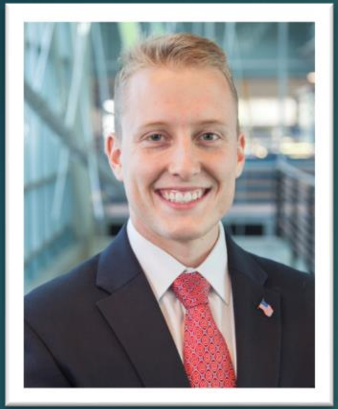
EML4551-2

Team 512

Temperature-Sensitive Medication Storage for Natural Disasters

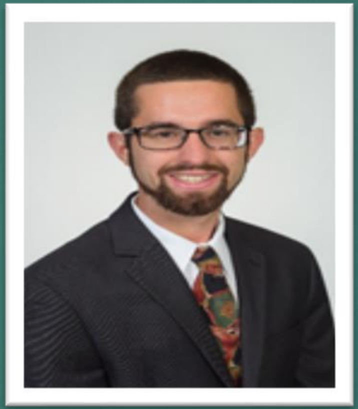
05-MAR-20

Meet the Team



Jesse Arrington
Design Engineer

Christian Torpey
Technical Engineer



Matthew Israel
Thermal Process Engineer

Tyler White
Energy Systems Engineer

Timothy Willms
Production Engineer

Team & Sponsor | Background | Targets & Metrics | Generation | Selection | Current Progress | Future Tasks

Sponsor

Tom Derzypolski
President of BowStern Marketing

- Florida State University graduate
- Bachelor's in Communications with an emphasis on Public Relations
- Decorated veteran of the U.S. Navy
- Member of:
  - Florida Public Relations Association
  - American Advertising Federation
  - Veterans of Foreign Wars

BowStern MARKETING COMMUNICATIONS

Overview

- Project Brief Summary
- Targets and Metrics
- Concept Generation
- Concept Selection
- Current Progress
- Planned Tasks/Future Work

Project Brief Summary

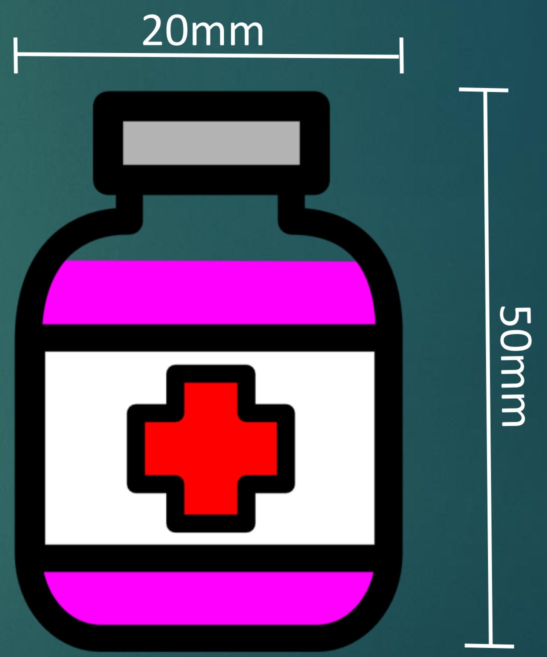
Background

- The objective of this project is to provide an affordable and accessible means to keep temperature sensitive medications cool during natural disasters and the days following.
- Puerto Ricans were out of power for an average of 84 days following Hurricane Maria
- 46% spike in diabetes related deaths
- Most common medications need to be between 2°C and 8°C

Targets & Metrics

Targets & Metrics

- Internal volume should accommodate 3 vials of medication
  - 20mm diameter, 50mm tall
- No vials should be broken
- Keep vials within range for at least one week
- Reasonable power usage
  - Common voltages (1.5V-12V)
- Temperature regulation
  - Internal temperature between 2°C and 8°C
  - <15min to reach temperature range



Concept Generation

Concepts

- Liquid Cooling
  - Immersion System, Active System (with pumps & tubing)
- Gas Cooling
  - Ranque-Hilsch Vortex Tube, Compressed Gas System
- Endothermic Chemical Reaction System
- Miniaturized Refrigeration System
- Thermoelectric Cooling System

Concept Selection

Final Selection

- Pugh chart & AHP determined the Compressed Gas Cooling System would be the optimal selection
  - In practicality, this concept is infeasible due to:
    - Difficulty obtaining large quantities of compressed gas
    - High safety risk in handling compressed gases
- Therefore, the TEC System was selected as the final design
  - Second lowest cost & consumption of power
  - Most feasible of remaining concepts

