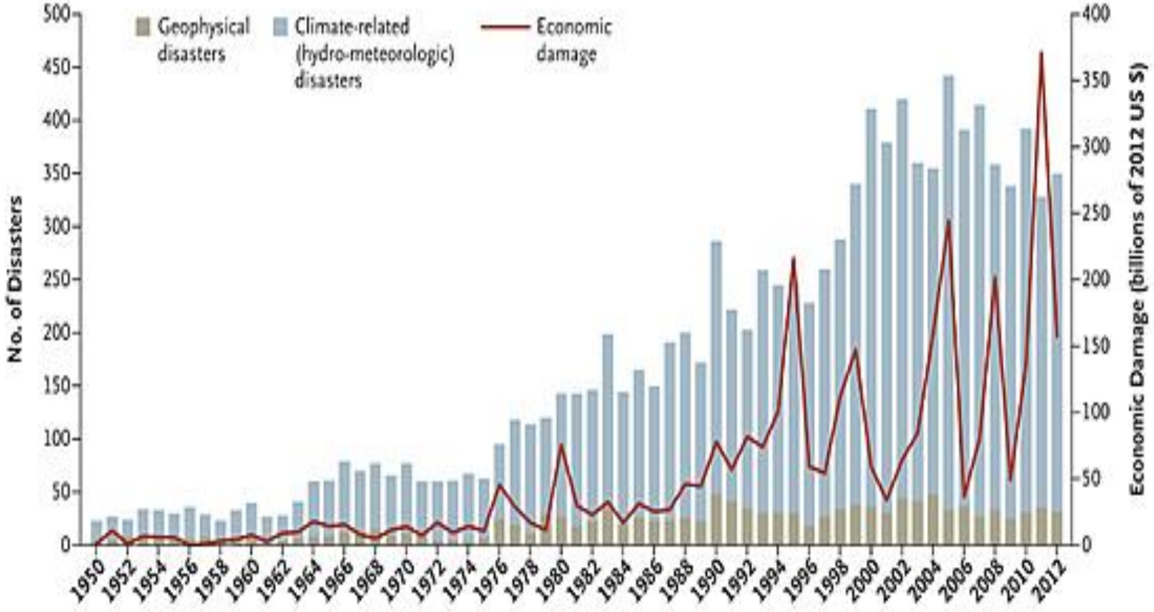
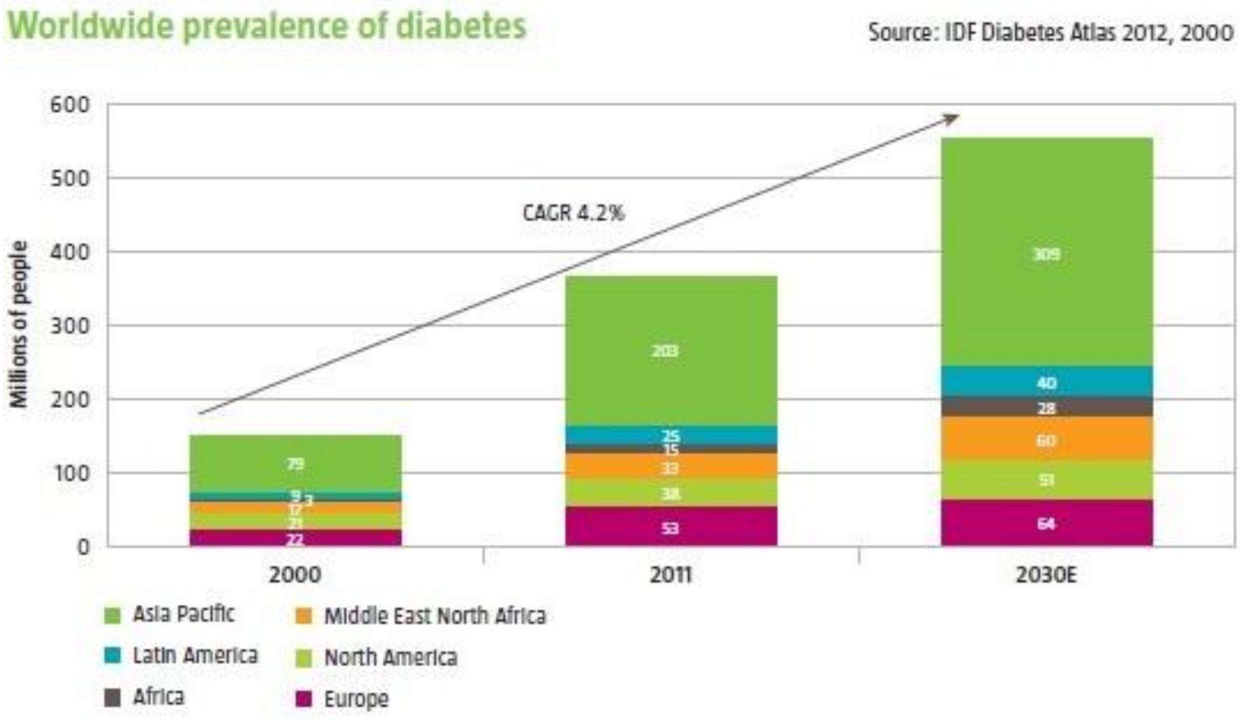
Final Design Review

