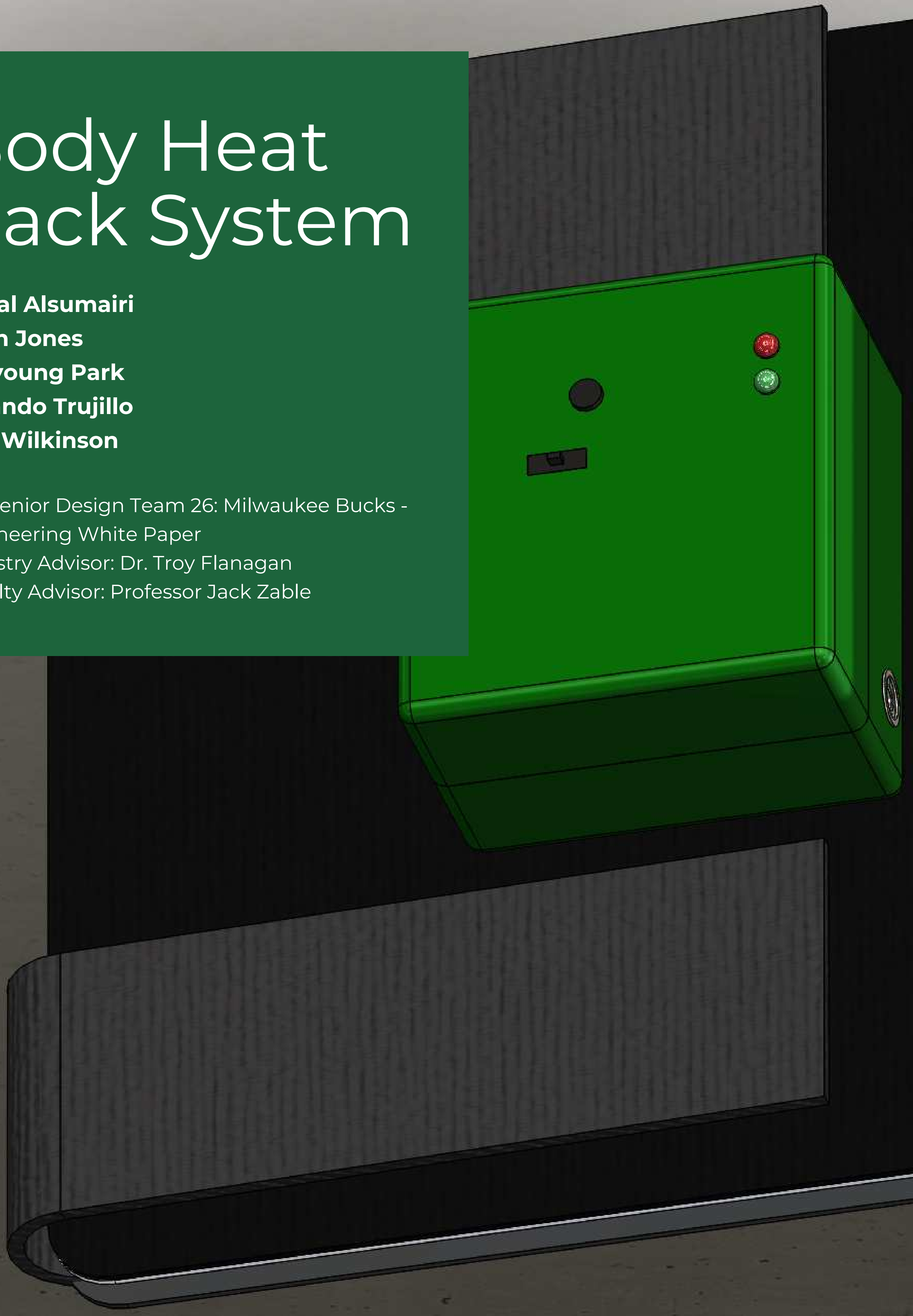
Body Heat Pack System

Faisal Alsumairi
Ryan Jones
Jaeyoung Park
Rolando Trujillo
Eric Wilkinson

ME Senior Design Team 26: Milwaukee Bucks - Engineering White Paper

Industry Advisor: Dr. Troy Flanagan
Faculty Advisor: Professor Jack Zable



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Key Takeaways

- Heat packs are critical to reducing NBA player injury
- Electric-based designs are the most viable option to solve the existing heat pack issues
- These designs provide added features for the user beyond just solving existing problems

A Brief Introduction

Heat treatable injuries are the most common injury in today's NBA.