Current Progress

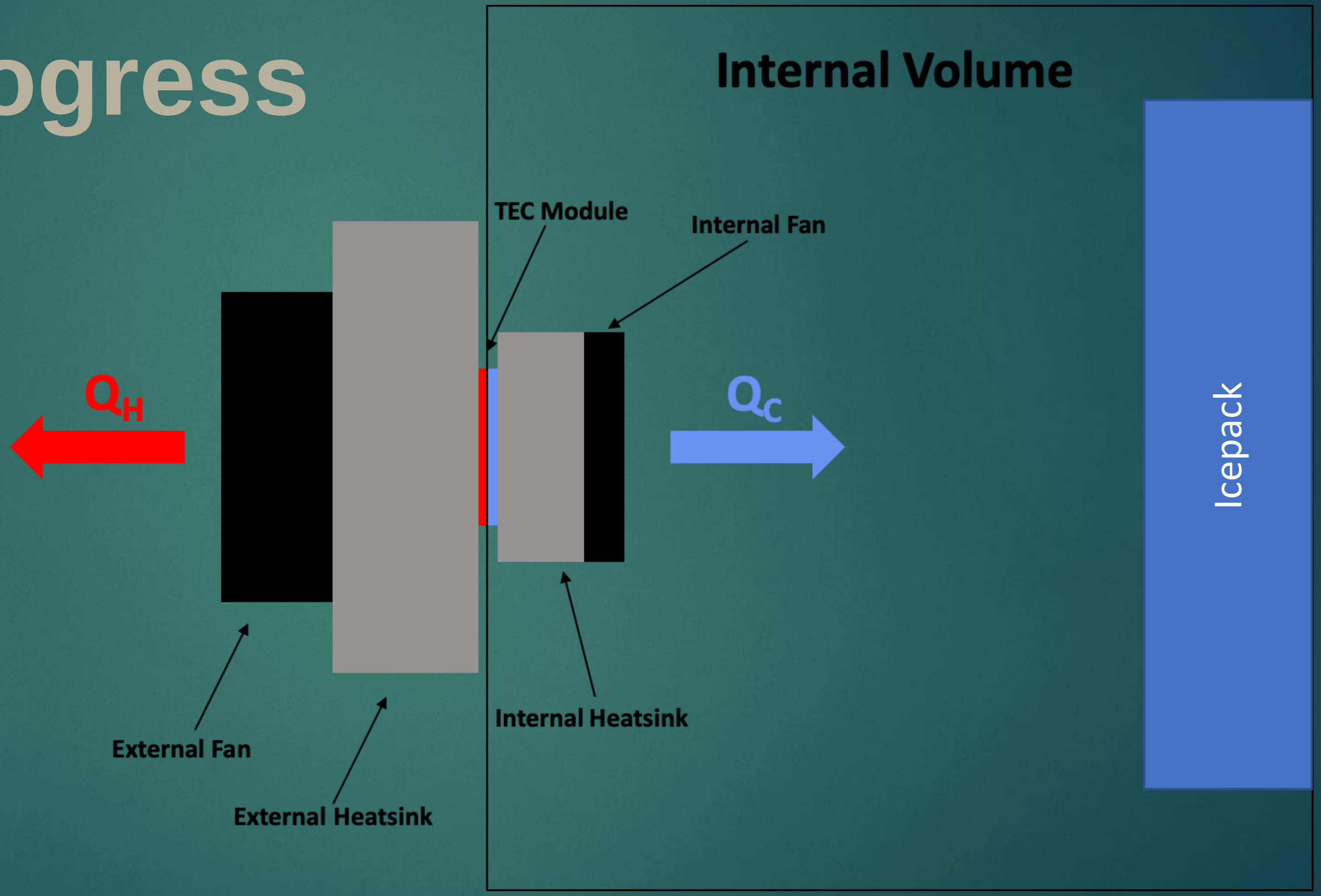
Current Progress

Thermoelectric (TEC) Module Testing:

- Current Prototype model utilizes a hard-shell cooler
  - Temperature controller with thermocouple to measure temperature/regulate power
  - Two fan, two heat sink configuration
  - Minimized internal volume using foam insulation to approximately 144 in^3
  - Use of icepack to maintain cold within the system
  - Improved insulation around TEC border with cooler

Current Progress

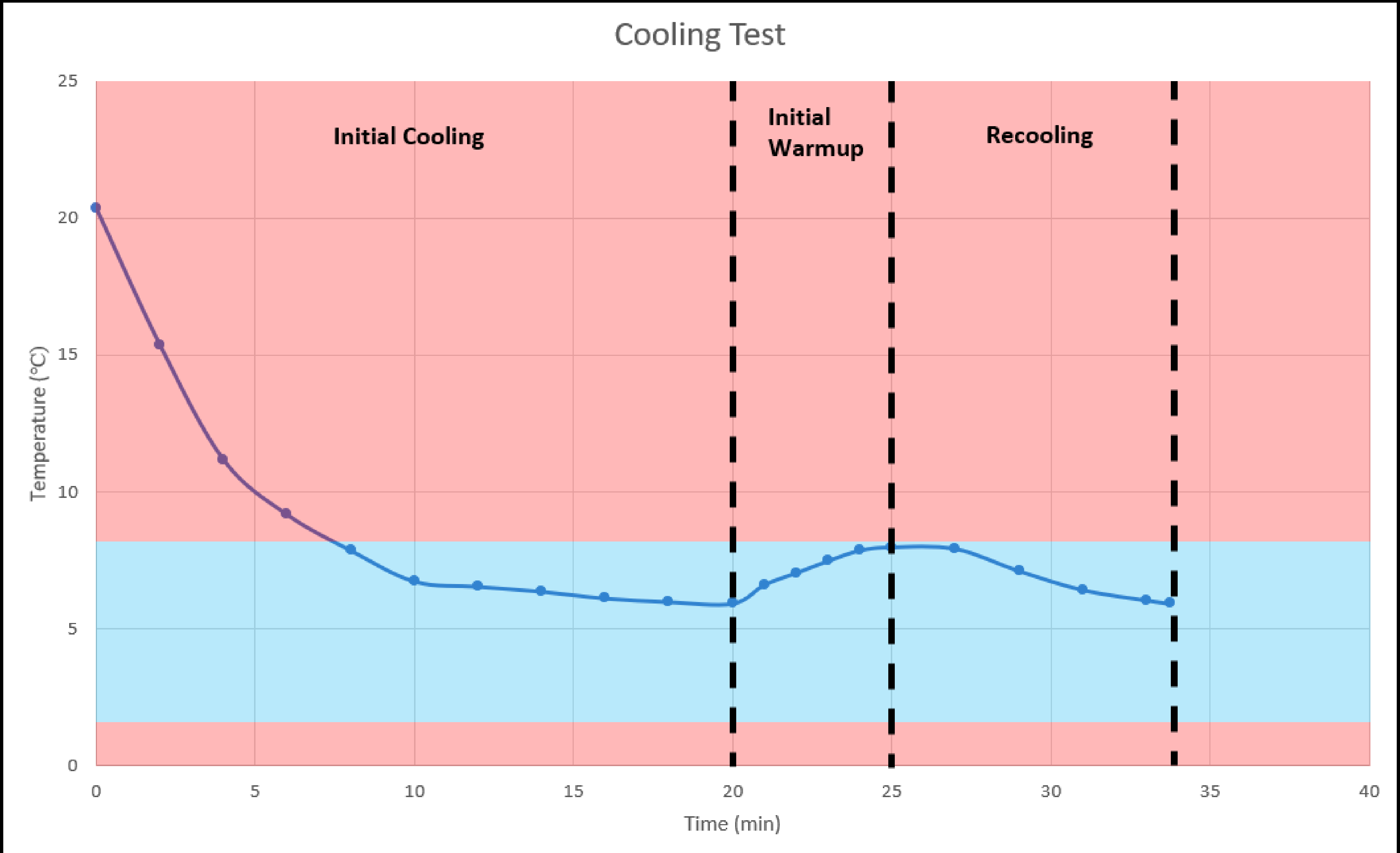
System Design



Early Prototype Testing

Testing Phases:

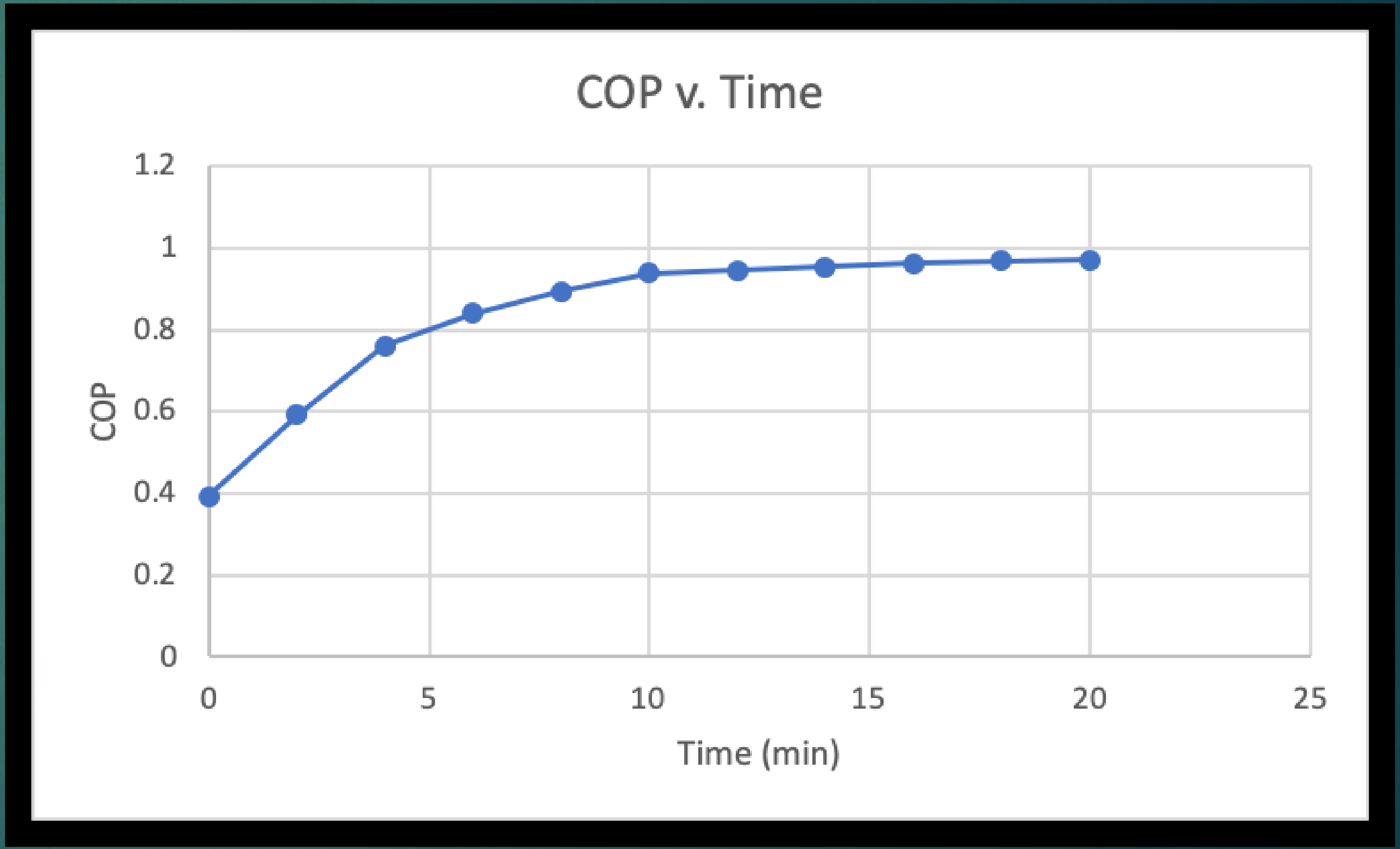
- Initial Cooling
  - Required time to reach appropriate refrigerated temperature from ambient conditions
  - TEC turned on at beginning of this phase
- Initial Warming
  - Once equilibrium temperature is reached, this phase measures the time required to exceed the required temperature range
  - TEC is turned off at beginning of this phase
- Recooling
  - Once the temperature range is exceeded, this phase measures the time required to reach equilibrium temperature again
  - TEC turned on at beginning of this phase


Cooling Test
Initial Cooling
Initial
Warmup
Recooling
Temperature (°C)
25
20
15
10
5
0
0
5
10
15
20
25
30
35
40
Time (min)

Current Progress

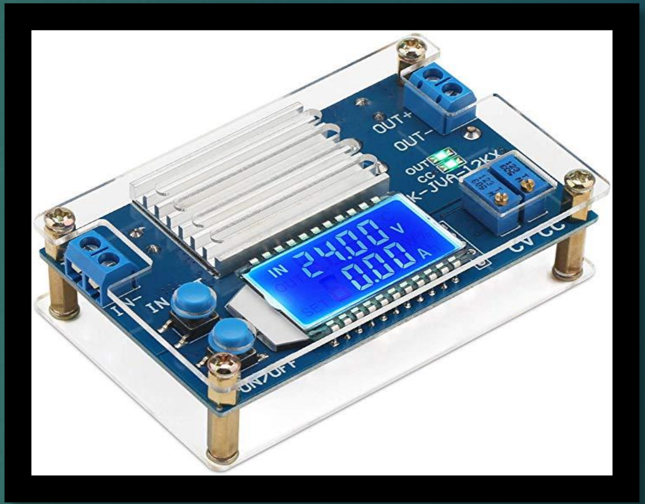
COP of System:

