Electric Vehicle Optimization Team 2

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Sponsor: Dr. Michael Hays
Advisor: Dr. Juan Ordonez

Background

- Cabin electronics drain semi-truck batteries
- Cold weather conditions reduce battery output
- Hotel System of Charging

- Dr. Hays presented the design team with two major problems:
  - ✦Current range is unsatisfactory
  - ✦Cannot operate in -29°C (-20°F)

Presenter: Samantha Beeler

Overview

Goal Statement:

- "To increase the current range and operable conditions of the electric vehicle by utilizing a secondary power source in efforts to apply this to semi-trucks."

Objectives

- Increase the lower temperature limit to -29°C
- Document current system
- Incorporate generator
- Integrate a battery monitoring system
- Model design for ISX-15 diesel engine.
- Ensure the vehicle can charge while running.

Presenter: Samantha Beeler

Golf Cart Features

Current Features

- Powered by 6 8-V lead/acid batteries
  - The batteries do not work
- On-Board Charger
- 5,000 Watt DC Motor

To Be Added

- Generator
  - Battery Monitoring System
- New Batteries
  - Will be selected by independent EE team

Figure 1. Picture of golf cart

Presenter: Samantha Beeler

HOQ

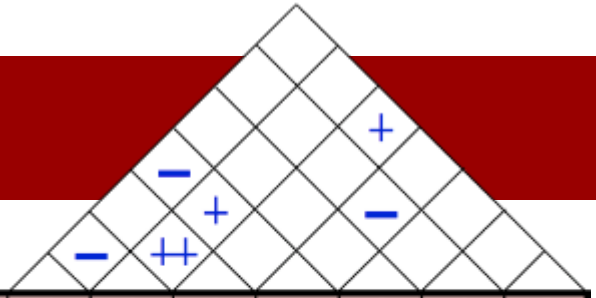

Table 1. House of Quality

Row #	Relative Weight	Weight / Importance	Engineering Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	1 Charge Time (hr)	2 Cost ($)	3 Durability	4 Battery Life (yr)	5 Noise Level (dB)	6 Operable Temperature Range (ΔT)	7 Weight (kg)
			Direction of Improvement: Minimize (▼) or Maximize (▲)	▼	▼	▲	▲	▼	▲	▼
1	4.5	1.0	Aesthetics		1					1
2	13.6	3.0	Cost	1	6	3	1			
3	22.7	5.0	Ease of Use	3				1	3	
4	18.2	4.0	Reliability		1	3	6		6	
5	22.7	5.0	Safety	1		3		3		3
6	18.2	4.0	Serviceability			1	1			
			Target or Limit Value	10	<2000	N/A	6	<70	-40°C to 40°C	100
			Weight / Importance	104.5	104.3	181.8	141.0	90.9	177.3	72.7
			Relative Weight	12.0	12.0	20.8	16.2	10.4	20.3	8.3

Legend	
6	Strong Relationship
3	Moderate Relationship
1	Weak Relationship
++	Strong Positive Correlation
+	Positive Correlation
−	Negative Correlation
▼	Strong Negative Correlation

Presenter: Samantha Beeler

Design Concepts

Table 2. Morphological Chart

Parameter	Option 1	Option 2	Option 3
Generator Location	Under back seat	On a Carriage	In place of the back seat
How to warm the batteries	Use generator exhaust	Use heating pad	Insulate the batteries
Ensure generator operation	Synthetic oil	Oil pan heater	Oil dipstick heater
Charging system	Use onboard charger system	Develop new charger system	Modify present charger system

Selected Option

Complications in Selection

Presenter: Jeremy Randolph

Figure 2. Photo of the back of the golf cart with recessed region under the rear seat.