EPICS Natural Disaster Preparedness Team

Introduction





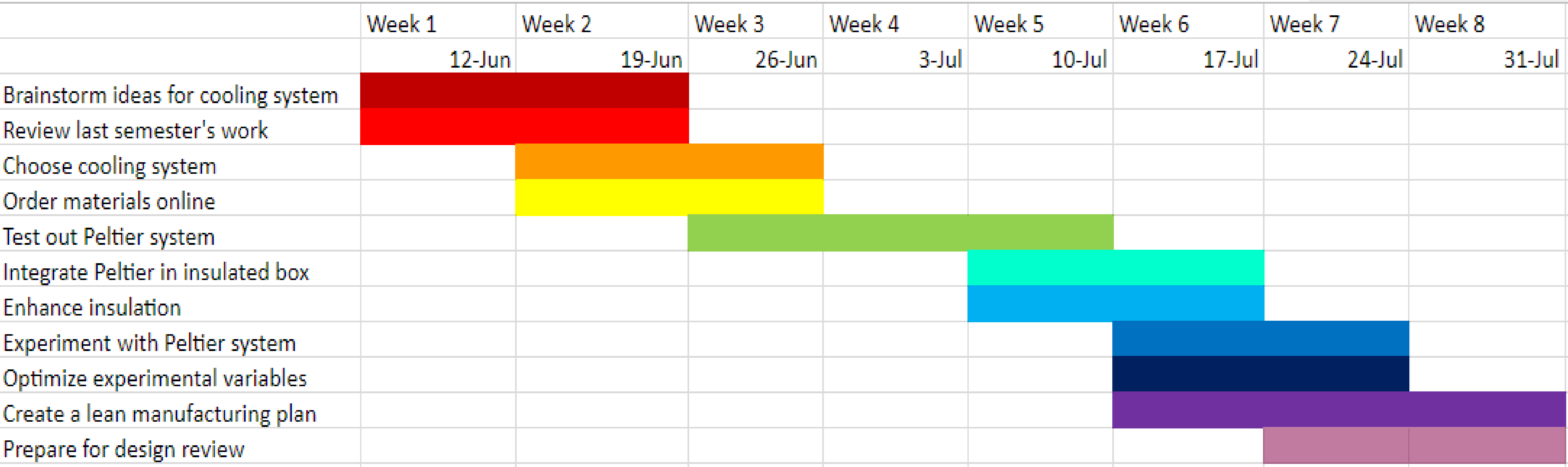
Problem Definition and Inspiration

- 100% of Puerto Rico's population lost access to power due to hurricane Maria.

- 20% of the population has diabetes.

- Diabetics could no longer store their medicine within specified temperatures due to lack of refrigeration.

Action Plan


Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
12-Jun
19-Jun
26-Jun
3-Jul
10-Jul
17-Jul
24-Jul
31-Jul
Brainstorm ideas for cooling system
Review last semester's work
Choose cooling system
Order materials online
Test out Peltier system
Integrate Peltier in insulated box
Enhance insulation
Experiment with Peltier system
Optimize experimental variables
Create a lean manufacturing plan
Prepare for design review

Current Solutions and Design Inspirations

- Costs $115
- Not insulated
- Short cooling time
- Rechargeable/Reusable
- Portable

Current Solutions and Design Inspirations

- Costs $45
- Enclosure design doesn't serve our purpose
- Lasts 24 hours
- More Portable

Insulin Storage

- Unused vials need to be kept between 2 and 8 degrees celsius until expiry date.
- Vials in use can be kept at room temperature for 30 days.
- Average consumption for adults is 1-1.5 vials per month.

Product Vision

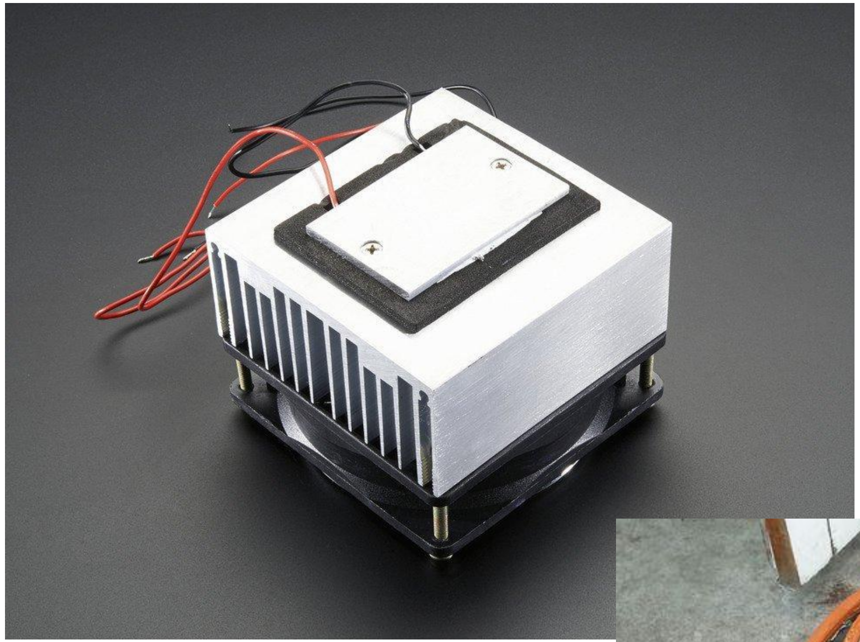
- Store insulin vials in maintained cool storage.
- Be portable and easily transported for distribution.
- Operate with a removable power source.
- Manufactured and assembled as a complete product in advance.
- Product would be provided to relief agencies to distribute to people in need.

Design Specifications and Constraints

- Cooling: Maintain inside temperature between 2-8 degrees celsius.
- Storage: Able to store 5 vials of insulin enough for two months of consumption.
- Size and Weight: ~8 Kg ; able to be carried.
- Operation: Maintain insulin cool for two months.
- Power: Attached battery that can be replaced or recharged.