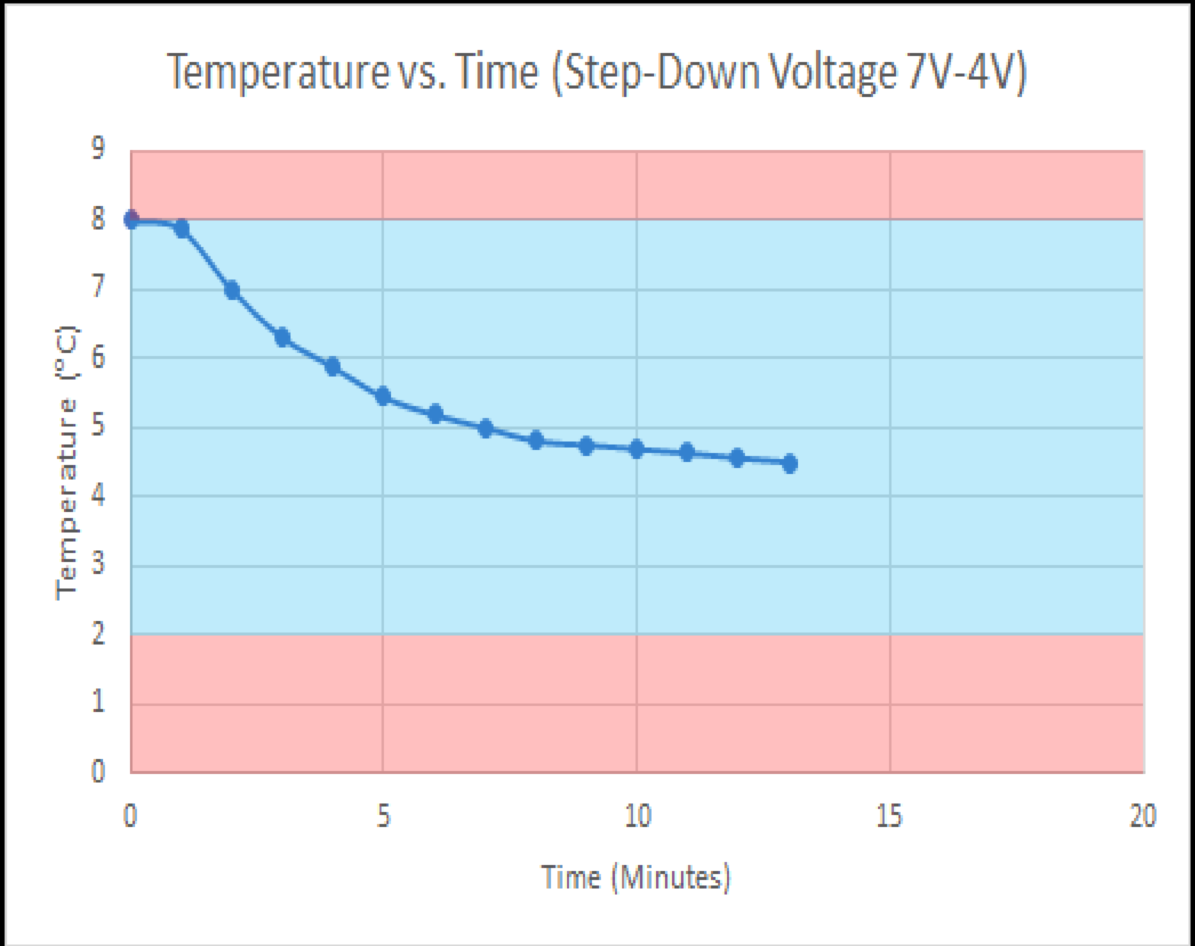
- Highest COP achieved: 0.97
- Lowest COP: 0.39
  - Attributed to the initial startup of the system from room temperature
- Typical maximum COP values for TEC modules are approximately 0.4-0.7 without modification

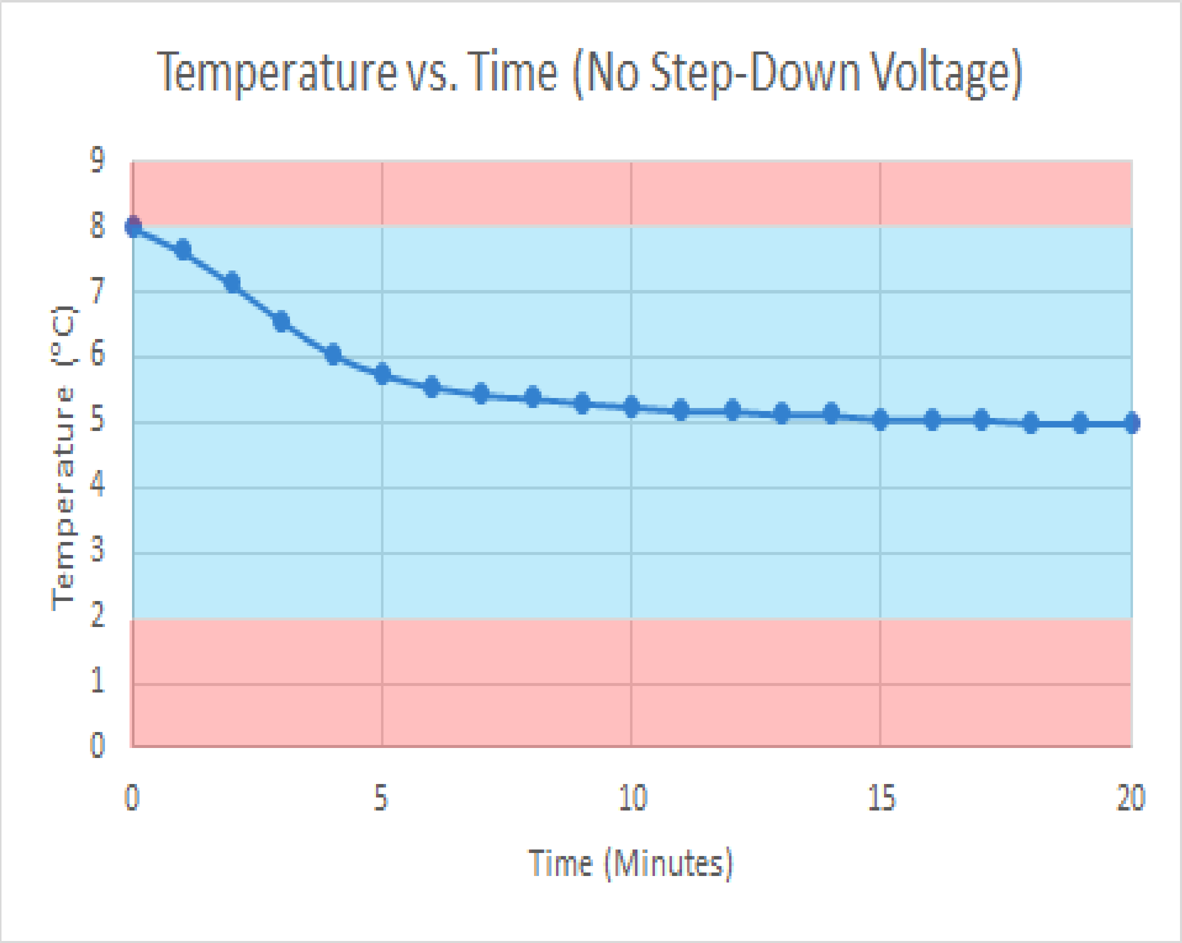


Addition of a Buck Converter

- Reduces the voltage supplied to the TEC module
  - Reduces overall current consumption while maintaining power
  - Reduces cool down time
    - Step-Down to 4V: 13 minutes to cool from 8C to 4.5C
    - No Step-Down: 20 minutes to cool from 8C to 5C
- Improves maximum COP of the module to 1.21 compared to 0.97
- Enables source voltage to increase to 12V
  - Previously unfeasible due to large current draw
  - Allows fans to run at full power, enabling more effective internal and external heat transfer
  - Sizes the voltage to a common value for typical deep-cycle batteries and solar panel configurations