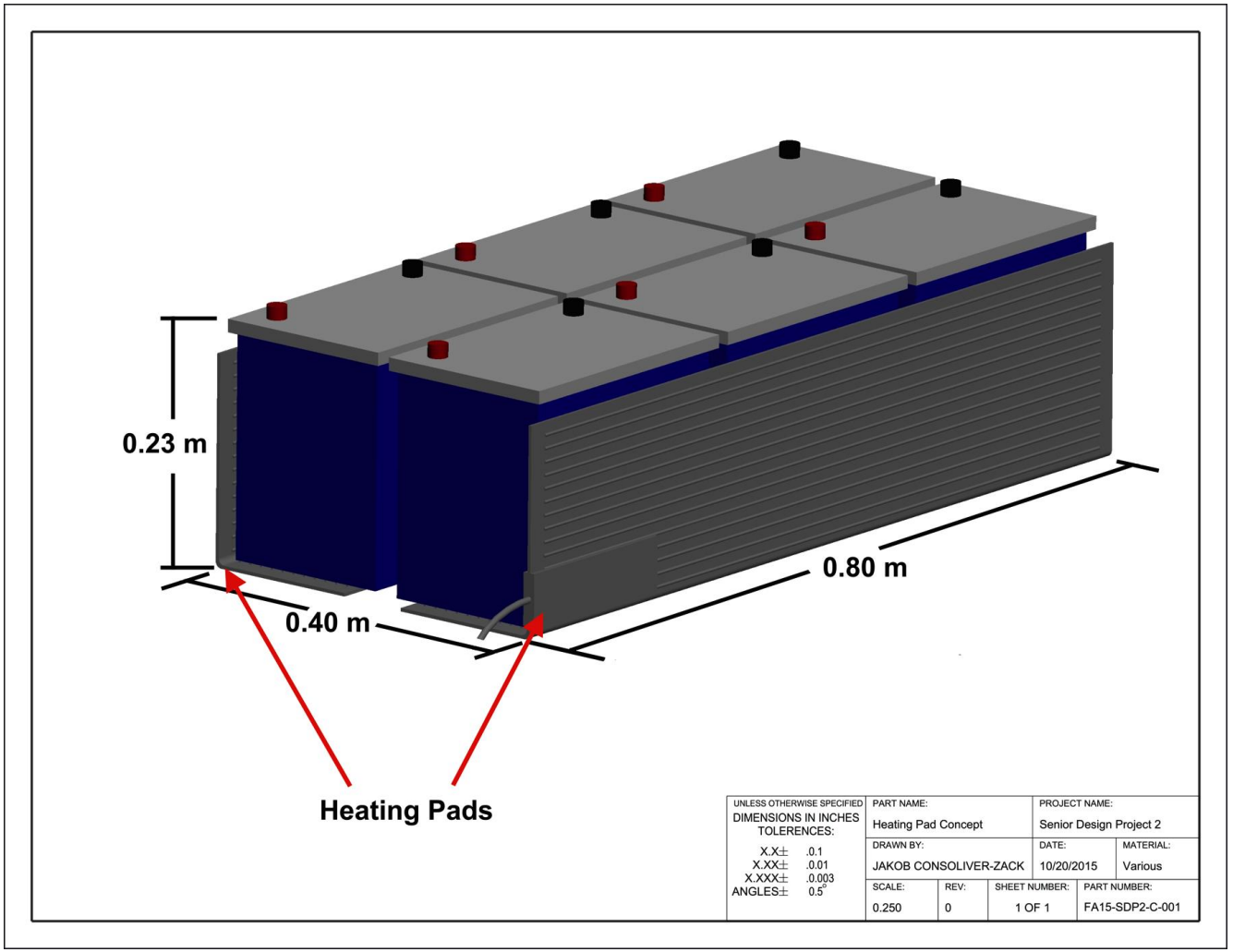

Figure 3. Initial concept of batteries and heating pads

Presenter: Jeremy Randolph

Initial Proposed System

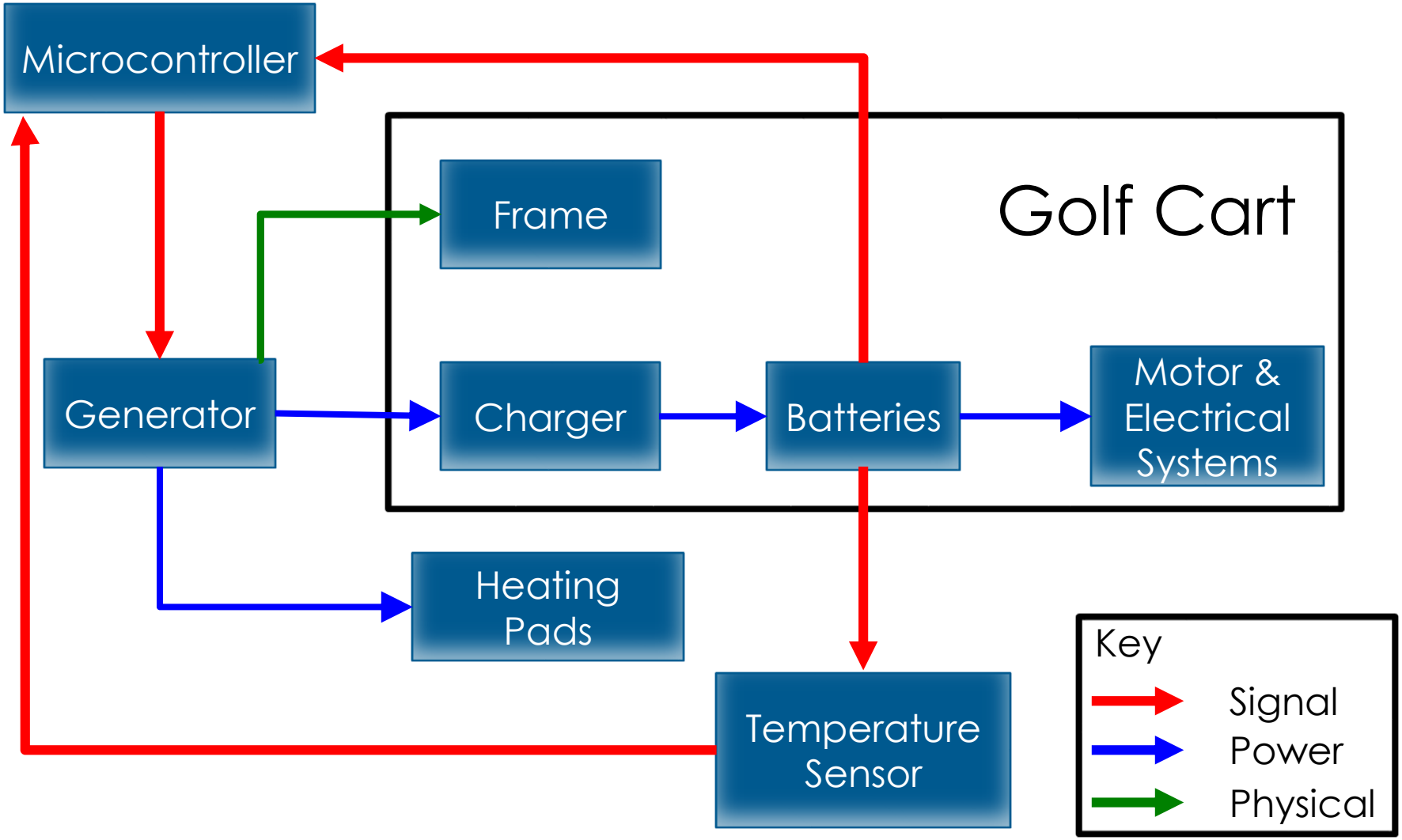

Figure 4. Revised system diagram of proposed design for golf cart

Presenter: Jeremy Randolph

Revised Proposed System

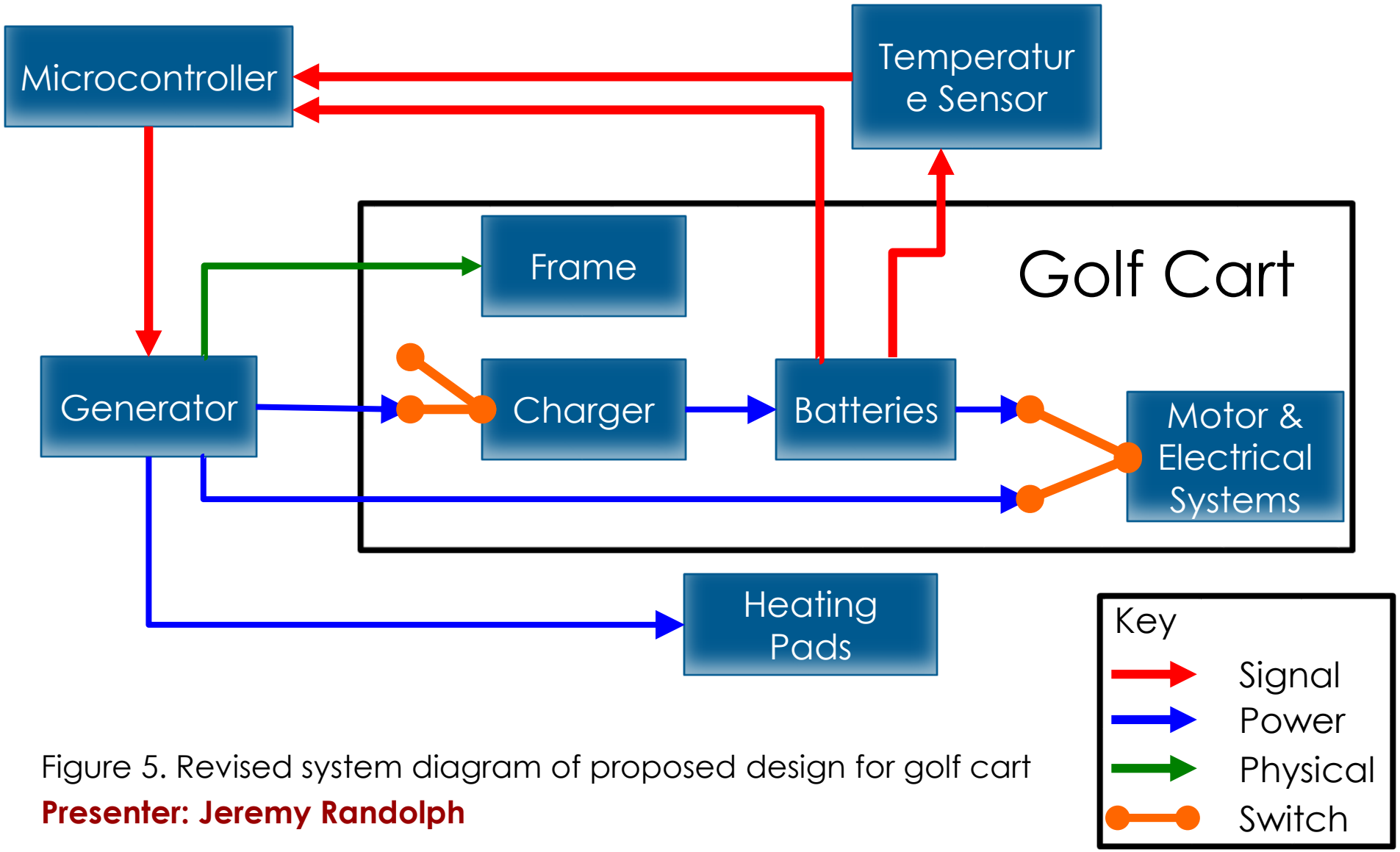

Figure 5. Revised system diagram of proposed design for golf cart

Presenter: Jeremy Randolph

Proposed Truck Charging System

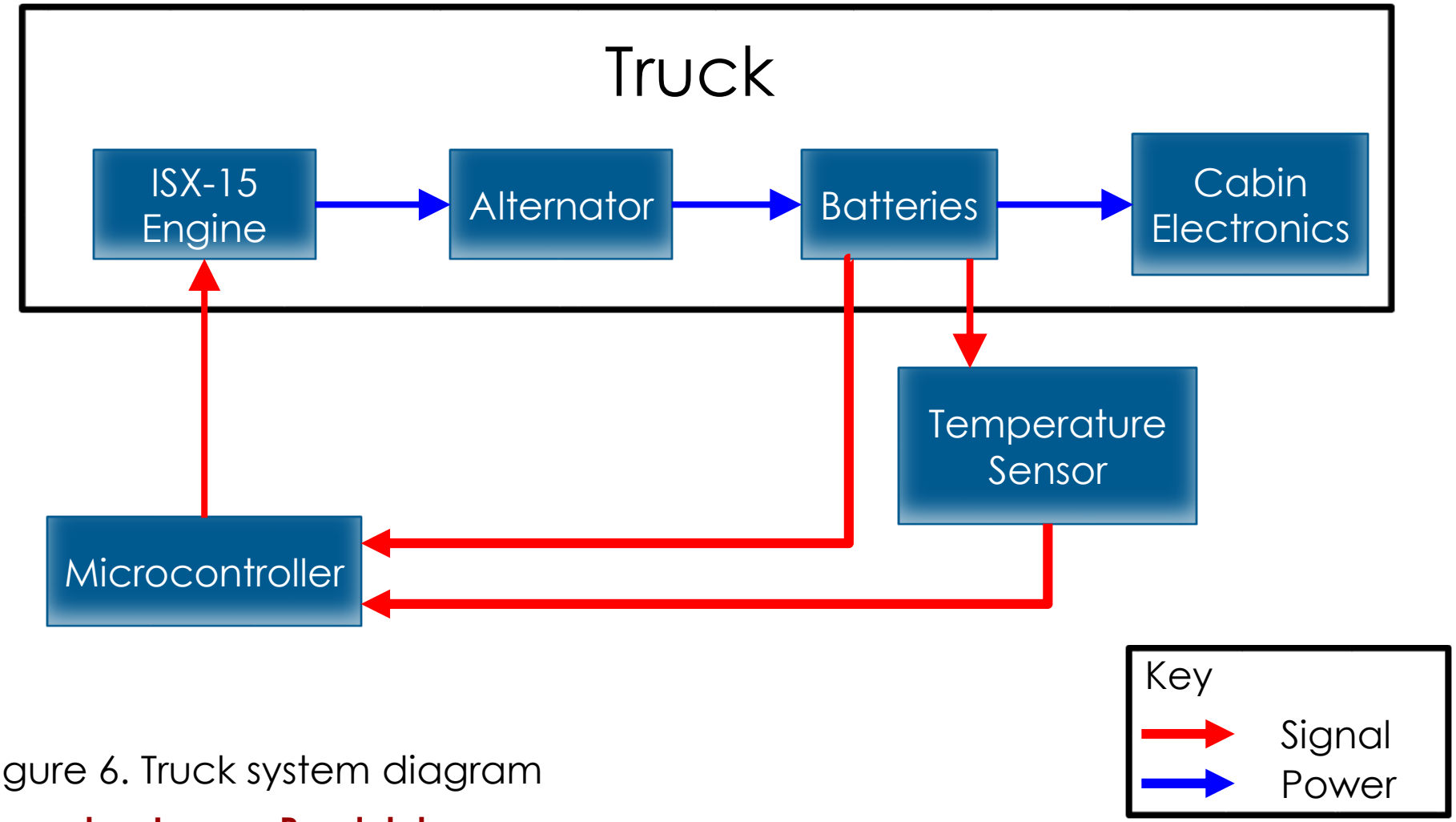