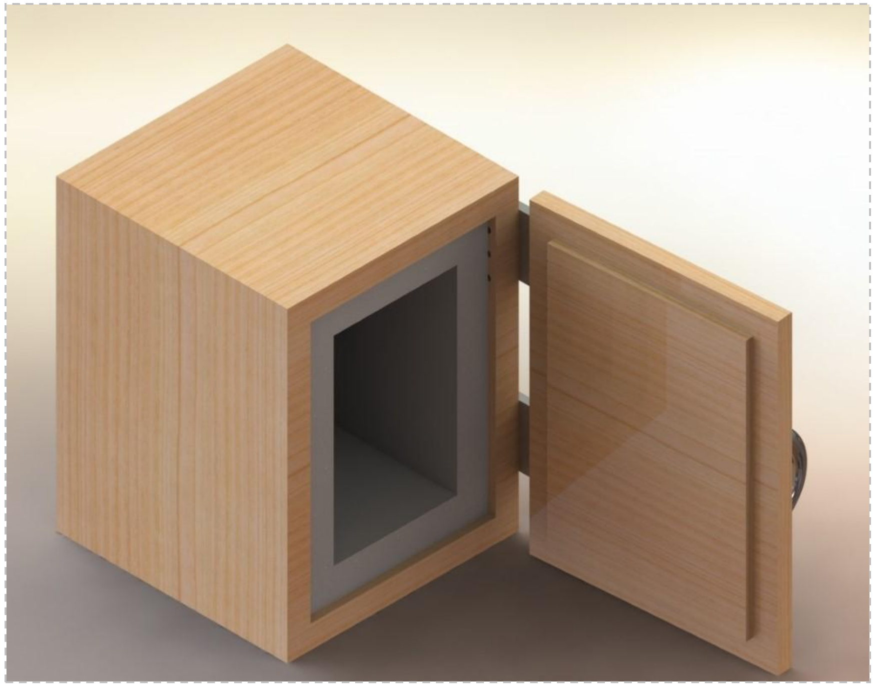
Concept Generation

- **Evaporative Cooling**
  - Pros
    - Cools without power
    - Requires no electronics
  - Cons
    - Unreliable
- **Active Cooling**
  - Pros
    - Always works with a power source
    - Compact Design
    - Reliable
  - Cons
    - Requires a power source

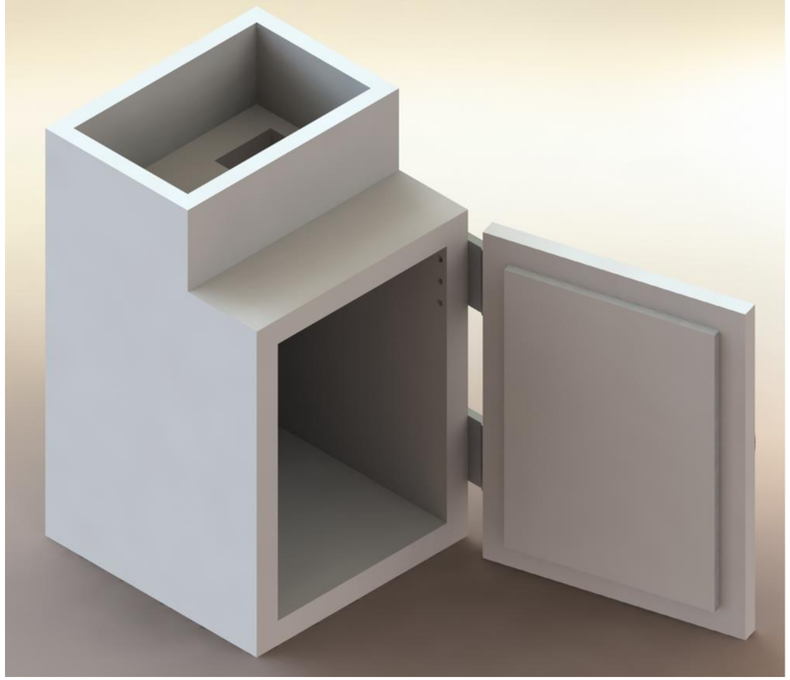


Concept Design

Design #1



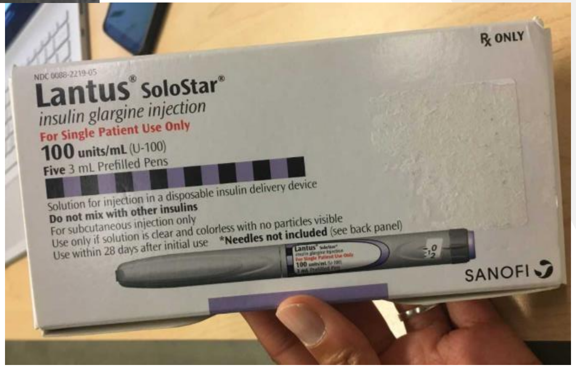
Design #2



Prototype Insulation

15x13x22 cm box

Insulating Materials	R value
Expanded polystyrene (EPS)	4
Extruded polystyrene (XPS)	5
Eco friendly Mycelium/Sawdust insulation	3.35
Silicone Gel Adhesive	2.5
Polyethylene	0.65
Nylon	0.65