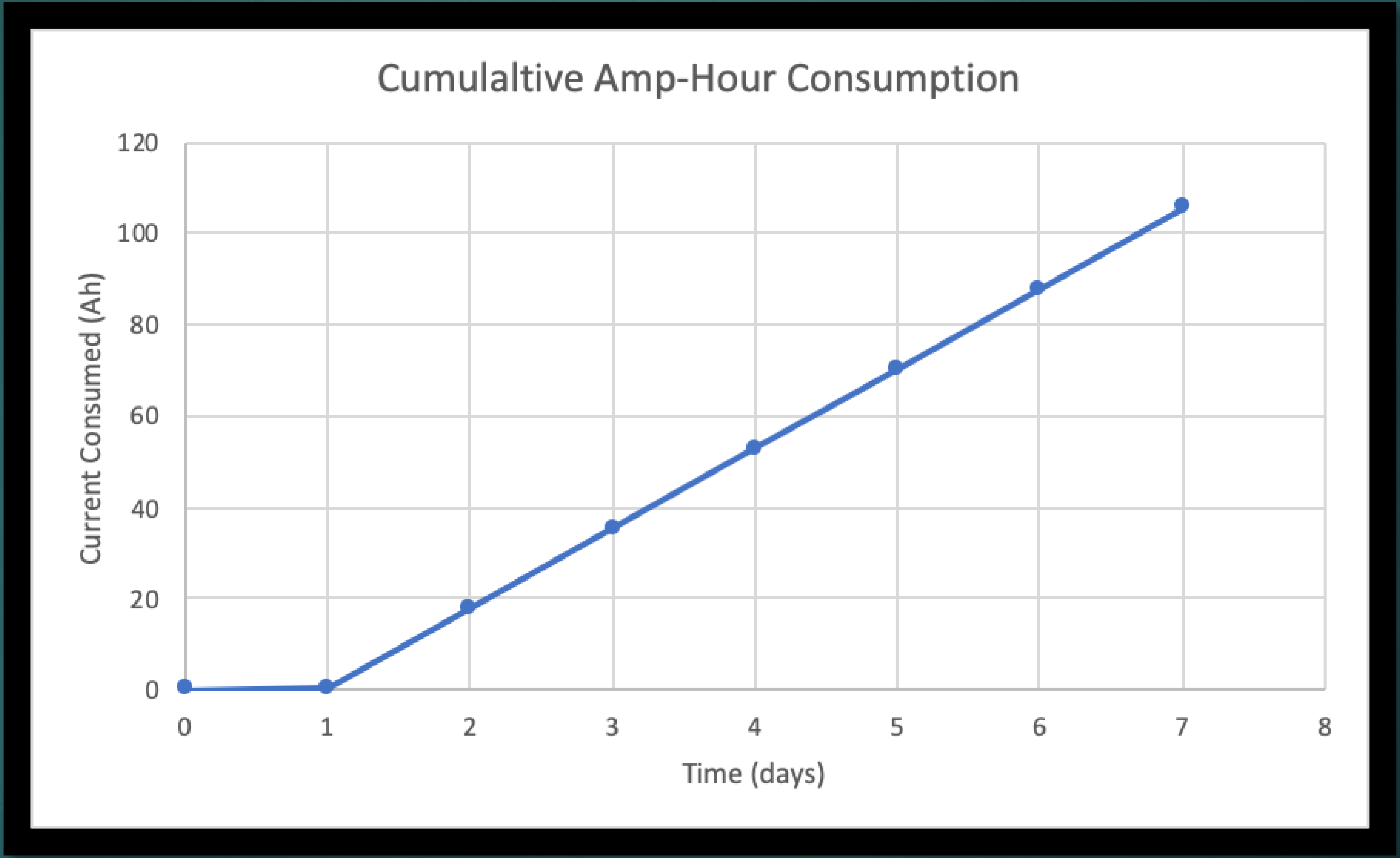


- Both Trials Draw 10 Watts of Power

Continuous Run Inputs

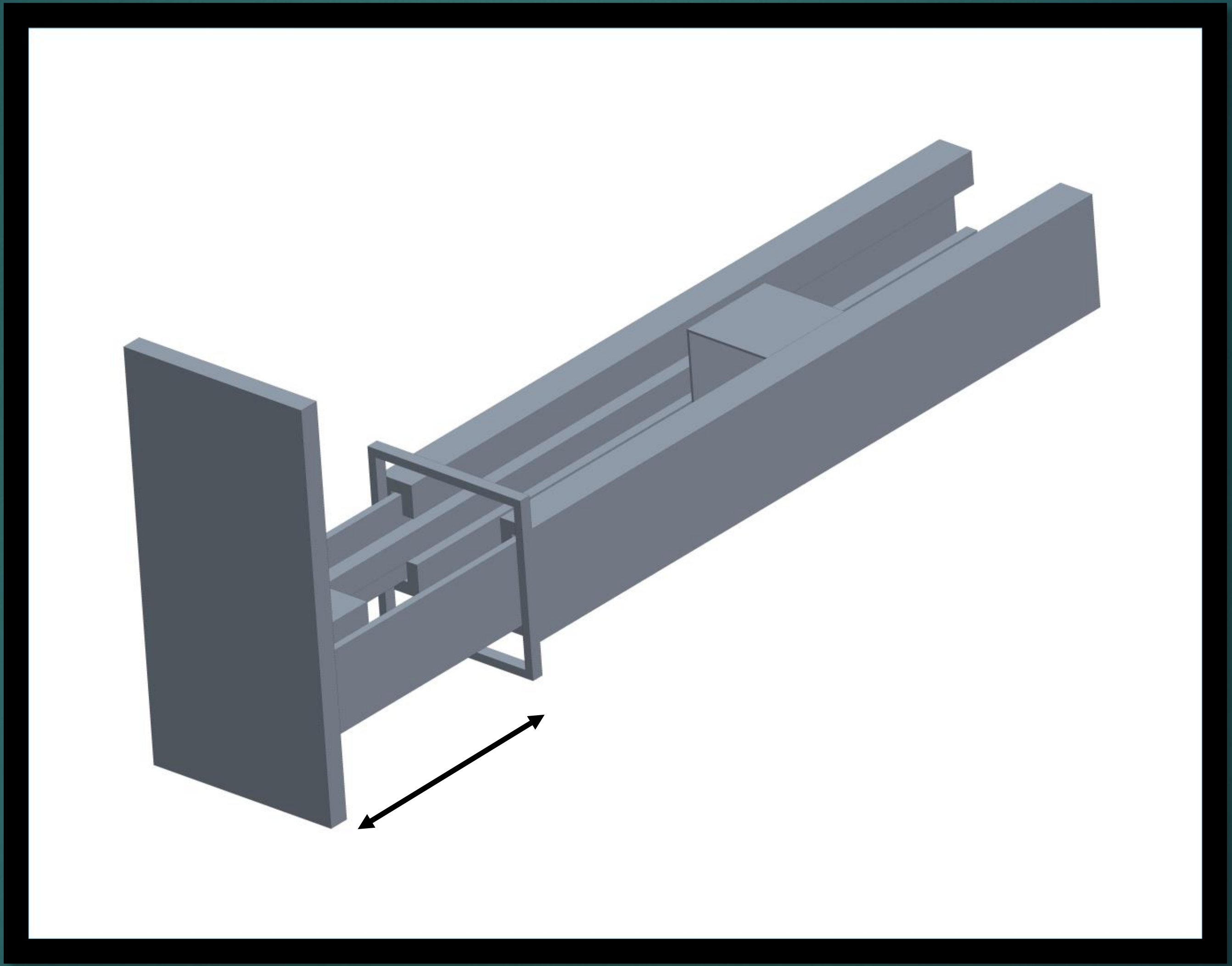
- Initially, using an "on" and "off" phase provided a more optimal power ratio
  - Initial ratios of 3 minutes on and 5 minutes off resulted in 11.5Ah per day
  - After the first day, the ratios flipped to 4.5 minutes on, 2.5 off (~19.5Ah)
  - Resulted in a need to analyze continuous runs
- Fully frozen Nortic ice pack allows approximately one day of "off" time for the system
  - Temperature controller running at 12mA during the "off" phase
- Minimum voltage supplied to TEC Module to stay within the range: 3.0V
  - Equates to a supplied current of 0.725A for the system
  - Approximately 17.4Ah consumed per day

