Costa Rica Fire Protection Academy Heat Training Simulator

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Abstract

Our team designed a heat-controlled laboratory simulator for the Bomberos of Costa Rica to prepare themselves for the conditions that they will face in their work. This simulator contains exercise equipment and heating controls for use in testing human responses to heat and humidity. Our team also created a readiness survey to determine how mentally prepared a trainee is to begin work as a firefighter, as well as an anxiety scale to be used to monitor a trainee's condition while in the simulator.

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Executive Summary

The Bomberos of Costa Rica defend their entire country from all natural disasters ranging from wildfires to earthquakes. Becoming one of the Bomberos is a strenuous process, requiring training, studying, and countless hours of service. The Bomberos national training academy is constructing a new facility to expand their 75 station reach and help train future generations of the country's protectors. Inside this new facility will be a heat and humidity-controlled chamber, where the Bomberos want to replicate the interior conditions to be closer to those of the conditions that will be present in their work environment.

The heat acclimatization chamber is an important addition to the training regimen of these brave firefighters due to the lack of experience in intense conditions that beginners, and even sometimes seasoned veterans have. Heat stroke and heat exhaustion have lasting effects on the human body; and psyche, leaving some unable to resume in their line of work after an incident. A large number experience intense Post Traumatic Stress Disorder (PTSD) long into their life after such incidents. Training for up to thirty-minute increments in this heat chamber should help to prepare the Bomberos for the stresses involved in their everyday job. Firefighters across the globe have neglected addressing problems related to PTSD, and psychic trauma stemming from their line of work. In this study, besides addressing physical heat acclimatization, we explored how firefighters can get training in mental preparedness; as well, as this has already been proven to increase people's overall endurance.

The heat-training chamber proposed by the Bomberos is an 8' x 20' x 8' metal shipping container with no added lighting or electricity as it currently stands. The goal of this project was to propose how to outfit this container with insulation, heating equipment, electricity outlets,

lighting, and thermostat and humidity controls that can accurately and easily change the conditions in the chamber. We explored, compared, and contrasted different options for each parameter and developed the best feasible designs for the Bomberos to use to build the chamber according to their needs, as well as fit within an allotted budget. The chamber needs to be able to accommodate two active Bomberos while exercising, the necessary workout equipment such as treadmills, air bicycles, ergometers, stair steppers, as well as equipment for the Bomberos to conduct small drills inside the chamber. To arrive at an appropriate design we drew inspiration from existing laboratories, and chambers from across the globe, as well as routinely consulted with the Bomberos sponsorship team to make sure we were staying within their expectations.

Prior to developing the design of the chamber, we were also tasked with evaluating the current state of mental preparedness training of the Bomberos, as well as evaluate the importance of psychological topics in the first responder profession. Of which, we studied how firefighters experience fear, stress, and anxiety, what the Bomberos as well as other fire departments are doing about it, and developed suggestions on how to better train new employees on how to manage these mental obstacles. In doing so, we interviewed mental health professionals as well as firefighters with firsthand experiences of trauma, gathering data to draw conclusions.

Forest fires, building fires, and natural disasters all present great threats to the Bomberos and the people of Costa Rica. The expansion of the training and fitness regimen of the Bomberos has never been more important, as they are the country's first line of defense for a multitude of tragedies. They must always be ready. The heat acclimatization chamber's development will prove useful as it will greatly aid in the mental and physical preparedness for the Bomberos, and serve as a benchmark in their training routine.

1. Introduction

Fire safety is a worldwide problem. Governments of most countries all over the globe invest in ensuring that their territory and their citizens are safe from fires, natural disasters, and emergencies. These investments provide resources for training, equipment, and also research and development to improve fire safety and emergency response technology. The firefighters handling the emergencies need to be both physically and mentally prepared in order to do their jobs effectively. If they are not prepared, then they put themselves and those involved in the emergencies at a higher risk than they are already at (Universitas 21, 2019).

Costa Rica's Bomberos are no exception to the fires caused by human activity or nature. Costa Rica's high lowland temperatures, as well as its mountainous regions require that the Bomberos are well prepared to handle a range of emergencies. Since 1965, training must be completed to earn one's place within the Bomberos (Bomberos de Costa Rica, 2021). Founded in the 1990s, la Academia Nacional de Bomberos (The Costa Rican Fire Training Academy) has been available to introduce and refine firefighting skills for new members of the Bomberos. Since the inception of this training academy, the training locations and equipment of the Bomberos have improved. New technology has been developed, new techniques have been refined, and methods of training have been improved. However, there are still conditions that the Bomberos seek to improve their readiness for, such as the high heat conditions of fires, and the mental stresses related to responding to life-threatening emergencies.

There have been many organizations, universities, homeowners, etc. who have created heat-controlled simulators (Athlete365, 2021). This has been done to help those in need of high temperature training. The main categories of people who these simulators have been designed to

help include athletes, race car drivers, and others seeking special training (Oliveira, 2017). While a majority of these simulators do not target firefighters, designing one that is for firefighter training is possible.

What the Bomberos and their training academy want to improve on can be split into two main components, the physical wellness and the mental wellness of the Bomberos. The mental health of the Bomberos is a factor when it comes to their overall well-being. It is known that firefighting is a dangerous profession, and many firefighters experience difficult scenes which they can struggle with mentally (SAMHSA, 2018). This problem opens a research gap in the profession, due to the lack of evidence proving that a heat-controlled simulator will alter the effects of Post Traumatic Stress Disorder, along with other lasting mental conditions caused on duty. This mental burden can cause firefighters to work less efficiently and feel emotionally drained, which does not allow for a safe work environment as they cannot work to their full potential. Providing a support system for the Bomberos to talk about these difficulties may allow them to get that load off of their chests and feel better mentally.

The goal of this project was to propose to the Bomberos an infrastructure design, estimated budget, and recommendations for further action for a new heat-controlled training simulator, and to identify how to address the physical and mental stressors of firefighting. To do this, our team proposed an inventory of what equipment would be needed to accomplish this goal, proposed a layout and design for the simulator, developed a cost analysis of the simulator, and interviewed the Bomberos to determine what the training procedures would entail and to identify the mental stressors that they may face and how to best prepare them for these stressors. This project will be important to the Bomberos and to Costa Rica as the more experience that the

Bomberos have in their training in this environment, the better prepared they will be to help those in need when an emergency occurs.

2. Background/Literature Review

As we identified what belongs in a heat-controlled laboratory simulator, we reviewed general fire data in Costa Rica and the fire codes provided by the NFPA to understand how to replicate that data within the simulator. Additionally, we reviewed similar simulators such as: Fresno State Hydration Exercise and Thermoregulation Lab, Porsche Human Performance Center Heat Chamber, Ohio Fire Academy Mobile Search and Rescue Training Lab, and some DIY heat training. This gave us a better picture as to what our final design would look like and helped us piece together the materials and components needed. We would like to touch on what the Bomberos have done so far to make sure their firefighters are physically fit, as well as what their current training procedures are. This is needed to understand the Bombero's specific needs for this simulator and customize the design based on these needs. Finally, we took an extensive look at how mental health is affected in the firefighting profession worldwide, and how we may address the varying mental stresses involved in the profession. This is critical because it gave us some idea as to what we could provide to the Bomberos in terms of mental health assistance.

2.1 NFPA Codes and Fire Safety

Governments are not the only organizations working towards fire safety. The National Fire Protection Agency is an international organization that works to standardize safety practices related to fire and electrical safety (National Fire Protection Association, 2006). The NFPA has published "more than 300 consensus codes and standards intended to minimize the possibility and effects of fire and other risks". This organization can be depended on to keep a structured set of codes to keep people safe from the avoidable dangers of fire and electrical hazards. Code 1582

touches on the safety and wellbeing of firefighters. There is a list of requirements that each fire department must follow that requires firefighters to get physical examinations and tests done annually. This code is set to make sure that the physical well-being of firefighters is being consistently checked on and to make sure that they will be able to work safely as well as efficiently.

2.2 Fresno State Hydration, Exercise and Thermoregulation Lab

Fresno State University in California developed their Hydration, Exercise and Thermoregulation Lab in 2017. Dr. Luke Pryor, the leader of this project, spent time completing research on how athletes' bodies respond to completing various exercises in the heat, (*Fresno state hydration, exercise and thermoregulation lab*, 2017). The project is a heat-controlled chamber for athletes to train in with the goal of increasing performance in the hot sun on game day. They aimed to create better hydration and conditioning plans based on the information they collected by studying student athlete's performance while exercising in the chamber. The university also planned to open the chamber up to firefighters in the community looking to train and better understand how their bodies react to the high temperature conditions of firefighting.

In 2017, Howard Pechter, a Southern California fire captain suffered two heat-stroke related episodes in a short period of time (Hashem, 2019). Pechter wanted to learn more about the cause of this and to acclimate his body to be able to handle these conditions. Thanks to the power of the chamber, Pechter was able to get appropriate training and acclimatization, as well as answers about what was going on in his body.

The Fresno State chamber has proven to be useful, and it is clear that it can be used as a model for the development of a system in Costa Rica (ABC, 2017). Further supporting this is a

firefighter specific study published by the Federation of American Societies for Experimental Biology Journal (FASEB) in 2019 stating that “The heat acclimation program performed in fire stations during daily duty in firefighters wearing thermal insulation clothes reduced heat stress with enhanced thermoregulatory responses…” (Takeda et al., 2019, p. 1). This makes the benefits of the heat acclimatization testing undeniable, and more imperative for the Bomberos to have the proper acclimatization, as the average temperature in Costa Rica is around 88 degrees in summer months with over 180 hours of straight sunshine.

2.3 Porsche Human Performance Center Heat Chamber

Similar to the heat chamber at Fresno State University, the automobile manufacturing company Porsche has developed a heat-controlled exercise chamber located in Towcester, United Kingdom (Porsche cars Great Britain ltd., 2021). For Porsche, this chamber was important to develop as “Dealing with the heat whilst racing is one of the biggest physiological challenges faced by any athlete, particularly in motor racing and endurance events” (Porsche cars Great Britain ltd., 2021, Heat acclimation, para. 2). This chamber, which contains a treadmill and a high temperature climate, allows for drivers, athletes, and others to train in high temperatures in order to prepare for the heat that they will face.

2.4 Ohio Fire Academy Mobile Search and Rescue Training Lab

The Ohio Fire Academy has a mobile training lab that simulates an apartment on fire and allows firefighters to learn how to search and rescue people who are in danger (Piorkowski, 2012). This lab contains two floors with very little light and smoke machines to simulate the

conditions of an apartment fire. Firefighters in training are assigned to search for three people within the lab while wearing full gear in order to give them the most realistic experience possible. This lab can move around to different locations and brings training to firefighters who may not have access to such facilities otherwise. Real life situational training similar to this simulator is valuable to firefighters both new and experienced as any practice on situations one may face on the job allows one to make better decisions in the moment.

2.5 Do-It-Yourself Heat Training

Designing high-cost heat training chambers is not the only way for individuals to train for high temperature events. For some, creating a "do-it-yourself" heat training exercise space at home is a simpler and more affordable option. This method is used by some training for the Olympics, according to Dr. Yannis Pitsiladis, a member of the IOC Medical and Scientific Commission Adverse Weather Impact Expert Working Group (Athlete365, 2021). Dr. Pitsiladis states "High-tech environmental chambers are great, but you don't need a chamber costing half a million dollars to prepare. When I worked with elite runners in Africa, we went into one room of a house and put in pots of boiling water, heaters, gadgets to measure the temperature and a treadmill. You don't need specialist equipment to prepare" (Athlete365, 2021, Will it cost a lot of money?, para. 3). This statement shows that heat training could be accessible to anyone, not just those with the high technology solutions funded by large budgets.

2.6 General Data Regarding Fires in Costa Rica

Fires in Costa Rica peak in the summer months, as forest fires soar exponentially and out of control (Zúñiga, 2020). Costa Rica experienced 50,000 hectares of forest fires in 2019. Trees in a forest fire will burn at approximately 572 degrees fahrenheit and will sit at a burning temperature over 1,000 degrees fahrenheit. It is of the utmost importance that the Bomberos are prepared to fight these fires in the most extreme of circumstances. In recent years, the Bomberos have made serious efforts to attempt to entirely eliminate forest fires with a "Summer Without Forest Fires" Campaign in 2019.

