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Team 508: Smart Integration of Climatic Chamber Operations (SICCO)

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Abstract

Graduation year: 2019

Disclaimer

Graduation year: 2019

Acknowledgment

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1.1 Project Scope

1.1.1 Project Description

The objective of this project is to ~~install~~ develop a prototype of a smart integration network and an observation system with remote accessibility for climatic chamber tests. The networking system will eliminate the need for human interfacing and USB drives when retrieving test data. It will allow data to be analyzed during testing and from anywhere in the world. The observation system will provide a risk assessment of the overall system to define the level of risk. Test and observation data will be accessible during and after testing.

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1.1.2 Key Goals

The goals of this project have been broken up into two phases by the sponsor liaison. The first phase deals mainly with the planning and design phase while the second phase includes building and prototyping of the system. The current plan is to finish Phase I as quickly as possible, at least by the beginning of December, to ensure enough time for the second phase. The testing needed to validate and verify the prototypes will require more time than Phase I and completion of the project is a priority. By the end of phase II, the prototype will be built so that another team can be made into a fully functional system for Danfoss.

Phase I:

1. To develop a system architect and networking diagram
2. To develop a SICCO concept and specifications
3. To develop and understand the needs
4. To develop a risk matrix

Phase II:

1. To validate SICCO requirements
2. To verify SICCO requirements
3. Final project report

1.1.3 Primary Market

The primary market for this project is Danfoss Turbocor Compressors, Inc. Specifically the project sponsor and Reliability Engineering Manager Vinayak Hegde. All Danfoss branches will be considered a primary market but the project will be in Tallahassee, FL. Other primary markets include similar companies to Danfoss, who need temperature, humidity, and vibration test remote monitoring.

1.1.4 Secondary Market

Secondary markets for this product include the Thermatron and Cincinnati Sub-Zero are two climate chamber manufactures who could implement this device to their products. Surveillance companies, VIVOTEK and Dedicated Micros Inc., could benefit from this project and expand their market to extreme climate regions. Additional secondary markets are the aerospace industries or electrical companies.

~~The secondary market for this product is the FAMU-FSU College of engineering. The final product of this project is affiliated with the FAMU-FSU College of engineering because the team goes to this college. All team members are also a secondary market. This project will represent each members' engineering potential and experience. Additional secondary markets are the manufactures for the climatic chambers.~~

1.1.5 Assumptions

The assumptions involved in this project are: Climatic Chamber is provided and assessable for testing. The climatic chamber will focus on temperature, humidity, and vibration (not Thermal shock or stability).

1.1.6 Stakeholders

The direct beneficiary of this project is Danfoss Turbocor Compressors, Inc. Any company that would like to test and monitor conditions of parts inside a climate controlled chamber is an indirect beneficiary that will benefit from this technology. Danfoss Turbocor Compressors, Inc. is the project sponsor and customer; therefore, they risk losing the money and time invested into this project. The FAMU-FSU College of Engineering is another direct stakeholder of this project. The team members for this project represent the college and poor job results in a poor representation of FAMU-FSU. Within the college, both the advisor Dr. Yaghoobian as well as Dr. McConomy are stakeholders as they fail if the team is unable to understand successfully or have the resources to do the project.

1.2 Customer Needs

Danfoss's reliability engineer, Vinayak Hegde, at Tallahassee Turbocor plant, has requested our team to solve two issues under a budget of $4,500. First, a way to remotely access climatic chamber test data. Second, remotely access observation data of climate chamber tests. Both the data and monitoring will be accessible during and after testing.

1.2.1 Sponsor Interview

Team 508: How did this project idea come about? Has it been started in any way?

Hegde: Danfoss wants to decrease human interfacing when collecting data. They do not have a way to visually monitor test equipment. No, it has not been started.

Team 508: Are we building the chamber? If yes, what size? If yes, which type?

Hegde: We are not building the chamber, only the system to connect test data to a server for remote accessibility. Two chambers are at Danfoss and are constantly being tested. We can observe their current data retrieval process. The two chambers are Thermatron and Cincinnati Sub Zero.

Team 508: What data needs to be collected and monitored? What is the duration of the tests?

Hegde: Temperature, humidity, vibration, and equipment power are already being collected by a data logger. Our job is to connect the data logger to a server for remote accessibility. The tests can last 4 days or a couple weeks depending on the test. There are cyclic and step tests. The tests begin with temperature changing, then temperature and humidity change, then temperature, humidity, and vibration changing.

Team 508: How do you want the data to be collected?

Hegde: The data is already organized by the data logger. All that is needed is sending the data to a server.

Team 508: Is the budget $4500?

Hegde: Yes but prefers to be as low budget as possible.

Team 508: What components are being tested in the chamber? What sizes?

Hegde: Part or whole compressors. Smaller than chamber size.

Team 508: What conditions do the monitoring components need to be able to withstand?

Hegde: Temperature, humidity, vibration.

Team 508: Will we be able to use your workspace or do testing at Danfoss?

Hegde: Yes. Just need to set up a time and date to come.

1.3 Functional Decomposition

The SICCO project has two main functions. The first is to remotely send the data from the data collector to the user. This will prevent the user from having to physically go to the data collector to extract the data. The second function is to monitor the test. This will serve to electronically save the data for future use. Monitoring the test will also allow for live streaming of the test. Through this function, the user will be able to visually see the test while it is taking place without being in the physical location of the test.

Graduation year: 2019

Table 1
Functional Decomposition Matrix

	Remotely Send Data to Accessible Network	Monitor Climatic Test Visually
Save Recording for Database		X
Allow for live monitoring of test		X
Connect Data Logger to Network	X	

1.4 Target Summary

Per our functional decomposition, our team came up with four primary functions. These functions along with their individual targets and metrics are listed in Table 2. Each function has at least one metric. The first function, that the SICCO must connect to the data logger, will be validated based on the number or megabits uploaded through a speed test. Our target we are required to meet is greater than 30 megabits.

