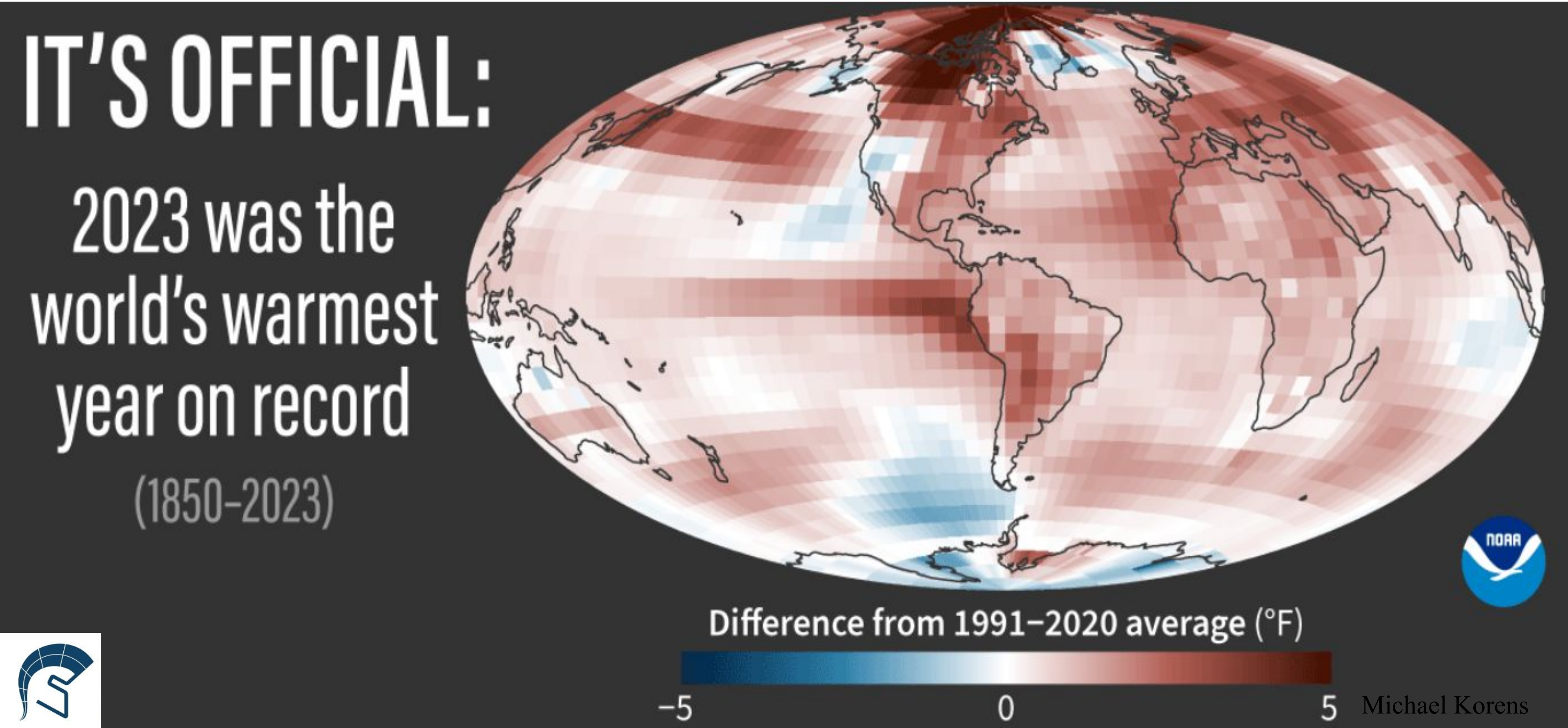
Why do we need the Spartan Superway?

SPARTAN SUPERWAY

Michael Korens

Global warming is an issue we cannot ignore or “pass off” or hope that “someone will find a solution to”



Michael Korens

We are not doing enough to reduce CO_2 emissions, and the convenience of cars is still large

Current Bay Area public transportation solutions are facing financial struggles…

AC Transit and BART survive 'fiscal cliff'—for now—with $5 billion state budget agreement

East Bay transit advocates warned of a "death spiral" for bus and train operators if Gov. Newsom didn't adjust funds in the state budget.

Inflation and Other Factors Boost Estimated Cost of VTA BART to Silicon Valley Completion

California Senators Float Plan to Plug Bay Area Transit Budget Gaps

- Bay Area region has 27 transit operators across nine counties
- New proposal seeks at least $750 million for transit agencies

Michael Korens

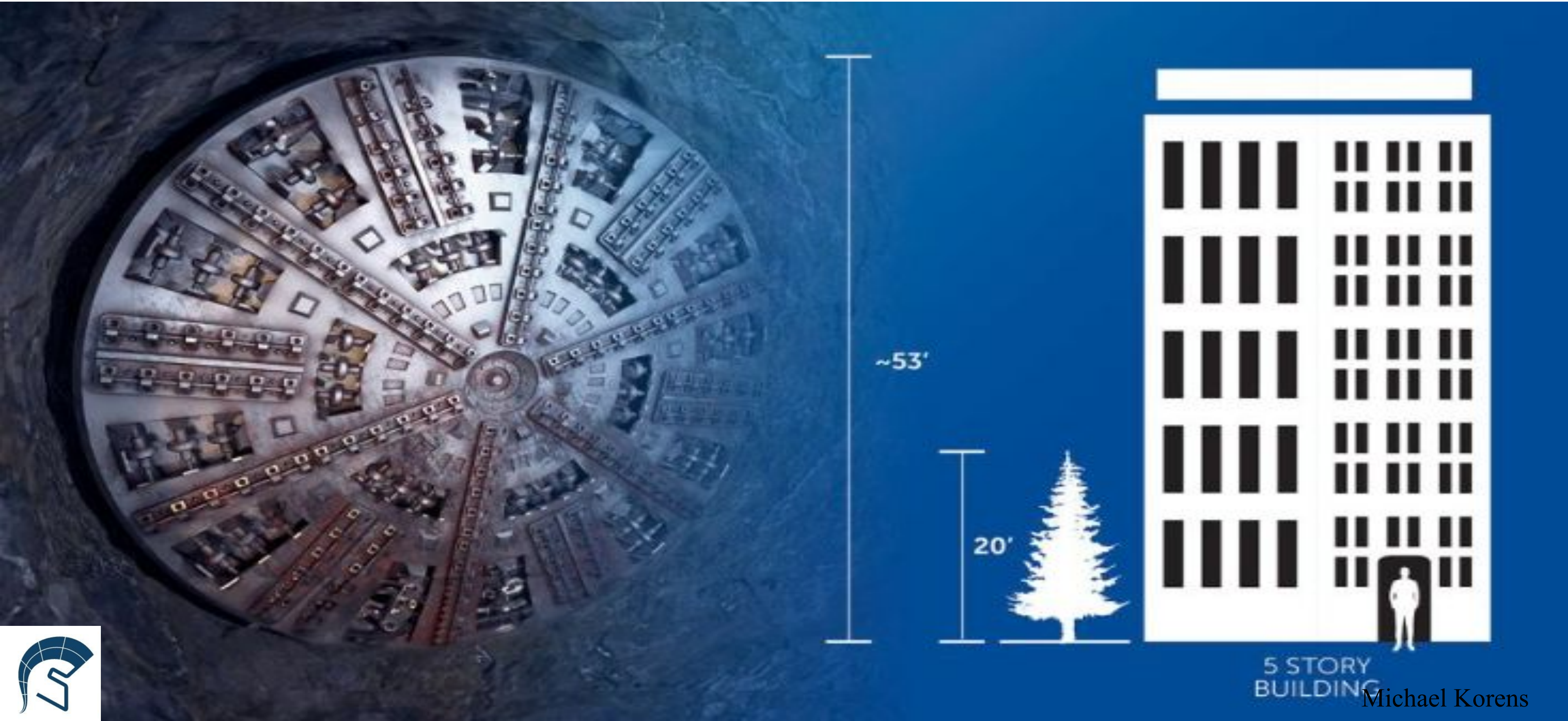
…and sometimes, the cost to expand these services makes no economical sense!

South Bay BART extension faces another cost increase

the six-mile extension project for the rail line is expected to cost taxpayers

$12.75 billion

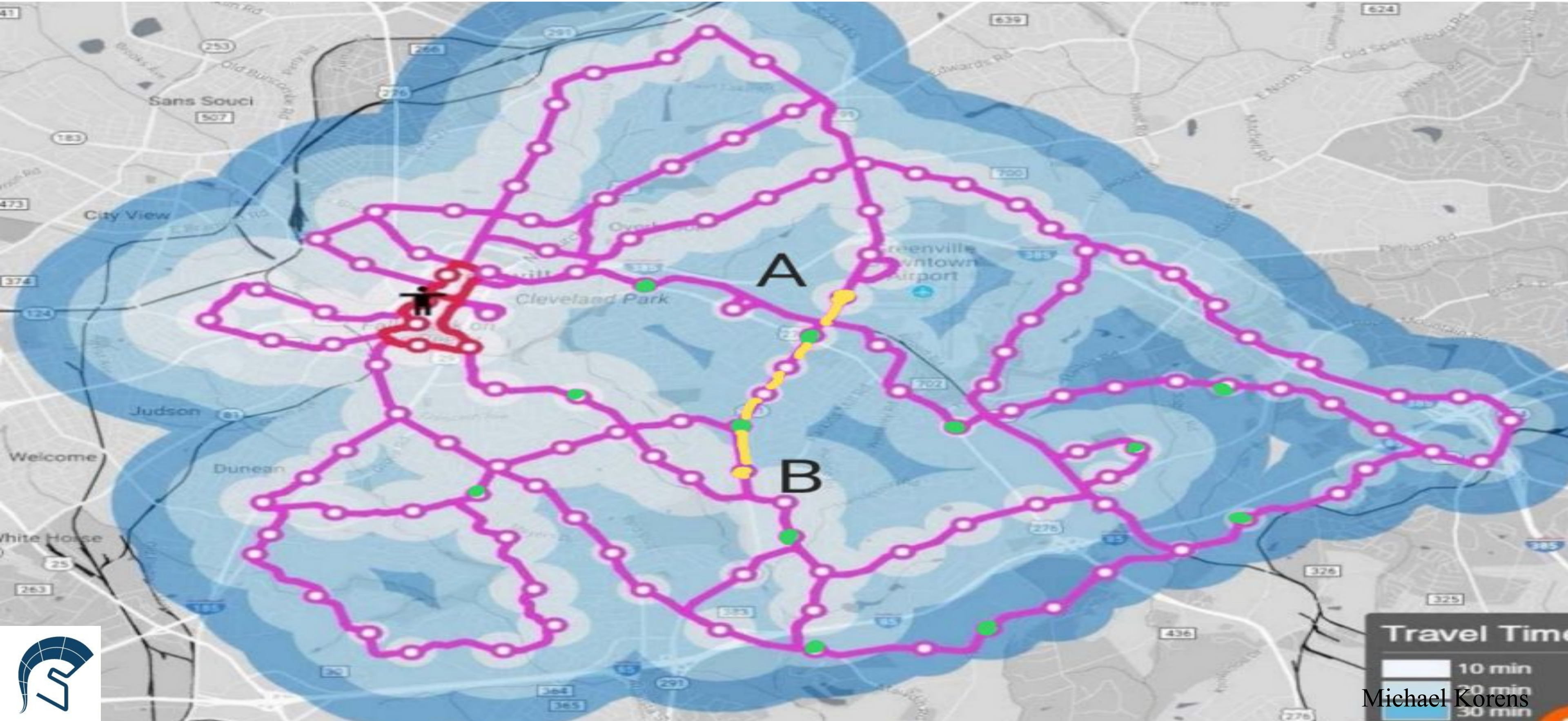
Billions of dollars, months of labor, constant problems… just for only 6 miles of track?? Is there a better way?



Michael Korens

Why not utilize an Automated Transport Network (ATN) to reduce labor, costs, and GHG emissions?