In 2010 Answorth A. Allen, MD, et. al[1] published the results of a 17-year study they conducted to give an overview of injury in the National Basketball Association. The authors concluded that, of the 6,154 players they studied who experienced a total of 12,594 injuries, ankle sprains were the most common and accounted for about 14.7% of all injuries studied. Other sprains/inflammations and heat-treatable injuries followed closely. Today, these injuries continue to plague the league.

To combat these potentially season-ending wounds, many of the teams in the league have adopted the use of therapeutic heat packs. The majority of these packs are extremely low-tech. They use sand and hot water to provide heat and are smelly and unsanitary. Moreover, they lose their heat quickly. This results in teams being forced to use multiple packs per game as they lose their heat along with numerous towels to cover the packs and protect players from the germs and smells they carry. These towels reduce the effectiveness of the packs and making administering them cumbersome.

The Milwaukee Bucks Performance team is interested in finding a new material and management system for these heat packs to increase their effectiveness in treating player injury. These packs should be portable, hygienic, moldable, adjustable, and long-lasting. They should also have an overall aesthetically pleasing feel and be easy to administer to increase the number of players who opt to use them.

1. Drakos, Mark C et al. “Injury in the national basketball association: a 17-year overview.”
Image courtesy of brewhoop.com

The Competition

To get a better idea of the current heat pack market prior to entering the design phase, the team conducted a market study of existing off-the-shelf products. The study showed that there are two general styles of heat pack available to consumers today: *chemical* and *electrical* based.

Electrical

Existing electric packs are similar to electric blankets. They use a resistance coil to generate heat by dissipating electricity. The problem with this design is that it requires connection to a wall power outlet and can absorb sweat/germs.

Chemical

The most common chemical heating packs on the market are of the hand/foot warmer type. These packs rely on an iron rust/oxidation reaction as their heat source; they last anywhere from 1 - 4 hours with varying levels of heat consistency.

A secondary, though still popular, type of existing chemical pack is the sodium acetate crystallization pack. These packs rely on the clicking of an aluminum tab to serve as a starting point for a crystallization process that spreads throughout the unit. They can reach high temperatures, though they are capable of holding that temperature for just 30 to 60 minutes and become extremely hard in the process.

Electric pack image courtesy of electricblanket.com
Chemical pack image courtesy of sodiumacetatepacksyo.com