2.7 Current State of the Bomberos

Benemérito Cuerpo de Bomberos de Costa Rica is the Spanish title representing the Costa Rican Firefighter Corps (Bomberos de Costa Rica, 2021). A series of fires in San Jose prompted the founding of this institution in 1865. This organization handles multiple responsibilities for all of Costa Rica, which include firefighting, fire safety, and fire prevention. The responsibilities do not end there. The Bomberos are also responsible for assisting with the aftermath of natural disasters such as floods and earthquakes, as well as other disasters such as car accidents and building collapses. Both volunteer firefighters and paid firefighters participate in the services the Bomberos provide, and now, with governmental support, both receive training to ensure they are properly prepared for their emergency response jobs.

Currently, the Bomberos continue to work to provide fire protection and emergency response services to Costa Rica. According to their mission statement, they are "providing prevention and protection services to safeguard life, property, and the environment" (Bomberos

de Costa Rica, 2021, Mission and vision, para. 1). Today, they have 75 total fire stations positioned around the country working towards this mission. Los Bomberos de Costa Rica have their own academy and have worked hard over several decades to improve training mechanisms and systems to better condition the firefighters.

The University of Costa Rica already has a research fitness lab called the PRIS Lab. This lab description is as follows: “By coordinates generated by an advanced motion capture equipment, you can read the positions of points in space, and use that information to improve methods of physical therapy, sports performance, and other applications related to digital animation” (PRIS Lab, 2016, para. 2).

La Academia Nacional de Bomberos would like to continue with its research and development, and it has plans to create a Heat Controlled Laboratory Simulator to allow for more rigorous training. Their goal is to create a safe, controlled, simulated environment that mimics conditions the Bomberos may have to face on duty, such as high heat and low humidity. Exercise equipment is required so the Bomberos can practice strenuous physical activities in these conditions. It must also be a secure environment, ensuring the safety of all participants. The Academy has a metal container that could be used for creating this environment, and plans are already underway to complete this laboratory.

2.8 Bomberos Training Procedures

Dehiver Ruby, a physical instructor for the PAF program at the Bomberos Academy. (personal communication, January 19, 2022) has explained the training procedures for approximately 3,000 firefighters is as follows:

- Training is done three times a year including:

- A twelve-minute running test
- A strength test including pull-ups
- A flexibility test
- Training on maneuvering fire ladders and hoses while wearing equipment
- A written test provided by the training academy.

This information gave our team further insight into the current training procedures of the Bomberos and what the expectations are for their employees.

2.9 Existing and Future Simulators at the Bomberos Academy

La Academia Nacional de Bomberos has multiple simulators that allow trainees to practice skills that they will need on the job. Some are in development right now, and some have been tried and true methods for the trainees for years. These simulators include a fire truck driving simulator, a burn building simulator, and a fire truck pump system simulator.

2.9.1 Future Training Facility

The Bomberos are building a new training facility that will consist of office space on the second level and space for training on the first floor (see Appendix G). On the rear end of this building is where a Heat Acclimation Chamber will be placed. The building also contains a main office, meeting rooms, a terrace on the second floor, as well as a reception area on the first floor.

2.10 Mental Health

Mental health issues plague approximately one in three first responders across the world. Problems that workers have experienced include post-traumatic stress disorder (PTSD) and depression. This is roughly 10 percent more than in the general population, who experience an estimated 20% of some form of mental health disorder (SAMHSA, 2018).

First responders are trained to keep their emotions controlled while on the job, because doing so ensures a level-headed response to all situations. However, coming home afterward is often a challenge faced by many firefighters. For instance, following the most traumatic event on U.S. soil in recent history, 9/11, "Among retired firefighters, 22% were found to have symptoms indicative of PTSD four to six years after the attacks…" (Neria, DiGrande, & Adams, 2011, p. 1). In addition, there were mental effects associated with the high cancer rate among first responders following the attacks as well. First responders in 9/11 saw a 41% higher risk of leukemia, and a 25% increase in prostate cancer, with an overall 9% risk to develop any type of cancer. For context, one third of all cancer patients develop depression. If a first responder is experiencing a mental illness from trauma caused in their line of work and then develops a deadly disease from that work, their mental health is surely at risk far more than the average person.

The mental health of first responders is very important, and, sadly, often overlooked. The moving story of Howard Pechter using a simulator to train his body and his psyche back to peak form, is an example of how physical and mental health go hand in hand (Hashem, 2019). Examples of different mental health theories and exercises can be seen in the following sections.

2.10.1 Anxiety and Fear

Anxiety is a leading problem across the world and affects every living person on the planet. This is why it is difficult to define it, as it is ever changing from person to person, situation to situation. For the purpose of this project, anxiety may best be defined as: an abnormal and overwhelming sense of apprehension and fear often marked by physical signs (such as tension, sweating, and increased pulse rate), by doubt concerning the reality and nature of the threat, and by self-doubt about one's capacity to cope with it (Webster, 1977).

Fear is a leading problem in returning to work following a traumatic experience, and combined with anxiety is a debilitating factor, causing first responders to be ineffective in their work. Fear is defined as: an unpleasant emotion caused by being aware of danger: a feeling of being afraid (Webster, 1977).

2.10.2 Maslow's Hierarchy of Needs

Maslow's hierarchy of needs is a widely endorsed psychological concept that outlines what every human needs in order to achieve happiness. This is incredibly important for first responders as their needs are often overlooked for the benefit of others.

The hierarchy is described as a pyramid with the bottom layer being physiological needs such as food and water, basic consumption needed for survival (McLeod, 2020). The next layer is safety needs, which outlines the necessity of jobs, money, and security. Love and belonging is next, and is described as the need for family and loved ones. Next is esteem which is the need for status, respect, and self-esteem. Lastly, and most importantly, is self-actualization, which is "the desire to be the most that one can be".

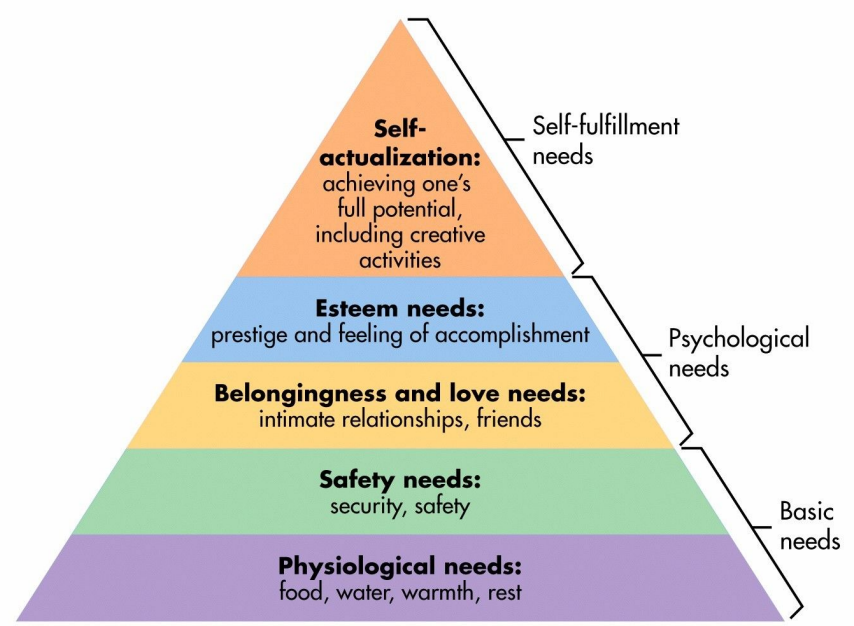

Figure 1: Maslow's Hierarchy of Needs

For this project, the area of concern are the top two layers of esteem and self-actualization. Included in these top sections is the response to fear and anxiety and how it can affect the mind. The six responses to fear and anxiety according to Maslow are defined as Fight, Flight, Posture, Submit, Attend, or Befriend.

In a fight or flight situation, one's mind will either try to fight feelings of fear and anxiety by pushing back against them or avoiding them entirely. This was coined by Walter B. Cannon, who first studied the fight or flight response in 1929. Cannon describes the fight or flight response as an immediate reaction following a "freeze phase" in which an organism is contemplating the situation (McCarty, 2016). According to clinical psychologist Dr. Tom Balistrieri (personal communication, February 3, 2022), he related these responses to that of what a firefighter may see on their first day of training in climbing a three story ladder. The trainee is either scared and decides not to climb, or is scared and does it anyway.

Dr. Balistrieri (personal communication, February 3, 2022) described posturing and submission similarly, where someone who postures is gloating and pretending to be something they're not. A person posturing may "climb the ladder right away, but once he reaches the top he gets vertigo and falls and dies!" explained Dr. Balistrieri. Someone submitting would just be giving up and admitting they could never climb the ladder, never even trying.

According to Dr. Balistrieri (personal communication, February 3, 2022), befriending and attending are the most constructive forms of response to fear and anxiety. By attending one is showing empathy for someone struggling with fear and anxiety. Relating to the previous example, you could ease a frightened trainee up the large ladder slowly day by day until he or she was comfortable at the top. Similarly, befriending will help one in the attending process, as being kind and friendly instead of showing abrasiveness will encourage a trainee up that ladder even faster rather than judging them and avoiding their problems.

2.10.3 Willingness Ability and Confidence

Training firefighters intelligently before even entering an acclimatization chamber will increase their performance significantly, which is why there is such a focus on mental health for the Bomberos. Dr. Tom Balistrieri (personal communication, February 3, 2022), who has worked on the topic of mental health at several fire departments over many years, has outlined three key components to returning to work after a traumatic incident: willingness, ability, and confidence.

Willingness can be described as the personal desire to complete a task. Looking at the previous example, does the trainee want to climb the ladder even if he's scared? A good role model should be able to recognize that the trainee is struggling, and show an attending and befriending nature as described above in order to build willingness. Shaming or showing a

negative attitude to fear and anxiety will cause a flight response from the trainee. (Kopstein et al., 2014).

Ability is the technical prowess of the person returning to duty. Do they have the strength to carry on physically? Is their body prepared for what's to come? You want to make sure that every first responder returning to the line of duty is prepared physically for the tasks at hand. If they're not, dire consequences may result. David Grilla, chief of the Worcester Fire Department (personal communication, January 28, 2022), outlined that in the return to duty process, firefighters must pass the Candidate Physical Ability Test (CPAT) which is a sequence of breathing, running, and strength exercises to determine if they're fit for the job.

Confidence is built by the strengthening of both of the previous pillars. With the willingness, and ability to do the task at hand, the trainee will be confident to move forward. If there is no confidence in one's ability, then their performance will dwindle at the same time. All three of these pillars must be strong, or the mental health of the trainee will overall fail. If one has ability, confidence, and willingness, then their esteem will strengthen, satisfying Maslow's pyramid of needs, and strengthening the overall team.

2.10.4 CISM Training

Addressing mental health in a safe and intelligent way is incredibly important. The Bomberos must be prepared to address mental health the correct way. According to Dr. Thomas Balistrieri (personal communication, February 3, 2022), there is a type of training that can help called the Critical Incident Stress Management (CISM) training. CISM works as a treatment for PTSD best in the hours following a traumatic incident experienced by a first responder. The method urges a counselor to use compassion and understanding voices to discuss with the victim

what they are feeling and how it is affecting them directly after the incident. The method urges questions like “where are you feeling what you’re feeling?” and “what are you feeling?” in order to achieve a level of honesty. Dr. Balistrieri described anxiety in the aftermath of a traumatic incident as “a balloon full of air” and these types of questions slowly let out the anxiety built up inside in a safe way. “Saying it out loud makes them realize…” When a patient hears their own thoughts, it causes them to evaluate their mental situation for the better (personal communication, February 3, 2022) said Dr. Balistrieri when discussing coping with anxiety. They must learn to cope with their experience in a healthy way, and the CISM training model offers a safe coping strategy to relieve the anxiety building up inside of them. (Everly et al., 2000)

CISM is under a lot of scrutiny from various sources. A 2009 study conducted by Bryan Bledsoe concluded that “...several meta-analyses and RCTs found CISM to be ineffective in preventing PTSD.” (Bledsoe, 2003, Conclusions, para. 1). Yet the side effects of PTSD can be lowered through the techniques of CISM training. A comprehensive study from Regent University in 2014 concluded that the CISM method is overall effective in treating PTSD, and saves money by getting affected first responders back to work faster than ever before. This same study takes into account the opinion of Bryan Bledsoe, and his argument against CISM, as well as multiple other sources with different opinions and has remained confident in its position, but lacks a control group to perfectly evaluate the situation (Bledsoe, 2003).