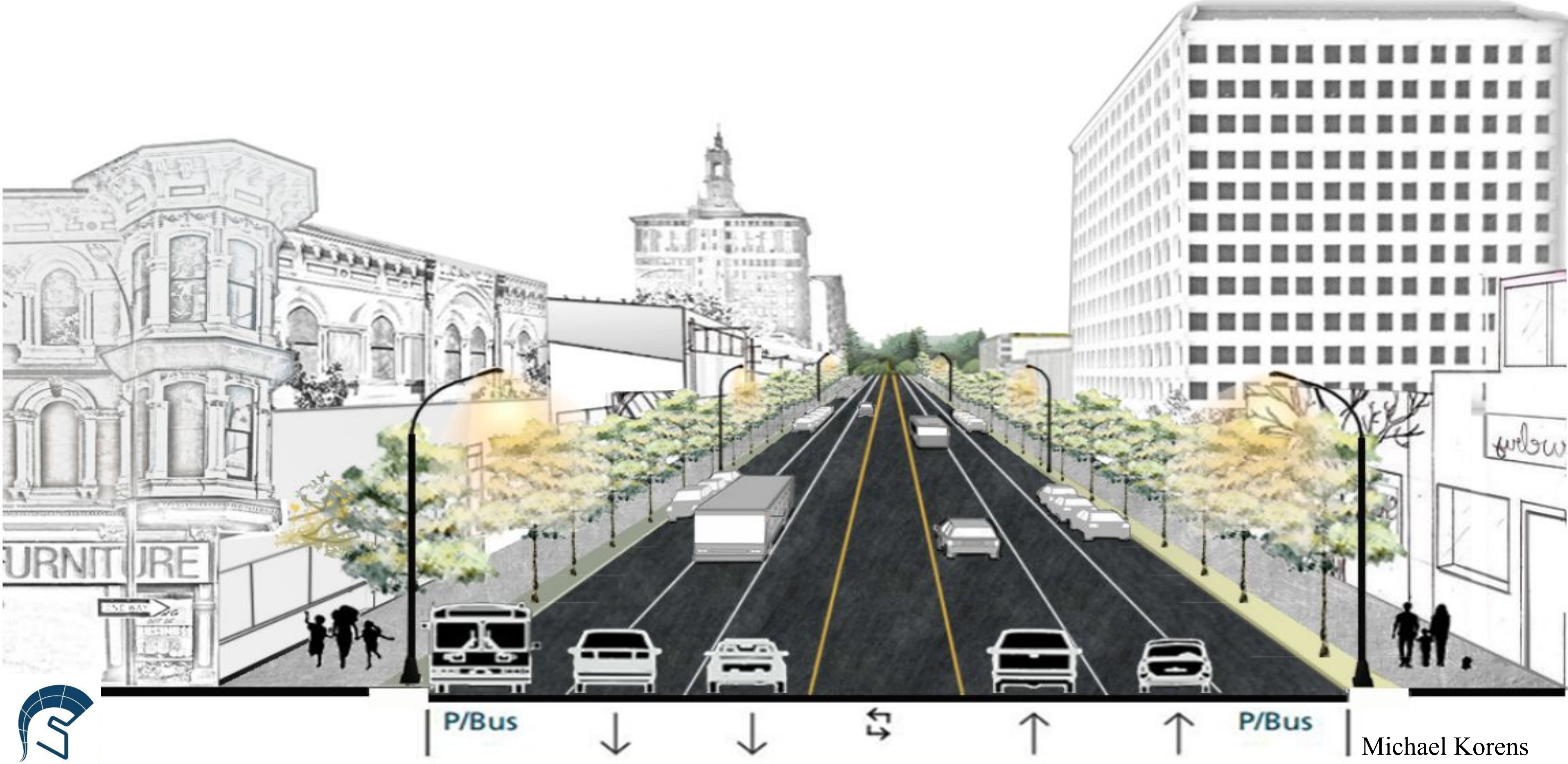
The main difference between an ATN and current solutions, is that it’s a 24/7 automated transit system



Michael Korens

The Spartan Superway extends the ATN concept with a focus on using renewable energy to power the system

The Spartan Superway can take cars off the road

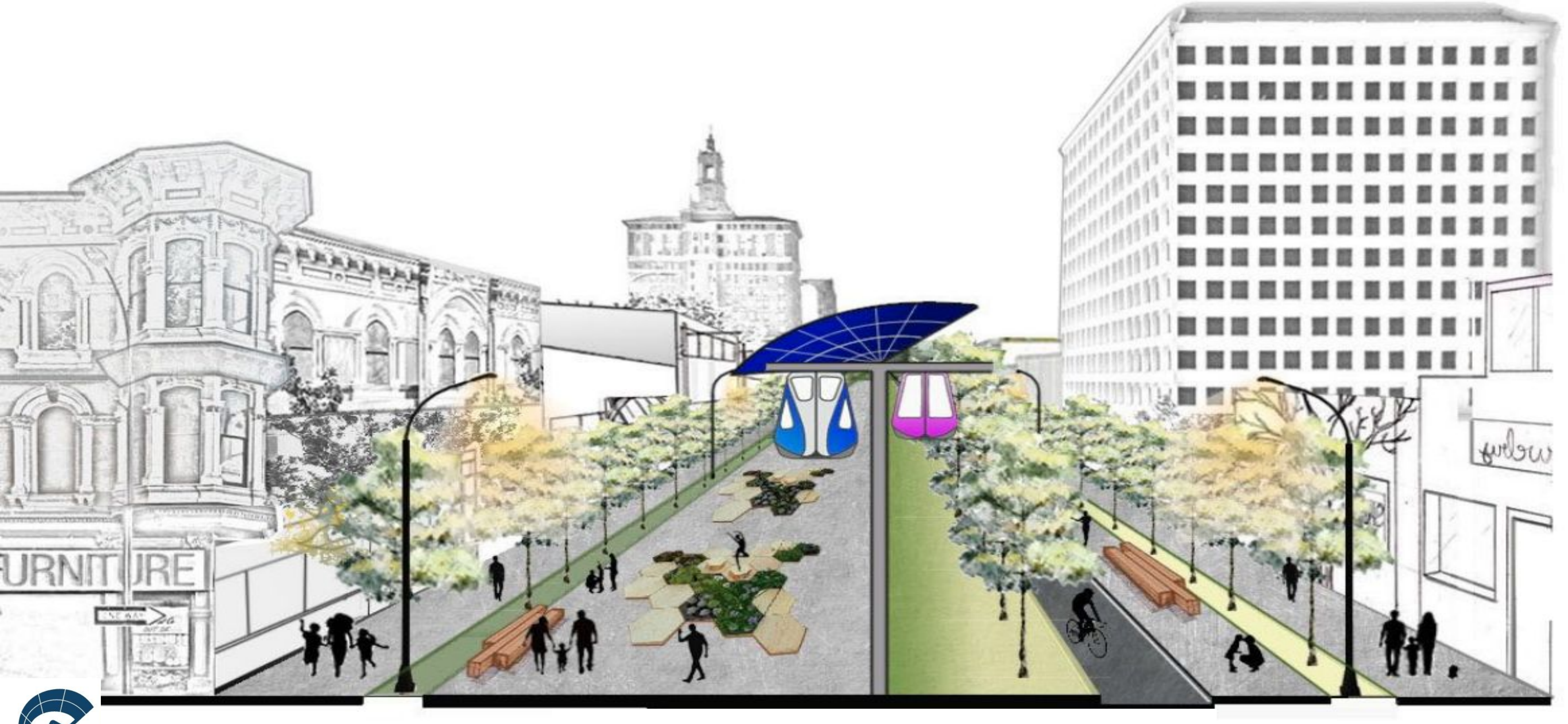


Michael Korens

The Spartan Superway can take cars off the road

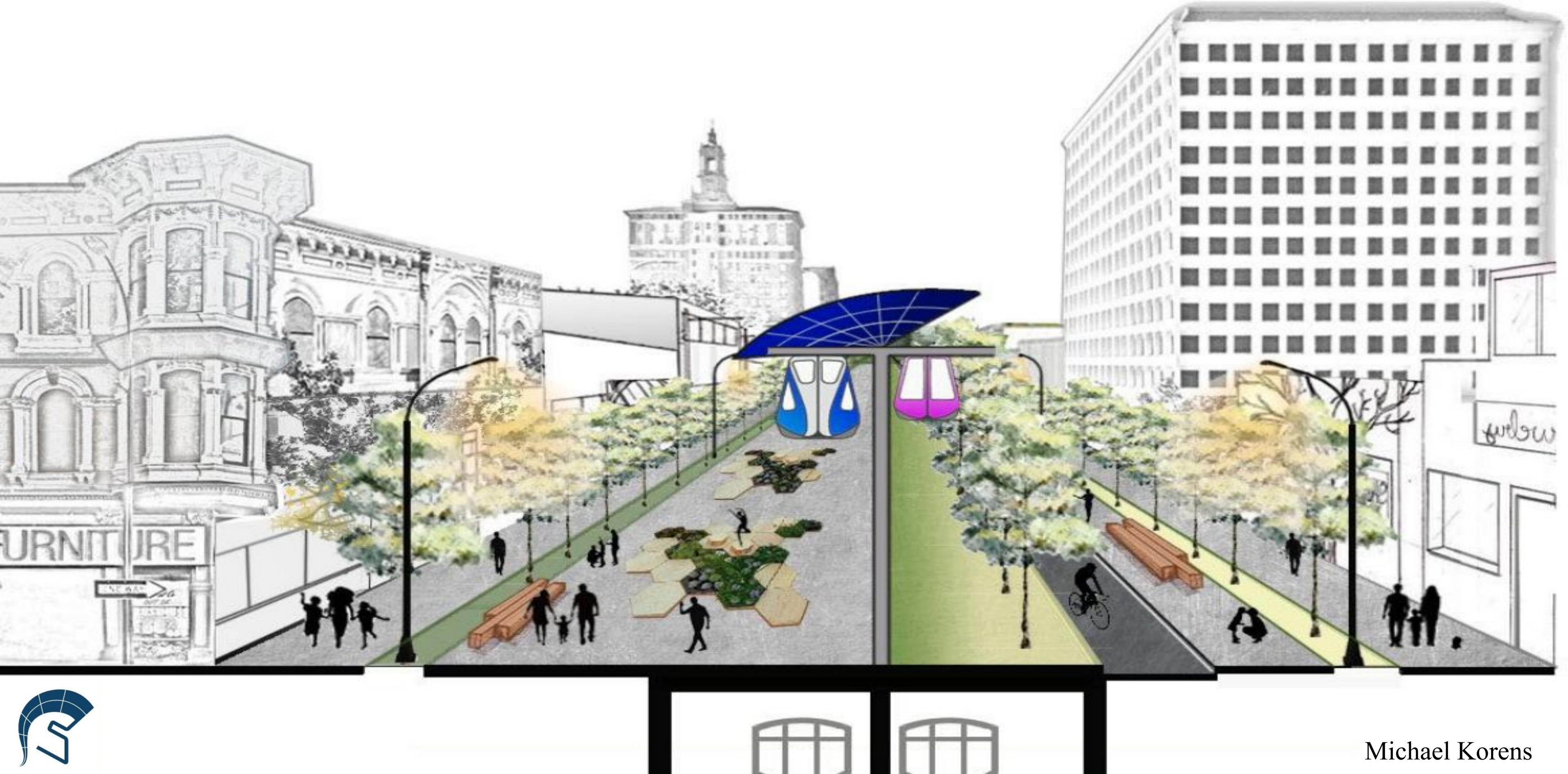
Michael Korens

The Spartan Superway can take cars off the road



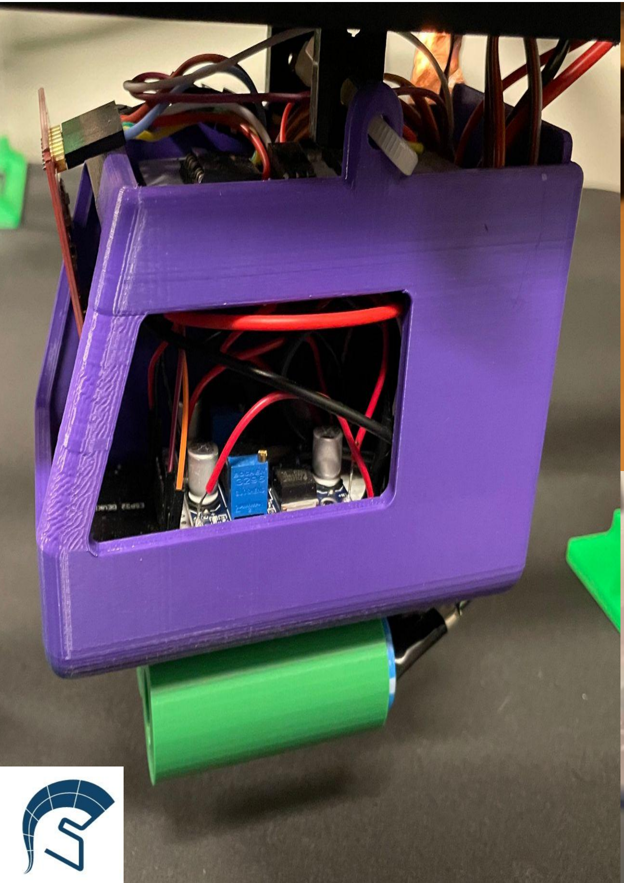
Michael Korens

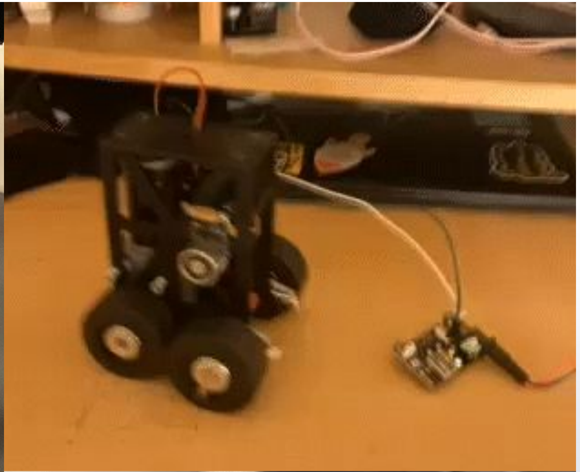
The Spartan Superway can take cars off the road

