not need to be on the final BOM since the BOM needs to contain replacement parts. There is no need to replace something that is not broken, so this part is removed from the final BOM.



- 8) The component number is already on the static BOM and the part is bad. In this case no action is needed because the part is already on the static BOM and the part needs to be replaced. If no action is taken the part will be replaced correctly.
- 8) Another scenario to consider is if you chose to enter bad inputs. Those two scenarios are depicted below. The first is if you chose to check the good and the bad checkbox at the same time. The second is if you enter an invalid part number. More details on how to troubleshoot these errors are given in the troubleshooting section of the document.

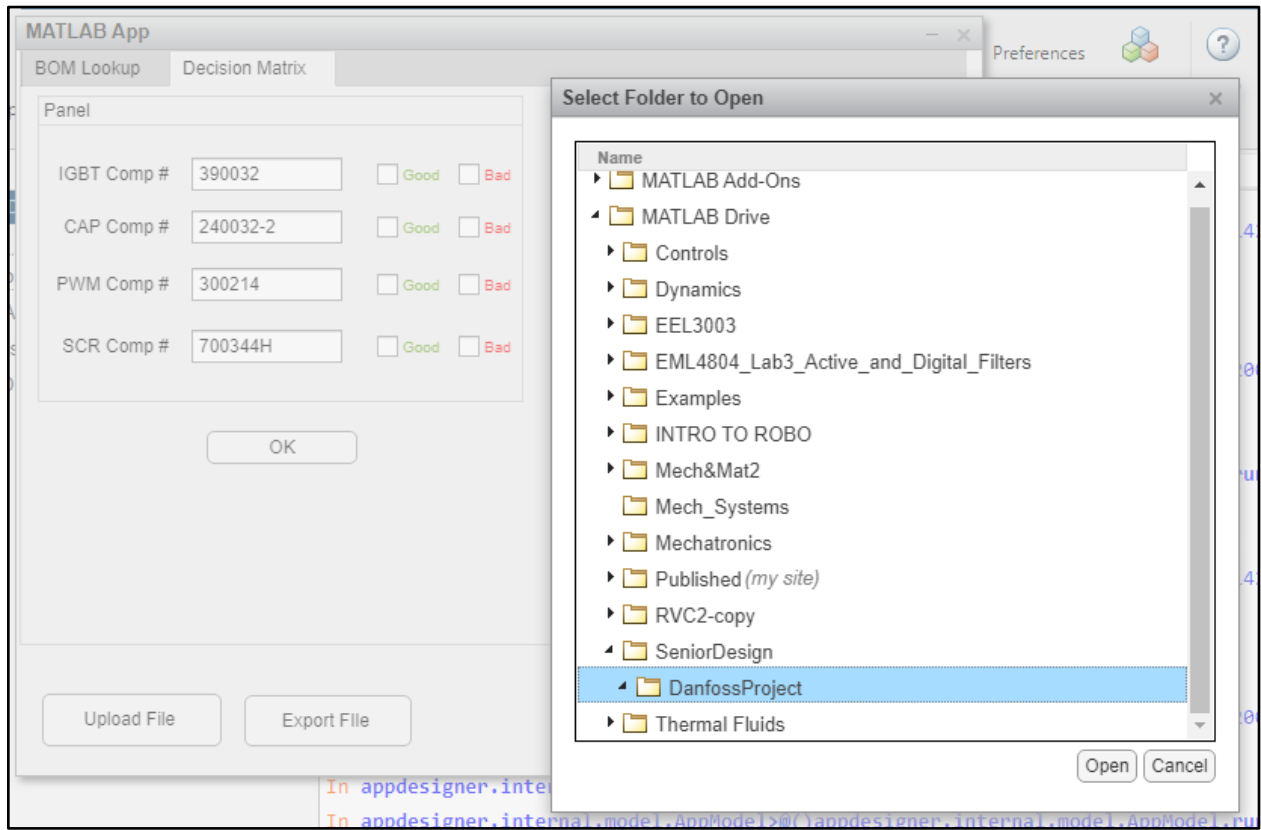


- 9) After these four main components are entered into the interface, the script will perform the action prescribed in the action textbox. The next step in this stage is to upload the repair list. This is done by selecting the upload button on the decision matrix panel as seen below.