Our second function is the live stream monitoring by visual component function. There are multiple metrics for this function. The first is the number of frames per second (FPS). Our target for this is 60 FPS because this is the lowest amount seconds in which the human eye will not notice the buffering of the video. This metric covers a customer need that was not covered by our functions. Our customer asked for a clear video stream of the test, we took this further by determining that a clear video would stream at 60 FPS. Additionally, like the connect data logger to network function the internet speed uploaded in megabits will also be a metric for the live stream monitoring by visual component function. Our target will be greater than 30 megabits. Additionally, the live stream monitoring system must fit within the usable space. Per our customer, the request is that the visual monitoring system does not exceed $6 \times 6 \times 6$ inches. This is an additional customer need that was not included within the functions themselves. The final metric for the live stream monitoring function is the weight. This was also a request from the customer that the live stream monitoring system does not exceed a weight of 20lbs. Since the customer would like to make installation easy, an additional customer need not be addressed by the functional decomposition.

The third function is to save recordings to a database, it will also be validated by a speed test, but by megabits uploaded. Our target goal for this function is greater than 20 Mbps.

The fourth and final target from the functional decomposition is the thermal analysis of the visual component. The metrics for this function is based on the temperature and humidity levels the climatic chambers can test. For the SICCO the temperature range is -73℃ to 180℃ while the humidity levels reach a relative humidity of 98%.

Table 2

Targets and metrics catalog

Functions	Metric	Target
*Connect Data Logger to Network	Internet Speed Uploaded, Megabits (Mbps)	30 Mbps
*Live Stream Visual Monitoring	Frames per Second (FPS)	60FPS
	Internet Speeds Uploaded, Megabits (Mbps)	30 Mbps
	Useable space	6 × 6 × 6 in
	Weight	20lbs
Save Recordings to database	Internet Speed Downloaded, Megabits (Mbps)	20 Mbps
Thermal Analysis of Visual Monitor	Temperature	-73℃ - 180℃
	Relative Humidity (RH)	98% RH

* Critical targets.

1.4.1 Method of Validation

To connect the data logger to the network, Danfoss needs to review and approve of a proposal before granting permission to access their network. Download unclassified chamber test data to use as an experimental data transfer file. A portable laptop with the data transfer file will be connected to the network with an ethernet cable. The laptop provides a screen to more easily debug problems as they arise. Once connected to the network, a design engineer will remotely download the data file from the network onto Vinayak Hedge's office computer. After a successful transfer, the ethernet cable will be connected to the data logger instead of the laptop and another chamber test file will be uploaded to the network. Again, a design engineer will download the data file from the network.

The climatic chamber is constantly in use by Danfoss, therefore, it is not available for us to test data collection directly from a chamber. To test database recording, the data logger will be connected to a video camera, humidity, vibration table, temperature sensor, and component power sensor. A portable laptop computer will be connected to the data logger to display data collected by the sensors and recorded to the database. A Danfoss software engineer has already set up the data logger to organize data from the humidity, vibration table, temperature sensor, and component power sensor; the video file organization will need to be converted to a viewable file. The type of file depends on the devices playing the videos and that has not yet been specified by the customer.

After a suitable camera is selected, the thermal analysis of a visual component can begin. Danfoss has offered their climatic chambers for us to use during testing. The camera without insulation will be placed in a Danfoss climatic chamber and connected to a laptop to display a live video feed. A series of four tests will occur to mimic the tests Danfoss performs on their components. In the first test, the chamber will not be humid and temperature will decrease until the minimum chamber temperature is reached or the camera shows signs of failure. Then the temperature will increase until the maximum temperature the chamber can withstand is reached or until the camera shows signs of failure. The second test will implement humidity and repeat the chamber temperature variations as in test one. The third testing environment will not be humid and the temperature will oscillate for twenty-four hours or until the camera shows signs of failure. The fourth testing environment will repeat the third test with humidity implemented for twenty-four hours or until the camera shows signs of failure.

To test the live monitoring system, the video camera will be set up outside the climatic chamber and connected to the data logger. The data logger will be connected to the network by ethernet cable. In order to test a Danfoss computer, a design engineer will use Vinayak Hegde's office computer to test access to the live video feed from a remote location to the data logger.

1.4.2 Discussion of Measurements

The temperature range target for the Thermal Analysis of Visual Component function was taken from the performance specifications found in the climatic chamber manuals. The range our equipment needs to withstand is -94 to 356 deg F. This is the minimum and maximum temperature that the chamber can create. The humidity target of 98% relative humidity (RH) was found from the Full-Range humidity specifications table from the climatic chamber manuals. Relative humidity is the amount of water vapor in the air expressed as a percentage of what is needed for saturation at a given temperature. The >30Mbps target was arrived at because that is the speed one would need in order to stream live video. Since the testing needs to be live-monitored, the internet upload speed of the data logger must be greater than 30 Mbps. For the live stream monitoring function, we determined that the test must be streamed at 60 FPS or greater so the video is smooth and easily viewable. The usable space metric of 216 in^3 was arrived at because this is the size of most small-scale cameras on the market, and we believe that a camera of this size will not consume too much space in the climatic chamber. A weight fewer than 20 pounds was decided on because most cameras on the market weigh less than 10 pounds. With our mounting system included in the weight of the camera metric, less than 20 pounds will be achievable and will ensure that our camera system is not too heavy for the chamber walls. The target of a download speed greater than 20 Mbps was arrived at so the data is delivered quickly to the user.