2.10.5 Progressive Muscle Relaxation

Progressive Muscle Relaxation (PMR) is a technique utilized in the CISM method, and is used to target exact areas of anxiety in the body and relieve stress (Matsumoto & Smith, 2001).

The procedure involves tensing a group of muscles and breathing in deeply and exhaling slowly. PMR is proven to reduce stress in almost all conditions, and most recently, a study concluded that “Progressive muscle relaxation as an auxiliary method can reduce anxiety and improve sleep quality in patients with COVID-19.” (Liu et al., 2020).

Balistrieri noted that the use of PMR can target exact areas of stress, and the consistent use of PMR can help patients ease the effects of PTSD from their conscience, as well as help them talk about their feelings (Blanaru et al., 2012).

3.0 Methodology

Our project goal was to recommend to the Costa Rica Fire Protection Academy the design of a heat-controlled simulator that will allow the firefighters of Costa Rica to be exposed to specific temperature and humidity conditions during training exercises so that they are better prepared to function in real conditions they will encounter. We also worked to identify the physical and mental stressors that affect first responders and how to address those stressors effectively. To achieve our goal we identified the following research objectives:

1. Identify the specific conditions of a burning building;
2. Determine the characteristics of similar simulators;
3. Design the simulator;
4. Identify a comprehensive inventory of training equipment;
5. Develop an estimated budget for the facility;
6. Identify the existing procedures and mental stressors of firefighting and other emergency response;
7. Identify how to address the physical and mental stressors of firefighters.

In this chapter, we provide a description, an explanation, and a justification of the methods utilized to achieve our objectives and ultimately our goal.

3.1 Identify the Specific Conditions of a Burning Building

In order to add the environmental controls to this fitness lab, we identified the specific conditions of a burning building so that they could be applied to the lab. This required us to obtain the effects of heat, moisture, humidity, and dehydration on firefighters by gathering data

about the temperature, moisture, and humidity of the environment the Bomberos have to experience when responding to a fire. We obtained this data through online research and speaking with our sponsors. Once this data was obtained, we could more accurately simulate the environmental conditions the Bomberos face and could move on to designing the simulator.

3.2 Determine the Characteristics of Similar Simulators

A key element to the success of designing this lab was to use similar labs for reference. There are numerous labs similar to the one we designed, and we examined and cross-referenced what these labs provide along with the costs involved in building and equipping the labs. These projects include but were not limited to, the *Fresno State Hydration, Exercise and Thermoregulation Lab*, the *University of Costa Rica PRIS Lab*, the *Ohio Fire Academy Mobile Training Laboratory*, and even more abstract solutions such as the *RiVR Link Firefighter Training Virtual Reality System*. We contacted the teams responsible for these projects. We consulted them regarding what systems they used and what the cost layout of their projects were. By examining the costs of these simulators, along with what they provide, we were able to design an optimal simulator specified to the requirements, requests, and limitations of the Bomberos, based on their intentions, budget, and available space.

3.3 Design the Simulator

Our team worked to develop three designs for the Bomberos to choose from. These designs each had its own pros and cons as well as different inventories. To create these designs, we used the software SolidWorks to create 3-D models of the simulator and its contents. We

were able to determine the best possible methods of designing the simulator by speaking with professors as well as those involved with similar simulators. Our team spoke with Professor Shichao Liu of WPI, Francisco Siles and José Moncada of the University of Costa Rica, and Dr. Luke Pryor who worked with the Fresno State lab. These individuals provided us with insight on how to best design this simulator, including what heating elements would best suit our needs, what insulation would be appropriate, and where to locate spots for ventilation in the chamber. For clarification, the interview protocols for these interviews are contained in our Appendix chapter.

3.4 Identify a Comprehensive Inventory of Training Equipment

Our team required a comprehensive inventory of what training equipment should be in the lab, and what sensors would be needed to monitor the conditions of the firefighters in the lab, as well as the lab itself. We toured the Academy to obtain a list of all of the equipment they currently have and asked them about any other equipment that they were planning to obtain in the near future. With this, we were able to develop a cost estimate and initial design of the facility and the simulator. We also took into account the other facilities that we have referenced. For example, the Fresno State Hydration, Exercise, and Thermoregulation Lab, described in section 2.2, provided us with an idea of the monitors and regulation systems that would be needed for this project. We contacted Dr. Luke Pryor to collect more information about their system, including what equipment they used, and what pitfalls to watch out for when constructing a similar system.

3.5 Develop an Estimated Budget for the Facility

We needed to develop an estimated budget for the training laboratory in order to account for all factors ranging from labor, to equipment, and building costs. To develop this budget, we conferred with our sponsors to receive price estimates from their equipment distributors. After determining how much the Bomberos had budgeted for this project, our team found the equipment that was both sufficient for completing the job and financially realistic. The Bomberos were able to provide all of the exercise equipment for the simulator. The mechanical and electrical equipment was found through online research and price comparisons. We then compiled all of the equipment costs that we were looking to use for the simulator and proposed this to the Bomberos as an estimated budget and inventory list.

3.6 Identify the existing procedures and mental stressors of firefighting and other emergency response

Our team interviewed the Bomberos employees to determine what the difficulties of the job are both physically and mentally. We interviewed our sponsor liaisons in order to get a better understanding of what they were looking for from this project. We asked them about the current training procedures, how these procedures could be enhanced, and also if they had ever had an experience that affected their abilities on the job. (see Appendix A for Interview Protocol)

3.6.1 Interview Methodology

As we conducted interviews over the course of this project, we ensured that the identities of those being interviewed were protected. Our team started the interview process by

interviewing our sponsor liaisons. During these interviews, we asked them about the current training facilities, how they think this training could be improved, and if they had ever had any experiences that affected their ability to work.

3.7 Identify How to Address the Physical and Mental Stressors of Firefighters

One of the factors we wanted to consider in the design of the lab was the physical and mental toll that firefighters endure on their job. Firefighters face a plethora of harmful conditions that can provide both short-term and long-term damage to their bodies and minds. This includes heatstroke, smoke inhalation, burns, depression and Post Traumatic Stress Disorder. Through speaking with specialists and firefighters we determined what needs to be done in order to be prepared for the physical and mental challenges of the job. For example, by researching the causes and effects of heatstroke, we tried to identify what conditions the lab should be able to simulate as preparation for actual conditions in the field. This should allow trainees to acclimatize and thereby avoid heatstroke in the future.

Additionally, we determined what the mental stressors of the job generally are. Firefighting is a stressful job with many potential traumatic incidents that can damage the mental health of firefighters. Through interviewing our sponsors, and consulting mental health professionals, we learned more about these mental stressors and determined how to appropriately address them in our system.

3.8 Summary of Methods

We worked to consider all factors of this project, consult professionals of the subject, and consult all stakeholders involved. This allowed us to design the optimal lab for the Bomberos to train and have maximum preparation for what they will face in their work. In the next chapter, we will present the results of our research and an analysis of these results as a preparation to achieve our goal.

4.0 Results and Analysis

In this chapter, we explain and discuss our findings from the research which we completed to meet our objectives. In order to provide the design of the heat acclimated chamber as well as a manageable procedure to address the mental health of first responders such as the Bomberos, our team established the following objectives, as discussed in the previous chapter:

1. Identify the specific conditions of a burning building in Costa Rica;
2. Determine the characteristics of several similar simulators;
3. Design the simulator;
4. Identify a comprehensive inventory of training equipment;
5. Develop an estimated budget for the facility;
6. Identify the mental stressors and existing procedures of firefighters and other emergency responders;
7. Identify how to address the physical and mental stressors of firefighters.

By achieving these objectives we were able to develop multiple designs and budgets for the heat-controlled chamber and a method to reduce mental stressors that the Bomberos of Costa Rica may utilize.

4.1 Specific Conditions of a Burning Building

The specific conditions of a burning building play a key role in the range of temperatures and associated conditions that a heat-controlled simulator must be able to emulate. For this, we examined a data collection from University of Illinois regarding this exact situation. In this study, data were collected across 25 live-fire training exposures. These data displayed that within

mild training environments, firefighters were subjected to temperatures centering at 50ºC and heat fluxes around 1 kW/m^2. For severe training conditions, the temperatures endured by the firefighters in training ranged from 150ºF and 200ºF, with heat fluxes ranging from 3 kW/m^2 and 6 kW/m^2 (Willi et al., 2016). We took this data as reference and incorporated it into our design to ensure that these conditions could be met.

4.2 Similar Simulators

To gain a further understanding of how a simulator should be designed, we consulted teams responsible for simulators with a similar purpose. First, we consulted with Francisco Siles and José Moncada of the University of Costa Rica. By touring their facilities, we were able to make some adjustments to our design. We took inspiration from their linoleum flooring for its easy-to-clean surface, double door system for insulation, and more.

We interviewed Dr. Luke Pryor, the professional responsible for designing the Hydration, Exercise and Thermoregulation Lab at Fresno State University. He provided us with an in-depth set of critiques on our design that allowed us to come up with a better method of ventilating and lighting the heat-controlled simulator, as well as ways to improve the morale of those using the simulator.

4.3 Heat Acclimation Chamber Design

After our first tour of the Bomberos Academy we were able to accurately model the chamber using Solidworks software. According to the head of physical training, Vinicio Alvarez Morales, the Bomberos desire that the 20ftX8ftX8ft metal container have a double door system

that opens out, which can be built outside of the container to save space. This double door vestibule system will help keep the container insulated. Additionally, they require these doors to be 1.1 meters in width by 2.1 meters in height so that there is enough capacity for multiple firefighters to enter. We wanted to think ahead and cover the case of an emergency, where someone may have to release the heat inside quickly, in which case the Bomberos in training could open the metal container doors located at one end of the container. In addition to the vestibule doors, the Bomberos also required a window 1.2 meters high, .5 meters above the bottom of the container, 2.5 meters wide and centered between the left side of the container and the vestibule doors. In theory, this will be made of thermoglass, a heat-resistant borosilicate glass and will be necessary for the safety of the Bomberos inside because it will allow for the physical trainers to view the situation inside. Lastly, the Bomberos require a 1.10 meter desk next to the window so that the trainers may have a place to work and safely view the trainees inside. Norman Chang Diaz, subdirector of the Bomberos Academy, informed us that the container will be adjacent to the new facility the Bomberos are constructing which indicates that the desk will be inside the facility looking outwards onto the container window.