This repair list contains the additional components that are given to the planners from investigations and are in the format (part number, quantity). The script will add these components to the final BOM.

- 10) The final step that must be performed is the data must be exported to an excel file so the planner can review the final results to ensure their accuracy. The app is only as accurate as the inputs that are put into it. It is best practice to ensure that the inputs at each stage of the process are both correct and up to date.



Below is a sample image of the final result that will be seen by the planners upon completion of step 10. These results can be compared to previous repairs and validated to ensure that this process encapsulates all of the necessary information into the aftermarket repair process.



Item	Component	Description	LT	Reqmt Qty	UM	IC	S..	SLoc	Plnt	Op...	Batch	Proc. Category
0000	197126	TTS350FGS15030X0XS331			1	PC	L	DT20	1351	0010		Reservation for Order
0010	100329	KIT - O-RINGS (PORTS CONNECTION)			1	PC	L	DT20	1351	0010		Reservation for Order
0020	187229	SWV 4-1-0 TT350-G-1-ST-F SCG				PC	L	DT20	1351	0010		Reservation for Order
0030	720250	HOUSING - MAIN TT350H				PC	L	DT20	1351	0010		Reservation for Order
0040	200084	SHAFT KIT ASSY - S1.23 +5% S1.2 -10...			0	PC	L	DT20	1351	0010		Reservation for Order
0050	290005-1	IGV HOUSING ASSEMBLY - S1.23 +5%				PC	L	DT20	1351	0010		Reservation for Order
0060	200238	BEARING ASSEMBLY -FRONT TWIN -174 ...				PC	L	DT20	1351	0010		Reservation for Order
0070	200193	MODULE SOFTSTART ASSEMBLY			1	PC	L	DT20	1351	0010		Reservation for Order
0080	200237	BEARING ASSEMBLY-BACK-1740D, 22.5LG			1	PC	L	DT20	1351	0010		Reservation for Order
0090	200125	MODULE BACKPLANE ASSEMBLY - Main A...				PC	L	DT20	1351	0010		Reservation for Order
0100	300214	MODULE BEARING PWM ASSEMBLY				PC	L	DT20	1351	0010		Reservation for Order
0110	783011	HOUSING. LABYRINTH SEAL PLATE TT-3...				PC	L	DT20	1351	0010		Reservation for Order
0120	702020	HOUSING DIFFUSER - 1st STAGE MC S1.2...			1	PC	L	DT20	1351	0010		Reservation for Order
0130	702027	HOUSING 2nd STAGE DIFFUSER AND VO...			1	PC	L	DT20	1351	0010		Reservation for Order
0140	300046	MODULE BEARING MOTOR COMPRESSOR...			1	PC	L	DT20	1351	0010		Reservation for Order
0150	300047	MODULE SERIAL DRIVERS - Main Assy			1	PC	L	DT20	1351	0010		Reservation for Order
0160	310003	SHAFT ASSY - TURNING - 135LG 2*11-2...			1	PC	L	DT20	1351	0010		Reservation for Order
0170	333008-6	MOTOR WINDING ASSEMBLY: 135LG - 8...				PC	L	DT20	1351	0010		Reservation for Order
0190	300287	ASSEMBLY - DC/DC CONVERTER			1	PC	L	DT20	1351	0010		Reservation for Order
0200	390032	IGBT ASSEMBLY - SEMIKRON SKIP613GD...				PC	L	DT20	1351	0010		Reservation for Order
0210	701712-2	VALVE - ORIFICE SOLENOID - 2.0				PC	L	DT20	1351	0010		Reservation for Order
0220	701712-25	VALVE - ORIFICE SOLENOID - 2.5 TT500...				PC	L	DT20	1351	0010		Reservation for Order
0230	710028	HOUSING_END CAP			1	PC	L	DT20	1351	0010		Reservation for Order
0240	750206-2	BRACKET-MAINS INPUT 2"				PC	L	DT20	1351	0010		Reservation for Order
0250	880188-1	COVERS - KIT - BLACK EN/FR			1	PC	L	DT20	1351	0010		Reservation for Order
0260	792017	SPACER 1st STAGE IMPELLER S1.69			1	PC	L	DT20	1351	0010		Reservation for Order
0270	795017	SPACER 1st STAGE IMPELLER 90 TON HE...			1	PC	L	DT20	1351	0010		Reservation for Order
0280	790306	SPACER SLEEVE 2nd STAGE IMPELLER 1...			1	PC	L	DT20	1351	0010		Reservation for Order
0290	201132	CABLE HARNESS COMPRESSOR DC SUPPL...			1	PC	L	DT20	1351	0010		Reservation for Order