Preliminary Designs Electrical

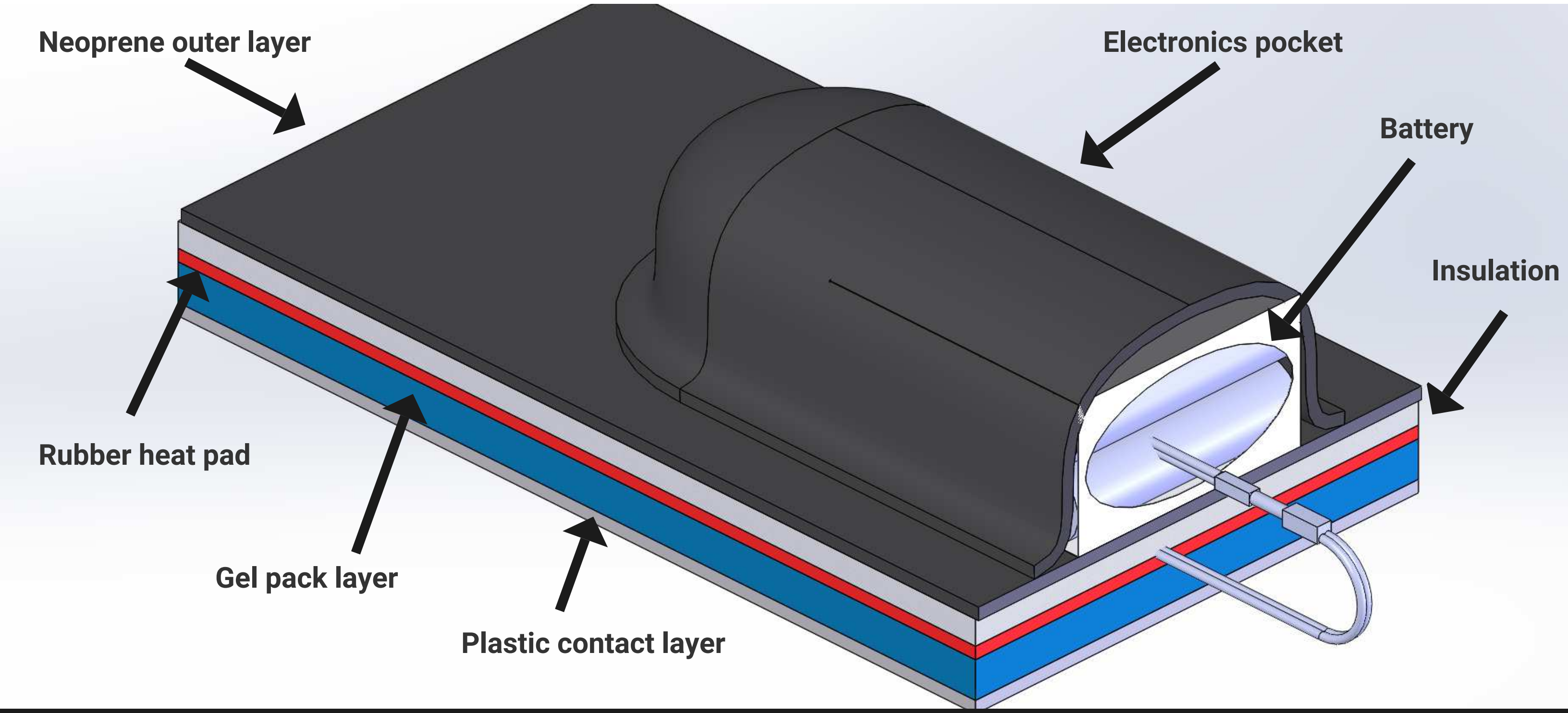
Based on their market study and consultations with CU professors, the team developed a few preliminary design concepts. The first of these designs was an electrical-based pack made of neoprene that featured a built in temperature control system (TCS). This device would rely on internal power so as to not require any tethering to a wall; neoprene was selected as its base material for its breathability and flexible nature.

This first solution the team explored was an electric-based brace-style design. The team settled on a simple layered design that is sewn together and could be wrapped around the user's limb.

Design Highlights

- Adjustable temperature with upper limit 200ºF
- Consistent heat generation
- High power consumption

Temperature Control System (TCS)
The largest benefit to this design is its adjustability and consistency: both of which are made possible by a custom-designed temperature control system (TCS). The TCS functions by activating and deactivating the battery of the heat pad. The heating element is activated when the pack temperature drops below the set activation point. When the pack temperature is equal to or above the activation point, the TCS shuts the pad off. The system is completely contained on a printed circuit board, including a built in safety fuse.



Preliminary Designs Chemical

The second solution explored by the team was a chemical-based pack that would rely on a collection of cells that each represented a miniature version of the sodium acetate pack. These cells would be connected via a series of channels so as to allow the reaction to spread throughout the device from a single activation point.