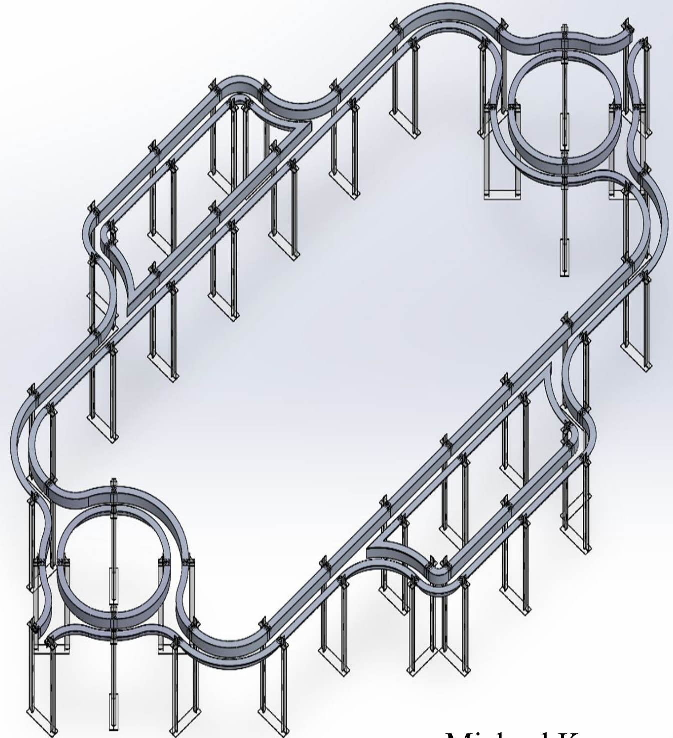


Michael Korens

This is an ambitious project, but to run, we must first learn how to walk

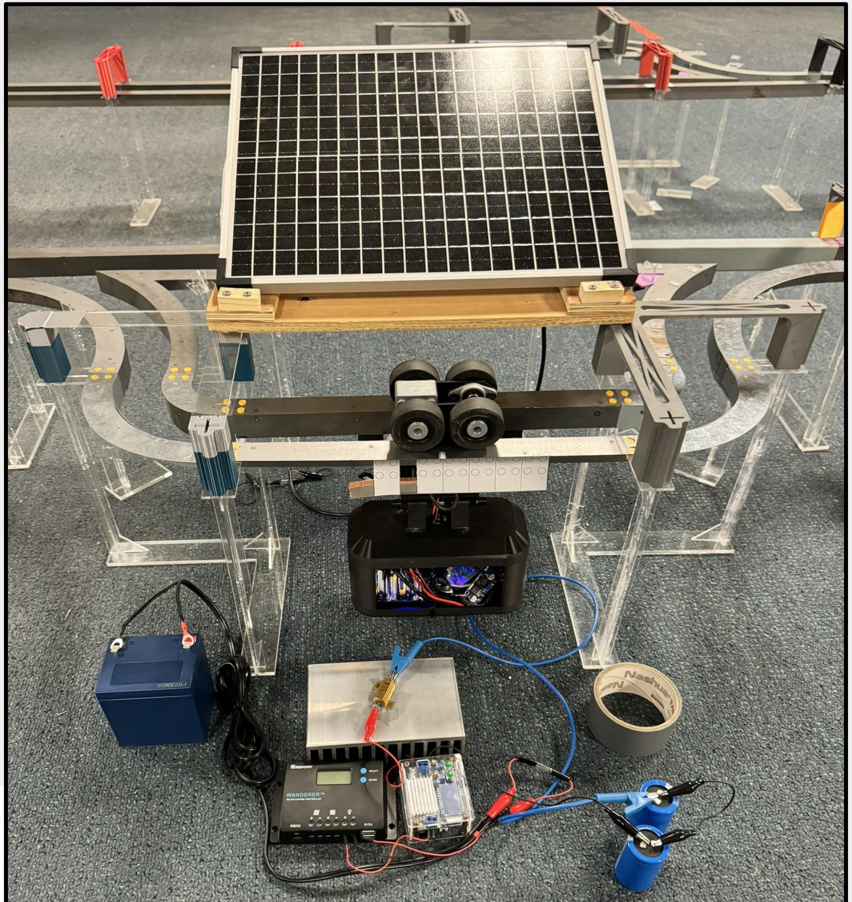






Michael Korens

Vehicle Energy Storage and Charging Team



San Jose State University
Charles W. Davidson
College of Engineering
ME195B Senior Design
Project II
Dr. Burford Furman
Section 03
May 10th, 2024

We are the Energy Storage and Charging Team!

Michael Korens

Roman Ortiz

Nyalah Payne

Patrick Chiu

Anton Loeb

Everyone

Project Background and Introduction

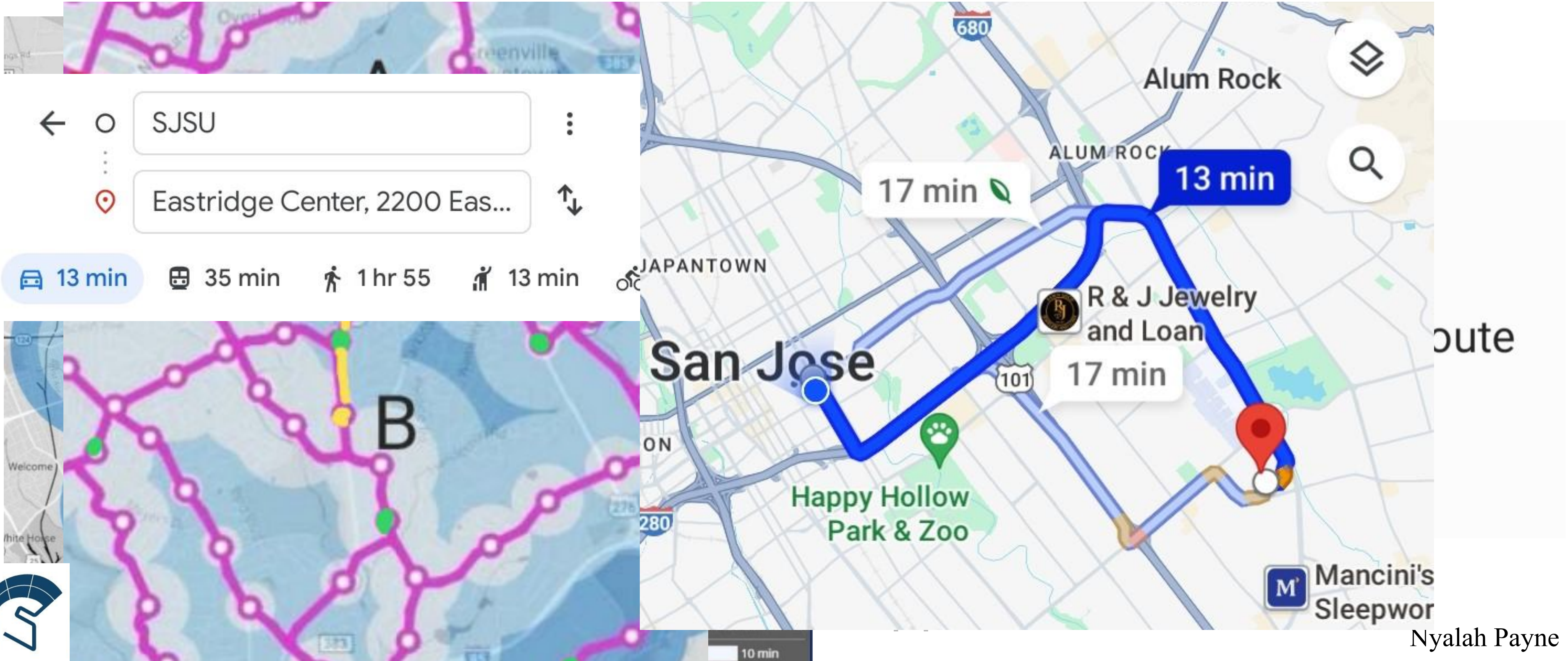
Nyalah Payne

We decided to develop an Energy Charge & Storage System, which utilizes batteries and supercapacitors to power the motor on the vehicle (Bogie)

[9]

Nyalah Payne

The hybrid energy storage system is crucial for the SSW as it continuously supplies power to keep the Bogie operational over long distances

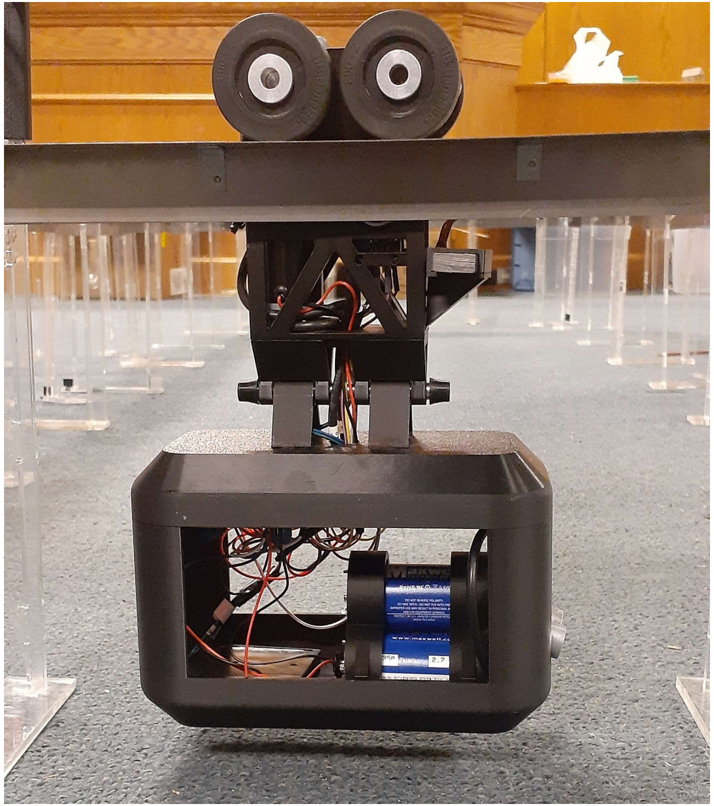


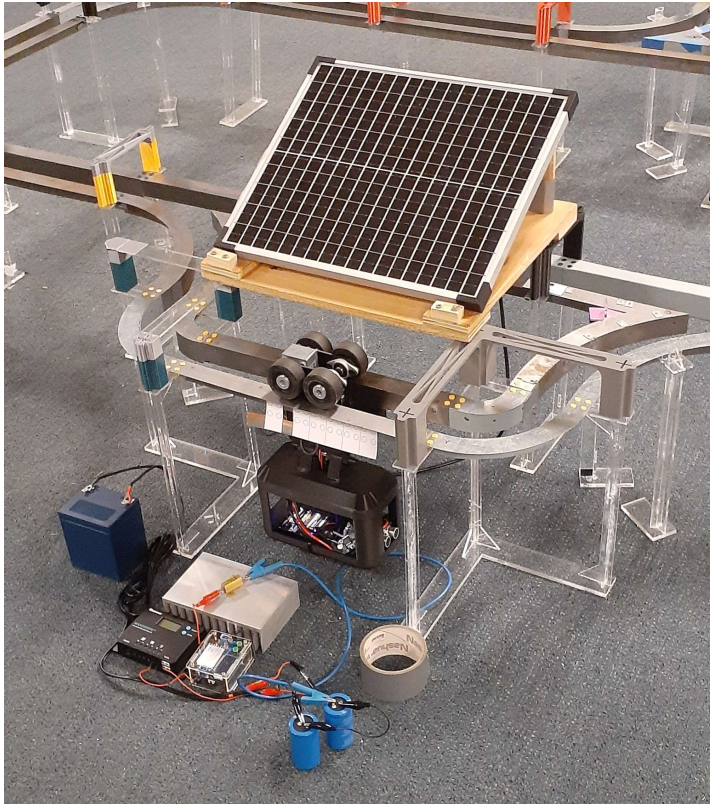
Nyalah Payne

Project Objectives & Design Specifications

Patrick Chiu

Our objective is building a stable, fast charging energy storage with large capacity for the vehicle