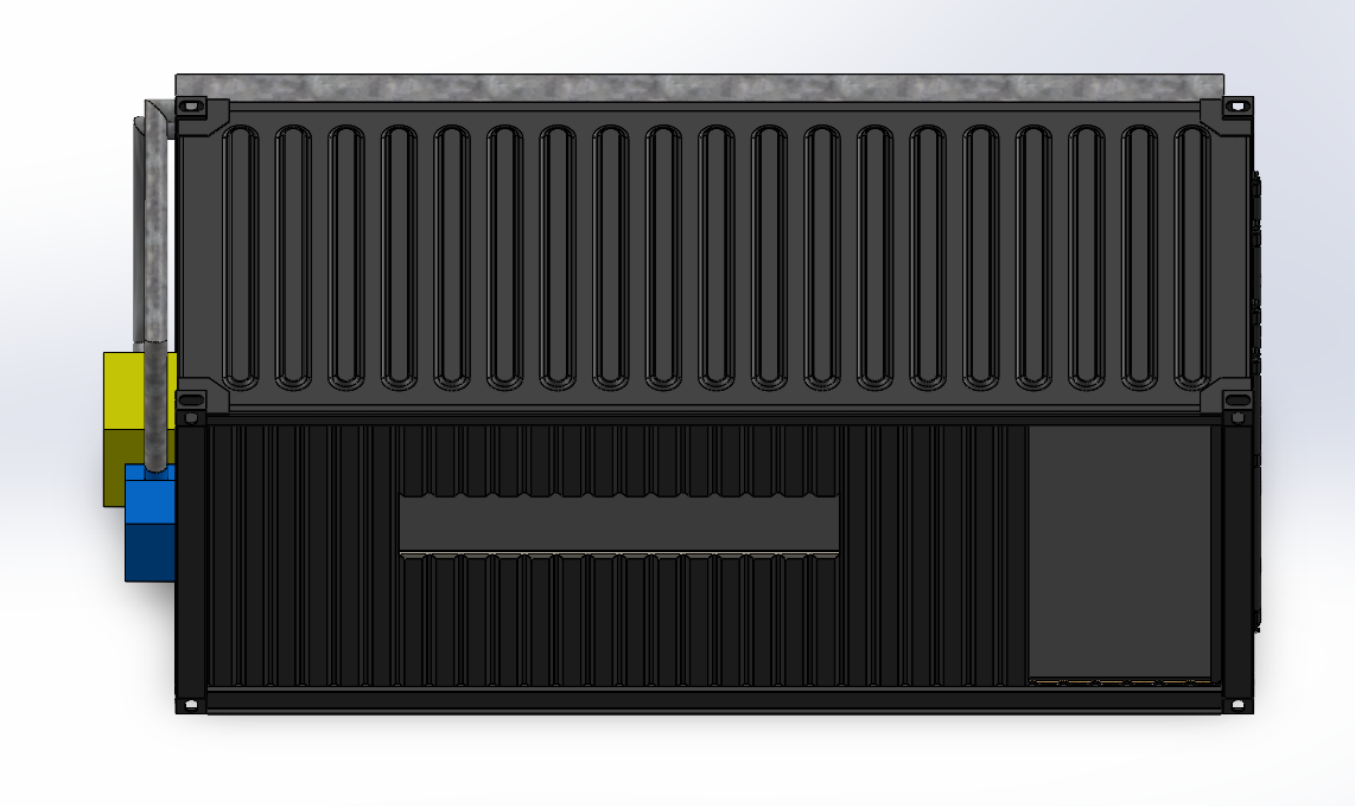

Figure 2: Top edge view of final container design

4.3.1 Components

Heat

For heating components, “all we need is a heat pump!” (Shichao Liu, personal communication, February 2, 2022). Heat pumps take in air and use electrical coils powered by high voltage to heat the air and then pump the heated air into an air vent ducted to the rest of the system. For this project we looked at several heat pumps and compared and contrasted them to see which fit our preferred performance and budget.

Americool WFHE-30

The Americool WFHE-30 is the heater we decided on for this application due to the fact that it has the highest operational range ranging from 32 to 104 degrees fahrenheit. It also has the ability to heat at 101,350 Btu/h of power (AmeriCool, 2020). “A British thermal unit is an internationally used measure of energy. It measures how much heat is needed to raise one pound of water by one degree fahrenheit.” (Trane, 2014, How is BTUH measured?, para. 1) With this much power it will be more than capable of heating the chamber to the necessary standard that the Bomberos need. Other heat pumps we considered were the Americool WPCD-3000 because it contains a dehumidifier, which is also a requirement for the Bomberos, but the WPCD-3000 did not have the proper heating power necessary (AmeriCool, 2020). The same problem was seen with the MovinCool Climate Pro D12, which only had up to 95 degrees fahrenheit of operational range. (SpotCoolers, 2020). The selected heater is also portable which fits with the needs of the Bomberos. The WFHE-30 appears to be an excellent product for the requirements of the Bomberos.

Figure 3: Americool WFHE-30

Sunwarmth™ CIR Short-Wave Infrared Electric Heater

The Sunwarmth™ CIR Short-Wave Infrared Electric Heater was recommended to us by the University of Costa Rica, as they use four of the same systems in their heat laboratory. The Bomberos have declared that they want these units installed in the heat chamber because they want the ability to add extra heat, if needed. The Sunwarmth™ CIR Short-Wave Infrared Electric Heater comes in four variations, but either the CIR 200-2 0 or CIR 200-4 0 models are viable for the Bomberos to use due to the square footage ranges. Both units are capable of heating the 160 square foot base of the chamber (Stiebel Eltron, 2021).

Figure 4: Sunwarmth™ CIR Short-Wave Infrared Electric Heater

Humidity

The Bomberos also made clear that they want the system to be able to reach 100% humidity in order to simulate the most extreme conditions inside of the chamber. Professor Shichao Liu stated that “you need a humidifier such as these ones” when referring us to the products listed on globalindustrial.com (personal communication, February 2, 2022).

Global Industrial® Ultrasonic Humidifier

This humidifier is capable of pumping 300 pints of water each day while at full power (Global Industrial, 2009). It pumps in an operational range of 30-90% humidity with a +/- error of 5%. This means that it can reach up to 95% humidity output, but while the humidity is being condensed inside of the chamber, it will eventually reach 100% inside the chamber, or even more per request of the Bomberos.

This humidifier was contrasted against ones such as the Honeywell Electrode Humidifier HM750A1000 - 11/22 GPD, and the Ideal-Air Industrial Grade Humidifier, 200 pint humidifiers which were viable options but fail in certain requirements (Ideal-Air, 2017). The Honeywell model is unable to deliver on operational range with specifications to reach the 100% humidity requirement (Honeywell, 2019), and the Ideal-Air model fails to deliver on convenience due to its small size and need for regular maintenance (Ideal-Air, 2017). The Global Industrial Ultrasonic Humidifier is portable, has a direct water connection line, and is high powered making it an excellent solution for the Bomberos' needs. (Global Industrial, 2009).

Figure 5: Global Industrial® Ultrasonic Humidifier

Dehumidifying

Considering the requirements of an environment with 100% humidity, the moisture levels will be very intense following a complete workout session. When the sessions are concluded for the evening, the environment must be properly cleaned, and dehumidified, or there will be mold buildup which poses great health risks of which the Bomberos cannot afford (Environmental Protection Agency, 2022). Considering the scale of this project, an industrial grade dehumidifier was needed.

Originally, we were searching for a combination unit with a dehumidifier built into a heat pump, but the heat pump failed to meet other requirements necessary for the Bomberos. Instead, it was decided that a standalone industrial grade dehumidifier was needed considering that the

circumstances surrounding this environment were more extreme. The M120 Desiccant Dehumidifier appears to be the best solution for the Bomberos in this case. The M120 is small, portable, and can dehumidify on an industrial level being able to pump airflow at 35 m^3/h, which will dry the area inside the chamber in a matter of hours (Munters, 2018).

Figure 6: Munters M120 Desiccant Dehumidifier

Lighting

For lighting inside the simulator, we found multiple options, but we recommend the Aquaforce Pro by Thorn Lighting. This is because the conditions this light will be under are rather extreme such as high heat, and high humidity. This light fixture was chosen due to its lumen rating up to 8,000 depending on model. The Bomberos only need 3,300 lumens

(Waveform Staff, 2017) and one single fixture will be able to achieve this. The Aquaforce Pro was chosen specifically for its water and mold resistant characteristics, meaning that it would be able to withstand the intense atmosphere inside the chamber.

Figure 7: Aquaforce Pro by Thorn Lighting

Vestibule Door System

The Bomberos have asked us to come up with a vestibule door system so that when trainees are entering and exiting the chamber, the inner environmental conditions are not lost. The door must meet the NFPA requirements of 2.1m high x 0.81m wide, and be insulated. The outer structure was modeled on the Solidworks software to be 2.5 meters long so users will be able to comfortably close the door behind them, and open the next one with gear on and still

have enough room to move easily. The Bomberos requested that the doors be sealed, which can be accomplished by the company constructing the chamber in the future.

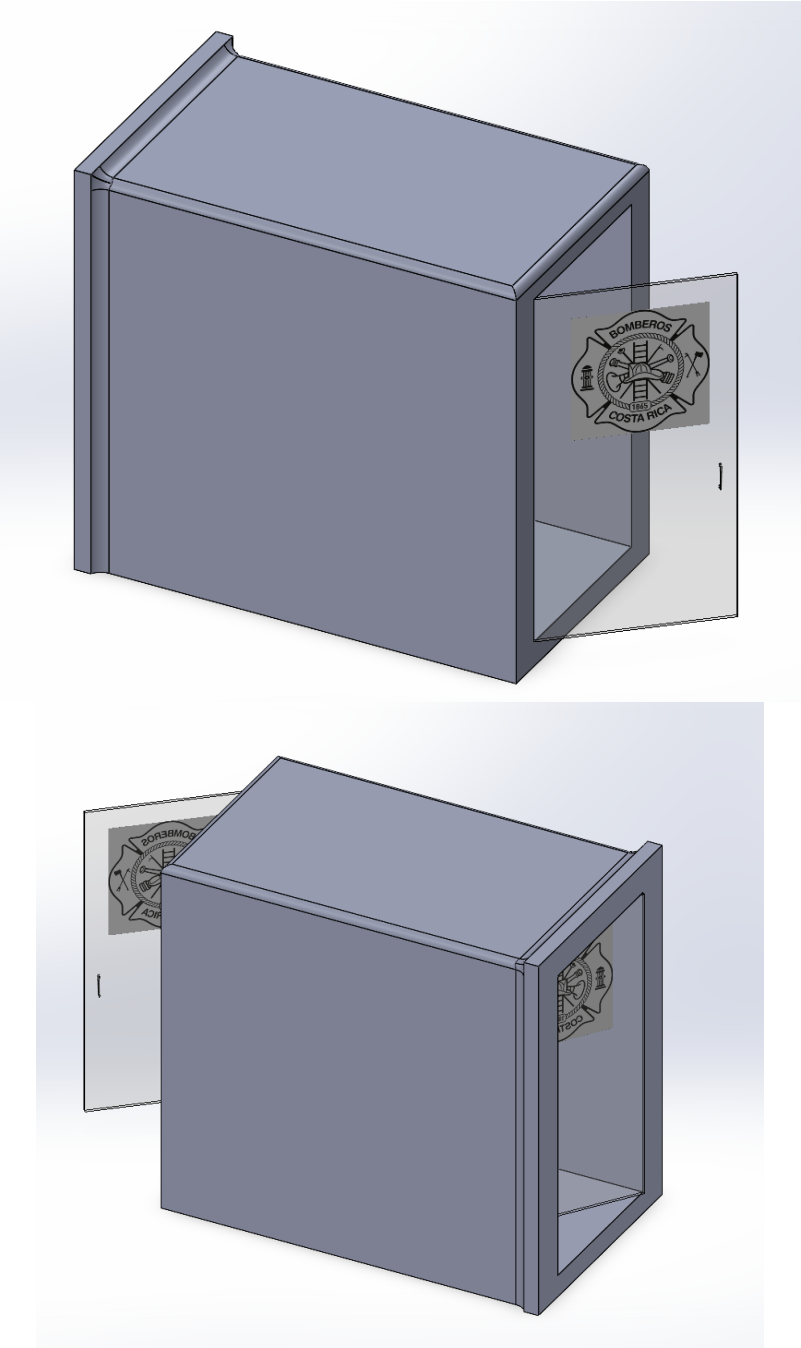

Figure 8: Vestibule Door design with outward opening, equal sized insulated, and sealed doors

Vaisala viewLinc Continuous Monitoring System

The Bomberos want a continuing monitoring system to be able to watch multiple factors of the chamber while in use. They needed a system that can monitor temperature, and humidity, while seeing trends over the duration of training exercises. Many items can accomplish this task such as rudimentary thermometers and hygrometers, yet for a comprehensive experience, the Vaisala viewLinc Continuous Monitoring System provides all services needed and more. “The Vaisala Continuous Monitoring System provides: viewLinc software for real-time monitoring and alarming of temperature, humidity and other parameters.” (*ViewLinc continuous monitoring system,* 2021). The system provides the service of data loggers that can be sent via WIFI, and have full reports over time of the conditions inside the chamber. The system is also expandable, allowing the Bomberos to buy multiple attachments such as oxygen, and carbon-dioxide monitoring nodes to further ensure the safety of the chamber.

Figure 9: Vaisala Monitoring Homescreen

PA System

For the purposes of communication within the chamber, the Bomberos need a Public Address (PA) system to be able to communicate properly. The PA system needs to be waterproof and loud enough to be able to hear through heavy breathing and a loud HVAC system. The options are very broad here for the Bomberos, however, there are top rated waterproof systems, such as the Enrock 200 Watt Indoor/Outdoor Waterproof Home PA. This system is Bluetooth enabled, allowing the Bomberos to connect multiple microphones, and more speakers (Amazon, 2017). However, more speakers are not necessary, as the 200 watt supply will provide plenty of noise.