1.5 Concept Generation

Concept 1.

Build a prototype that has one corner mounted camera that will fit within the temperature and humidity constraints or be insulated. The cameras will be mounted on opposite top corners of the prototype of the climatic chamber. The prototype of the climatic chamber will be made full size into two pieces that will fit through a doorway. The camera will be live streamed and record by a security system recording device. The data will be made accessible by connecting the existing MEMORY HiLOGGER LR8400 Series data logger to the internet using an Ethernet cable and its ability to create an Https access point.

Concept 2.

Build a prototype of the climate chamber with one outside mounted camera. The camera will be mounted on the right side of the prototype viewing into the chamber through an access port. The prototype of the climate chamber will be built full size into two pieces that will fit through a doorway. The camera will be live streamed and record the test by a security system recording device. The data will be made accessible by connecting the existing MEMORY HiLOGGER LR8400 Series data logger to the internet using an Ethernet cable and its ability to create an Https access point.

Concept 3.

Build a prototype with one camera placed in the front right of the climate chamber. The camera will be mounted to a stand placed in the chamber so it can be removed with ease. The prototype chamber will be three-fourths of the full-scale climate chamber dimensions. The camera will be recorded using a security recording system. The MEMORY HiLOGGER LR8400 Series data logger will be used and connected to the internet with an Ethernet cable. A website provided by the manufacturer will be used to remotely access the data collected.

Concept 4.

A camera suited to work in the temperature range of the chamber will be mounted on a vertical rail in the corner of the climatic chamber. This will allow for the camera to be moved without damaging the walls of the chamber. The data logger that Danfoss currently has will continue to be used to minimize cost and will utilize an ethernet cable to connect to the internet. The prototype of the chamber will consist of a ¾ scale wooden box that will house the camera and mount design.

Concept 5.

A camera will be mounted to a rail on the chamber ceiling so that it can be maneuvered to get the desired view of the component being tested. The MEMORY HiLOGGER LR8400 Series data logger will be used and connected to the internet with an Ethernet cable. The prototype will be a full-scale wooden box of the climatic chamber that is easy to assemble and disassemble so that we can transport it.

Concept 6.

Build a prototype with one camera placed in the front right of the climate chamber. The camera will be mounted to a stand that will be placed in the chamber so it can be removed with ease. The prototype box will be a ¾ scale box of the climatic chamber. The camera will be recorded using a security recording system. The MEMORY HiLOGGER LR8400 Series data logger will be used and connected to the internet with an Ethernet cable. A website provided by the manufacturer will be used to remotely access the data collected.

Concept 7.

A camera will be placed outside of the chamber facing the glass looking into the climatic chamber. The prototype will be a ¾ scale wooden box of the actual chamber. There will be a working door with a plastic “window” with the camera mounted on it to recreate the actual climatic chamber. The MEMORY HiLOGGER LR8400 Series data logger will be used and connected to the internet with an ethernet cable.

Concept 8.

A thermal camera will be used to capture the changing temperature of the components during testing. The camera will be mounted in the corner of the climatic chamber and will be able to capture the component of the part being the test as it heats up and malfunctions. The MEMORY HiLOGGER LR8400 Series data logger will be used and connected to the internet with an Ethernet cable. The prototype will be a ¾ scale wooden box of the actual chamber.

Concept 9.

This concept, to start will use a similar mounting system of a security camera shown below for inside the Climatic Chamber.

The mount will be located directly in the center point of the chamber and be held down by an adhesive glue such as silicone due to it temperature resistance of -50˚ C to 204˚ C. The mount will be fixed and secure while the camera will have the ability to be removed to either change the type of cameras such as thermal or regular vision, or to add insulation to the camera if need be. The camera will record the live stream data and transfer it to a microcomputer such as a Raspberry Pi where it can be collected VIA from the data logger MEMORY HiLOGGER LR8400 Series. The data logger must be connected to the internet where it will transfer the data from the thermal couples and the recordings from the camera into an Https server.

Concept 10.

One way to mount the camera to the climatic chamber is through the ventilation holes. The chamber itself contains small square ventilation holes along the sides and back of the chamber. We will use these holes to hook on the mount for the camera. This mount will be able to be installed and uninstalled with relative ease and without leaving permanent effects on the chamber. The risks of this include blocking the holes reducing the flow in and out of the chamber. Therefore, the chamber itself has a regulating system that will maintain the proper environmental conditions if one or two of the holes were slightly blocked.

Figure 1. Camera mount with hooks to attach to the chamber wall.

Concept 11.

Another possible mounting system introduces screwing on the mount inside the walls of the chamber. This is the most secure option when compared to the other mounting concepts. This would introduce additional holes into the climatic chamber, which could present some issues as the hole could affect the testing environment. It is noted that this might not be a huge risk since the chamber has a self-regulating system that maintains the proper testing conditions even with the additional holes. Another effect of this mounting system is that it is permanent. Once the holes are drilled for the screwed they cannot be undone. While the mount could be unscrewed, it will leave at least two holes in the camber behind.

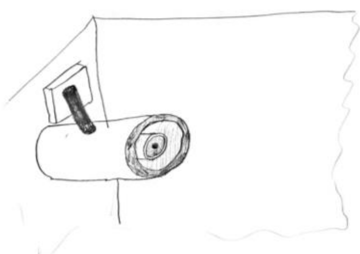

Figure 2. The camera mount is screwed to the chamber walls.

Concept 12.

Using an adhesive or type of glue is one possible mounting option. This option would have to withstand the environmental conditions of the chamber. In the extreme hot and cold temperatures, the adhesive or glue will have to hold its form and not fail. Additionally, it will have to maintain top performance in the humidity environments. The adhesive could be permanent or could be removed with a special chemical. While the chemical will remove the mount from the chamber walls it would still leave some sort of residue on the chamber. How the adhesive itself would chemically react to the metallic walls of the chamber will need to be investigated. The advantages of this mount are that it will require little maintenance and not add additional holes or block any current holes in the chamber.