Figure 6. Truck system diagram

Presenter: Jeremy Randolph

Generator Selection

Table 3. Generator Requirements Vs. QG2800

Selection Criteria	QG2800 Generator
Must output at least 2,200 W	Can output 2,800 W
Dimensions should not exceed: 685 mm x 360 mm x 400 mm	Dimensions: 560 mm x 415 mm x 325 mm
Must operate at -29°C (-20°F)	Can operate at -29°C (-20°F)
Lightweight	56.7kg (125 lbs.)
Inexpensive	Provided free of charge

Figure 7. Cummins QG2800 Generator [1]

Heat Transfer Analysis

- Average heat capacity of lead acid batteries
  - $C_p = 1{,}985 \frac{J}{kg°C}$
- Mass of 6 lead acid batteries
  - m = 192 kg
- 1 heating pad supplies 160W to the batteries
  - P_{total} = 960 W

Table 4. Time needed to heat batteries

Parameters	Ideal	Goal
Initial Temperature	-29˚C	-29˚C
Final Temperature	20˚C	-10˚C
Heat Required $q = C_p m\Delta T$	19,253 kJ	7,466 kJ
Time = $\frac{q}{P_{total}}$	5 hrs 34 min	2 hrs 9 min

Presenter: Tyler Mitchell

The Current Problem...

- Initially the design would not allow the batteries to be heated and charged at the same time.
- Time required to heat batteries is way too long
- **Solution**: heating pads will be used to prevent temperature from dropping below -10˚C.

Figure 8. Heating pad for batteries. [2]

Mechatronic System Objectives

- Control when generator turns on and off.
- Control when heating pads are on.
- Monitor the battery temperature.
- Monitor the battery voltage.
- Control the motor power source.
- Control when the batteries are charging.