Figure 10: PA System by Enrock

4.3.2 Insulation, Flooring, and Ducting

Keeping the heat inside of the chamber is of paramount importance for this project, which is why the best insulation is required for this system to function properly. The best insulation across the board is rigid foam board insulation. Defining the efficiency of foam board is done by its "R-value" which is determined by the equation:

$$Rval = \frac{\Delta T}{\Phi_q}$$

Figure 11: R-Value Equation

Where ΔT is temperature difference across the material, and Φ_q is heat flux through the barrier. The higher the R-value, the higher the insulation efficiency. For the simulator chamber we chose the best foam board insulation that took up the least amount of space inside the chamber, which ended up being Pro Select R-Matte Plus-3, 3/4 in. x 4 ft. x 8 ft. R-5.0 Foam Insulation Board due to its high R-value of 5.0, its overall size, and its availability. This type of board is an industry standard used for multiple purposes. This would line the entire interior of the chamber except the floor.

Behind the foam board will be small gaps due to the unique shape of the container's outside wall. While these spaces may be left empty, we recommend filling those gaps with spray in foam insulation. Spray foam insulation has R-values that range from 3.6-3.9. Spray foam behind the foam board will greatly increase the insulating ability of the chamber. Although it is not essential for the Bomberos to do this, the extra spray foam insulation will increase the chamber's insulative efficiency.

On the interior side of the insulation, there must be a layer to protect the insulation. The material that is chosen must above all be mold resistant, but also light in color to reflect light back into the chamber. The material must also be very durable due to the fact that heavy equipment will be used inside the chamber and thus might bump up against the wall. Ideally it must also be relatively inexpensive, as well as available in Costa Rica. There are a few options for this: mold resistant drywall, mold resistant wood, concrete, fiberglass, and/or PVC plastic. Drywall and wood don't have the insulating or durability properties that are required, and fiberglass does not have the insulation necessary. The two best materials in terms of all characteristics would be concrete or PVC plastic. Concrete is highly insulating, as well as durable, but does not repel water easily. PVC is highly durable, water resistant, mold resistant, and fairly insulating. PVC wall panels are also already very common, as well as inexpensive. For these reasons, we recommend the PVC panels be used for the final layer of walling.

The floor of the chamber must be durable as well as have insulation characteristics. The floor chamber is already made of plywood, but there will be an inch thick layer of Quikrete Crack-Resistant Concrete Mix to cover the plywood. This provides further insulation with an R-value of 5.24 per square foot. The concrete will also be topped with a ¾" thick Extreme Mats gym mat flooring. Gym mat flooring is shock absorbent as well as moisture resistant, and will provide an ideal surface for the Bomberos to train on and not worry about damaging the floor, while also providing a comfortable ground on which to do body exercises.

Ducting is universally made of galvanized steel sheets that are highly accessible and renowned for efficiency. This is what we recommend for the ducts on the simulator.

Figure 12: Ductwork overview showing connection of heating, and humidifying components to main duct

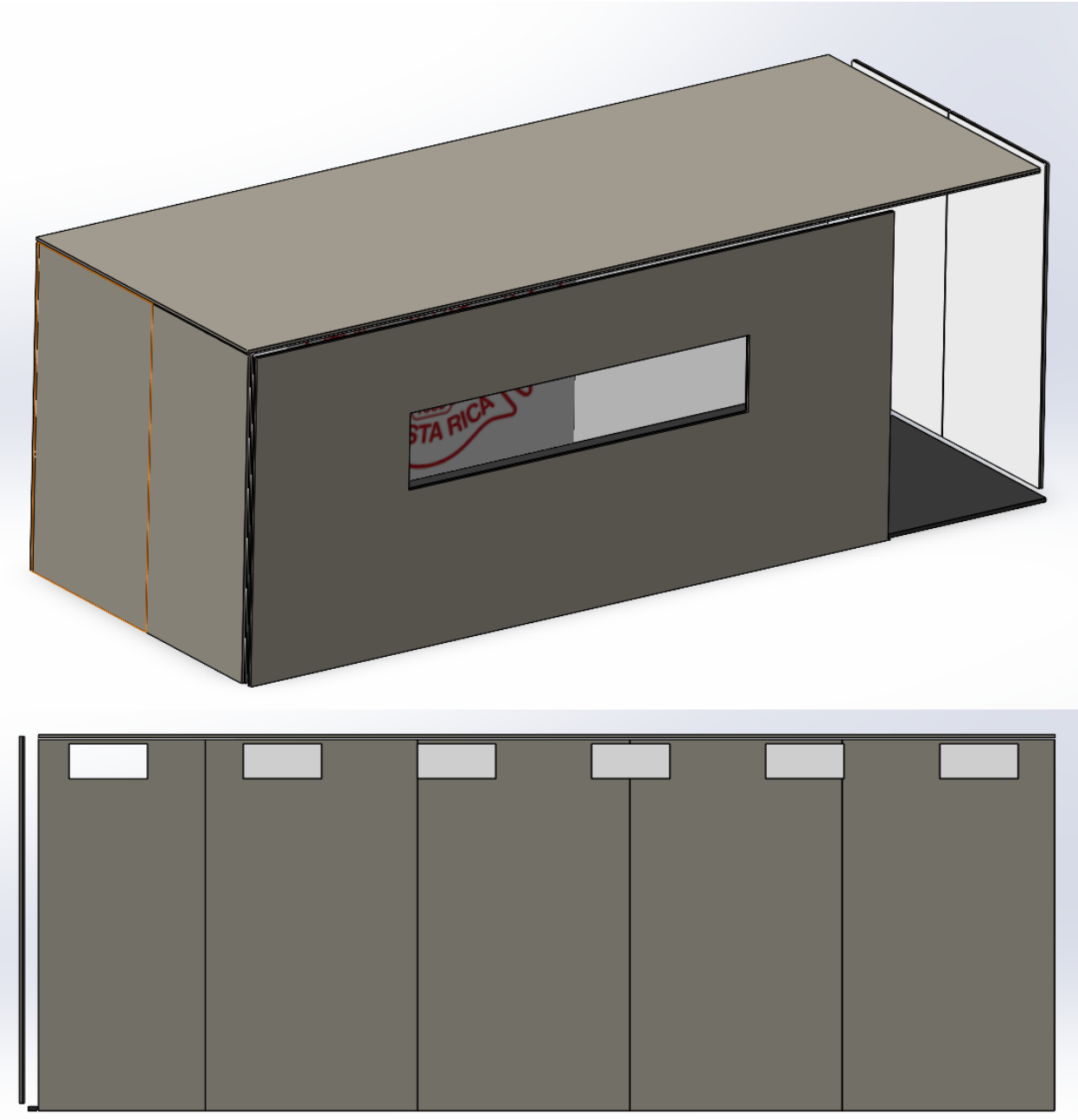

Figure 13: Inner Insulation shell overview showing the entire interior insulation shell

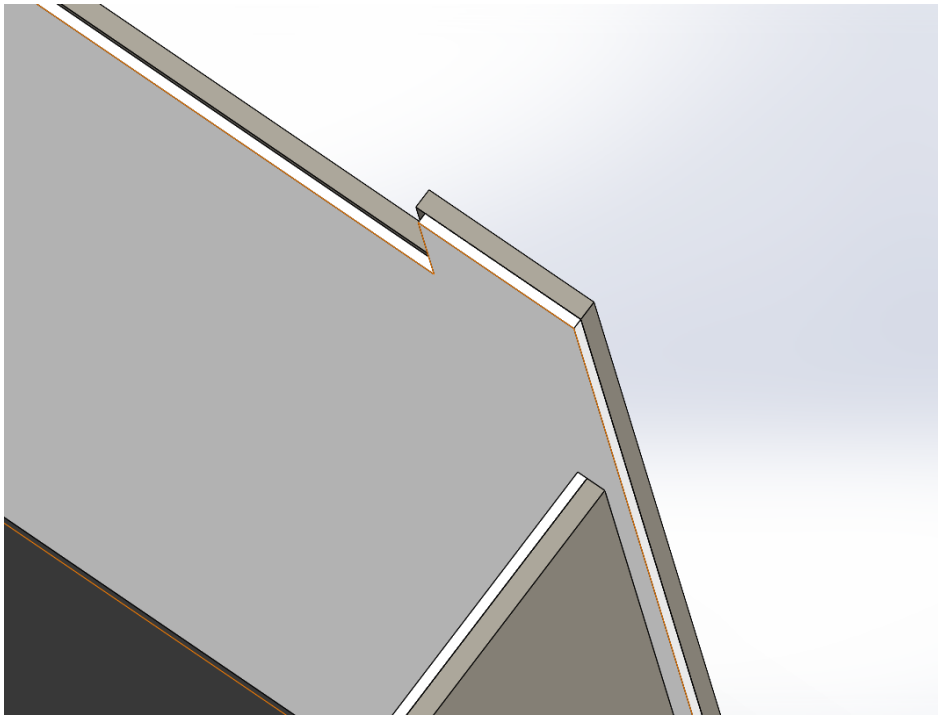

Figure 14: Close up showing relation of inner ¾” foam board insulation combined with PVC outer layer

4.3.3 Design Strategy

The Bomberos clearly stated that they would like the heat-controlled simulator to be semi-permanent but portable in case another part of the Academy would like to use it. Keeping the limited space inside the chamber in mind, we recommend that the ventilation duct be placed outside of the chamber on the rear wall to keep as much space to move inside the chamber as possible. With that in mind, the components for heating and humidifying the container will need to be placed on the rear end of the container to be able to fit on the back of a semi tractor-trailer truck for transportation (See Appendix F). If such components were placed on the top, the transportation truck might not be able to clear overhangs.

The circular ducting to the main duct from the components will be designed with thin stainless steel and be fitted to be as close to the container as possible. To keep the heat inside of

the ducts from escaping, we recommend that the entire duct system is coated with a layer of spray-on foam on the outside surface only.

The window will be double paned to retain heat from escaping the inside.It is designed to be transported on the same flatbed truck if need be, just behind the chamber when in transit. Looking at the window side of the chamber head on, based on discussions with the Bomberos, we decided to locate the large double doors to the right of the chamber so that it could be more easily accessible from the inside of the Bomberos' new building. The large double doors at the end of the container will be used to move large equipment in and out of the chamber, as well as to quickly dispel hot and humid air from the chamber in case of an emergency.