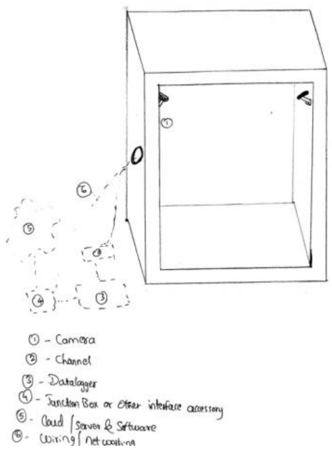

Figure 3. The camera mount is an adhesive and is placed inside the chamber.

Concept 13.

Another option for the mount of the system is a completely external mount. In this case, the camera will be outside the chamber. This mount will be placed outside the window of the chamber by the Thermocouples. With the mount in this location, the camera will have a side view of the equipment being tested. The advantages of this mount are that it will not have to withstand the harsh environmental conditions of the chamber. The main disadvantage of this mount is the possibility of it being in the way between tests.

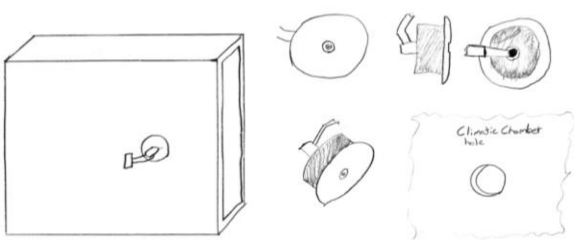

Figure 4. An external camera mount where the camera views the component from a window.

Concept 14.

The outside door mount shown below is like the previous outside window mount. This mount is externally located by the door window. Like the outside window mount, this mount will not have to endure the environmental extremes of the chamber but will create an obstacle when trying to open the door.

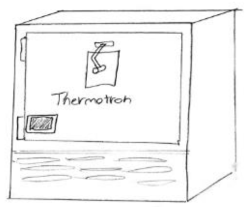

Figure 5. The camera mount is outside the chamber and views the component from the door window.

Concept 15.

Drilling holes through the top of the chamber and introducing fiber optics is also a mounting option. This option will have the camera at the ends of the fiber optics while the top of the chamber will hold the ends of the fiber optic cables. The advantage of this is there will be multiple cameras which will provide for multiple angles of the equipment being tested. Another advantage is the mounting system will be relatively small and out of the way considering the bulk of the mount will be on top of the chamber. The disadvantages of this mount are that it is expensive. Additionally, this mount introduces irremovable holes into the chamber. If the mount is removed these holes will stay on the top of the chamber.

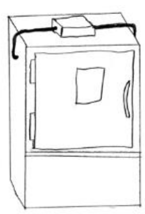

Figure 6. The camera mount is screwed to the inside chamber walls.

Concept 16.

The box mount will be like the mount with screws. The box mount will be larger and possibly require more screws. More screws will also require more holes to be drilled into the walls of the chamber. The advantage is the camera will be within the mount and therefore be more protected from the environmental conditions. Due to this, this amount will be larger than any of the other possible mounts. This could limit the size of the equipment being tested, but the size will still not exceed the max size within the project targets. The box mount will be able to be uninstalled with the removal of the screws.

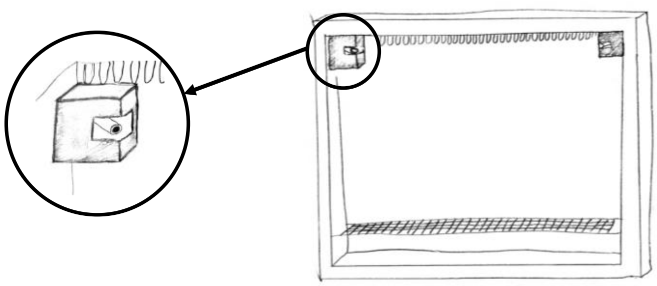

Figure 7. The camera mount, inside the chamber, surrounds the camera and is screwed onto the chamber walls.

Concept 17.

The camera can be suction cupped to the wall. This will eliminate the need to drill holes in the chamber and the camera will be able to be moved whenever necessary.

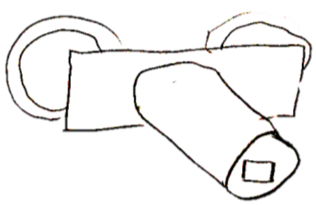

Figure 8. The camera mount is two suction cups.

Concept 18.

Inspired by flamingos, the camera can be mounted on legs placed at the chamber floor. This way, the camera can be easily moved and the climate chamber walls will remain intact.

Concept 19.

The camera will be mounted on a rail attached to the climate chamber ceiling. It will be able to slide along the rail to get a better angle on the components being tested, and the mounting system wouldn't take up very much space inside the chamber.

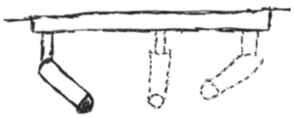

Figure 9. The camera mount is a rail track.

Concept 20.

The camera can be placed inside an insulated box inside the chamber. This will reduce the need for a camera that can survive the chamber climate itself, as the insulated box would protect the camera.

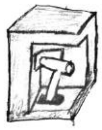

Figure 10. The camera mount with insulation.

Concept 21.

We can use a two-camera system. One will be placed in the chamber, and when it reached a certain critical temperature, it will automatically exit the chamber and be replaced by the second camera.

Concept 22.