Peltier Cooling Technology

Peltier - Current flows between 2 semiconductors causing a thermal gradient

Heat sink - allows thermal regulation

Fan - distribute cooler temperature

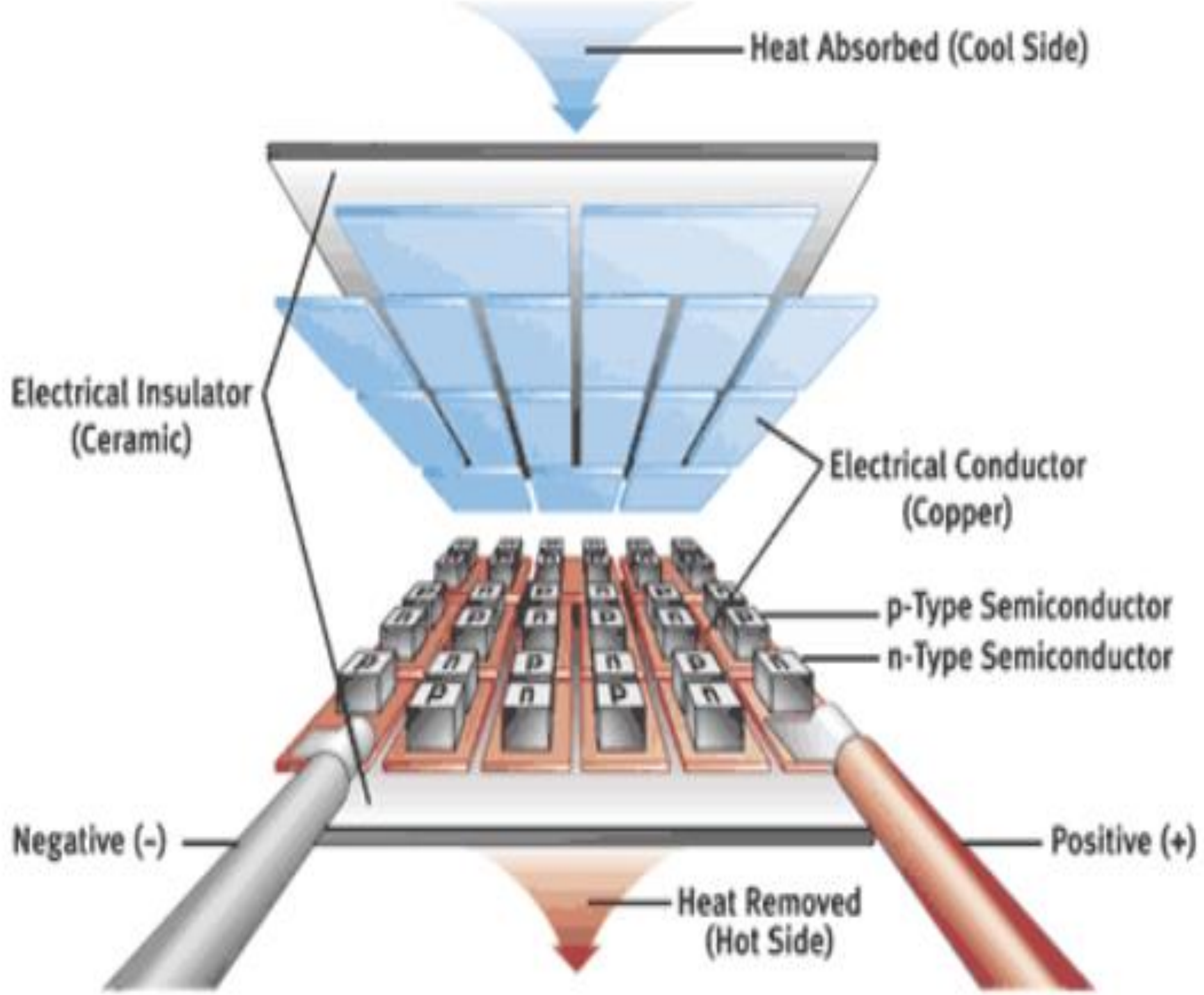


Figure 1. **Typical Cooling Assembly Thermal Diagram**

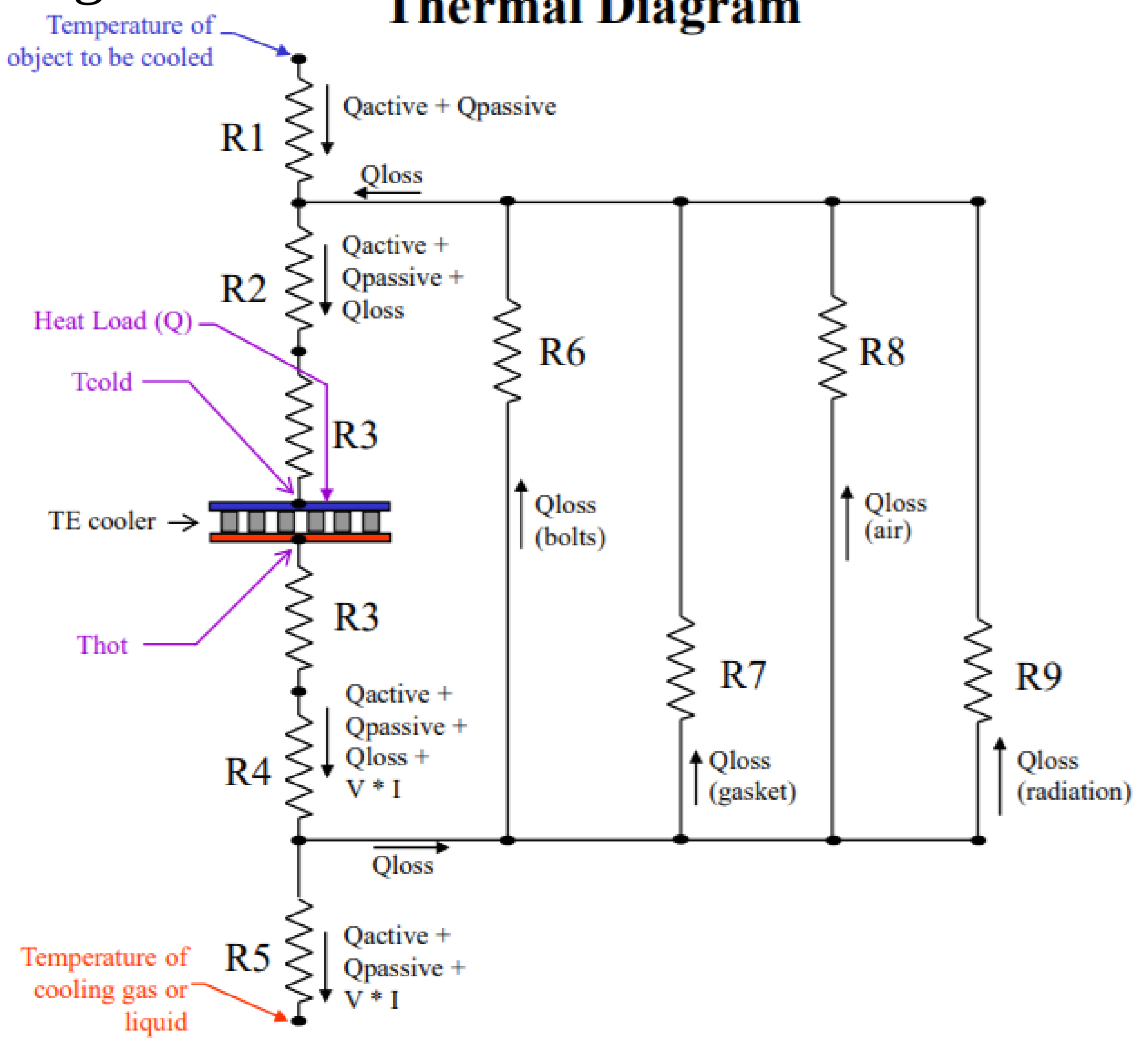
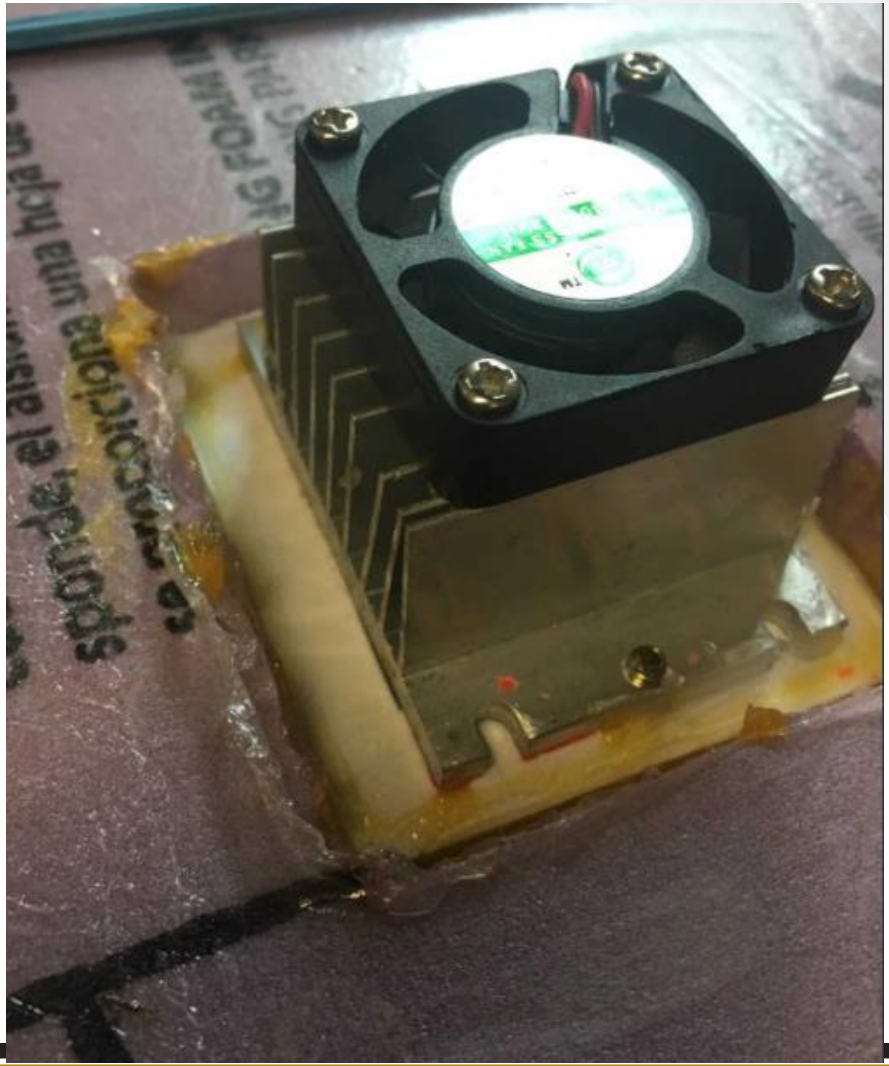


Figure 2. Peltier Semiconductor



Peltier Thermodynamics

- **Total Heat Transfer Rate from the Peltier Cell through the Copper Plate**

$$q = \frac{kA}{L}(T_h - T_c)$$

- **Heat Rate = Peltier Cooling Effect – Joule Heating –Heat Conduction**

$$Qc \cong -S\,I\,T_c + \frac{1}{2}I^2R + k\,\frac{A}{L}(T_h - T_c)$$

- **Heat on cold side of the Peltier Cell**

$$q_c = \frac{(T_{Bulk\ Fluid} - T_{Peltier\ Cell\ Cold})}{\frac{1}{h_{Cooling\ Block}A_{Cooling\ Block}} + \frac{L_{Copper\ Plate}}{k_{Copper\ Plate}A_{Copper\ Plate}}}$$

- **Heat on the hot side of the Peltier Cell**

$$q_h = \frac{(T_{Peltier\ Cell\ Hot} - T_{Ambient\ Air})}{\frac{L_{Copper\ Plate}}{k_{Copper\ Plate}A_{Copper\ Plate}} + \frac{1}{h_{Heat\ Sink}A_{Heat\ Sink}}}$$

Surface area	1600mm^2
Peltier Power	48 Watts
Delta T	*10 K*
Thickness(L)	3.9 mm
Thermal Conductivity of Styrofoam	.033 W/mK
Thermal Conductivity of copper (k)	401 W/mK
Resistance(R)	1.98 Ohm
Test Peltier + insulation heat transfer rate at room temperature	0.838 W/m^2*C