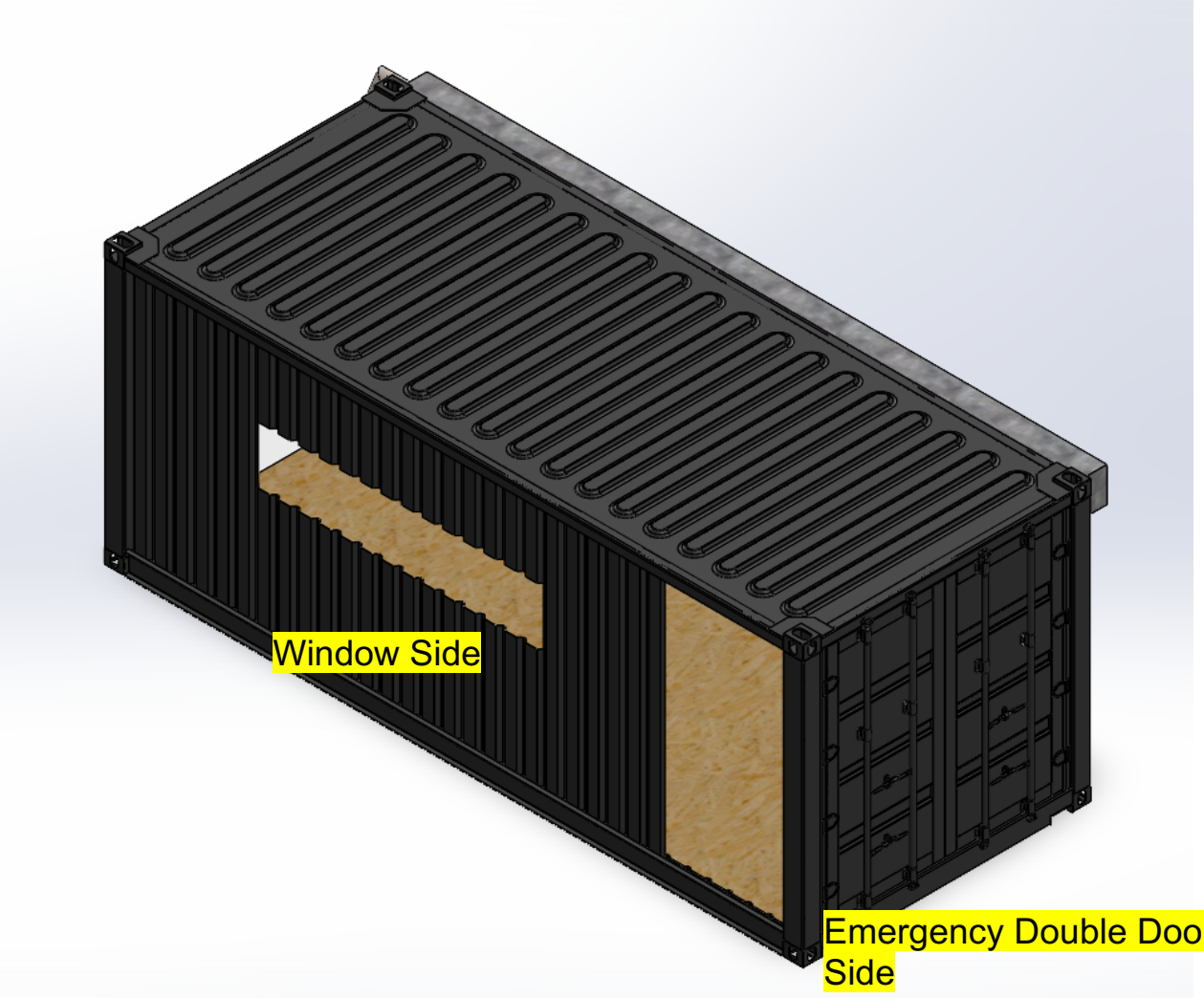

Figure 15: Isometric shell view of shipping container with Window Side, and Emergency Double Door Side labeled

4.4 Inventory of Training Equipment

Based on a tour of the National Academy of the Bomberos, and through interviews, we were able to make a comprehensive inventory of the training equipment they have available. They have numerous options for training equipment to be utilized in this lab. The Academy has available rowing machines, treadmills, elliptical machines, and stationary bicycles. They would

also like to be able to practice wielding fire hoses inside the simulator. This equipment would be interchangeable within the lab, depending on which form of exercise the Bomberos would like to simulate at the time.

4.5 Heat Acclimation Chamber Budget

The Bomberos had a rough budget of US $50,000 to $100,000 to work with when considering the design and inventory of the heat-controlled simulator. We considered the pros and cons of each component of the simulator carefully when deciding on our final design to ensure that we would be getting the best product for the money. The comprehensive budget spreadsheet can be found in Appendix E, but the specific number is approximately $18,387 USD or ₡11,729,377. This is only taking in the factors of buying components and materials. The labor and installation costs may raise this to be the total costs much higher.

4.6 Existing Procedures and Mental Stressors of Firefighting and Other Emergency Response

After interviewing William Hidalgo, an occupational health officer for the Bomberos, we found that there are no documents within the Bomberos at this time that touch on the current mental health procedures. It is our hope that the following methods and procedures in Section 4.7 will be a beginning to the organization and use of such procedures.

4.7 Methods to Reduce Mental Stressors

Based on our research, we identified a set of methods the Academy can focus on to reduce mental stress-among its trainees and the existing Bomberos staff. The findings were the following:

4.7.1 Trainee Readiness Questionnaire

Our team developed a Trainee Readiness Questionnaire that is divided into the three components of readiness: willingness, ability, and confidence, as explained in our Background chapter. By understanding where each trainee stands on these three components, the trainer will have a better idea of what needs to be worked on in order to get the trainee mentally prepared to enter the line of duty. Through this questionnaire, the trainers will be able to determine the mental strength of the trainees preventively before something unfortunate happens, rather than reactively after something stressful has happened causing a negative outcome. The questionnaire is presented in Appendix B.

4.7.2 Anxiety Scale for Simulator Use

Inside of the simulator, the trainees will be able to communicate with the trainers on the outside through headphones. Using experts' advice, we developed an anxiety scale that would allow the trainees to communicate how they are feeling while using the simulator. On this scale, a "1" would correspond to "I'm okay", a "2" would correspond to "I'm starting to get anxious", a "3" would correspond to "I'm anxious", and a "4" would correspond to "I need to get out of the simulator". We have created this scale in order to prevent any trainee from ever getting to the

point of a three or a four. Our team recommends that once a trainees get to the point of a two on the scale, they be removed from the chamber and then have them try again in a day or so. This would allow each trainee to be better prepared for the next day's training without having to feel as scared to go back in, as they probably would if they had been allowed to reach the level of a three or four on the scale. This is another method of training a firefighter preventively rather than reactively and could also be applied to other training procedures outside of the simulator. A figure of this scale can be found below.

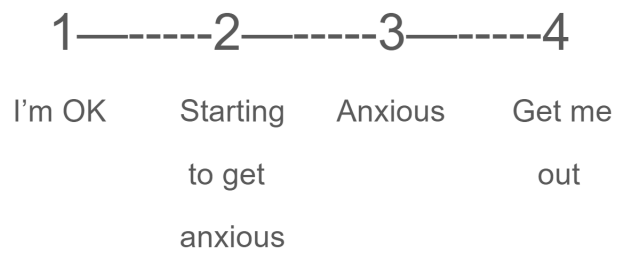

Figure 16: Anxiety Scale

4.8 Summary of Results

After providing a comprehensive design, budget, and inventory of the heat-controlled chamber, as well as a set of mental health procedures that can be used in the training of the Bomberos, our team still sees more work that can be done. In the next chapter, a conclusion of our work as well as three major recommendations for the Bomberos can be found. We hope that the Bomberos can take these recommendations to further improve and innovate upon the physical and mental training of their trainees.

5.0 Conclusions and Recommendations

Our team proposed a final design, equipment inventory, and budget for the heat-controlled laboratory simulator that the Bomberos plan to build. The heat-controlled simulator will be heated by a heat pump, heat lamps, and a humidifier. A dehumidifier will be used to reduce moisture in the container. The simulator will also have two entrance points as well as a window on the side for the trainer to view the trainee and communicate with them over radio.

Our team also proposed two methods of addressing the reduction of anxiety caused by mental stressors that firefighters face on the job. The first of these was the Trainee Readiness Questionnaire which allows trainors to understand how their trainees are feeling during the different aspects of the training modules and whether or not the trainee is ready to enter the field. The other suggestion we made is for the use of an anxiety scale for monitoring the mental state of anyone actively exercising within the heat-controlled simulator to ensure that no trainee is pushed too far in potentially very hostile conditions.

While we accomplished our goal of proposing multiple designs for the simulator and developing methods to address the anxiety and mental stressors of firefighters, there is still more work that can be done. Our team has recommendations for the Bomberos. The following sections are recommendations on how to further enhance the heat-controlled simulator as well as other ways to address the mental health preparedness and treatment for first responders.

5.1 Health Monitoring System

The Bomberos should explore options for a health monitoring system for trainees to use while inside the chamber to give the trainers a better look at how the human body reacts to the climate conditions inside the simulator.

5.2 Innovate the Current Simulator

After the current simulator is up and running, the Bomberos should discuss what seems to be working well and what could be improved in order to build upon what has already been done.

5.3 Full Mental Health Training Program

The Bomberos should continue to explore ways to improve on the current mental health program and develop a complex mental health training program for the Bomberos to use, both for prevention and treatment of mental health problems. This program could include some or all of the programs reviewed in the background chapter of this report. These include CISM training and progressive muscle relaxation.

5.4 Final Remarks

Our team hopes that this project will serve to improve the training procedures of the Bomberos both physically and mentally. By using the heat-controlled laboratory simulator as well as the new mental health procedures, the Bomberos should feel better prepared for the challenges they may face and the people of Costa Rica will be even better protected from the dangers that fires, natural disasters, and accidents may pose.

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Appendix

Appendix A: Interview Questions

Introductory Steps:

1. We will introduce ourselves and explain the nature of our project
2. We will explain why we would like to interview the individual
3. We will explain that all responses can remain anonymous
4. The participant may skip any question that they do not want to answer.
5. We will provide a method of contacting our team should any questions arise (i.e. email)

Questions for Bomberos:

- Have you ever had an experience that affected your ability to perform on the job?

¿Alguna vez ha tenido una experiencia que afectó su capacidad para desempeñarse en el trabajo?

- If so, can you please describe how you processed that experience?

Si es así, ¿puede describir cómo procesó esa experiencia?

- How often do you think about it?

¿Con qué frecuencia lo piensas?

- Do you find yourself avoiding things that you associate with the memory?

¿Te encuentras evitando cosas que asocias con la memoria?

- Have you ever felt physically unprepared for your job?

¿Alguna vez se sintió físicamente mal preparado para su trabajo?

- If so, how so?

Si es así, ¿cómo es eso?

- Have you ever felt mentally unprepared for your job?

¿Alguna vez te has sentido mentalmente no preparado para tu trabajo?

- If so, how so?

Si es así, ¿cómo es eso?

- Are there any ways you think your training could be improved?

¿Hay alguna forma en que crea que se podría mejorar su formación?

Questions for Faculty / Sponsors

- Are there any ways you think training could be improved?

¿Hay alguna forma en que crea que se podría mejorar su formación?

- If so, how so?

Si es así, ¿cómo es eso?

- Have you ever had an experience that affected your ability to perform on the job?

¿Alguna vez ha tenido una experiencia que afectó su capacidad para desempeñarse en el trabajo?

- If so, can you please describe how you processed that experience?

Si es así, ¿puede describir cómo procesó esa experiencia?

- Do you find yourself avoiding things that you associate with the memory?

¿Te encuentras evitando cosas que asocias con la memoria?

Appendix B: Readiness Questionnaire

Trainee Readiness Questionnaire

Please answer the following questions directly or on a scale of 1-5.

For scale questions, circle the place on the scale that most closely fits your feeling or opinion.

Section 1: Well-Being

1. **How much sleep did you get last night?**
2. **How much have you had to eat today?**
3. **How much water have you had to drink today?**
4. **How much exercise do you do per day?**
5. **Have you recently been sick?**
6. **Have you had any emotional trauma that caused anxiety in the last 30 days?**

Section 2: Willingness

1. **How do you feel about fighting a fire?**

Not Prepared 1————2————3————4————5 Extremely Prepared

2. **How do you feel about fighting a fire in a high heat, high humidity climate?**

Not Prepared 1————2————3————4————5 Extremely Prepared

3. **How do you feel about fighting a fire in a high heat, low humidity climate?**

Not Prepared 1————2————3————4————5 Extremely Prepared

Section 3: Ability

1. **Overall, how prepared are you to enter the line of duty?**

Not Prepared 1———————2———————3———————4———————5 Extremely Prepared

2. **How comfortable are you with your equipment?**

Not Comfortable 1———————2———————3———————4———————5 Extremely Comfortable

3. **How do you feel about your physical ability?**

Not Confident 1———————2———————3———————4———————5 Extremely Confident

4. **How do you feel about your mental ability?**

Not Confident 1———————2———————3———————4———————5 Extremely Confident

5. **How do you feel about your knowledge of firefighting?**

Not Confident 1———————2———————3———————4———————5 Extremely Confident

6. **How much time would you need after using the simulator to answer to an emergency?**

Section 4: Confidence

1. **How confident are you in yourself?**

Not Confident 1———————2———————3———————4———————5 Extremely Confident

2. **How confident are you in your decision making?**

Not Confident 1———————2———————3———————4———————5 Extremely Confident

3. **How confident are you in your situational awareness?**

Not Confident 1———————2———————3———————4———————5 Extremely Confident

Appendix C: Interview Summaries

David Grilla

Our team had the opportunity to speak with Worcester Fire Chief David Grilla to get information on the current training procedures in Worcester as well as their current mental health procedures. He was able to give us useful advice on both the physical and mental aspects of our project.