Patrick Chiu

In order to facilitate the constant uptime of the Bogies, we are responsible for:

Keeping the Bogie SAFELY running for "24/7"

Implementing a hybrid system using Supercaps and a Battery

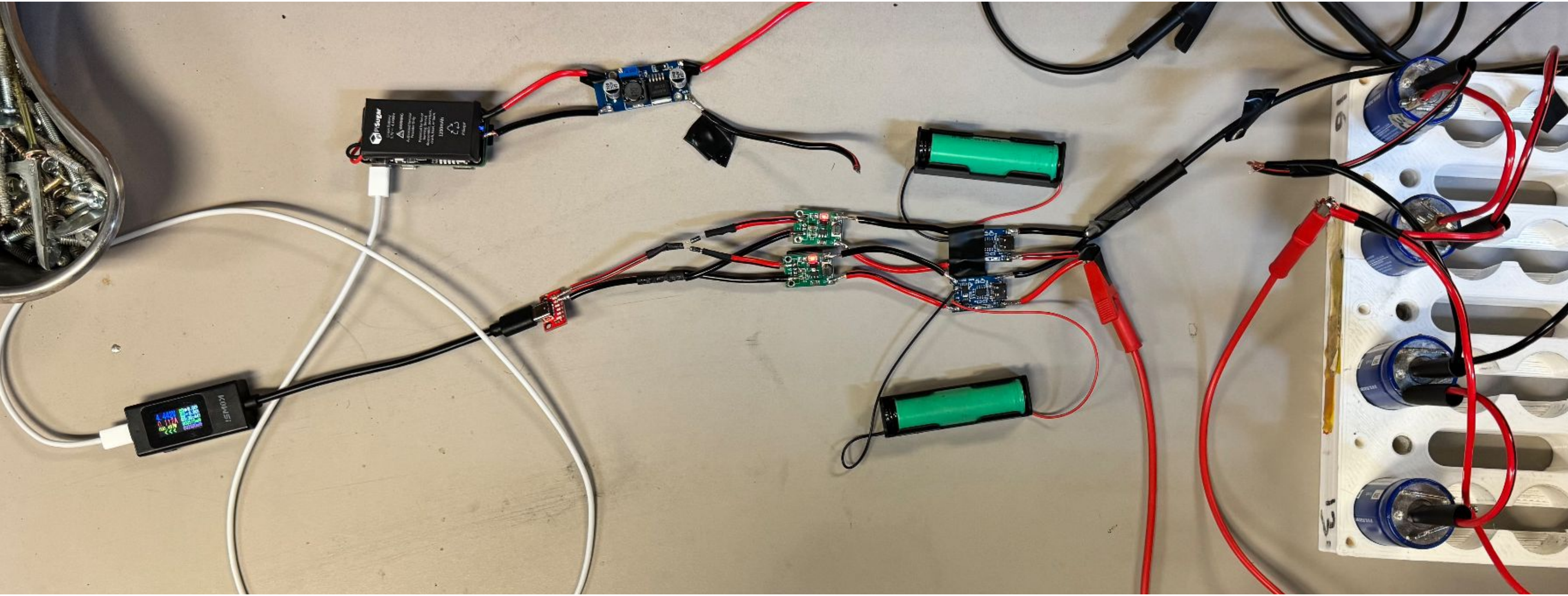
Patrick Chiu

We took advantage of the characteristics of supercapacitor and lithium ion battery

	Charge Time	Stored Energy
Supercapacitor	Fast	Low
Lithium Ion Battery	Slow	High

Patrick Chiu

We developed and tested a charging system with many iterations



Patrick Chiu

We achieved most of the functional specifications

Functional Specs		
Motor Output	Voltage	6 V -> 9V
	Current	3 A
	Power	18 W -> 27 W
Supercapacitor	Charging Time	< 1 min
	Charging Type	Constant Current
PiSugar	Input Voltage	5 V

Small Motor >0.6 A

5.4V
3.0A
16W

Patrick Chiu

Slide 7a Describe your design and how you arrived at it (start with state of the art review)

Anton

Describe your design and how you arrived at it. **7 min**
Start this section with your literature/state-of-the-art review, so you can show what research you did to, 1) Avoid reinventing the wheel, and 2) Use existing knowledge, **standards**, etc. to guide your design decisions to your final design. Make good use of multiple views of solid models, cut-aways, exploded views, etc. to communicate your design and how it works. Explain how your designs were or would be fabricated.

Literature Review & Design Approach

Anton Loeb

When approaching a complex engineering problem, looking at existing implementations of a technology is often beneficial.

[9]

Initially, we began to research ATNs in PRT system at West Virginia and hybrid system in UC Davis

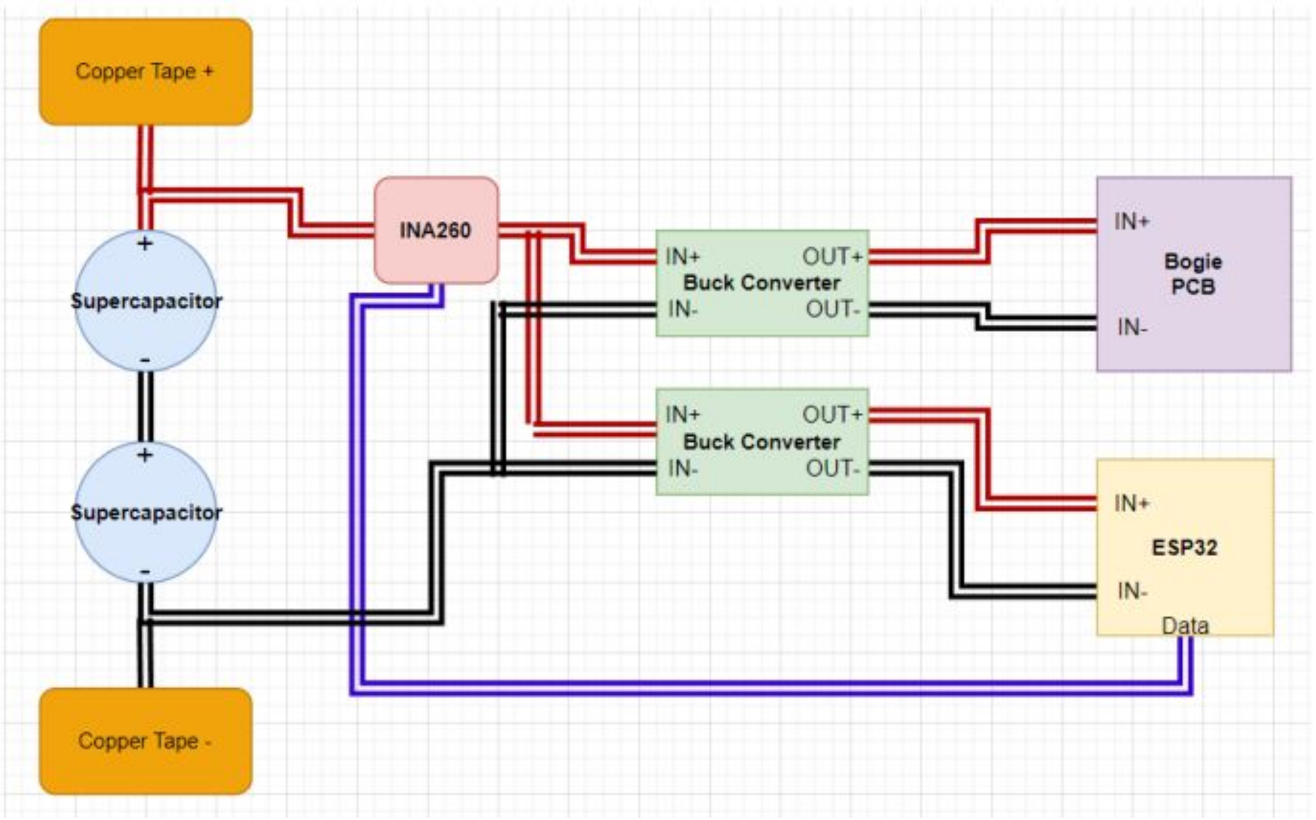
Anton Loeb

We found the hybrid supercapacitor-battery system developed by UC Davis

UC Davis recently published an article investigating the applications of supercapacitors in hybrid and electric vehicles, which may provide some background on understanding the technology behind supercapacitor and battery vehicle systems. The vehicles observed in the study combined supercapacitors and some advanced batteries found in electric cars. Their comparison was made towards vehicles with lithium-ion batteries typically found in hybrid vehicles. The cars with a supercapacitor replacing lithium-ion batteries performed more efficiently than their counterparts. Supercapacitor-equipped cars are physically faster, require less energy from the energy storage units, and have increased energy density efficiency (Burke and Zhao, 2015). This understanding of supercapacitors may prove helpful towards our supercapacitor integration into our bogie.

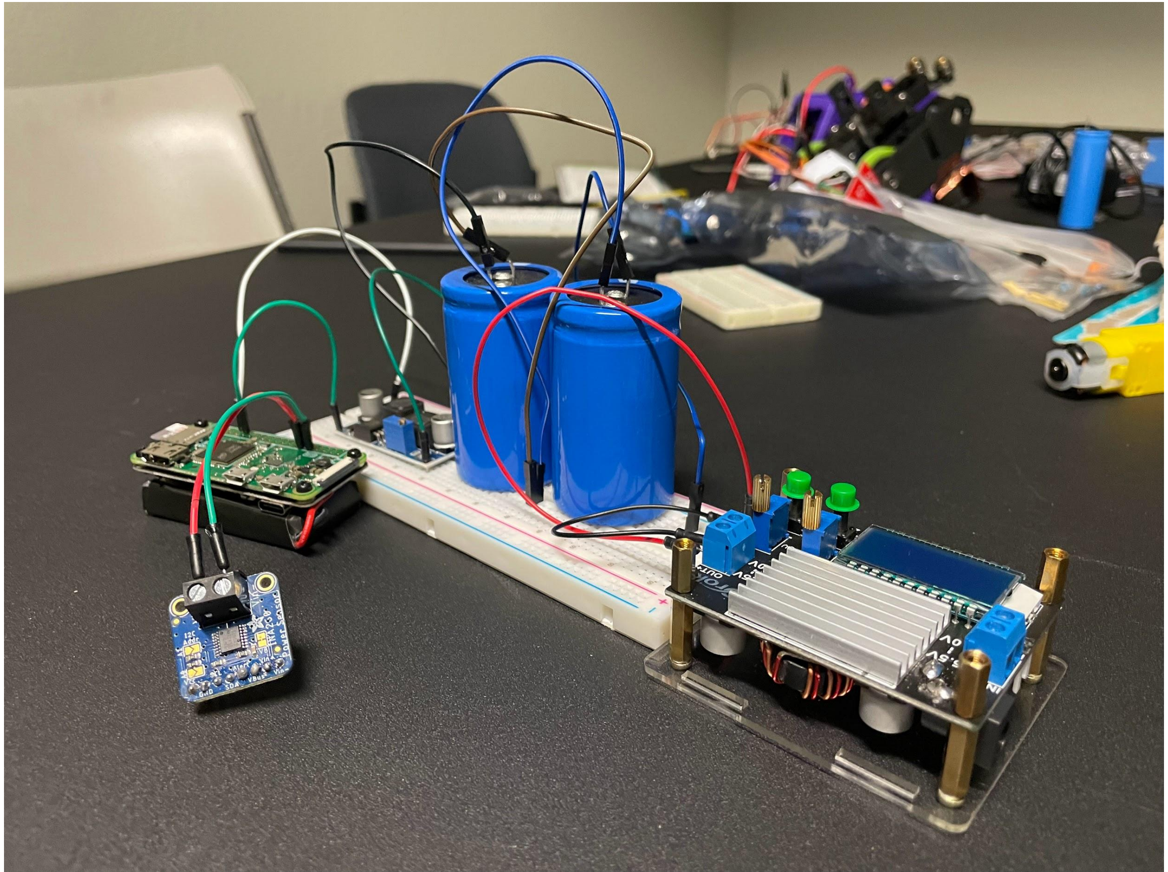
[9]

From there, we reviewed & analyzed results from previous teams



Anton Loeb

Based upon literature review, our 1st prototype was developed, but it had numerous issues



[9]

We applied standards and codes to our design

[9]

Anton Loeb

Codes & Standards

Nyalah Payne

Development of the Energy Charge and Storage System for the Bogie dealt with several codes and standards that were important to adhere to