Troubleshooting

When operating the app if an issue is encountered, be sure to double check the inputs are correct. Also make sure to not skip any step described in the operation section. Correct inputs include the import file (make sure the file is an excel file), manual strings put into the text input section, and associated checkboxes. If trouble still persists, more solutions can be found by going into the code section of the app and look up the built-in flags set up for said error. Most error cases can be due to wrong number inputs, so make sure to follow the static BOM format or match



the imported file string formats. Other errors may happen if two functions are called at the same time, an example being checking the good and bad boxes for part assessment as seen in step 8 of the operation section. Make sure to do one at time, if the code malfunctions a flag should pop up for the user to check the incode error message solution.

What to do if the error message pops up:

- If two boxes are checked at the same time a message will pop up in the action section of the app displaying "ERROR! Please only enter one check box. (good or bad)".
- Uncheck both boxes and select **ONLY ONE** box for the given part based on the investigations team report.
- If the error displayed is "ERROR! The component number you entered does not exist", Then the input text file string has an incorrect entree and needs to be fixed. Make sure the component number is typed correctly and matches the format of the imported file.

If there is trouble exporting the file give it a second for the program to load and make sure there is a place for the file to go. This can be done by already working on the exported file directory.

If the app does not respond upon initiation do close the app and open it back once more. If the text inputs work but no buttons do, then restart the app. If the import file function does not work also restart the app.



Appendix F: Risk Assessment

FAMU-FSU College of Engineering

Project Hazard Assessment Policy and Procedures

INTRODUCTION

University laboratories are not without safety hazards. Those circumstances or conditions that might go wrong must be predicted and reasonable control methods must be determined to prevent incident and injury. The FAMU-FSU College of Engineering is committed to achieving and maintaining safety in all levels of work activities.

PROJECT HAZARD ASSESSMENT POLICY

Principal investigator (PI)/instructor are responsible and accountable for safety in the research and teaching laboratory. Prior to starting an experiment, laboratory workers must conduct a project hazard assessment (PHA) to identify health, environmental and property hazards, and the proper control methods to eliminate, reduce or control those hazards. PI/instructor must review, approve, and sign the written PHA and provide the identified hazard control measures.

PI/instructor continually monitor projects to ensure proper controls and safety measures are available, implemented, and followed. PI/instructor are required to reevaluate a project anytime there is a change in scope or scale of a project and at least annually after the initial review.

PROJECT HAZARD ASSESSMENT PROCEDURES

It is FAMU-FSU College of Engineering policy to implement followings:

1. Laboratory workers (i.e. graduate students, undergraduate students, postdoctoral, volunteers, etc.) performing a research in FAMU-FSU College of Engineering are required to conduct PHA prior to commencement of an experiment or any project change in order to identify existing or potential hazards and to determine proper measures to control those hazards.
2. PI/instructor must review, approve and sign the written PHA.



3. PI/instructor must ensure all the control methods identified in PHA are available and implemented in the laboratory.
4. In the event laboratory personnel are not following the safety precautions, PI/instructor must take firm actions (e.g. stop the work, set a meeting to discuss potential hazards and consequences, ask personnel to review the safety rules, etc.) to clarify the safety expectations.
5. PI/instructor must document all the incidents/accidents happened in the laboratory along with the PHA document to ensure that PHA is reviewed/modified to prevent reoccurrence. In the event of PHA modification a revision number should be given to the PHA, so project members know the latest PHA revision they should follow.
6. PI/instructor must ensure that those findings in PHA are communicated with other students working in the same laboratory (affected users).
7. PI/instructor must ensure that approved methods and precautions are being followed by :
 - a. Performing periodic laboratory visits to prevent the development of unsafe practice.
 - b. Quick reviewing of the safety rules and precautions in the laboratory members meetings.
 - c. Assigning a safety representative to assist in implementing the expectations.
 - d. Etc.
8. A copy of this PHA must be kept in a binder inside the laboratory or PI/instructor’s office (if experiment steps are confidential).