Thomas Balistrieri

Professor Thomas Balistrieri of WPI spoke with our team to point us in the right direction on the topic of mental health in first responders. He gave us tips on different methods that first responders around the U.S. use to deal with the stressors that come with the job, and he has also worked with first responders himself on this subject.

Shichao Liu

Professor Shichao Liu of WPI was a great help to our team as he provided us with information on how to correctly heat and ventilate the heat-controlled simulator. He provided us with options for different components that we could use and also provided us with preliminary design ideas.

Rolando Lieva

Rolando Lieva, engineer for the Bomberos of Costa Rica, spent time with our team going over our plans for the design of the heat-controlled simulator and provided us with critiques and tips on how we should continue with our designs.

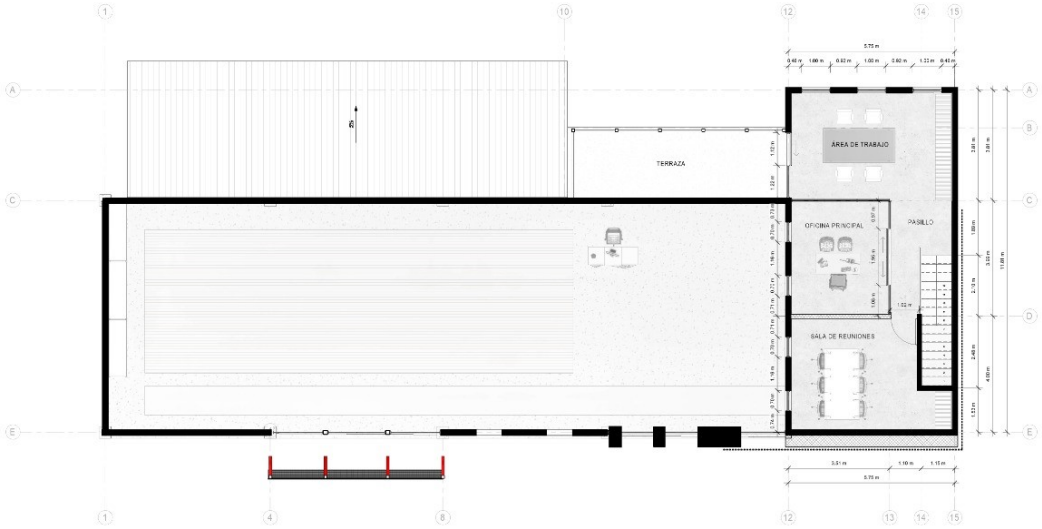
Luke Pryor

Dr. Luke Pryor, who worked on the Fresno State Lab, also spent time with our team reviewing our designs and providing us with critiques and tips based on his experience working on similar projects. He also gave us tips on how to increase the morale of those exercising in the simulator.

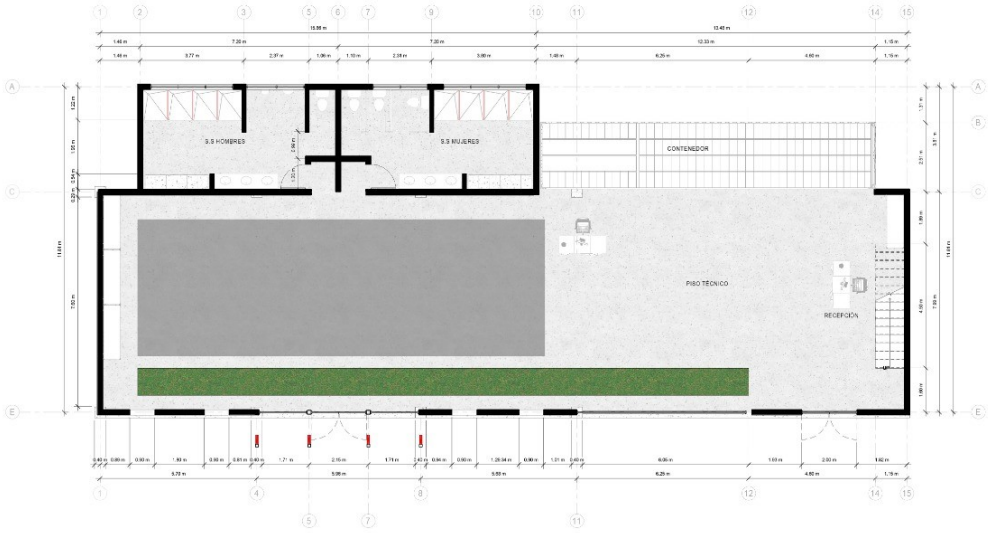
William Hidalgo

William Hidalgo spent time with our team reviewing our information on the mental aspect of first responders and helped our team to critique and edit the Trainee Readiness Survey and the anxiety scale for use inside the simulator. He also provided our team with information on the current procedures within the Bomberos organization

Appendix D: Blueprints of New Facility



PLANTA ARQUITECTONICA NIVEL 2
ESCALA 1 : 50



PLANTA ARQUITECTONICA NIVEL 1
ESCALA 1 : 50

Appendix E: Budget

	USD	Colones
Total Chamber Design Budget	**$18,387**	**$11,729,377**

Shopping Notes: Use the table below to help you plan your purchases and make note of items you have already bought.

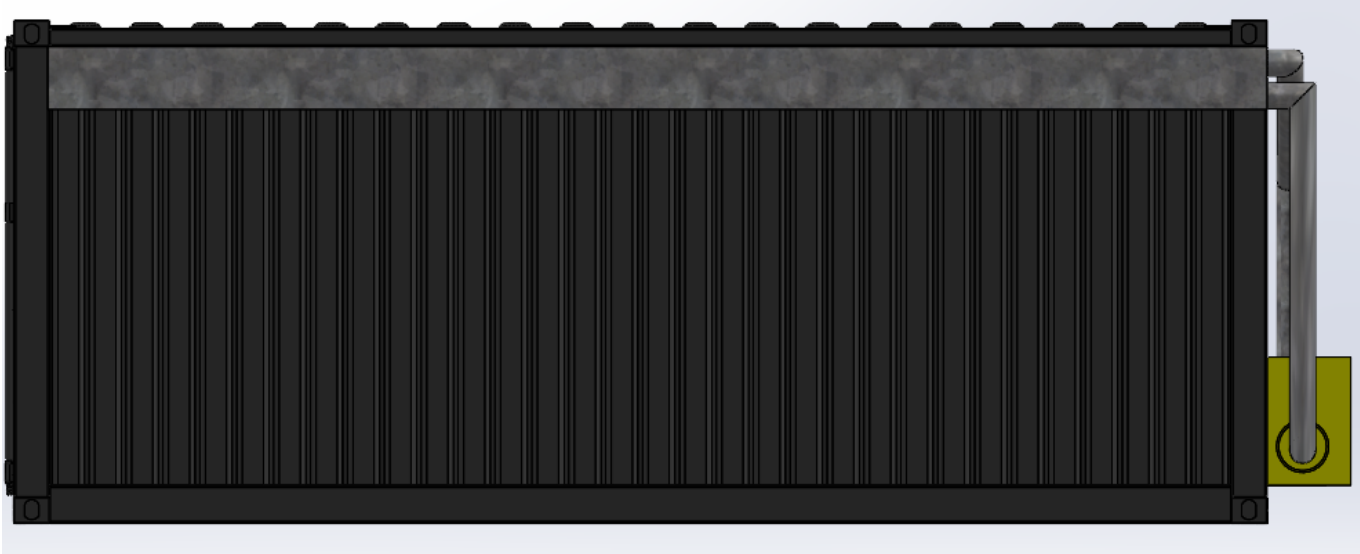
Components			Shopping Notes			
Item			*Date*	*Manufacturer*	*Model No.*	*Retailer*
Electric Heater	$2,644	$1,690,647	2/23/22	Global Industrial	Americool WFHE-30	Purchased online - FindItParts
Humidifier	$1,444	$923,410	2/23/22	Global Industrial	Global Industrial® Ultrasonic Humidifier	Purchased online -Global Industrial
Dehumidifier	$3,615	$2,311,404	2/23/22	Industry Surplus Australia	M120 Desiccant Dehumidifier	Purchased online - Industry Surplus Australia
Lighting ($185 Per Item)	$185	$118,354	2/23/22	Novel Energy Lighting	Thorn Aquaforce PRO S LED	Purchased online - Novel Energy Lighting
Vestibule Door System	$0	$0	2/23/22	Custom	Custom	Custom
Monitoring System	$3,050	$1,962,271	2/23/22	VAISALA SENSOR SYS	DSS70A	Purchased online - Radwell
Speaker System	$1,779	$1,144,551	2/23/22	AcousticBay	Outdoor PA Sound Public Address Speaker System KIT for Baseball Football Fields w/ 4 Weatherproof Speakers	Purchased online - Amazon
Labor & Installation			*Date*	*Vendor*	*Contact Info*	
XXX	$0	$0	2/23/22	XXX	XXX	XXX
XXX	$0	$0	2/23/22	XXX	XXX	XXX
Subtotals	**$12,796**	**$8,150,637**				

Materials			Shopping Notes			
Item			*Date*	*Manufacturer*	*Model No.*	*Retailer*
Duct Line (Liner Size: 5in x 10ft & Pulling Cone: 5in)	$865	$553,317	2/23/22	Fireside Chimney Supply	FireFlex 316L/Ti Pre-Insulated Stainless Steel Chimney Liner	Purchased online - Fireside Chimney Supply
Foam Insulation ($17.67 Per Item)	$371	$237,292	2/23/22	Sika	Pro Select R-Matte Plus-3, 3/4 in. x 4 ft. x 8 ft. R-5.0 Foam Insulation Board	Purchase online - HomeDepot
White Steel Baseboard ($13.49 Per Item)	$81	$51,760	2/23/22	Floor Registers-n-Vents	18inx8in Imperial White Steel Baseboard Return	Purchase Online - Floor Registers-n-Vents
PVC Wall ($ 730.81 Per Item)	$2,192	$1,402,017	2/23/22	Interstate Plastics	PALCLAD PRO PVC WALL CLADDING SYSTEM PANEL | WHITE - 2mm x 48" x 96" | 5 matte panel bundle	Purchase Online - Interstate Plastics
Concrete Mix ($6.58 Per Item)	$197	$126,234	2/23/22	Quikrete	80 lb. Crack-Resistant Concrete Mix	Purchase online - HomeDepot
Rubber Flooring ($65.99 Per Item)	$528	$337,595	2/23/22	Rubber Flooring Inc.	3/4" Extreme Mats	Purchase Online - Rubber Flooring Inc.
Infrared Electric Heater ($339 Per Item)	$1,356	$870,526	2/23/22	SunWarmth	Sunwarmth™ CIR Short-Wave Infrared Electric Heater CIR 200-2 0	Purchased online - HomePlumbing
Labor & Installation			*Date*	*Vendor*	*Contact Info*	
XXX	$0	$0	2/23/22	XXX	XXX	XXX
XXX	$0	$0	2/23/22	XXX	XXX	XXX
XXX	$0	$0	2/23/22	XXX	XXX	XXX
Subtotals	**$5,591**	**$3,578,740**				