The camera can be attached to the grate inside the chamber, so that nothing needs to be attached to the walls of the chamber.

Concept 23.

Metal fins can be attached to the camera. The idea is that the fins will dissipate the heat away from the camera so that our camera remains in working condition.

Concept 24.

Our camera can have a heating mechanism attached to it inside the chamber. When the testing conditions become too cold for the camera to operate, the heater will activate to protect the camera.

Concept 25.

A mirror can be placed inside the chamber so that we can get a view of both sides of the tested component without the need for multiple cameras or camera movement.

Concept 26.

Air from outside the chamber at ambient temperature can be pumped onto the camera to keep the camera at room temperature.

Concept 27.

The camera can be attached to the glass window, outside the chamber, looking into the chamber with a cat eye lens. This way, the camera will be protected from the conditions inside the chamber.

Concept 28.

A close hanger style mounting system where a rod is stuck in place with force on the top and bottom of the chamber. The camera will be attached to this rod so it can be adjusted vertically without having to damage the walls of the chamber.

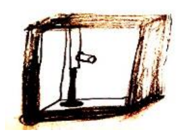

Figure 11. A rod camera mount with adjustable height settings.

Concept 29.

By using a small camera, we can insulate and mount it easier without damaging the walls of the climatic chamber and not take up too much room inside.

Concept 30.

Attaching strips of Velcro to the chamber wall and camera is one option to mount the camera. It would be easy to install and uninstall and give the option to have mounts in multiple locations in the chamber, therefore, it has some environmental limitations.

Concept 31.

Magnets can be glued onto the back of the camera as well onto the chamber walls. This would be able to withstand most intense environments as well as reduce the installation time. There could be issues with making the magnets stick to a non-magnetic surface.

Concept 32.

A metal or wood shelf can be added inside the chamber for the camera to sit on. This will reduce the need for any modifications, in terms of mounting, be done to the camera itself. The shelf will take up a good amount of room and require some holes drilled into the walls.

Concept 33.

Using the ventilation holes in the back of the chamber, the camera can be strapped down using elastic straps with plastic hooks on the ends, like bungee cords. This will reduce the need for any permanent changes be made to the chamber or camera.

Concept 34.

Using Copper or another similar metal, the camera can be welded onto the walls of the chamber. This will be a permanent mount and neither the weld or the camera will be able to be removed without significant effort.

Concept 35.

Using a 3D CAD application and a 3D printer, a mount can be specially designed for the camera and the chamber wall. But in extreme temperatures the mount can melt, leading to failure.

Concept 36.

The camera can be mounted to the wall using duct tape. This will be simple to install and uninstall if needed. Additionally, if applied under normal conditions the tape will be able to withstand the environments, therefore, it is unknown how long it will be able to maintain its abilities in these environments.

Concept 37.

Along the wall of the chamber, there will be a metal slot while on the back of the camera there will be two wheels. The wheels will then slide into the metal slot and be able to be adjusted along the side to an angle desired for viewing. The downsides of this concept are it can vibrate and shift during testing or fall off the slot altogether.

Concept 38.

We can use a thermal camera inside the chamber. Thermal cameras can withstand higher temperatures than regular cameras and have the potential to see the part fail easier.

Concept 39.

We can use a fiber optic camera. Due to its small size, we will be able to insulate the camera easier and the camera and mounting system will not take up much space inside the chamber.

Concept 40.

We can use a regular camera. They are easily accessible and relatively cheap compared with specialty cameras. Better lighting will need to be installed in the chamber.

Concept 41.

Using a night vision camera inside the chamber will is beneficial because there is no need for a light inside the chamber.

Concept 42.

Using a GoPro camera will eliminate the worry about the high humidity operation in the chamber. It is small, easy to mount, and it will not reach the upper and lower temperature limits of the chamber.

Concept 43.

A cellular device camera will be easy to set up and operate. Additionally, it will be able to easily send the final video of the test through email or SMS text message.

Concept 44.

Danfoss can hire someone to watch the test through the chamber door and write down observations as the test is taking place. This will remove the need of trying to find a camera that meets the specifications of the climatic chamber.

Concept 45.

Danfoss will use the HiLogger LR8400 to collect the data from the thermal coupler VIA wire. Data can be acquired and monitor through an ordinary web browser on a PC.

Concept 46.

Danfoss will use the LR8410 to collect data wirelessly from the receiver. Data can be acquired and monitor through an ordinary web browser on a PC or FTP server.

Concept 47.

This concept will use an Ethernet cord to connect the data logger to the Danfoss server. This will eliminate any wireless connection issues, but increase the number of wires on the floor of the climate chamber room.

Concept 48.

Using wireless internet connection between the server and data collector removes any issues that might be caused due to faulty wires or Ethernet cords.

Concept 49.

The user will be able to watch the live stream video feed through the secure URL provided to them. The brand *Livestream* uses Secure Sockets Layer (SSL) to secure a live stream from website hacker traffic free of charge.

Concept 50.

Vimeo Premium provides HD 24/7 live stream, ad-free, for $75 a month via their application or website. Up to 7 TB archived storage is provided. The setup is simple; only a camera and an RTMP-enabled encoder, which sends live recordings to Vimeo, are needed. It is unclear if the live stream is on a secured website.

Concept 51.

A software engineer with experience in live streaming classified videos will be hired to create the user interface. It is up to his discretion the best solution for the job. Preferably, a software engineer at Danfoss will be located.

Concept 52.

The videos can be live streamed and saved on a YouTube channel. The channel can be made private if Danfoss does not wish to have its tests visible to the public. YouTube is user-friendly and most Danfoss employees will already have some sort of experience with YouTube.

Concept 53.