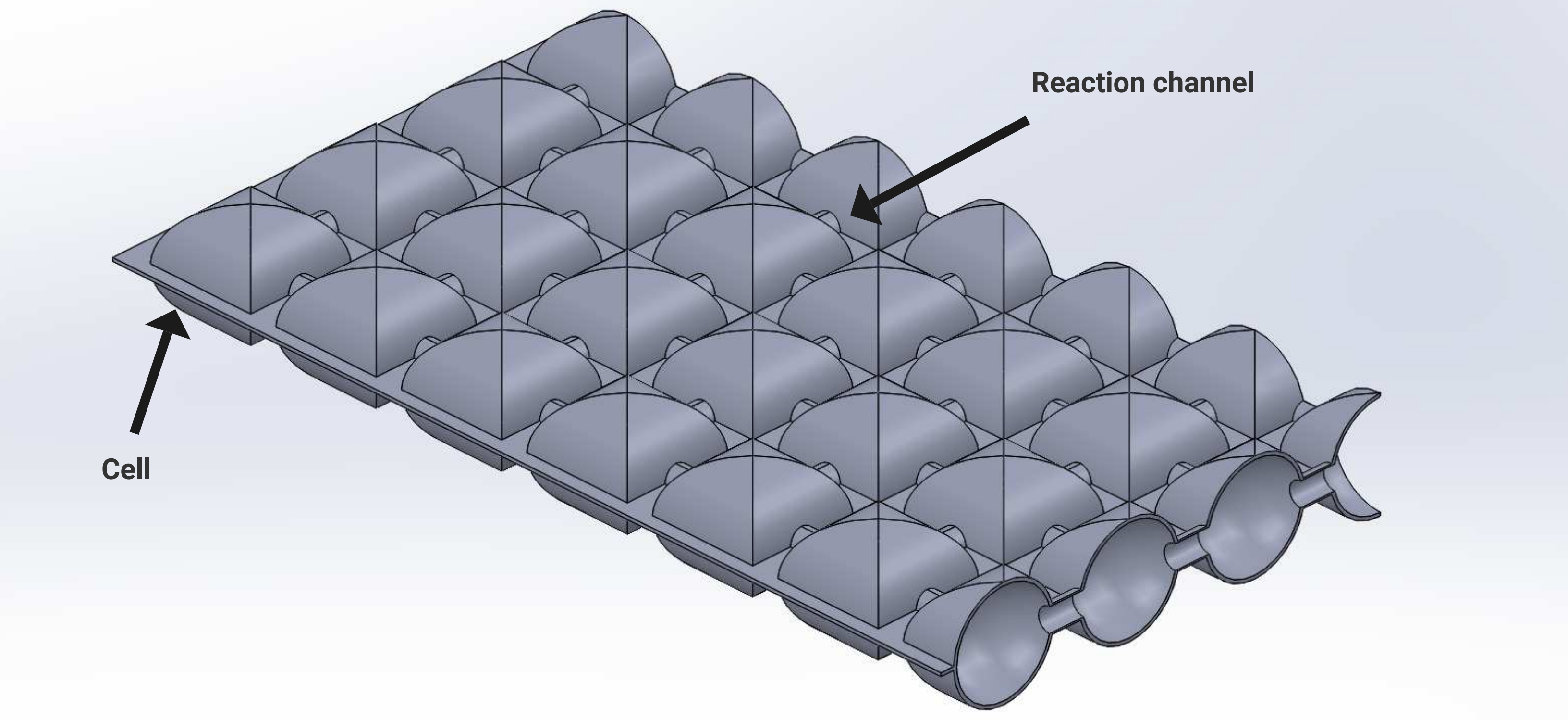
These packs generate heat through the freezing reaction of sodium acetate. The pack is made up of several pockets made from a plastic material filled with sodium acetate. Each is connected with small cylindrical channels, ¼” in diameter.
These pockets allow the pack to conform to the user’s limb and be more flexible as it undergoes solidification; the channels allow the reaction to be spread from just one aluminum tab.

In order to get close to target operating temperature the sodium acetate solution would have to be made in custom proportions: using more sodium acetate than water.

Design Highlights

- Easy to use and completely renewable
- Semi-consistent heat generation
- Difficult to manufacture
- Unclear as to if it will reach target operating temperature

After rigorous testing of each of these preliminary designs, the team decided to move forward with the electrical design.