Project Hazard Assessment Worksheet				
PI/instructor: Dr. McConomy	Phone #: (850) 410-6624	Dept.: ME	Start Date: 12/02/2020	Revision number: 1
Project: Danfoss Aftermarket Workflow and Implementation			Location(s): FAMU – FSU College of Engineering	
Team member(s): Kyle Youmans, David Bishop, James Wilson, Julian Villamil			Phone #: (404) 797-7667	Email: jaw15k@my.fsu.edu



Experiment Steps	Location	Person assigned	Identify hazards or potential failure points	Control method	PPE	List proper method of hazardous waste disposal, if any.	Residual Risk	Specific rules based on the residual risk
Coding the part replacement algorithm	Home or computer lab	James Wilson, Julian Villamil	Eye Strain due to staring at a computer screen for hours	Take 5-minute breaks every hour to stare at the horizon and blink for 20 seconds.	Blue light glasses	If glasses break, store the glass in a cardboard box labeled SHARPS and black sharpie.	HAZARD:1 CONSEQUENCE: negligible Residual: low	Safety controls are planned by both the worker and supervisor.
Machining the QR scanner housing.	Machine Shop	David Bishop, Kyle Youmans	Metal chips, heavy machinery	Proper training with operating heavy machinery. Supervision within the shop	Safety Goggles, pants, no loose clothing, no jewelry	Dispose of oil, and machine shavings. Lab	HAZARD:3 CONSEQUENCE: severe Residual: Med High	A second worker must be in place before work can proceed (buddy system)
Wiring up the Arduino	Mechatronics Lab	Kyle Youmans James Wilson	Low voltage exposure.	Electrical Grounding	Gloves	Proper disposal of batteries	HAZARD: 1 CONSEQUENCE: negligible Residual: Low	Safety controls are planned by both the worker and supervisor
	Senior design lab	David Bishop		Allowing appropriate	Glasses	Dispose to proper	HAZARD: 1	Safety controls



3D printing prototype for QR scanner housing		p, Julian Villamil	Hot 3D printed surface	e time for 3D printer to cool down		recycling plant	CONSE Q: negligible Residual: low	and proceed with supervisor authorization
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Principal investigator(s)/ instructor PHA: I have reviewed and approved the PHA worksheet.

Name	Signature	Date	Name	Signature	Date
<u>David Bishop</u>	<u></u>	<u>12/02/2020</u>	<u>Kyle Youmans</u>	<u></u>	<u>12/02/2020</u>

Team members: I certify that I have reviewed the PHA worksheet, am aware of the hazards, and will ensure the control measures are followed.

Name	Signature	Date	Name	Signature	Date
<u>Julian Villamil</u>	<u></u>	<u>12/02/2020</u>	<u>James Wilson</u>	<u></u>	<u>12/02/2020</u>
_____	_____	_____	_____	_____	_____

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DEFINITIONS

Hazard: Any situation, object, or behavior that exists, or that can potentially cause ill health, injury, loss or property damage e.g. electricity, chemicals, biohazard materials, sharp objects, noise, wet floor, etc. OSHA defines hazards as “any source of potential damage, harm or adverse health effects on something or someone”. A list of hazard types and examples are provided in appendix A.



Hazard control: Hazard control refers to workplace measures to eliminate/minimize adverse health effects, injury, loss, and property damage. Hazard control practices are often categorized into the following three groups (priority as listed):

- 1. Engineering control:** physical modifications to a process, equipment, or installation of a barrier into a system to minimize worker exposure to a hazard. Examples are ventilation (fume hood, biological safety cabinet), containment (glove box, sealed containers, barriers), substitution/elimination (consider less hazardous alternative materials), process controls (safety valves, gauges, temperature sensor, regulators, alarms, monitors, electrical grounding and bonding), etc.
- 2. Administrative control:** changes in work procedures to reduce exposure and mitigate hazards. Examples are reducing scale of process (micro-scale experiments), reducing time of personal exposure to process, providing training on proper techniques, writing safety policies, supervision, requesting experts to perform the task, etc.
- 3. Personal protective equipment (PPE):** equipment worn to minimize exposure to hazards. Examples are gloves, safety glasses, goggles, steel toe shoes, earplugs or muffs, hard hats, respirators, vests, full body suits, laboratory coats, etc.