State Diagram

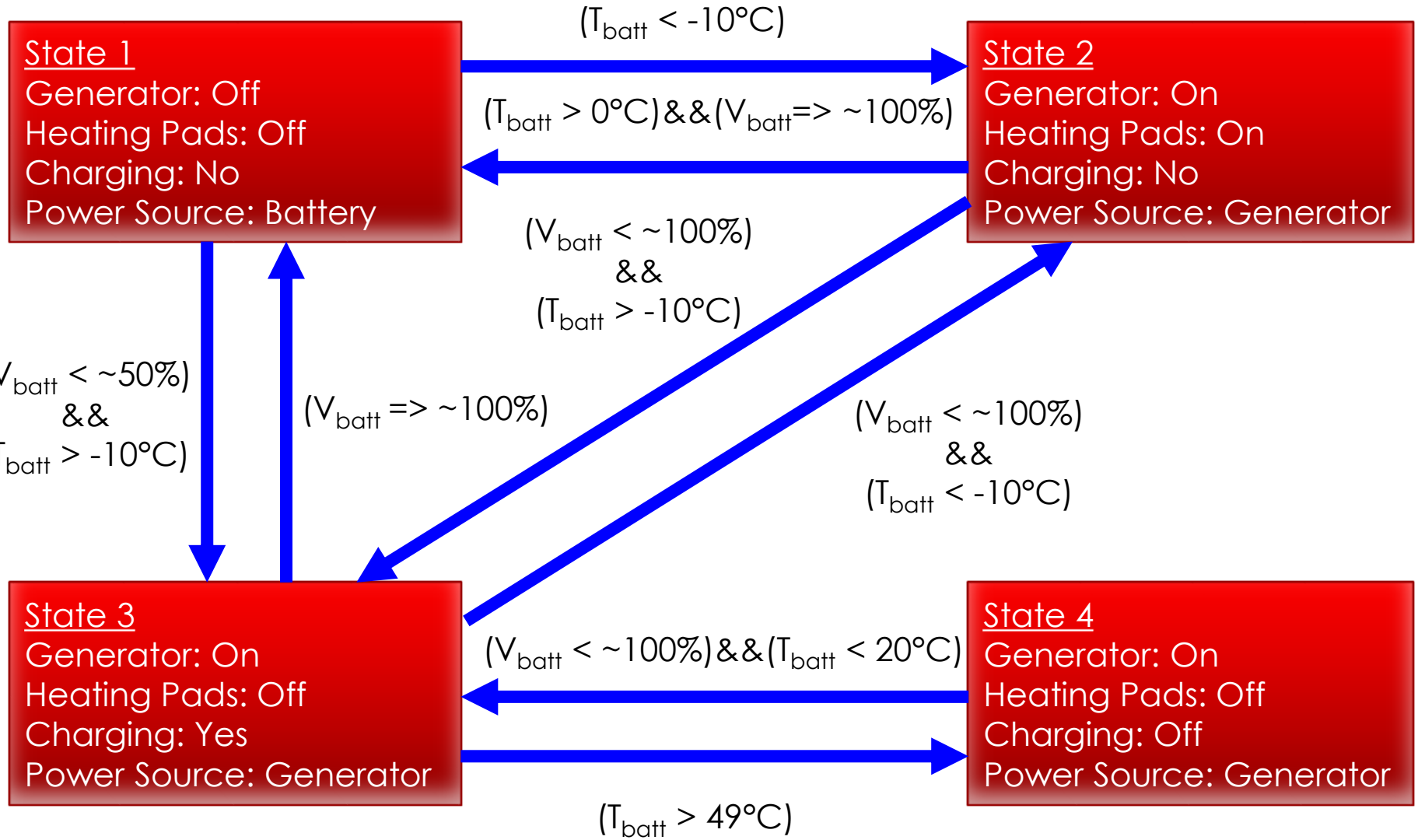

Figure 9. State Diagram of the proposed mechatronic system

Presenter: Jakob Consoliver-Zack

Detailed System Diagram

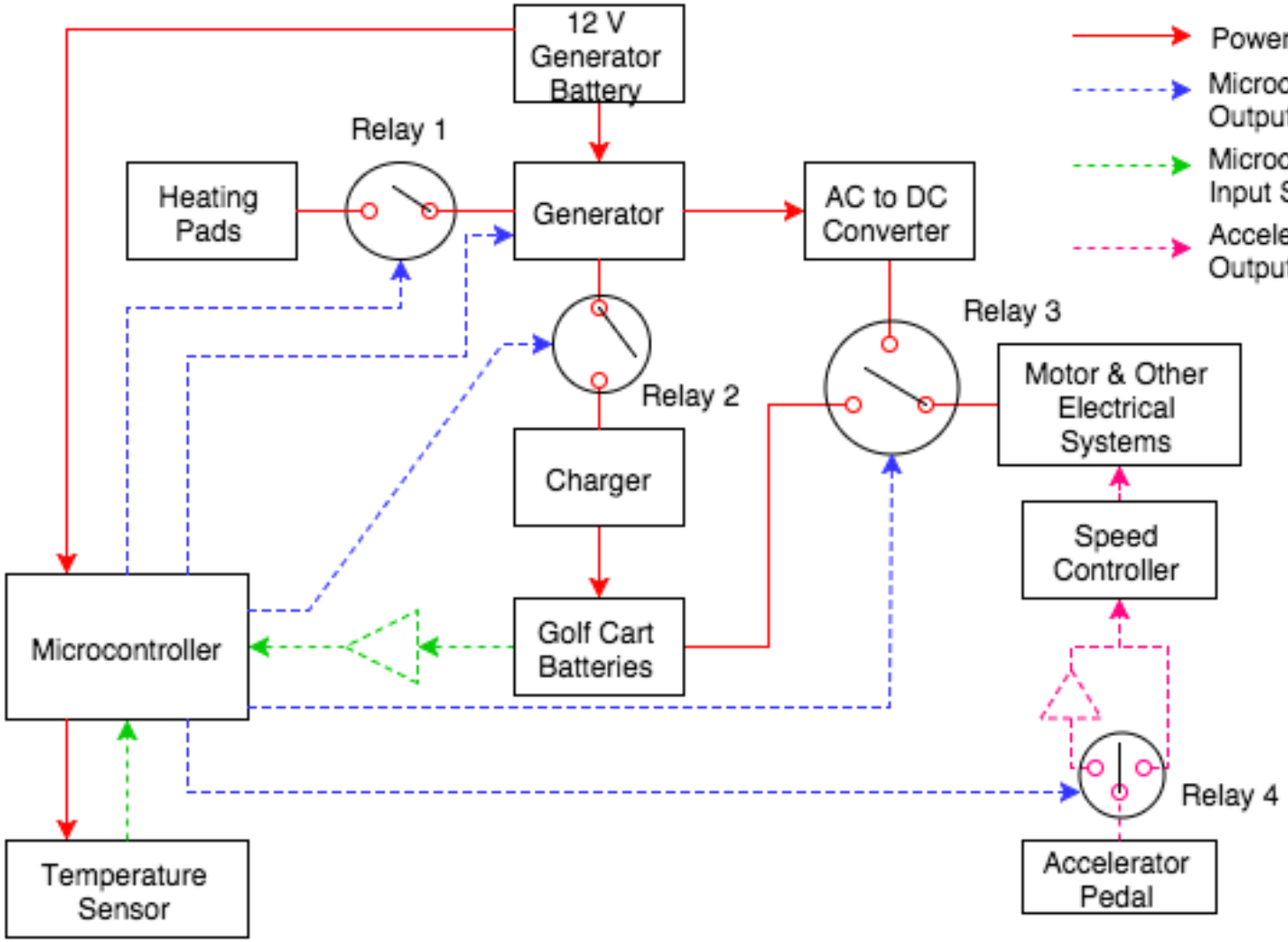

Figure 10. Detailed System Diagram

Presenter: Jakob Consoliver-Zack

Microcontroller & Sensor

- Ruggeduino-ET
  - 6 analog input pins
  - Can run on input voltage of 3.5V to 30V
  - Operable at temperatures from -40°C to +85°C
  - 68.6 mm x 54.4 mm

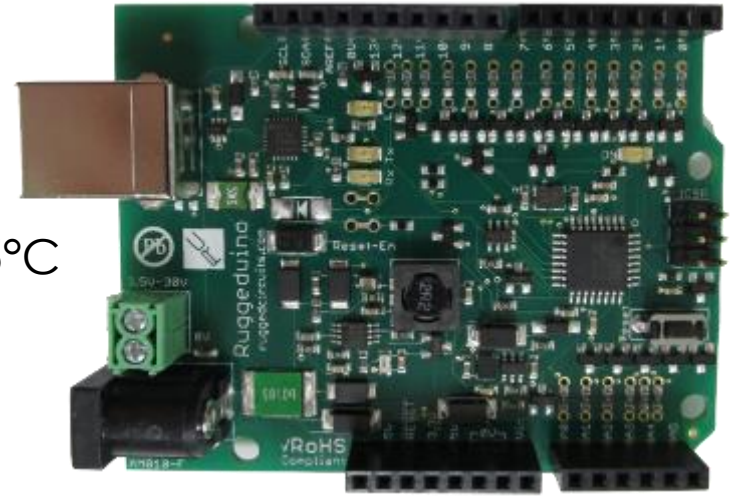

Figure 11. Ruggeduino-ET Board [3]

- TMP36 Analog Temperature Sensor
  - Low voltage operation (2.7V to 5.5V)
  - -40°C to +125°C temperature range

Figure 12. TMP Sensor. Quarter for scale [4]

Presenter: Jakob Consoliver-Zack

Potential Challenges & Risks

- Presently the golf cart is not in working condition
- Inductive kickback during power switching
  - ✦ Ensure safeguards in circuit design
- Difficult to test entire system at cold temperatures
- Maximum Charge threshold value is a function of temperature
  - ✦ Experimentally determine the relationship
- Ensure design compatibility with ISX-15 engine