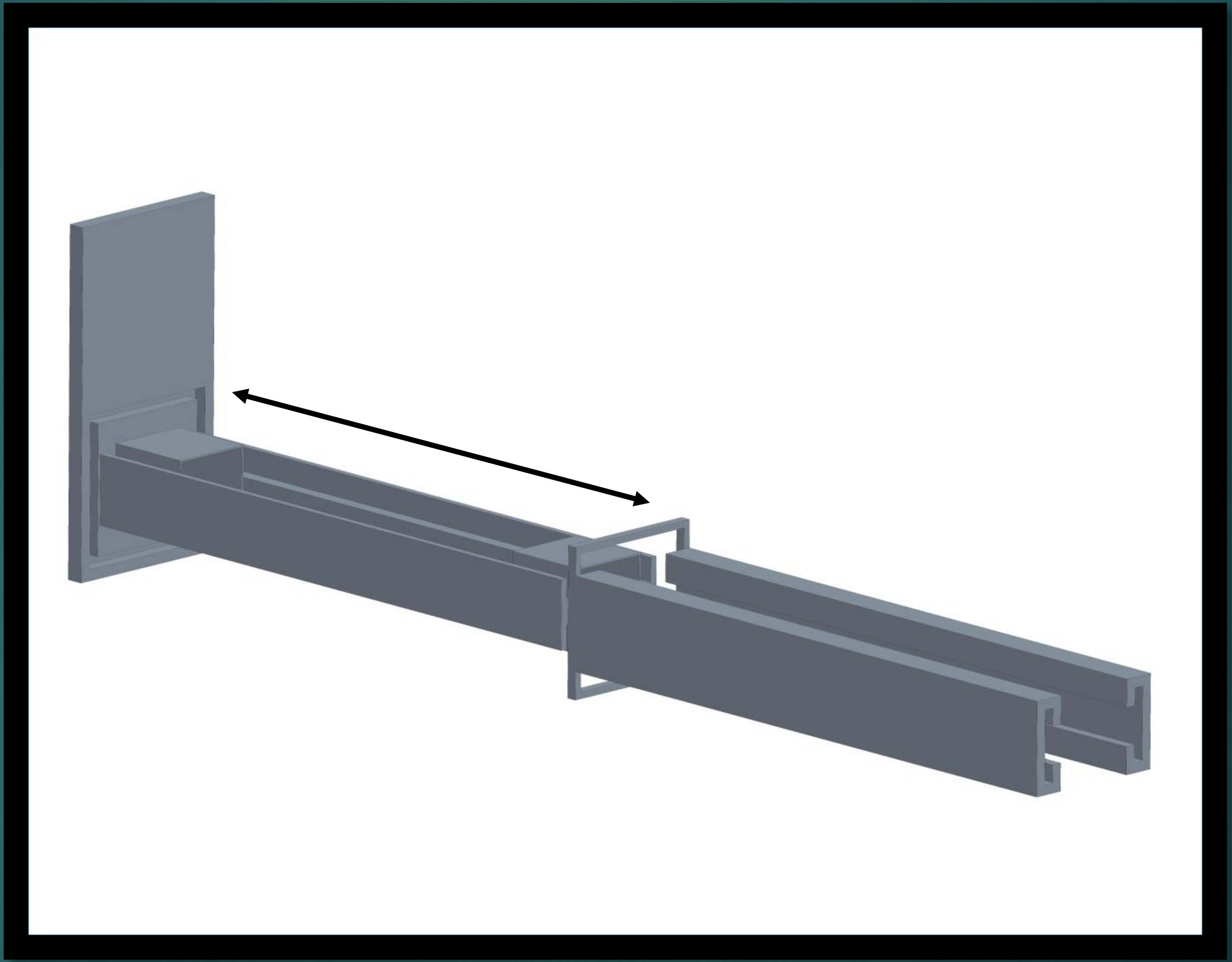
Continuous Run Analysis

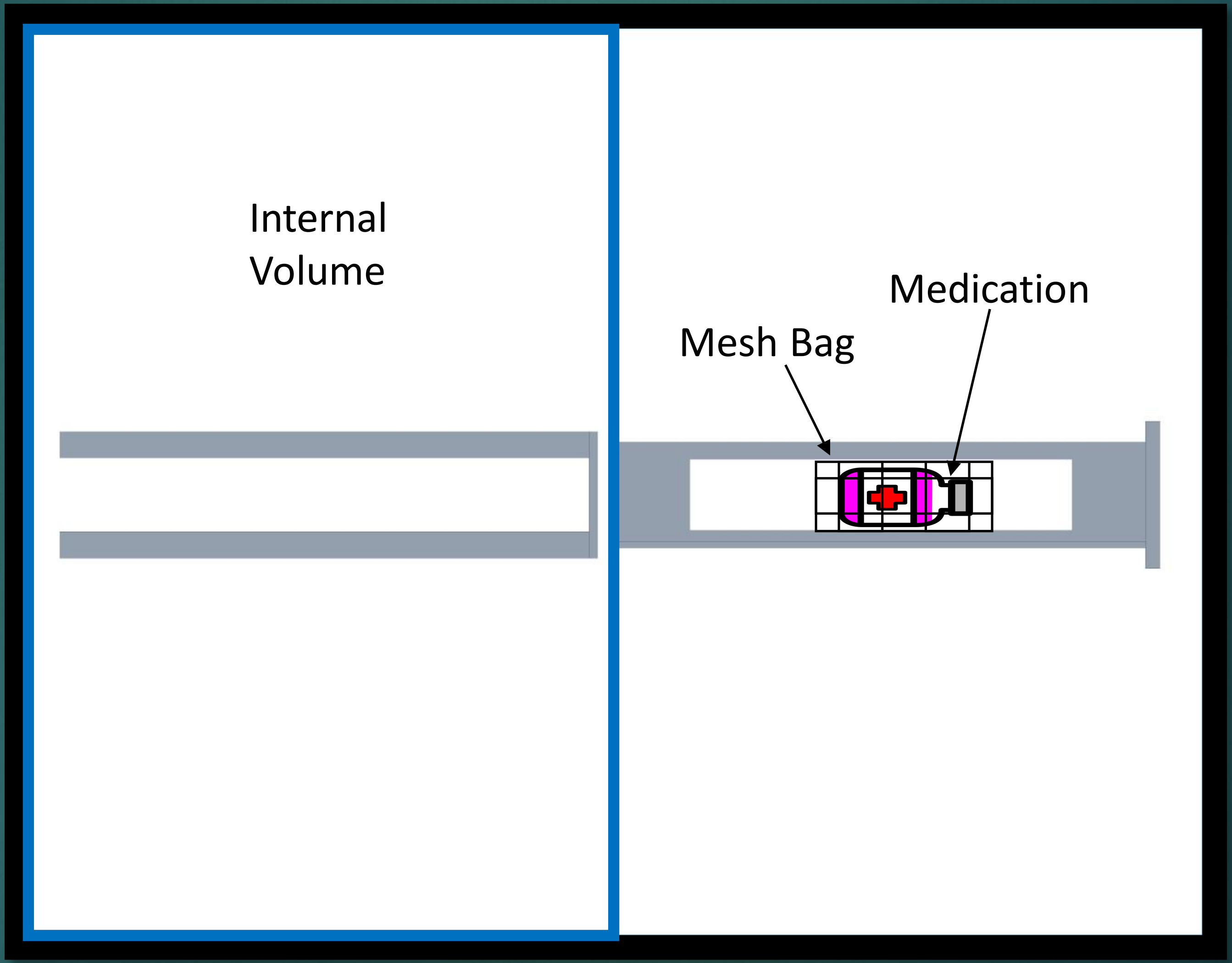


Medicine Storage Redesign

- New drawer design only requires one simple pulling motion
- Improved ease of use for users with mobility issues
- Simpler design is less likely to break or fail
- Roughly the same air flow as previous design