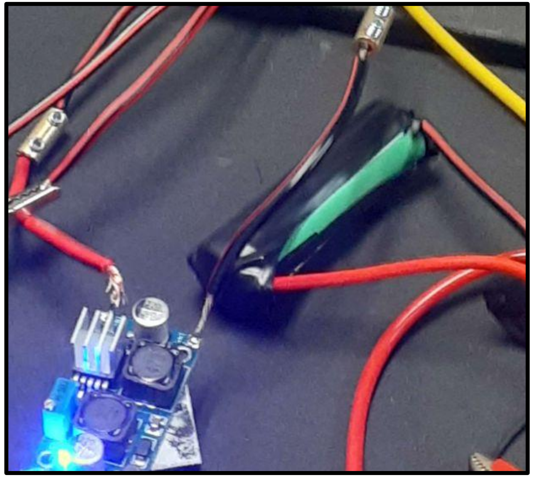
IEEE 1536
IEEE 1725
IEEE 1625

NFPA 70
NFPA 70B & 70E

ASME
Y14.5-2018 [9]

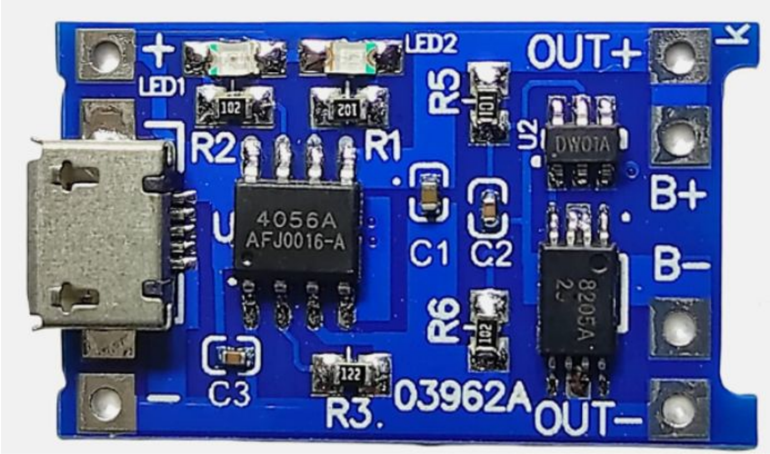
Nyalah Payne

IEEE 1536, the “Standard for Rail Transit Vehicle Battery Physical Interface” recommends utilizing a proper battery holder



Nyalah Payne

IEEE 1725 & IEEE 1625 discusses overcharge and short circuit prevention, while the NFPA 70, NESC 110A provide codes to prevent fires and electrical hazards



Implementation of TP 4056 & PI Sugar Battery Management System

Nyalah Payne

This lead to several other iterations that will be further discussed Roman

Insert

Slide 8a Analysis, validation, and tests

Roman

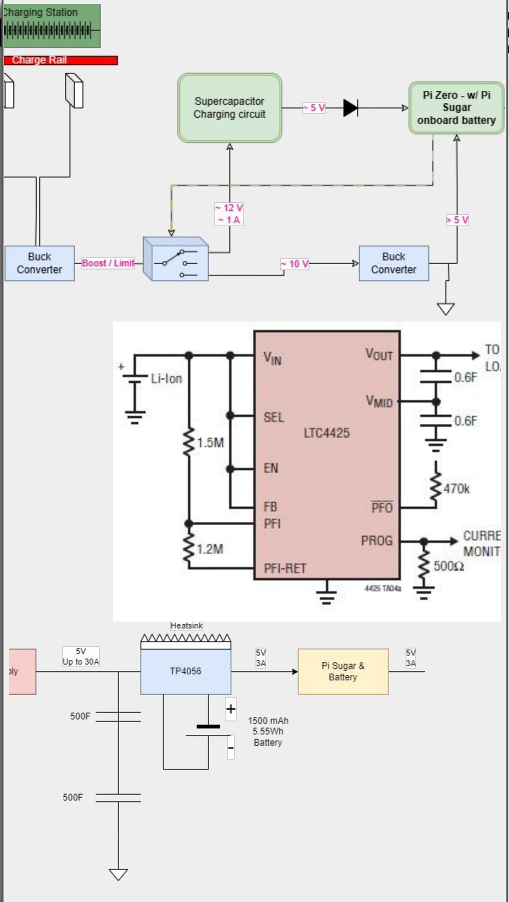
Describe your analysis, validation, tests, simulations, etc. that will give evidence that your design meets the design specifications **5 min**
Explain your design analyses, and how you validated and tested that your design meets your design requirements and specifications. Here is where you can show how you applied your engineering knowledge to frame, guide, and validate your design choices. Here is also where you can show simulations of how your design works.