Team member(s): Everyone who works on the project (i.e. grads, undergrads, postdocs, etc.). The primary contact must be listed first and provide phone number and email for contact.

Safety representative: Each laboratory is encouraged to have a safety representative, preferably a graduate student, in order to facilitate the implementation of the safety expectations in the laboratory. Duties include (but are not limited to):

- Act as a point of contact between the laboratory members and the college safety committee members.
- Ensure laboratory members are following the safety rules.
- Conduct periodic safety inspection of the laboratory.
- Schedule laboratory clean up dates with the laboratory members.
- Request for hazardous waste pick up.

Residual risk: Residual Risk Assessment Matrix are used to determine project's risk level. The hazard assessment matrix (table 1) and the residual risk assessment matrix (table2) are used to identify the residual risk category.

The instructions to use hazard assessment matrix (table 1) are listed below:

1. Define the workers familiarity level to perform the task and the complexity of the task.



- Find the value associated with familiarity/complexity (1 – 5) and enter value next to: HAZARD on the PHA worksheet.

Table 1. Hazard assessment matrix.

		Complexity		
		Simple	Moderate	Difficult
Familiarity Level	Very Familiar	1	2	3
	Somewhat Familiar	2	3	4
	Unfamiliar	3	4	5

The instructions to use residual risk assessment matrix (table 2) are listed below:

- Identify the row associated with the familiarity/complexity value (1 – 5).
- Identify the consequences and enter value next to: CONSEQ on the PHA worksheet. Consequences are determined by defining what would happen in a worst case scenario if controls fail.
 - Negligible: minor injury resulting in basic first aid treatment that can be provided on site.
 - Minor: minor injury resulting in advanced first aid treatment administered by a physician.
 - Moderate: injuries that require treatment above first aid but do not require hospitalization.
 - Significant: severe injuries requiring hospitalization.
 - Severe: death or permanent disability.
- Find the residual risk value associated with assessed hazard/consequences: Low –Low Med – Med– Med High – High.
- Enter value next to: RESIDUAL on the PHA worksheet.

Table 2. Residual risk assessment matrix.

	Consequences
Team 504	

Team 504

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2020



Assessed Hazard Level	Negligible	Minor	Moderate	Significant	Severe
5	Low Med	Medium	Med High	High	High
4	Low	Low Med	Medium	Med High	High
3	Low	Low Med	Medium	Med High	Med High
2	Low	Low Med	Low Med	Medium	Medium
1	Low	Low	Low Med	Low Med	Medium

Specific rules for each category of the residual risk:

Low:

- Safety controls are planned by both the worker and supervisor.
- Proceed with supervisor authorization.

Low Med:

- Safety controls are planned by both the worker and supervisor.
- A second worker must be in place before work can proceed (buddy system).
- Proceed with supervisor authorization.

Med:

- After approval by the PI, a copy must be sent to the Safety Committee.
- A written Project Hazard Control is required and must be approved by the PI before proceeding. A copy must be sent to the Safety Committee.
- A second worker must be in place before work can proceed (buddy system).
- Limit the number of authorized workers in the hazard area.

Med High:

- After approval by the PI, the Safety Committee and/or EHS must review and approve the completed PHA.
- A written Project Hazard Control is required and must be approved by the PI and the Safety Committee before proceeding.



- Two qualified workers must be in place before work can proceed.
- Limit the number of authorized workers in the hazard area.

High:

- The activity will not be performed. The activity must be redesigned to fall in a lower hazard category.

Appendix A: Hazard types and examples

Types of Hazard	Example
Physical hazards	Wet floors, loose electrical cables objects protruding in walkways or doorways
Ergonomic hazards	Lifting heavy objects Stretching the body Twisting the body Poor desk seating
Psychological hazards	Heights, loud sounds, tunnels, bright lights
Environmental hazards	Room temperature, ventilation contaminated air, photocopiers, some office plants acids
Hazardous substances	Alkalis solvents
Biological hazards	Hepatitis B, new strain influenza
Radiation hazards	Electric welding flashes Sunburn
Chemical hazards	Effects on central nervous system, lungs, digestive system, circulatory system, skin, reproductive system. Short term (acute) effects such as burns, rashes, irritation, feeling unwell, coma and death. Long term (chronic) effects such as mutagenic (affects cell structure), carcinogenic (cancer), teratogenic (reproductive effect), dermatitis of the skin, and occupational asthma and lung damage.