Facebook live is a new way to share live videos as well as save past videos. It is increasing in popularity and, like YouTube, is also able to restrict who views the videos. Since most Danfoss employees will have a profile on Facebook they will simply just need to be added to the Facebook page that will post the live stream and past videos.

1.5 Concept Selection

Arguably one of the most important steps in the design process is concept selection. The final decision is expected to satisfy not only the requirements of the customer but also the laws of engineering to guarantee safety and longevity. The first 9 concepts, previously described in concept generation, were compared by a House of Quality, Pugh chart, and Analytical Hierarchy Process.

1.5.1 House of Quality

The house of quality is an important tool for concept selection. It allows us to illustrate customer requirements, engineering characteristics, and the parameters with each ranking of weight factors. Below, the House of Quality is seen in Table 3.

Table 3
House of Quality

		Technical Requirements									
Customer Requirements		Priority	Weight (Lbs.)	Max Size (Inches Cube)	Life of Camera (Hrs)	Temperatures Range (°C)	Internet Speed(MB)	Frame per Second	Relative Humidity	Cost	Area of view
	Remote Transport	2	2		1		1				
	Real Time Visual System	4	4	3	1	9		3	3	9	9
	Risk Assessment	1	1	1	1	3		1	1		1
	User Interface	2					1	9		1	3
	Budget	1								9	
	Raw Score	**213**	**13**	**15**	**5**	**39**	**4**	**31**	**13**	**50**	**43**
	Relative Weight	**%**	**6.10**	**7.04**	**2.35**	**18.30**	**1.87**	**14.55**	**6.10**	**23.47**	**20.19**
	Rank		**6**	**5**	**7**	**3**	**8**	**4**	**6**	**1**	**2**

From what is shown above, Customer Requirements (CR), previously discussed in the Evidence Manuel, is listed in the first column. Out of the five CR, the real-time visual system was rated the highest priority with a score of 4 out of 5, while the remote transport tie in second with the user interfaces with a 2 out of 5. The CR help establishes the appropriate technical requirements (engineering characteristic) to achieve our customer needs. These engineering characteristics such as the system weight, the area of view, temperature range, etc. will play a major role when integrating our climatic system with a monitoring system. Combing our CR with our technical requirements will help validate which parameter can affect the overall design. Out of the nine parameters, the top three rankings was the cost of the system, the angle of view and the temperature range. The temperature range plays a crucial role in the real-time visual system, thru making sure our camera can withstand our target range. A high area of view will permit a better visual feedback on the monitoring system which plays a critical part on the location and setup of the mounting for the visual system. The last two parameter help establish a groundwork for our number one ranking parameter the cost. To design our climatic system with a monitoring system it must not exceed our budget, however, the majority of our budget goes to the selection of our camera that can withstand the temperature range. Therefore, our group will not make any large design changes or select concepts of the monitoring system, instead, we will move on to the Pugh matrix to help narrow our choice between our concepts.

1.5.2 Pugh Charts

Two Pugh charts were needed to compare the concepts. The first Pugh chart, Table 4, compares concepts one through nine to the datum, a standard security camera. 1080p HD Weatherproof Night-Vision Security Camera will be the camera that will be used as concept *A* for the Pugh matrix. The concept parameters used for comparison is the cost, temperature range, frames per second magnitude, maximum size, total weight, and relative humidity. The camera price is $119, the temperature range -22°F to 140°F, the recording speed is 30 FPS. The first concept had the majority the same characteristics as the datum except for a wider temperature range, making it the most favorable concept based on this chart. The eighth concept is the least favorable because it is lacking in six characteristics based on the datum. Ultimately, concepts one through 6 were selected for a second Pugh chart comparison because they ranked very similar to one another.

Table 4

First Pugh chart comparison of the top nine concepts.

	Concepts									
Criteria	A	1	2	3	4	5	6	7	8	9
Cost	Datum	S	-	-	-	-	S	S	-	-
Area View		S	+	+	S	+	S	-	-	S
Temperature		+	S	+	+	+	+	S	S	+
Frames Per Second		S	S	-	S	S	S	-	-	S
Max Size		S	-	-	-	-	-	S	-	-
Weight		S	-	-	-	-	-	S	-	-
Relative Humidity		S	S	S	S	S	S	S	-	S
	Pluses	1	1	2	1	2	1	0	0	1
	Minuses	0	3	4	3	3	2	2	6	3
	Net	1	-2	-2	-2	-1	-1	-2	-6	-2

In Table 5, as concept five as the datum, concept one and six ranked higher than all others. One and six have a perfect tie as each characteristic compared the same to the datum. The only negative of the two concepts is the viewable area and this can be combatted with the installation of mirrors or a different orientation of the test object. According to the second Pugh chart, concepts one and six should be further inspected to determine if they are in fact the best concepts for the project.

Table 5

Second Pugh chart comparison of concepts one through four and six to the new datum, concept five.

Criteria	5	1	2	3	4	6
Cost	Datum	+	-	-	S	+
Area View		-	+	+	-	-
Temperature		S	S	+	S	S
Frames Per Second		S	S	S	S	S
Max Size		+	S	+	S	+
Weight		+	S	-	S	+
Relative Humidity		S	S	S	S	S
	Pluses	3	1	3	0	3
	Minuses	1	1	2	1	1
	Net	2	0	1	-1	2

1.5.3 Analytical Hierarchy Process (AHP) (Kyle)

We used the Analytical Hierarchy Process (AHP) in order to mathematically rank the final 3 concepts and complete the concept selection process. To begin the AHP, a criterion selection hierarchy was established, in Table 6. These criteria included cost, area view, temperature, FPS, max size, weight, and relative humidity. A pairwise matrix was created in order to compare the criteria weight in each concept. This matrix was then normalized by dividing each element by the sum of the column it was in. The figure below shows the Normalized Criteria Comparison Matrix of the first concept, as an example of the AHP we went through.