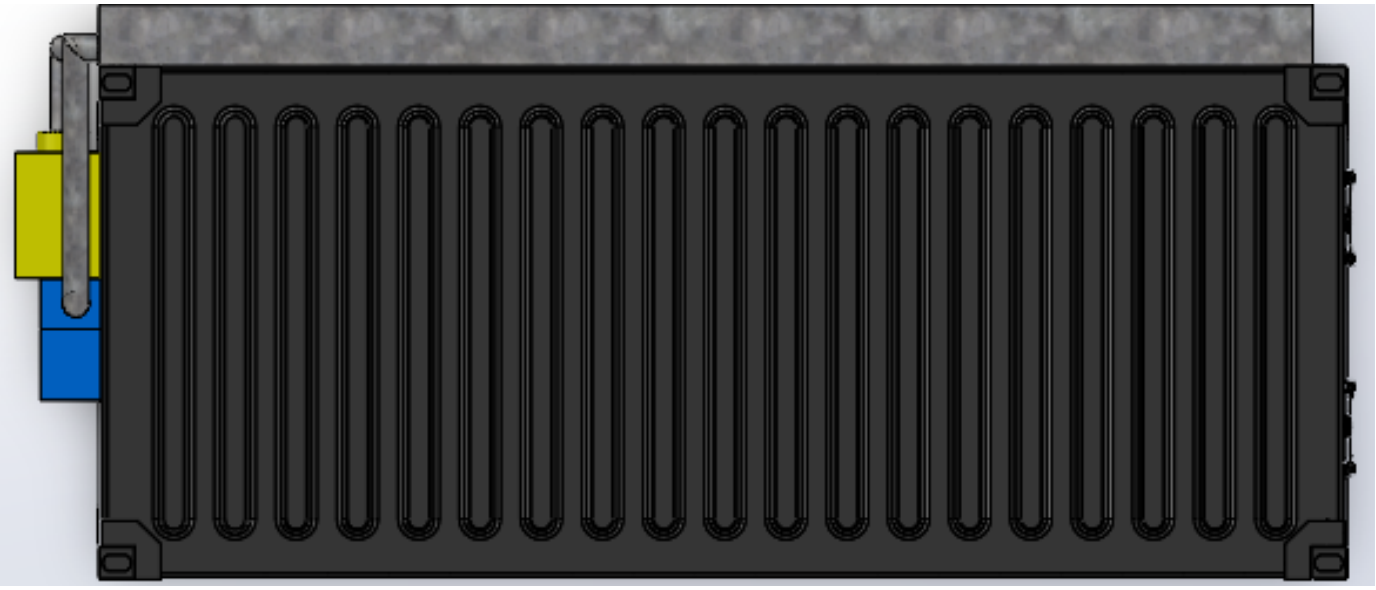
Appendix F: Design Screenshots

Front View (No Vestibule)

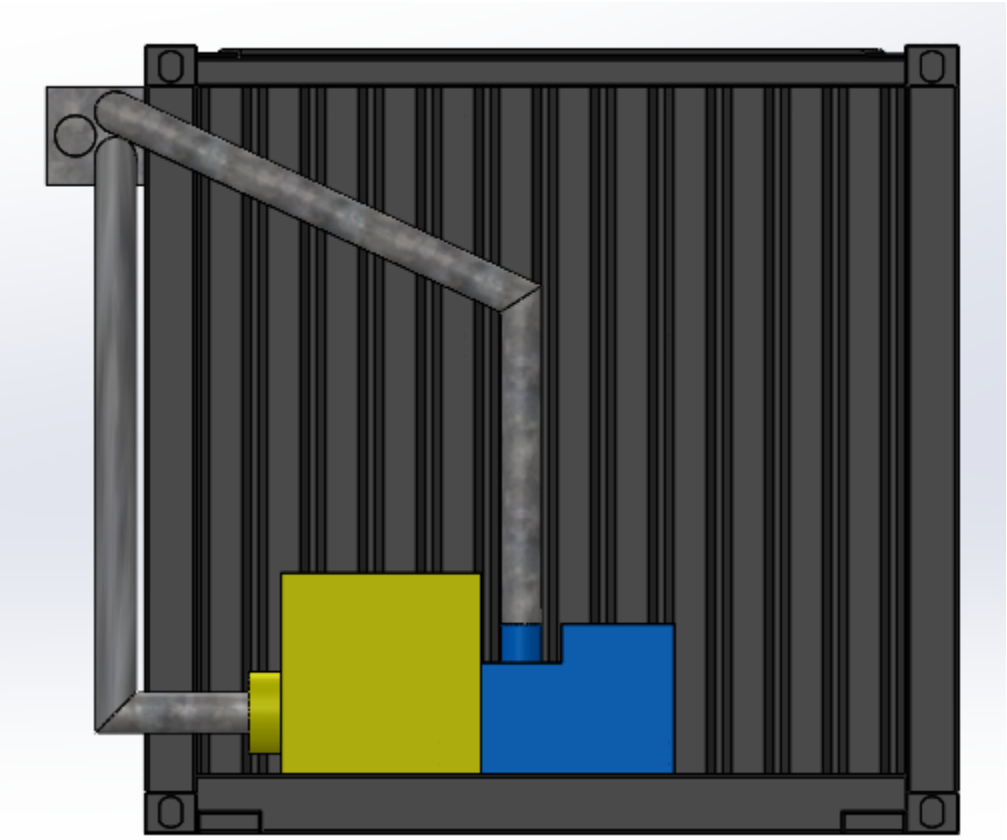
Front View (Cross Section)



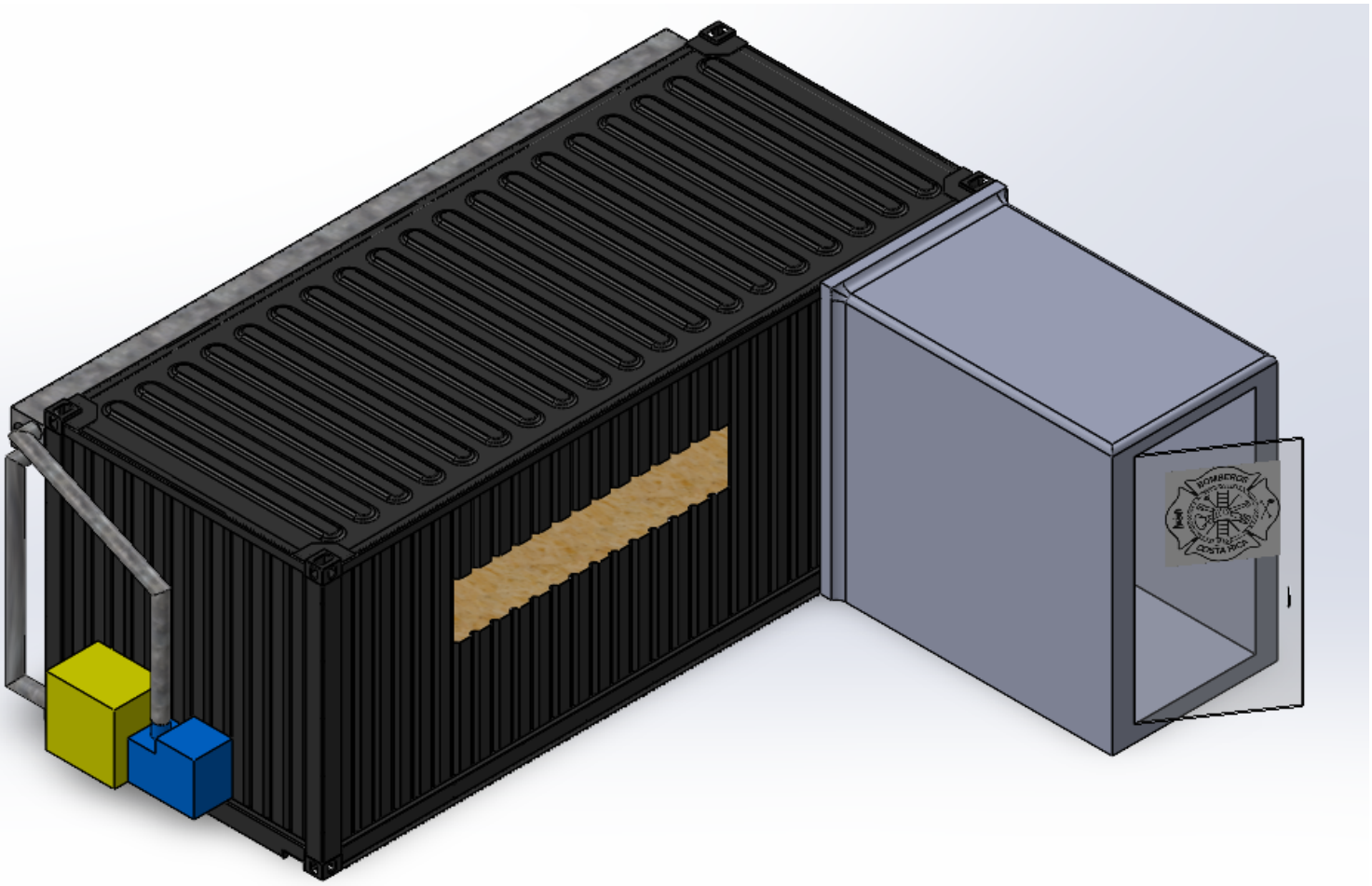
Back View



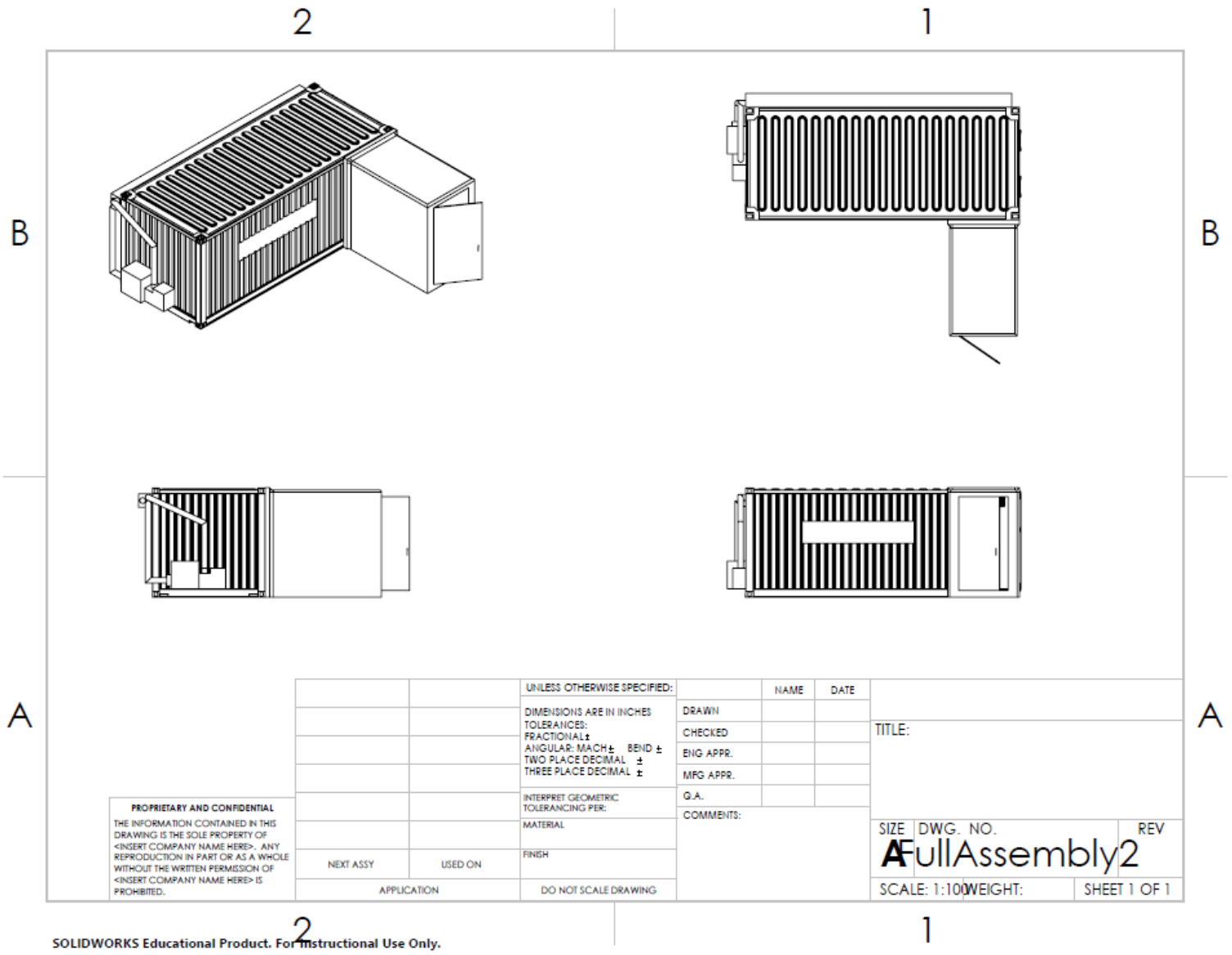
Top View (No Vestibule)



Side View of Heater and Humidifier (No Vestibule)



Full Design Isometric with Vestibule System



Full System Drawing File