Presenter: Jakob Consoliver-Zack

Gantt Chart

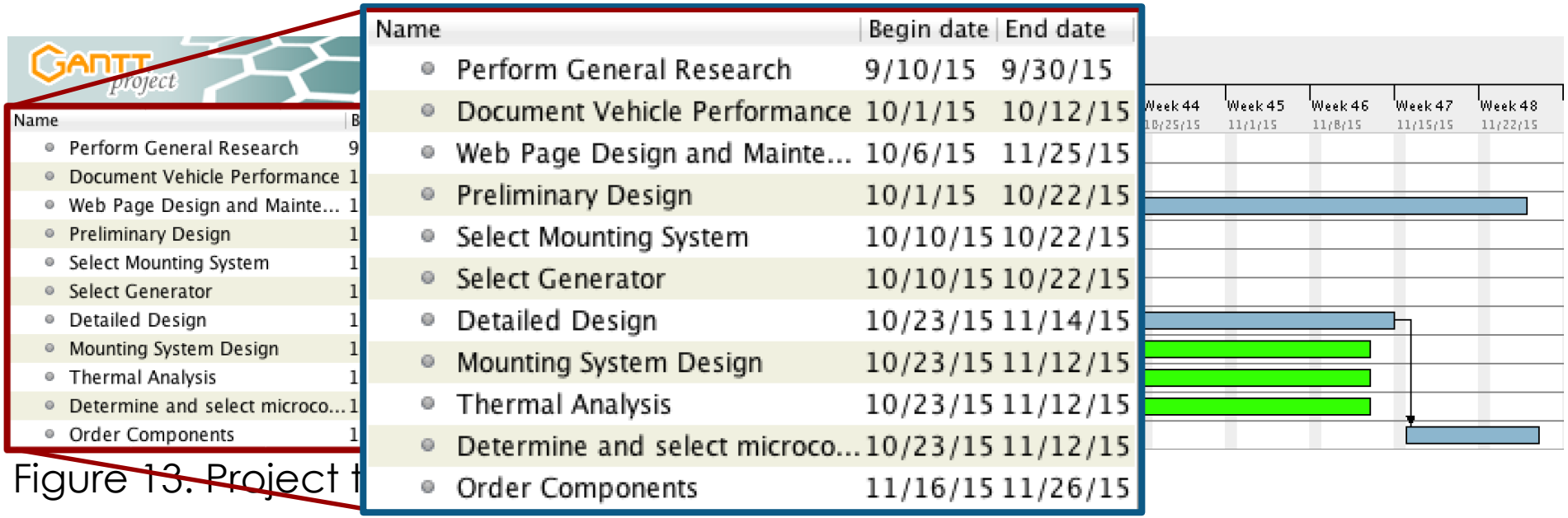

Figure 13. Project t

Conclusion

- Integrate a generator into the present system.
- Install new low-temperature batteries into the golf cart.
- Warm the batteries with heating pads.
- Difficult to test the performance at low temperatures.
- Model this technology for semi-trucks with ISX-15 diesel engine.

Future Plans

- Create detailed design of how to mount generator to the cart.
- Work in tandem with EE team to develop necessary circuitry required for the design.
- Begin programming mechatronic system for small scale model of design.

Presenter: Jakob Consoliver-Zack

References

[1] Cummins. *RV Generator Set Quiet GasolineTM Series RV QG 2800*. N.p.: Cummins, n.d. *Cummins Powersuite*. Cummins. Web. 20 Oct. 2015.

[2] *Zerostart Blanket Style Battery Heater*. Digital image. *Partdeal*. N.p., n.d. Web. 9 Nov. 2015.

[3] "Ruggeduino-ET." Rugged Circuits. N.p., n.d. Web. 09 Nov. 2015.

[4] "TMP36 - Analog Temperature Sensor." Adafruit. N.p., Web. 09 Nov. 2015.

[5] Sanders, Chris. Question mark. Digital image. *ON THE IMPORTANCE OF QUESTIONS IN AN INVESTIGATION*. N.p., n.d. Web. 20 Oct. 2015.

[6] Kiessling, Reiner. "Lead Acid Battery Formation Techniques." Digatron Firing Circuits (n.d.): n. pag. Web. 4 Nov. 2015.

Questions?

Presenter:

Decision Matrices

Table A. Generator Location

Criteria	Option 1	Option 2	Option 3
Cost	S	–	S
Weight	S	–	+
Noninvasive	S	–	–
Safety	S	–	–
Total	0	–4	–1

Table B. How to warm the batteries

Criteria	Option 1	Option 2	Option 3
Cost	S	+	+
Weight	S	+	+
Noninvasive	S	+	+
Safety	S	+	+
Total	0	+4	+4

Table C. Ensure Generator Operation

Criteria	Option 1	Option 2	Option 3
Cost	S	–	–
Weight	S	–	–
Noninvasive	S	–	–
Safety	S	–	–
Total	0	–4	–4

Table D. Charging System

Criteria	Option 1	Option 2	Option 3
Cost	S	–	–
Weight	S	S	S
Noninvasive	S	S	+
Safety	S	+	+
Total	0	0	+1