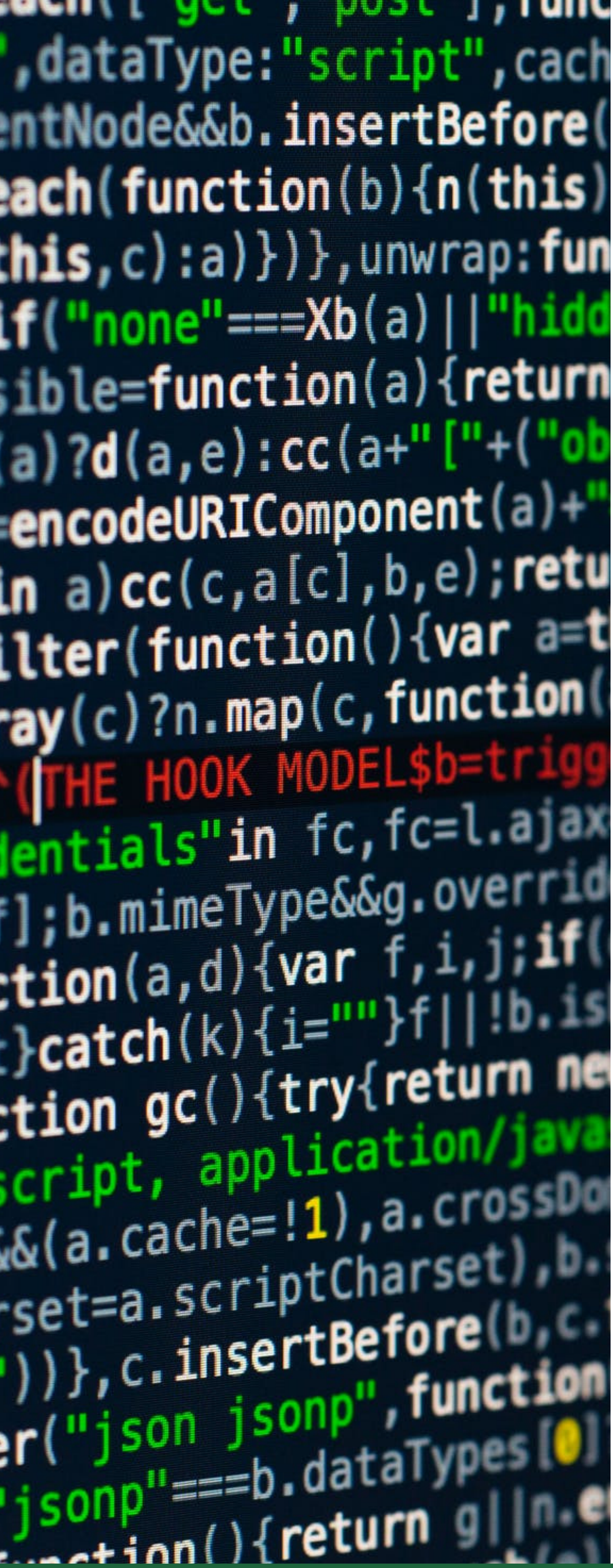


Image courtesy of pexels.com

Challenges

All engineering projects involve several challenges: the way these are overcome determines the success of the project.

Coding

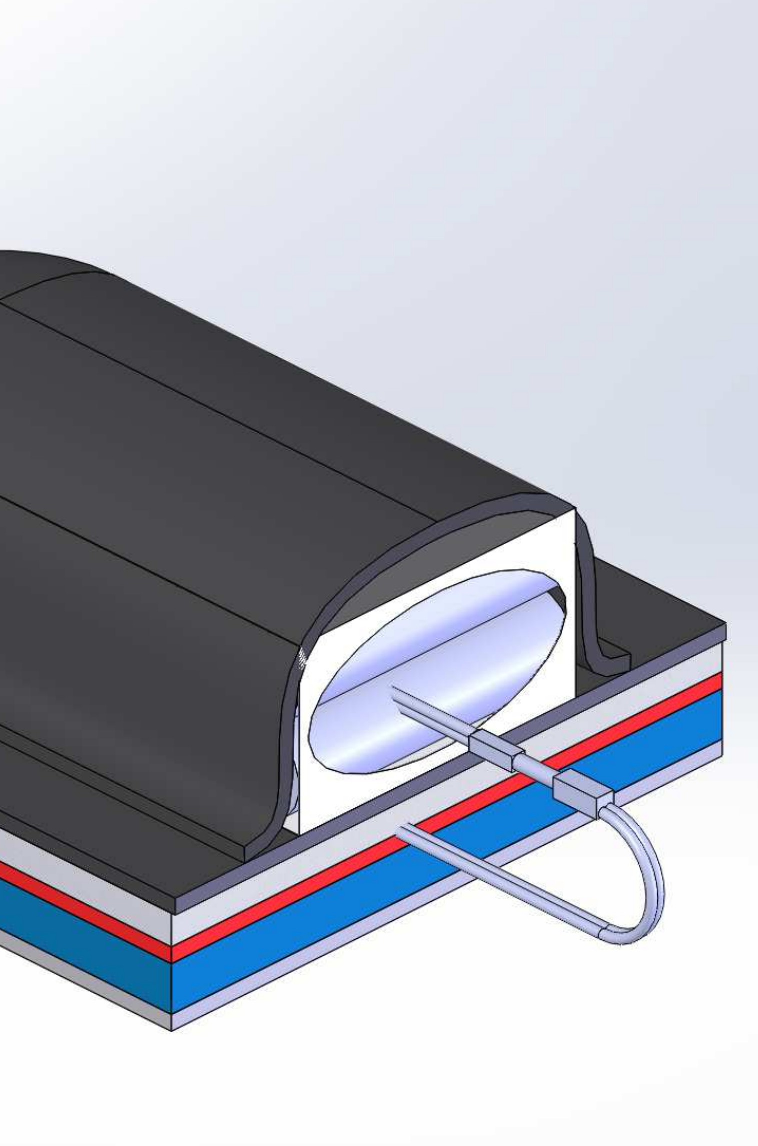
The code that went into this project was one of the main challenges the team faced. Developing code that accurately processed temperature readings was quite difficult.