Table 6
Normalized Criteria Comparison Matrix [NormC] Concept 1

	Cost	Area View	Temperature	Frames Per Second	Max Size	Weight	Relative Humidity	Criteria Weights {W}
Cost	0.050	0.019	0.059	0.033	0.205	0.017	0.066	0.064
Area View	0.149	0.057	0.083	0.033	0.014	0.153	0.039	0.075
Temperature	0.347	0.283	0.415	0.294	0.205	0.254	0.591	0.341
Frames Per Second	0.149	0.170	0.138	0.098	0.123	0.254	0.039	0.139
Max Size	0.010	0.170	0.083	0.033	0.041	0.017	0.028	0.055
Weight	0.149	0.019	0.083	0.020	0.123	0.051	0.039	0.069
Relative Humidity	0.149	0.283	0.138	0.490	0.288	0.254	0.197	0.257
Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Upon normalizing the comparison matrix, the criteria weight was established by averaging each row. The most important two criteria were temperature and relative humidity. The least important was found to be maximum size and cost, followed closely by weight. We completed the process of comparing each of our three concepts for all seven of our criteria. This allowed us to generate the final rating matrix shown below, Table 7.

Table 7
Final Matrix

	Concept 1	Concept 2	Concept 6
Cost	0.48	0.11	0.41
Area View	0.29	0.30	0.14
Temperature	0.16	0.50	0.19
Frames Per Second	0.19	0.25	0.16
Max Size	0.21	0.66	0.10
Weight	0.24	0.10	0.62
Relative Humidity	0.07	0.50	0.18
Sum	0.2331359	0.34642273	0.255760817

The cells of this final rating matrix contain the average of the normalized rankings for each criterion and concept. This data was transposed and multiplied by the weighting of each criterion to rank our final three concepts, shown below in Table 8.

Table 8
Alternative values for final concepts.

Concepts	Alternative Value
Concept 1	0.178421194
Concept 2	0.406682782
Concept 6	0.216784313

Concept 2 came in first place, which is ultimately the concept we have chosen. Concept 6 came in second, followed by concept 1. If for any reason concept 2 becomes unfeasible and we must abandon it, we will revert to concept 6.

1.5.4 Decision

Based on the results of the AHP process, Concept 2 is the final concept selected. The advantages of this concept include that it has two cameras. The benefits of having two cameras are it will allow for two different angles on the equipment being tested. Additionally, because the cameras will be mounted on the outside of the chamber the cameras themselves will not need to be able to handle the humidity and temperature ranges of the chamber. This will remove any need for insulation for the cameras. Therefore, some problems that the team could face include trying to get a clear view of the equipment under test. This is because the cameras will be mounted relatively low to the chamber floor.

1.8 Spring Project Plan

Chapter Two: EML 4552C

2.1 Spring Plan

Project Plan.

Build Plan.

Appendices

Appendix A: Code of Conduct

Mission Statement

Danfoss Turbocor Inc. has reached out to the FAMU-FSU College of Engineering for help to develop a Smart Integration Climatic Chamber Operation system (SICCO). During climatic testing, continuous monitoring of the testing and the collection of data is essential. The SICCO will use cameras and sensors to ensure the item being tested has not moved or failed. If the sensors detect any possibility of failure it will send a notification to the test monitor(s). The cameras will also be capable of recording video footage for the monitor(s) to watch the test live or go back and observe exactly where, when, and why the test failed. The current system requires the test engineer to walk to the test chamber and use a flash drive to manually collect the data from the chamber. The second part the SICCO will create a remote data collection system and a prototype of the systems created; where the data can be assessed during the test and stored on a server for post-test analysis.

Team Roles

All team members are responsible for every class assignment and project requirement. The following roles encompass the majority of all project needs however the duties that do not fall under one of the following roles is expected to be completed by anyone in the group with availability to do so.

Lead Engineer

~~Team Leader~~: Cassie Roby

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The team leader will be responsible for ensuring that all other members are on track and fulfilling their roles. The team leader will take attendance at all meetings as well as deal with absences. During meetings, the team leader will lead the meeting as well as ensure all members are actively participating. In the event of a conflict, the team leader will be responsible for resolving the issue or consulting Dr. McConomy to resolve the problem.

Engineering Design Lead: Daniel Lane
The engineering design lead is in charge of the technical engineering parts of the project as well as making the final decision on all design aspects. The design lead will be responsible for the accuracy of all CAD work, drawings, calculations, and code. The design lead will make sure the design is in line with what the sponsor desires and is asking. The design lead will manage the design engineer and ensure they are completing all tasks delegated to them.

Systems Engineer: Sara Steele
The communication and documentation manager will oversee all communication between team members, sponsors, and advisors. All email correspondence will be through the communication

manager with team members and Dr. McConomy carbon copied. The documentation manager will oversee converting any documents from the google drive to the final document format. This includes editing as well as checking for grammar errors. This manager will also supervise submitting all deliverables on Canvas for grading and sending the final document to the web designer so it can be added to the web page. The communication and documentation manager will also manage taking meeting minutes and uploaded those to Canvas as needed as well as sending these to all team members and sponsors.

Project Manager: Kyle Barber
The financial planner manages the budget and records all credits and debits to the project account. Expenditure requests must go through the financial planner, who will review and analyze alternative solutions. The financial planner will relay the budget information to the team and sponsor, and fulfill requests in a timely and professional manner. The project manager will lay out and keep track of the timeline of the project. They will ensure that the team is aware of all deadlines and makes the appropriate actions to complete the events on time. The project manager will be responsible for creating the Gantt Chart. The timeline will be reviewed by Dr. McConomy and the sponsor before a final draft is completed.