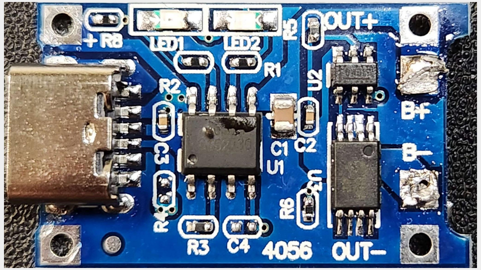
Analysis, Validation, & Tests

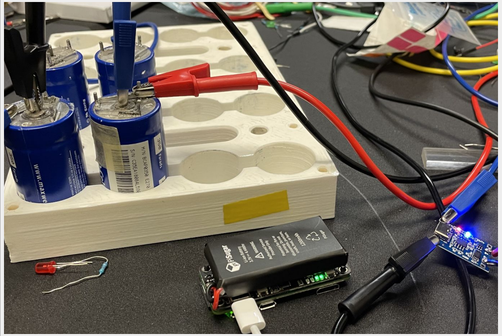
Roman Ortiz

A hybrid energy storage system was developed,

ous ... sts

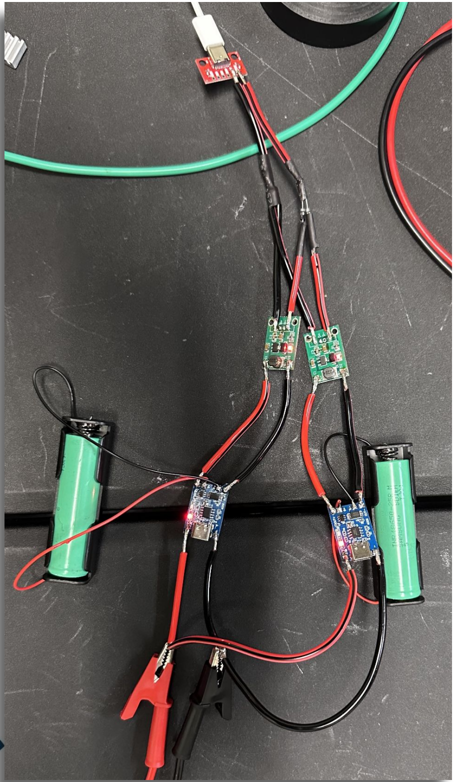


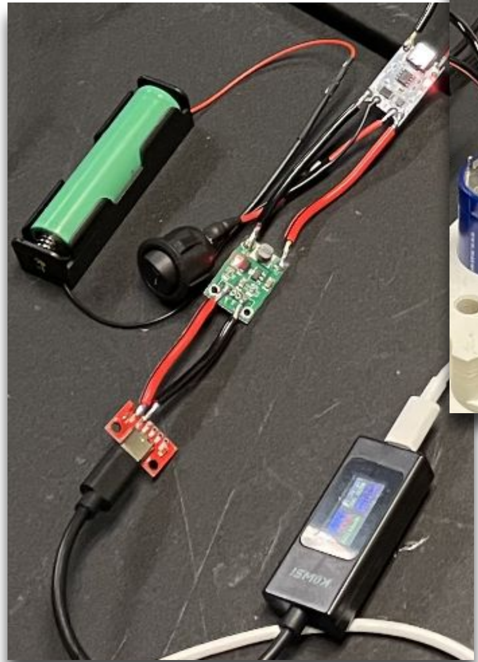


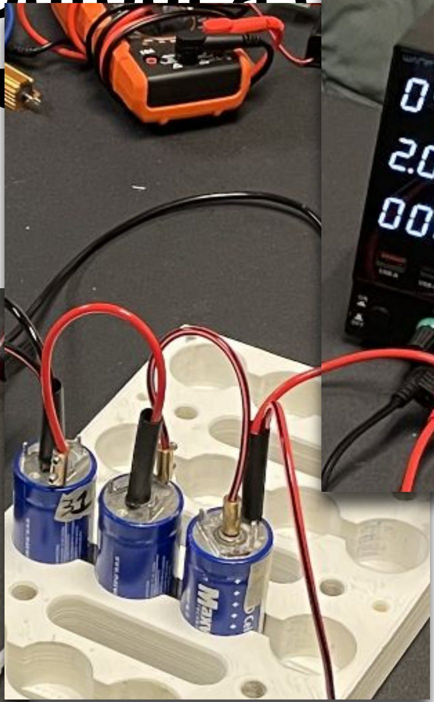


Roman Ortiz

With a TP chip we were able to output a c voltage, but it lacked power to ru

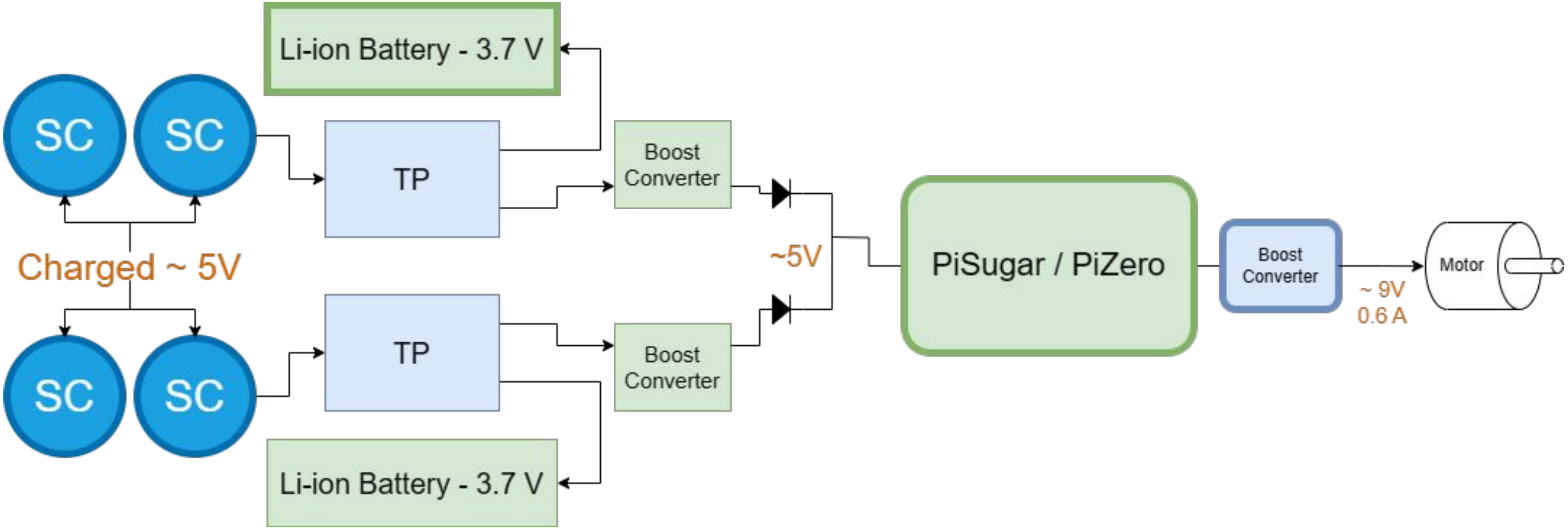




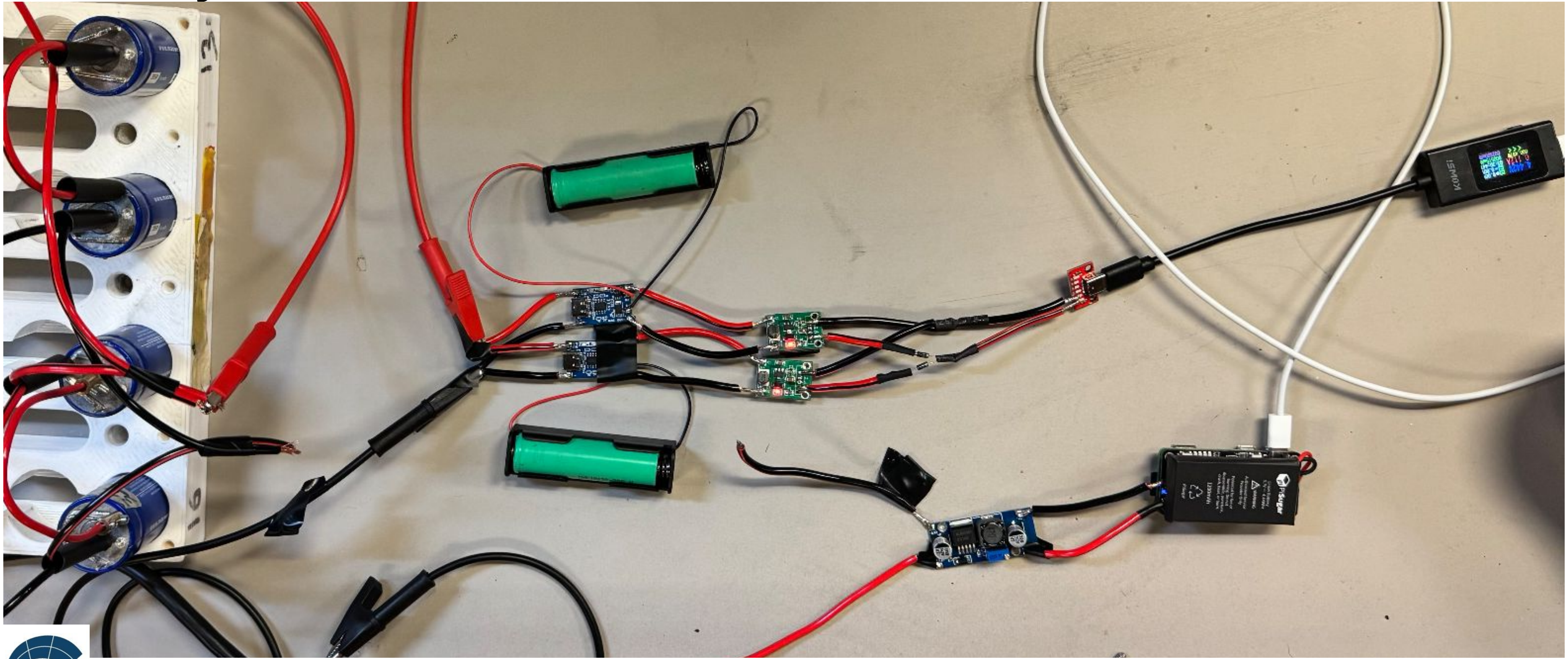


Roman Ortiz

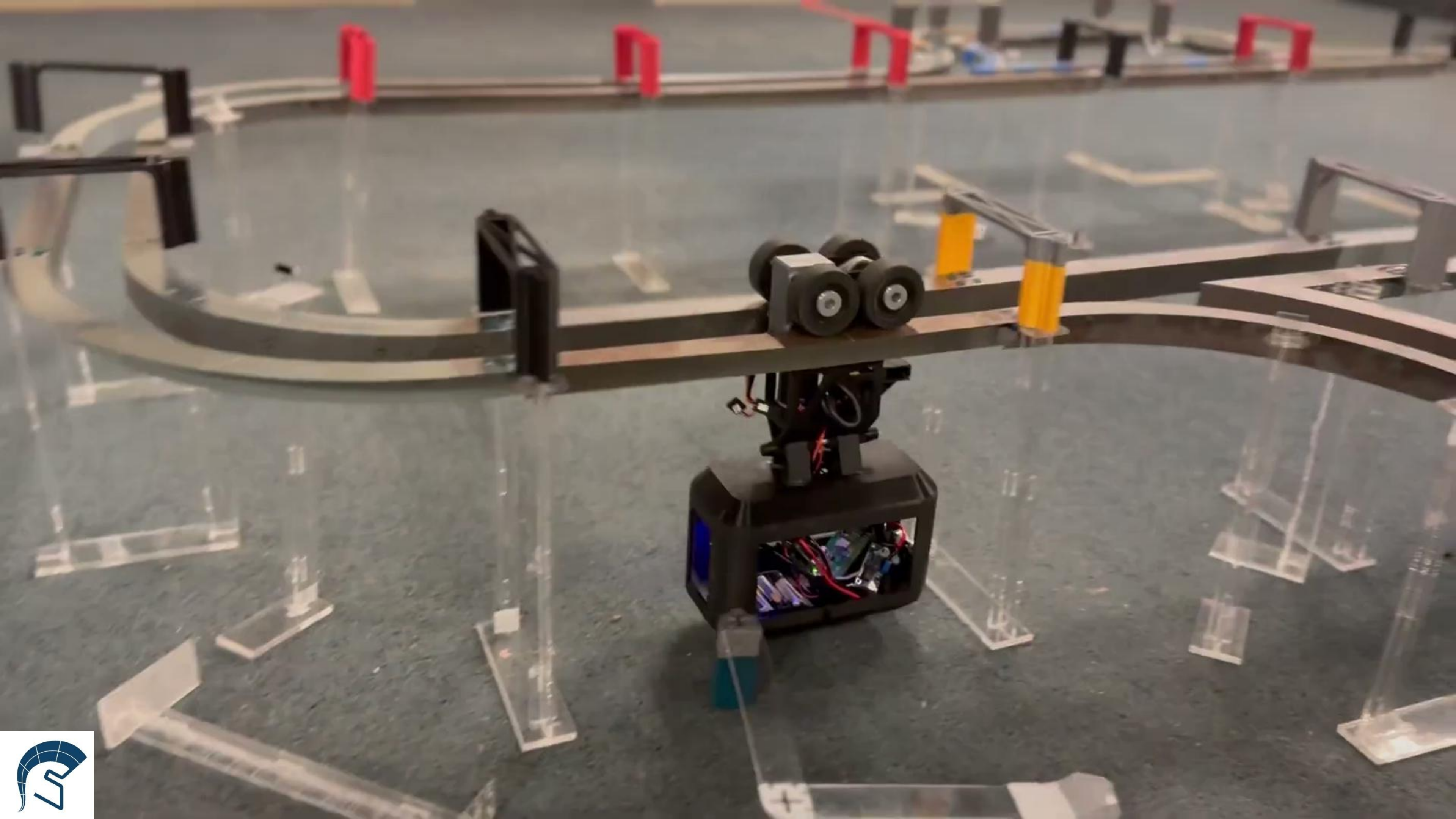
Final design is able to provide enough power to run the system



Final design is able to provide enough power to run the system



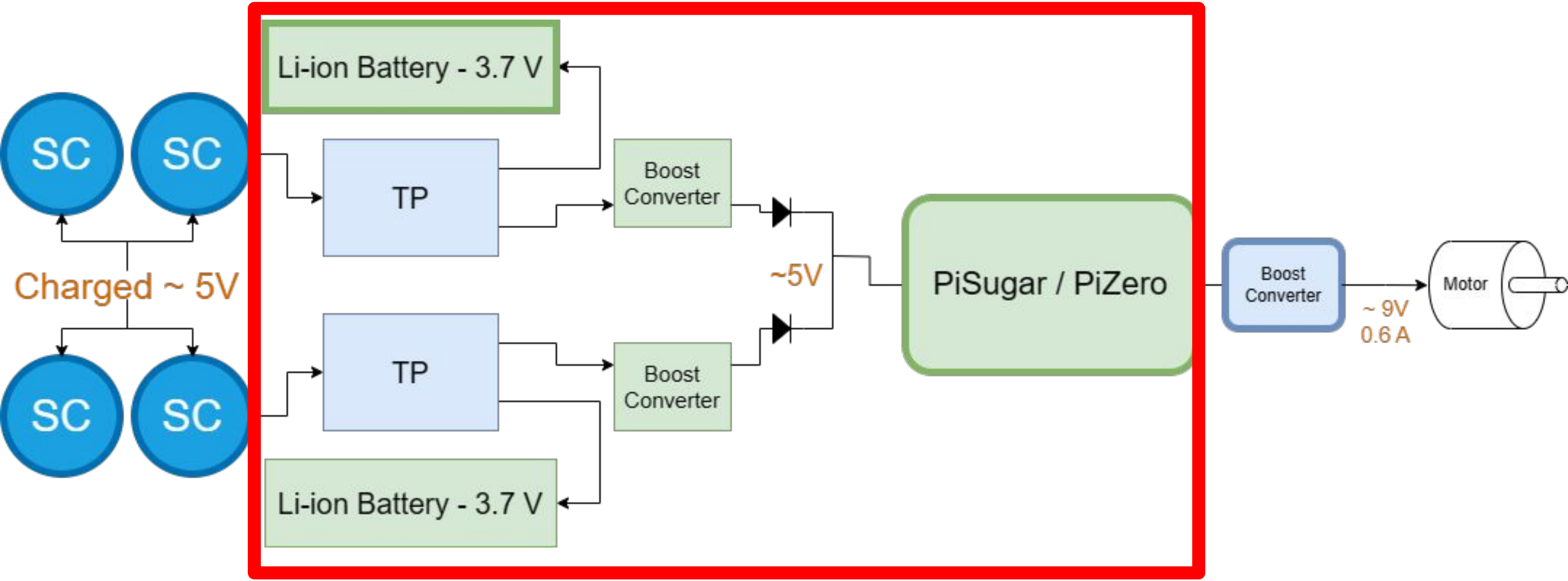
Roman Ortiz



Future Suggestion & Conclusion

Michael Korens

Our project works! But a question that every Engineer should ask themselves is: “can it be better?”

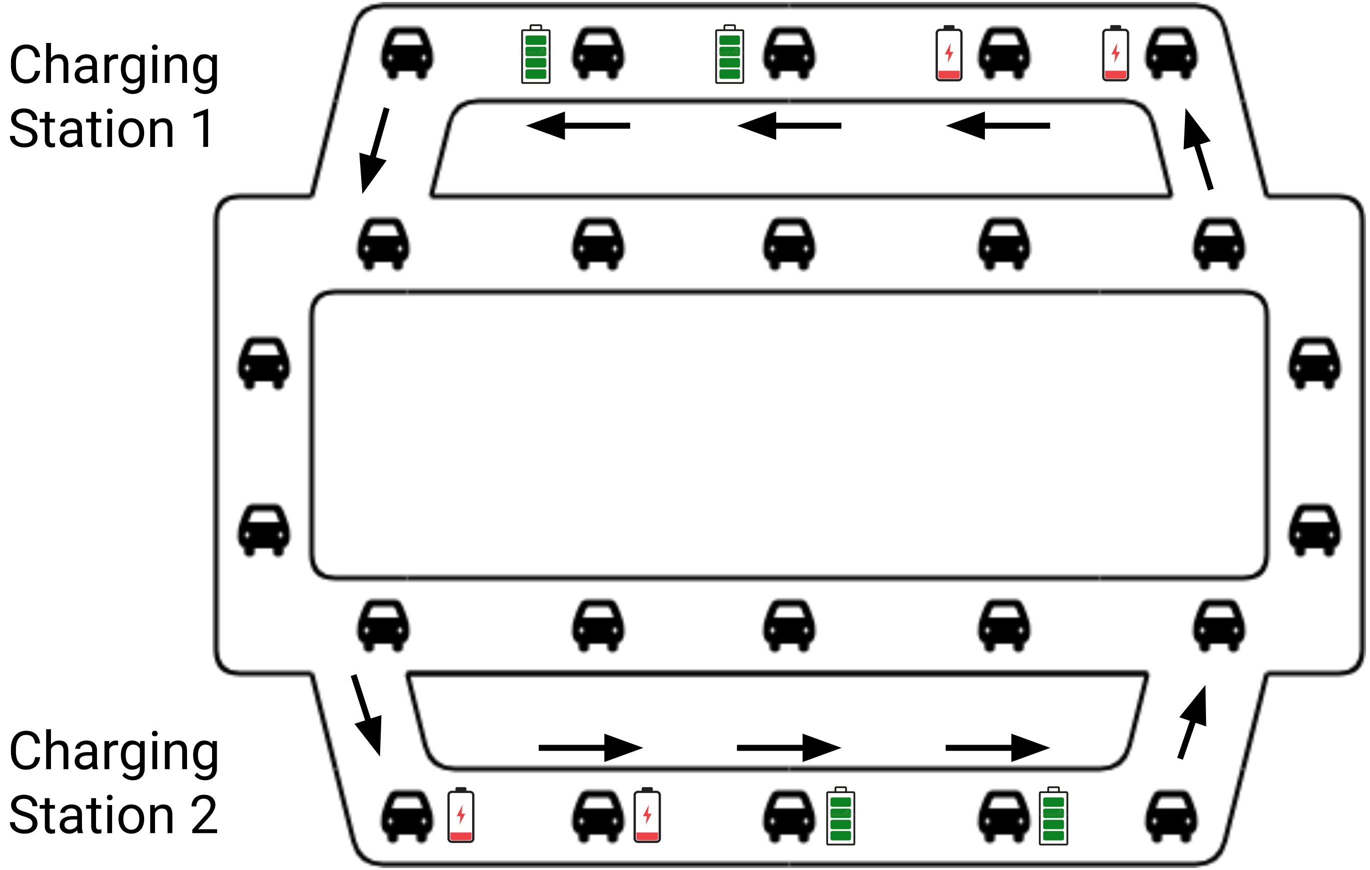


Michael Korens

The implications of our work will allow Bogies to quickly receive energy and cut down on “recharging time”