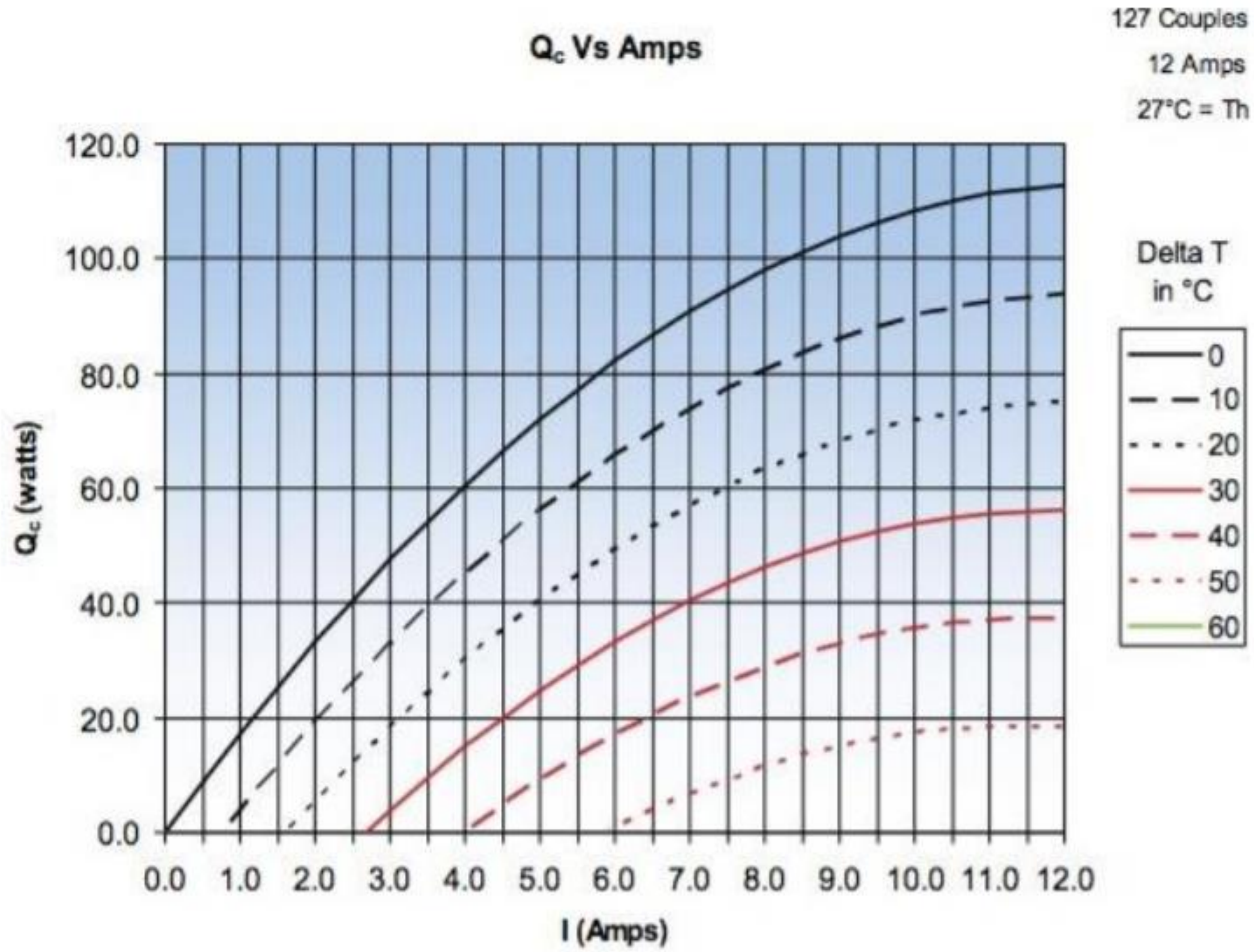


Figure 3. Chart of Peltier Cell Performance

Battery Formulas & Calculations

Assuming a 12V 50Ah battery

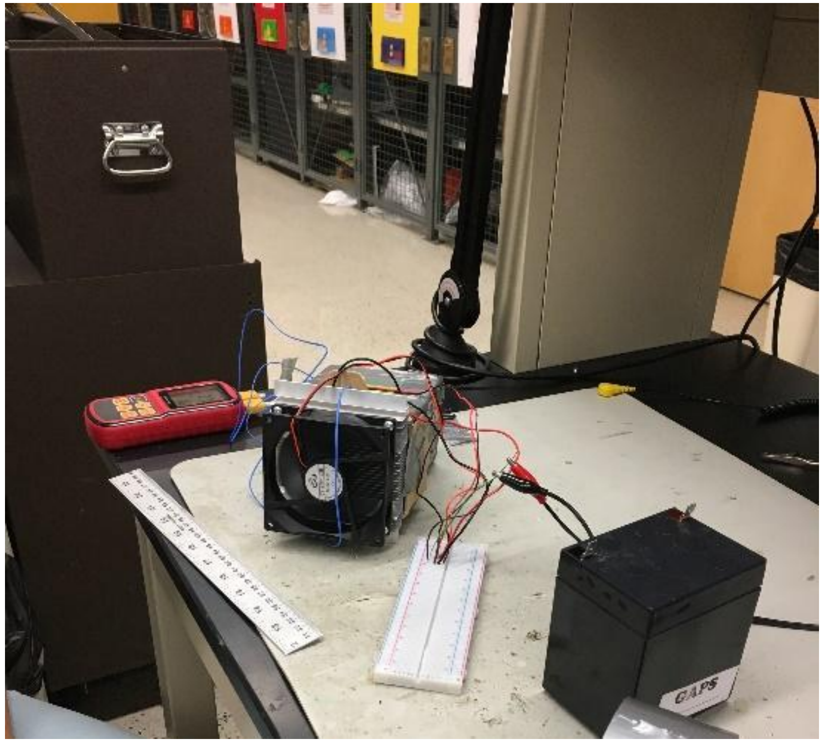
Capacity/Drain=Run time

50Ah/4Ah= 12.5 Hours

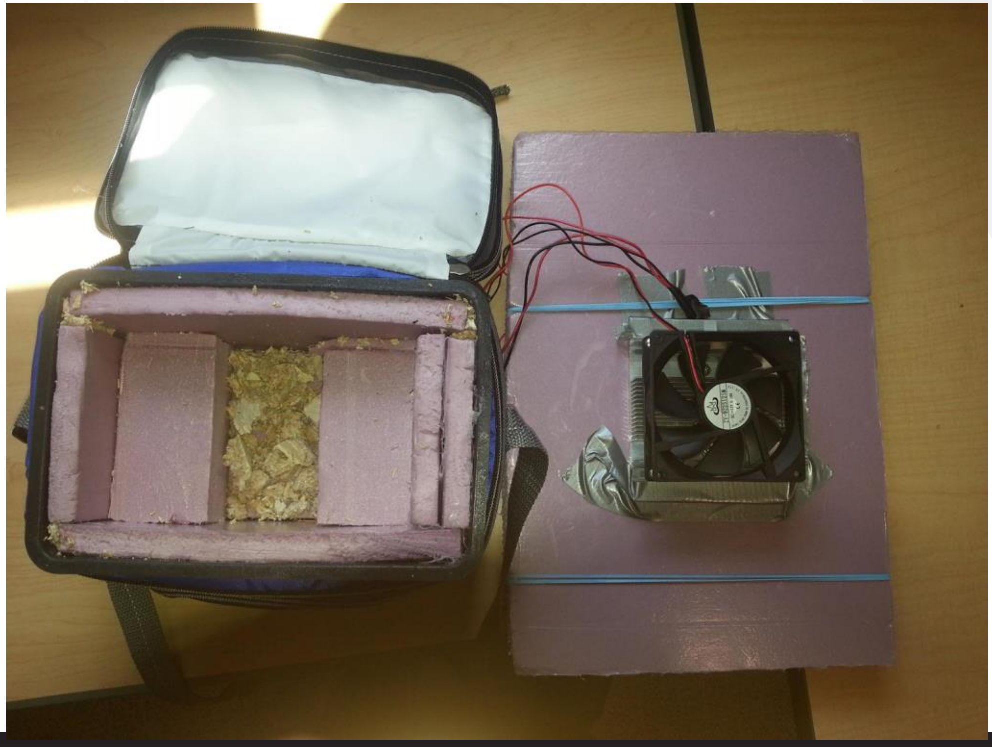
*With temperature controller we could achieve a longer run time by shutting down the system once optimal temperature is reached.

Rapid Prototype Iterations

Initial Design:

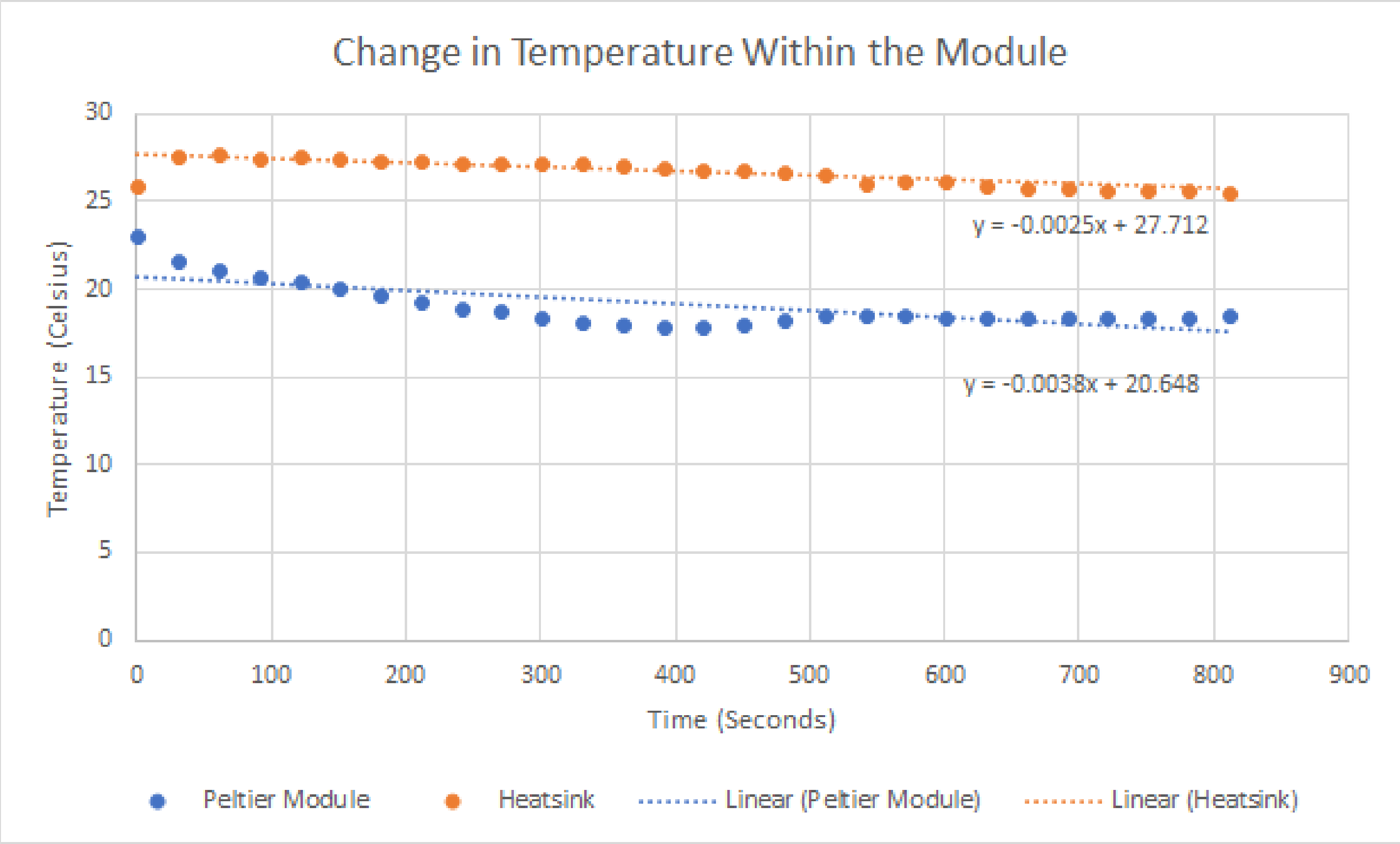


Final Design:



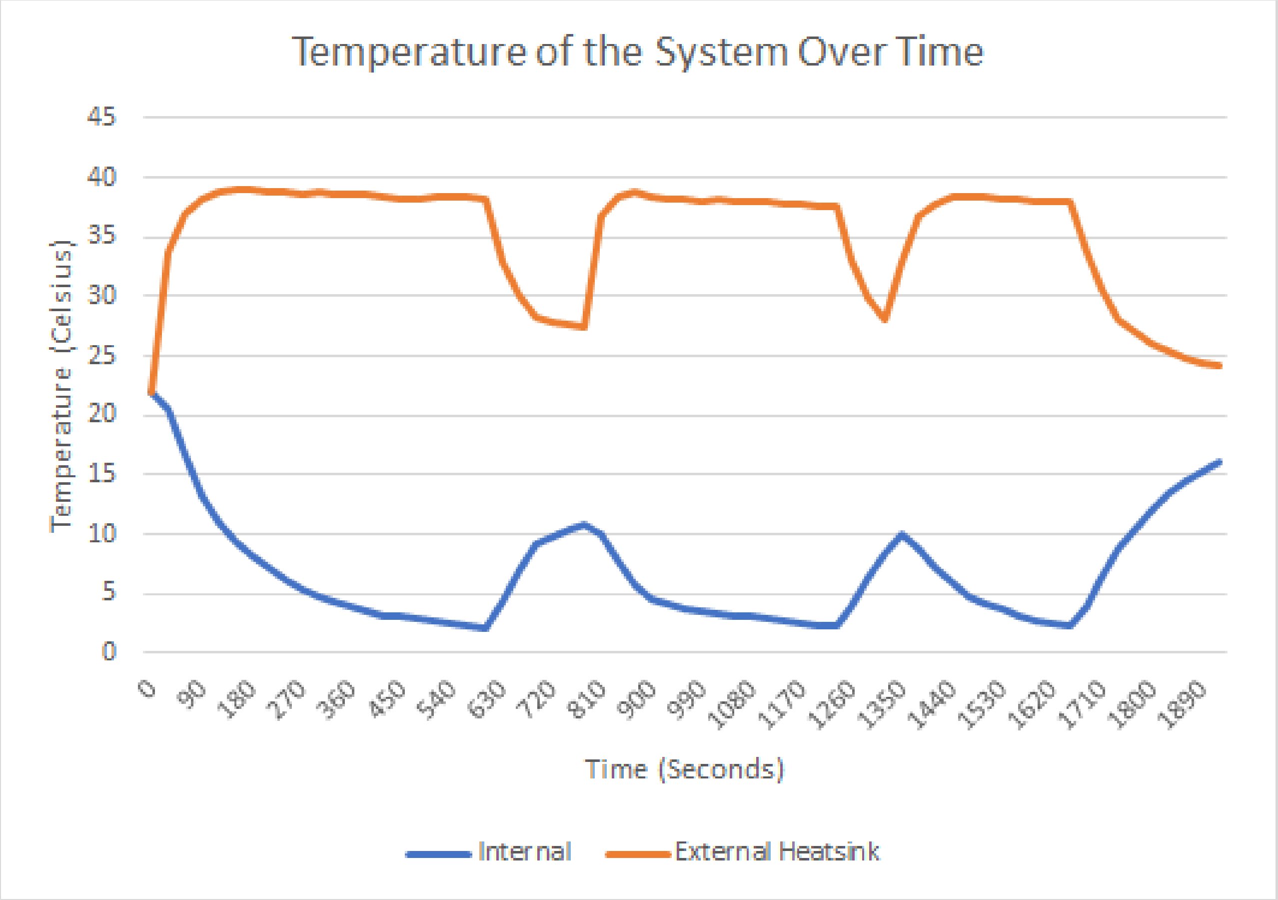
Experimentation and Test Results (#1)

- Powered by 12.6V and 1.35A
- Lowest Temperature: 17.9 C
  - Achieved in 390s
- Low Efficiency
- Very ineffective



Experimentation and Test Results (#2)

- Powered by 12.6V and 4A
- Previous temp. reached in 60s
- Lowest Temperature: 2 C
  - Achieved in 600s
- Significantly improved efficiency



Diagnosed Issues

- Temperature loss rate is much too high with the current prototype
- Prototype is not fully portable at the moment
- System consumes too much power currently to meet design target

Potential Manufacturing and Distribution Plan

- Have the design simple enough for easy manufacturing and shipping
  - Also ease of replication if needed in the area of disaster
- Preferably manufactured by external company and distributed to relief agencies such as the UN, FEMA, or Field Ready

Future Recommendations

- Conduct more insulation material testing
- Contact professionals with relevant background
- Create detailed manufacturing & distribution plan
- Conduct cost analysis
- Incorporate a rubber seal
- Fix flaws with temperature loss
- Make box more aesthetic

Questions?