Noise	High levels of industrial noise will cause irritation in the short term, and industrial deafness in the long term.
Temperature	<p>Personal comfort is best between temperatures of 16°C and 30°C, better between 21°C and 26°C.</p> <p>Working outside these temperature ranges: may lead to becoming chilled, even hypothermia (deep body cooling) in the colder temperatures, and may lead to dehydration, cramps, heat exhaustion, and hyperthermia (heat stroke) in the warmer temperatures.</p>
Being struck by	This hazard could be a projectile, moving object or material. The health effect could be lacerations, bruising, breaks, eye injuries, and possibly death.
Crushed by	A typical example of this hazard is tractor rollover. Death is usually the result
Entangled by	Becoming entangled in machinery. Effects could be crushing, lacerations, bruising, breaks amputation and death.
High energy sources	Explosions, high pressure gases, liquids and dusts, fires, electricity and sources such as lasers can all have serious effects on the body, even death.
Vibration	Vibration can affect the human body in the hand arm with 'white-finger' or Raynaud's Syndrome, and the whole body with motion sickness, giddiness, damage to bones and audits, blood pressure and nervous system problems.
Slips, trips and falls	A very common workplace hazard from tripping on floors, falling off structures or down stairs, and slipping on spills.
Radiation	Radiation can have serious health effects. Skin cancer, other cancers, sterility, birth deformities, blood changes, skin burns and eye damage are examples.
Physical	Excessive effort, poor posture and repetition can all lead to muscular pain, tendon damage and deterioration to bones and related structures
Psychological	Stress, anxiety, tiredness, poor concentration, headaches, back pain and heart disease can be the health effects
Biological	More common in the health, food and agricultural industries. Effects such as infectious disease, rashes and allergic response.


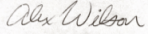


Project Hazard Control- For Projects with Medium and Higher Risks

Name of Project: Danfoss: Aftermarket Process Workflow and Implementation	Date of submission: 12/3/2020
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Team member	Phone number	e-mail
Kyle Youmans	(305) 962-7293	Kny16@my.fsu.edu
James Wilson	(404) 797-7667	Jaw15k@my.fsu.edu
David Bishop	(904) 525-0181	dbb16c@my.fsu.edu
Julian Villamil	(786) 489-8127	jav17b@my.fsu.edu
Faculty mentor	Phone number	e-mail
Dr. Shayne McConomy	(850) 410-6624	smcconomy@eng.famu.fsu.edu
<p>Rewrite the project steps to include all safety measures taken for each step or combination of steps. Be specific (don't just state "be careful").</p>		
<ol style="list-style-type: none"> 1) Machining the QR scanner casing with safety goggles and long pants, without loose clothing or jewelry. 2) Wiring up the Arduino with electrical grounding techniques and safety gloves. 3) 3D printing the prototype for the QR scanner housing with glasses and supervisor supervision. 4) Using computers in the computer lab with machines with frequencies and voltages that aren't harmful to humans. 		
<p>Thinking about the accidents that have occurred or that you have identified as a risk, describe emergency response procedures to use.</p>		
<p>If working in the machine shop and an accident occurs, we must notify the supervisor, Mr. Larson, and possibly call 911.</p> <p>If there is an accident at the Senior Design Lab, we are to notify the supervisor Dr. Shayne McConomy and if life threatening call 911.</p> <p>If there is an accident in the Mechatronics lab we should notify Dr. Ordonez and call 911</p>		
<p>List emergency response contact information:</p>		
<ul style="list-style-type: none"> • Call 911 for injuries, fires or other emergency situations • Call your department representative to report a facility concern 		



Name	Phone number	Faculty or other COE emergency contact	Phone number
Carol Bishop	(904) 716-3419	Keith Larson	(850)556-8529
Doris Youmans	(305) 401-3435	Dr. Camilo Ordonez	(850)410-6365
Eileen Wilson	(404) 259-7640	Dr. Shayne McConomy	(850) 410-6624
Miguel Villamil	(786) 999-3199	Donald Hollett	(850)410-6600
Safety review signatures			
Team member	Date	Faculty mentor	Date
	12/3/20		
	12/3/20		
	12/3/20		
	12/3/20		

Report all accidents and near misses to the faculty mentor.