Michael Korens

The implications of our work will allow Bogies to quickly receive energy and cut down on "recharging time"



Michael Korens

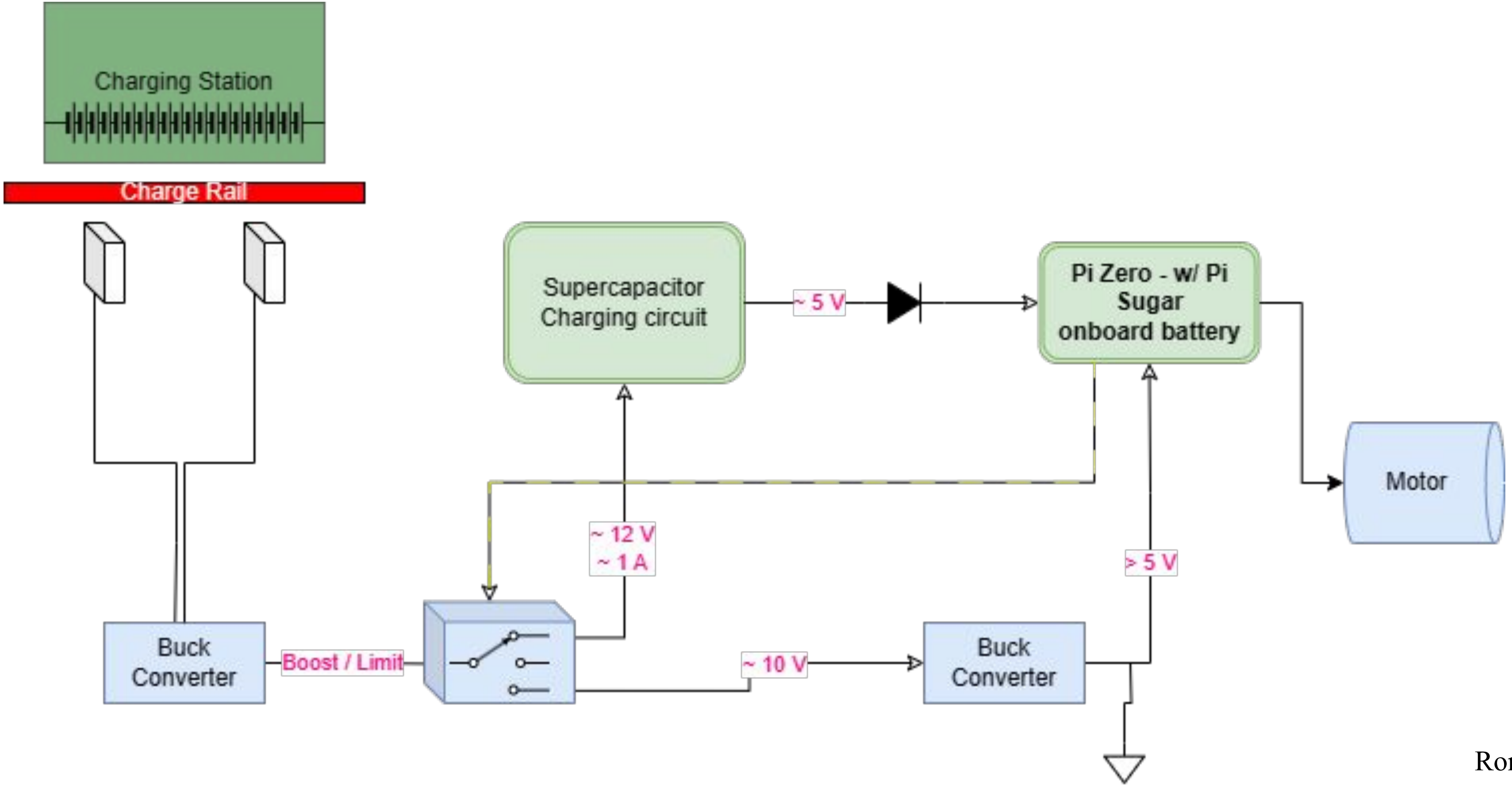
Before we conclude this presentation, lets ask ourselves, if we don't act now, who will?

We have been able to achieve parts of our functional goals, and our final goal of a hybrid system is getting close.

Functional Specs	
Minimum Output Voltage	5 Volts
Minimum Output Current	3 Amp
Minimum Power Delivery	15 Watts
Charging Time	< 1 minute
Charging Type	Constant Voltage*
Stored energy	9.3 Joules per bogie
Stored Battery energy	4.44 Whr

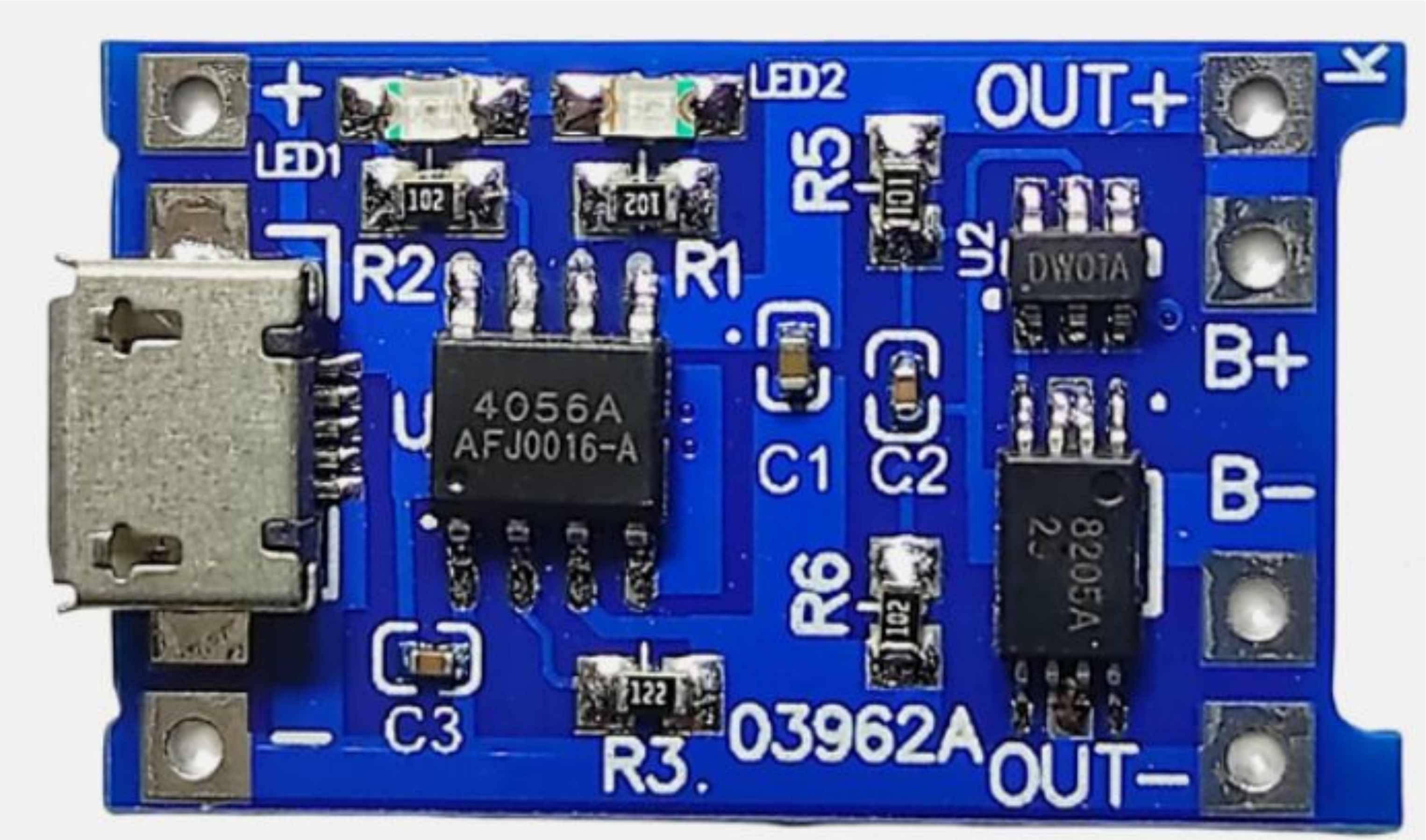
Roman Ortiz

The design from our previous presentation works in theory, but there were a few over-engineered aspects to it



Roman Ortiz

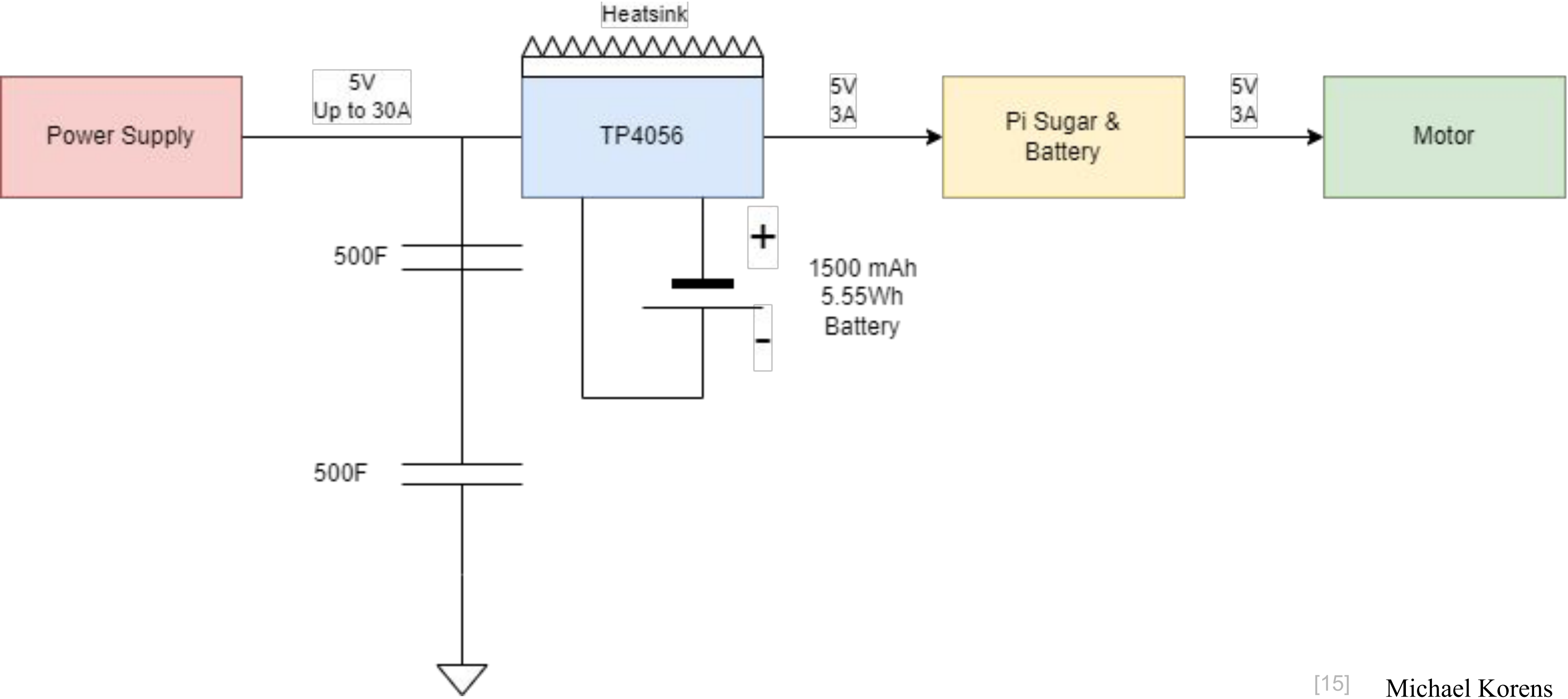
Thanks to the Core team, we were able to find a chip that can significantly cut down the complexity of our circuit



[15]

Michael Korens

The TP4056 module helps us accomplish our hybrid system goal and cuts down circuit complexity