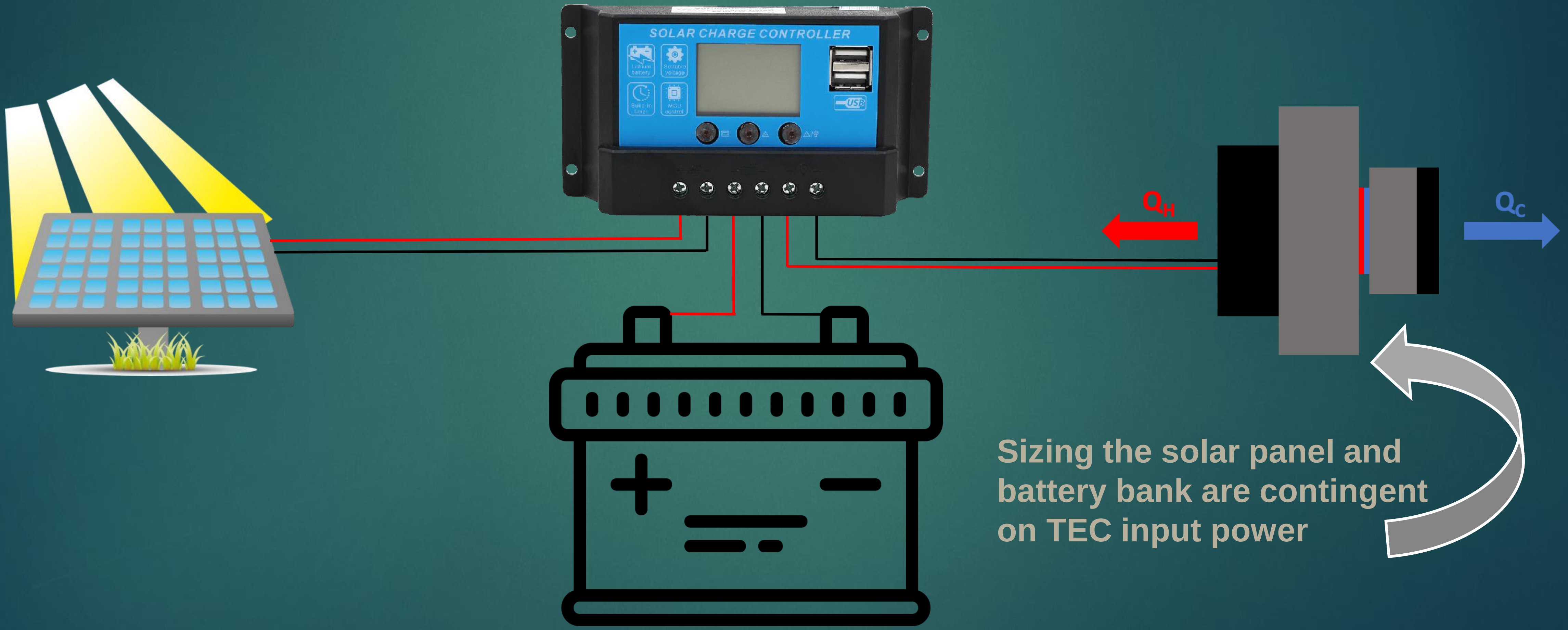

Internal
Volume
Medication
Mesh Bag

Current Progress

Power Generation and Storage System:

- Research indicates that solar power represents the most viable form of energy production
- Annual solar irradiance map illustrates that most areas struck by hurricanes have relatively high solar irradiance values
- Conservative estimate of 4.5 kWh/m^2 per day
- Hurricane season lasts from June 1st - November 30th, higher irradiance values than annual estimates will exist

Power Generation System Components

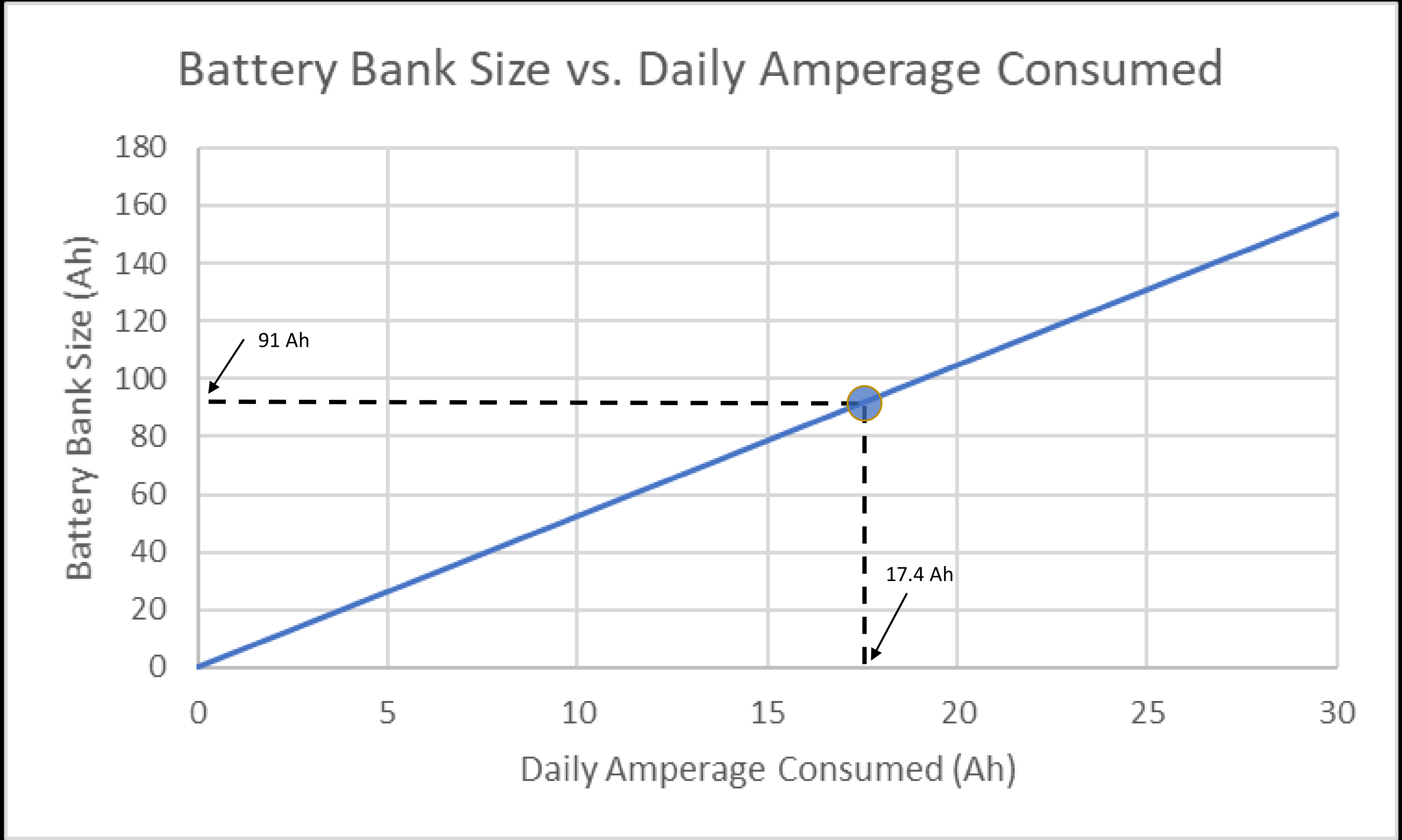


Sizing the solar panel and battery bank are contingent on TEC input power

Battery Bank Sizing

- CA: *Battery Capacity (Ah)*
- Q_{er}: *Daily Current Required (Ah)*
- N: *Autonomy Days*
- θ_{max}: *Allowable Depth of Discharge*
- ζ: *Circuit Loss*
- η_s: *Battery Efficiency*

$$CA = \frac{Q_{er} * N}{\theta_{max}(1-\zeta)\eta_s} \Rightarrow CA = \frac{Q_{er} * 4}{1(1-0.1)0.85}$$


Battery Bank Size vs. Daily Amperage Consumed
Battery Bank Size (Ah)
180
160
140
120
100
80
60
40
20
0
91 Ah
17.4 Ah
0
5
10
15
20
25
30
Daily Amperage Consumed (Ah)

Future Tasks

Future Tasks

- Assembly of system with final cooler
  - Testing associated with new, better insulated cooler
  - Implement vial storage
  - Print attachment casing to contain all electronic parts/wires
- Finalize power generation and energy storage system design
  - Calculate required battery bank capacity
  - Calculate necessary solar panel rated power
- Prepare for MUNIMOD competition April 4th-5th in Orlando, FL

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