Sanitation

Developing a pack that had very little chance of transferring germs was another challenge the team faced. This limited the materials that could be used to make the pack.

Power

Finding the perfect power source to keep the pack at target temperature for long periods of time was a challenge due to the trade-off between battery life and battery size.

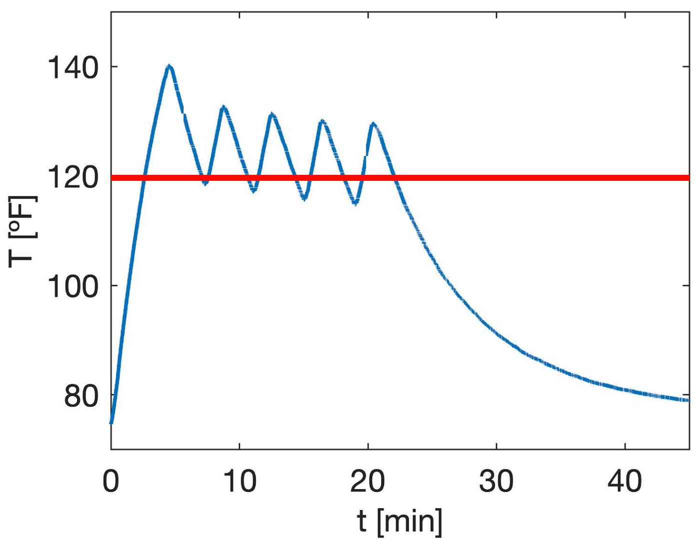


First Prototype

The first prototype electric pack the team constructed mirrored the preliminary design above. It was tested with a target temperature setting of 120°F using an off-the-shelf TCS which yielded the results shown in the bottom left.