Design Engineer and Web Designer: Danny Carlos
The responsibility of the web designer is to create and design the web page. The web page is expected to be professional in appearance and all deliverables are updated to the site as they are completed by the documentation manager. They will also be in charge of taking pictures at meetings or presentation and posting them on the web page. As a design engineer, they will support the design lead. This includes, but is not limited to, any CAD work or drawings that need to be done. They will also assist in testing the product for any issues as well as ensuring all calculations are done properly and correctly.

Communication

For team members, the main source of communication will be through regular meetings at 2:00PM every Tuesday and Thursday as well as the GroupMe application. We will also use Google Drive to help file transfer and proliferation. For communication with advisors and sponsors, we will use our FSU emails as well as in person weekly meetings. Dr. Yahgoobian has a busy schedule making in person meetings scheduled based on her availability. Sponsor meetings will be the first Wednesday of every month at 12:30PM at Danfoss Turbocor Inc. In person meetings and over the phone conversations will have minutes recorded and emailed to all whom the discussion concerns. Thus, each member of the group will be required to check GroupMe and their email multiple times a day. To cancel a meeting, the decision must be made 12 hours before the meeting. Additionally, a notification through email must be sent to those invited that it has been canceled.

Ethics

Team members are required to be accustomed to the National Society of Professional Engineers (NSPE) Engineering Code of Ethics. They are responsible for their obligations to the public, the client, the employer, and the profession and follow the NSPE Engineering Code of Ethics in their design.

Dress Code

The dress code for team meetings will be casual attire. Meetings with advisors and sponsors will be conducted in casual to business casual attire on a case by case basis. All presentations will be conducted in formal business attire. Meetings at Danfoss Turbocor, Inc. will require eye protection, steel toe caps, and hear protection all provided to the team by Danfoss. Business casual attire for men includes polos or button-down shirts and pants. For females, business casual includes a modest blouse and dress pants without rips. Formal business attire for males is defined as a suit, tie, and pant slacks. Formal attire for females is defined as business pants or skirt with an appropriate blouse. Men will be cleanly shaven or, at a minimum, have an up kept beard. Women will have a clean, professional hairstyle and avoid wild colors or looks. All team members are expected to present themselves in a professional manner at all times.

Attendance Policy

Attendance will be taken at the beginning of all meetings. All members are expected to be present to meetings and presentations. If any conflict arises that hinders a member from attending a meeting or presentation the member is expected to inform the team leader within 24 hours prior to meeting or presentation time. The electronic calendar invite will need to be changed to decline as well as sending a GroupMe message. In the case of an emergency, the member is expected to notify the team leader before the start of the meeting to not delay the meeting. All meetings will start promptly at their scheduled time. If any member is out of town for any reason, the member will be expected to Skype or call into the meeting. Members are expected to attend all meetings and repeated absences will not be tolerated. All team members are expected to be able to meet for a full team meeting once a week unless the entire team deems it unnecessary. The weekly meetings day and time will be determined a by all team members a week prior.

Statement of Understanding

The signing of this document means that I acknowledge and fully understand the contents of this Code of Conduct and agree to comply by all guidelines.

Danny Carlos	01/08/19
Kyle Barber	01/08/19
Sara Steele	01/08/19
Cassie Roby	01/08/19
Daniel Lane	01/08/19

Statement of Understanding

The signing of this document means that I acknowledge and fully understand the contents of this Code of Conduct and agree to comply by all guidelines.

Cassie Roby	9/13/18
Daniel Lane	9/13/18
Danny Carlos	9/13/18
Kyle Barber	9/13/18
Sara Steele	9/13/18

Appendix B: Functional Decomposition

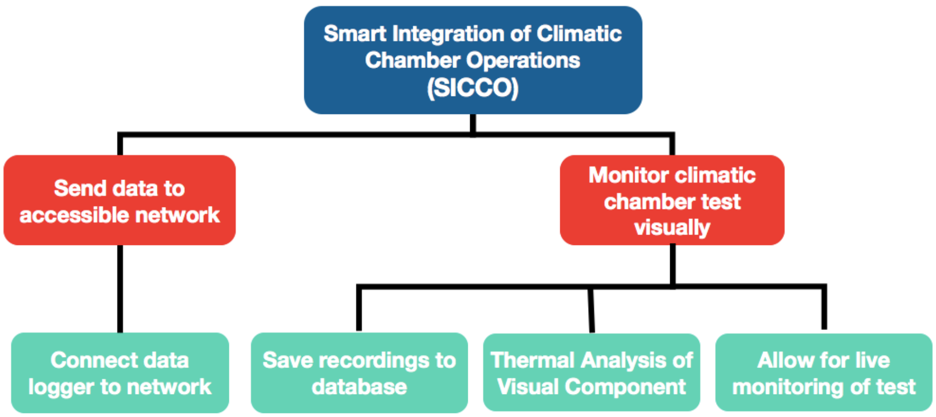

Figure 1. SICCO function structure.

Appendix C: Target Catalog

Functions	Metric	Target
*Connect Data Logger to Network	Internet Speed Uploaded, Megabits (Mbps)	30 Mbps
*Live Stream Visual Monitoring	Frames per Second (FPS)	60FPS
	Internet Speeds Uploaded, Megabits (Mbps)	30 Mbps
	Useable space	6 × 6 × 6 inches
	Weight	20lbs
Save Recordings to database	Internet Speed Downloaded, Megabits (Mbps)	20 Mbps
Thermal Analysis of Visual Monitor	Temperature	-73℃ - 180℃
	Relative Humidity (RH)	98% RH

* Critical targets.

Appendix D: Figures and Tables

References

There are no sources in the current document.