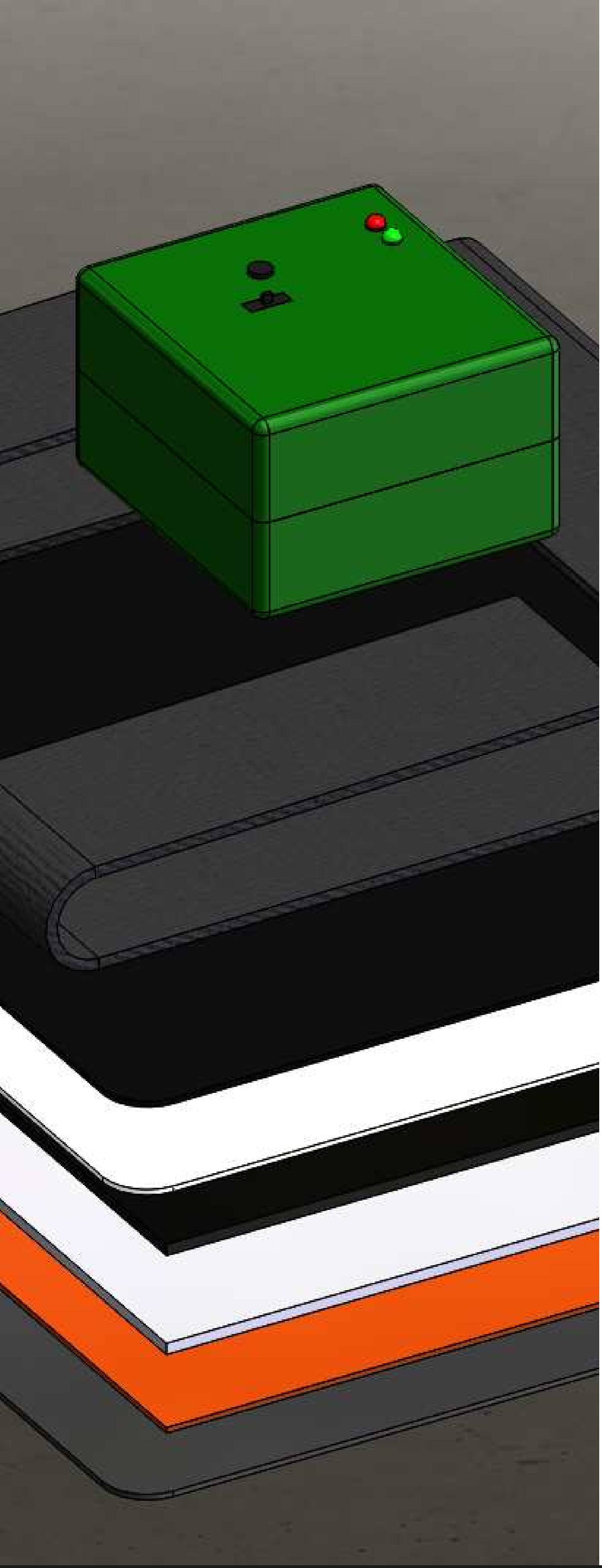
Armed with this working proof-of-concept, the team travelled to Milwaukee to present their work to the Bucks training staff. The feedback provided by the staff was mostly positive. **The primary recommendations they had were to slim down the device as much as possible and to increase its robustness to impact.**

This test measured the prototype pack's temperature; it served as proof that the design could reach target operating temperature of 120°F, unlike the chemical alternate.



"You are doing great work. The heat level you have been able to reach is perfect."
-Bucks Training Staff

During this time they also informed the team that a competitive consumer product, called the HyperIce Venom, had just entered the market. They noted that this device was similar in form to the team's design and **urged the team to look into incorporating one of its distinct advantages: vibration.**



Final Prototype

Based on the feedback received in Milwaukee, the team went back to the drawing board. It decided that, to secure the electronics, it would be more practical to replace the pocket with an electronics housing. This housing was also used to increase the device's robustness to impact through padding it with foam.

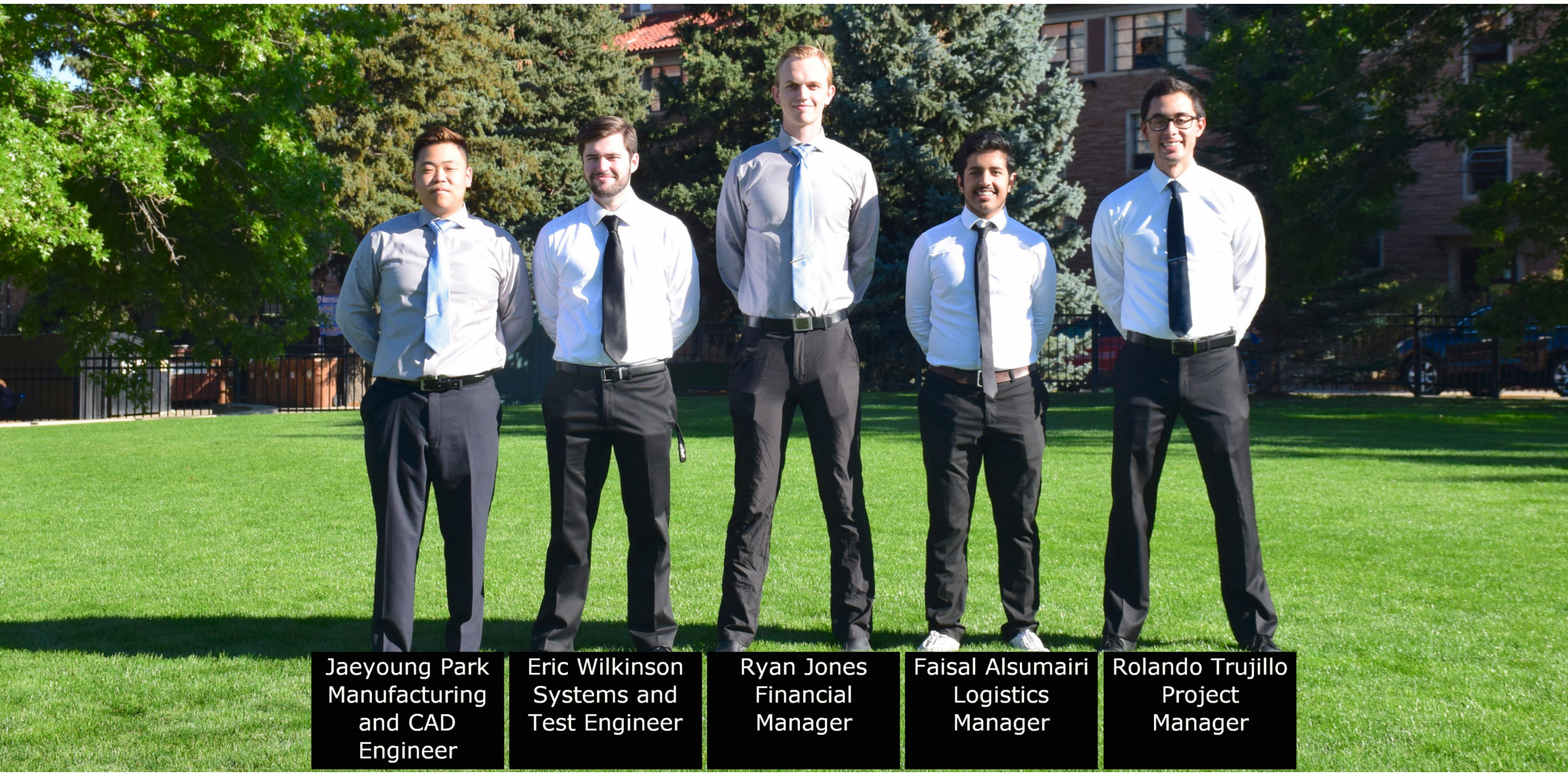
To slim the device down as much as possible, the team opted for a smaller battery noting that, to address the reduced battery life that this would result in, the Bucks could simply produce and use more devices in practice.

The team also changed the pack body material from neoprene to PVC coated vinyl. This allowed for more robustness to sweat, as well as easier sanitation.

Finally, the team managed to incorporate battery life sensing into the prototype so that the user could see how much charge was left. The controls on this prototype also allowed for the selection of one of three preset operating temperatures. The built in LEDs flash to indicate various error codes for different errors and temperature levels: these and other standard operating procedures for the use of the pack are laid out for the user in a User Manual.

Conclusion

As measured by the specifications given to the team by the Milwaukee Bucks, this project was a success. In addition to the prototype shown on the previous page, the team put together two other functioning prototypes with minor differences for the organization to move forward with. Each of these prototypes featured a different battery size and layout to give the Bucks choices in terms of which form factor they preferred. In addition, they all incorporated battery life indication, three temperature settings, multiple hour use time, and were water and dust resistant. They also all included an adjustable strap to help the user secure the pack to their body in their preferred fashion.



Future Work

To take the design to the next level, the team recommends continuing to explore the incorporation of vibration. Additionally, further reducing the size of the electronics housing and developing a more interactive user interface with a display could be helpful for the Bucks Medical Staff and players. Finally, scaling the design to different sizes for application to different areas of the body could expand its utility and render it an even more valuable tool for the enhancement of player performance.