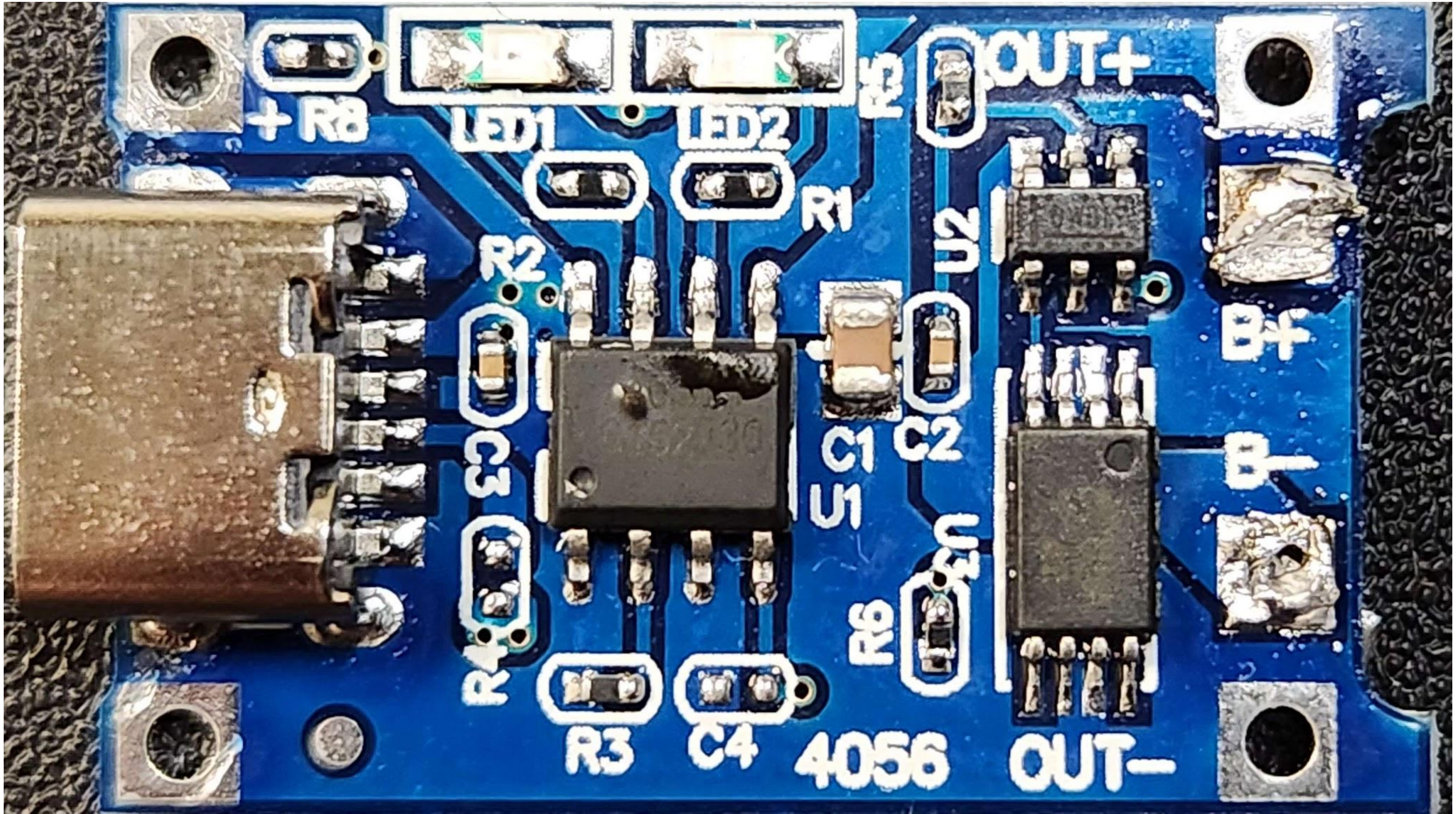


 Michael Korens

We’ve been using a USB power meter to test the TP4056

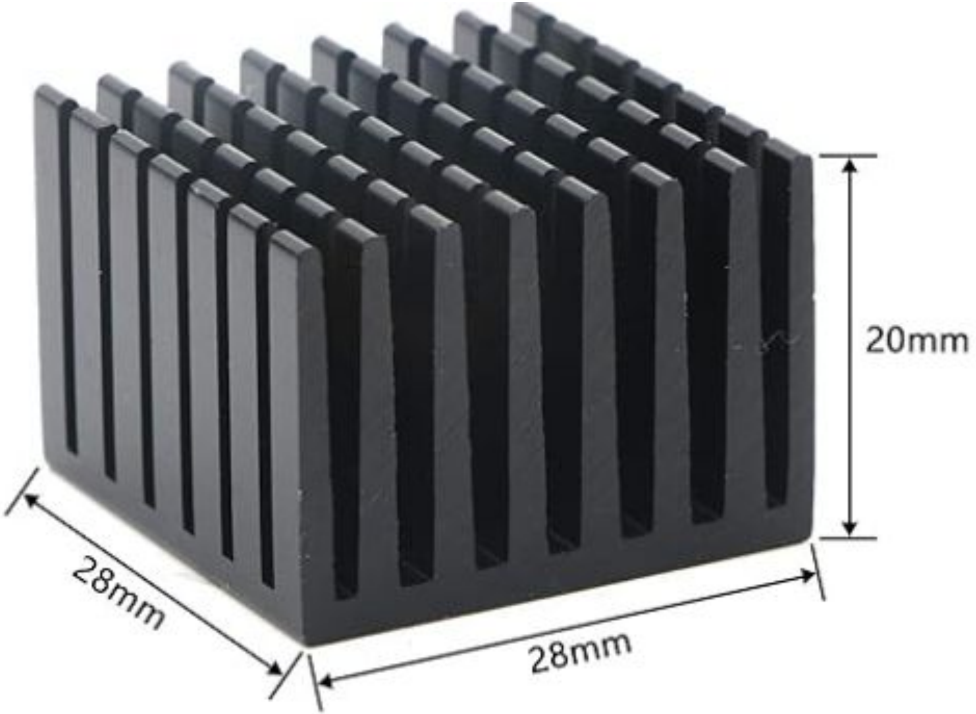
Michael Korens

Our internal testing have been very promising! … Until tragedy struck

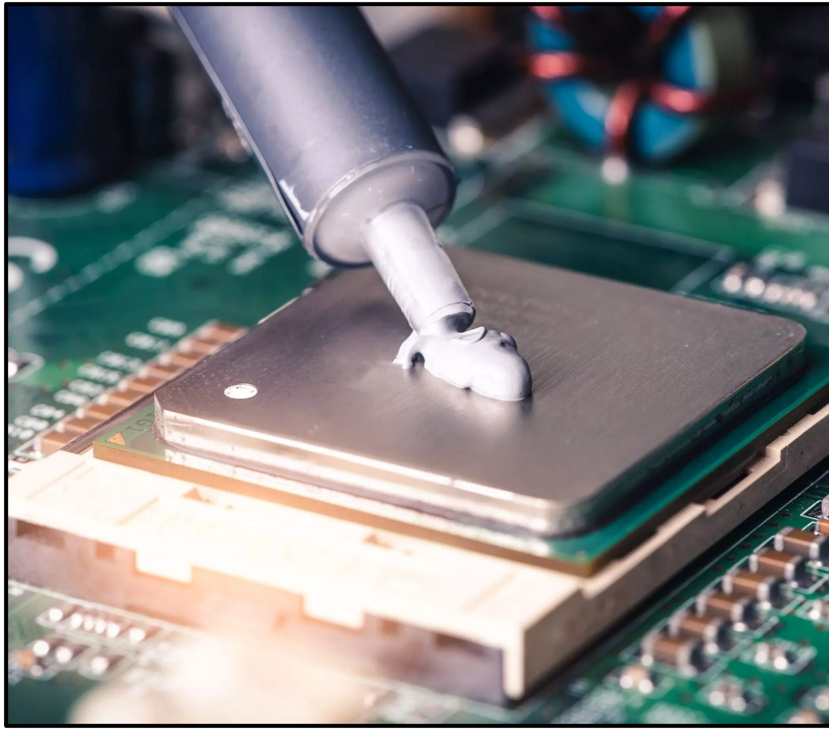


Michael Korens

However, all hope is not lost! It just means that we need to implement a heat solution system to the TP4056!



[16]



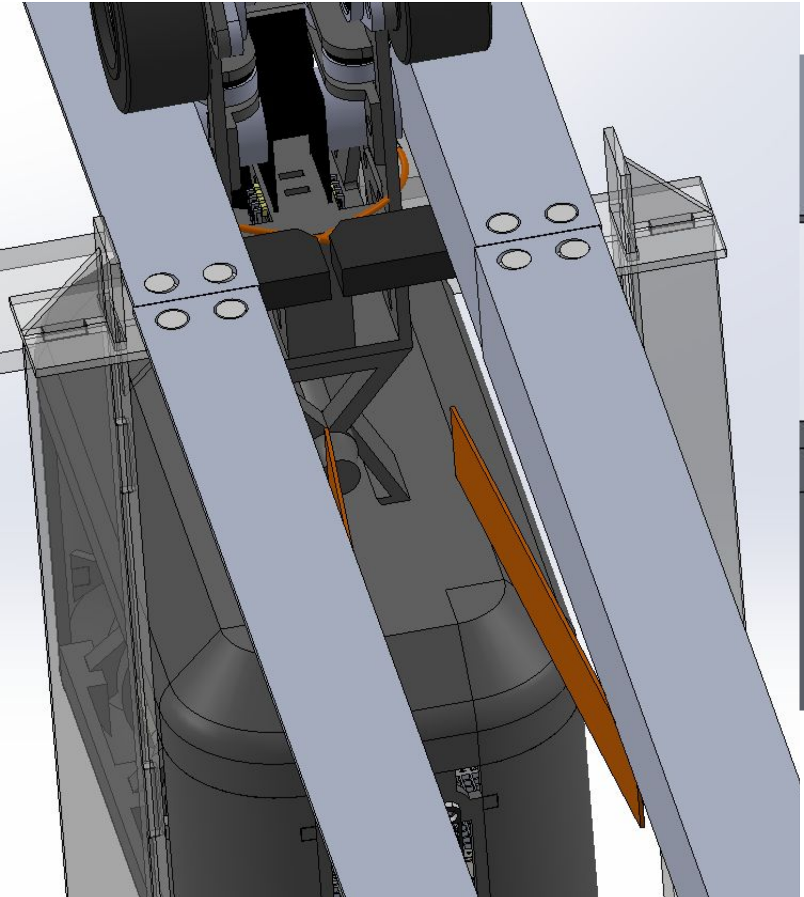
[17]

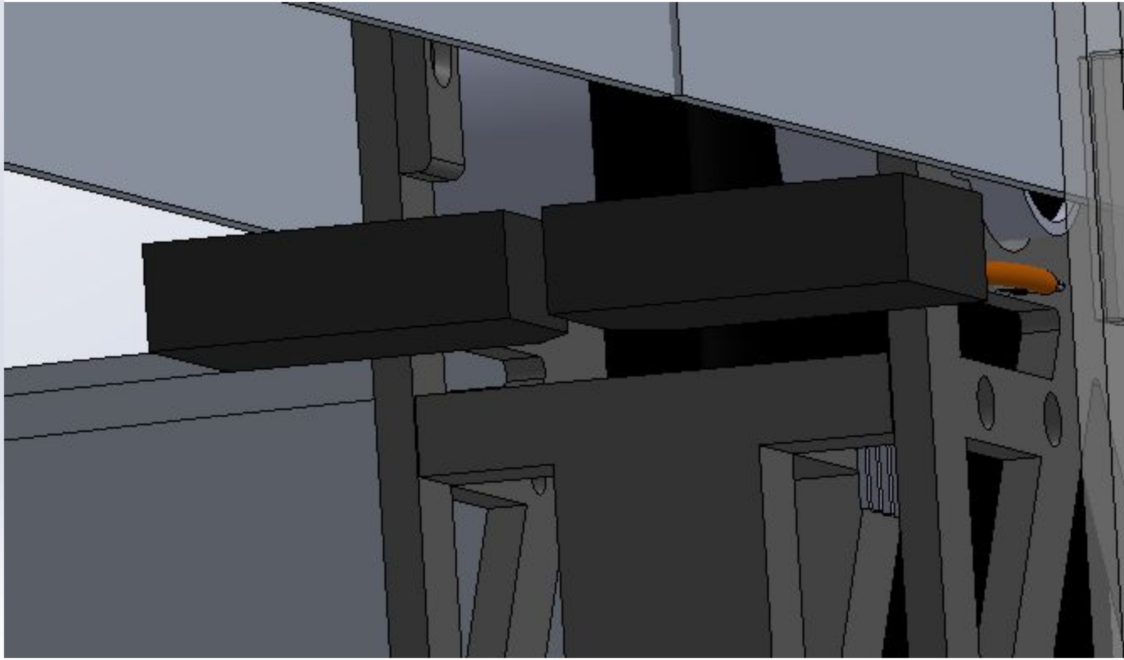
Michael Korens

Carbon brush contacts and a copper "third rail" system will facilitate power transfer to the bogie from the charging station

Anton Loeb

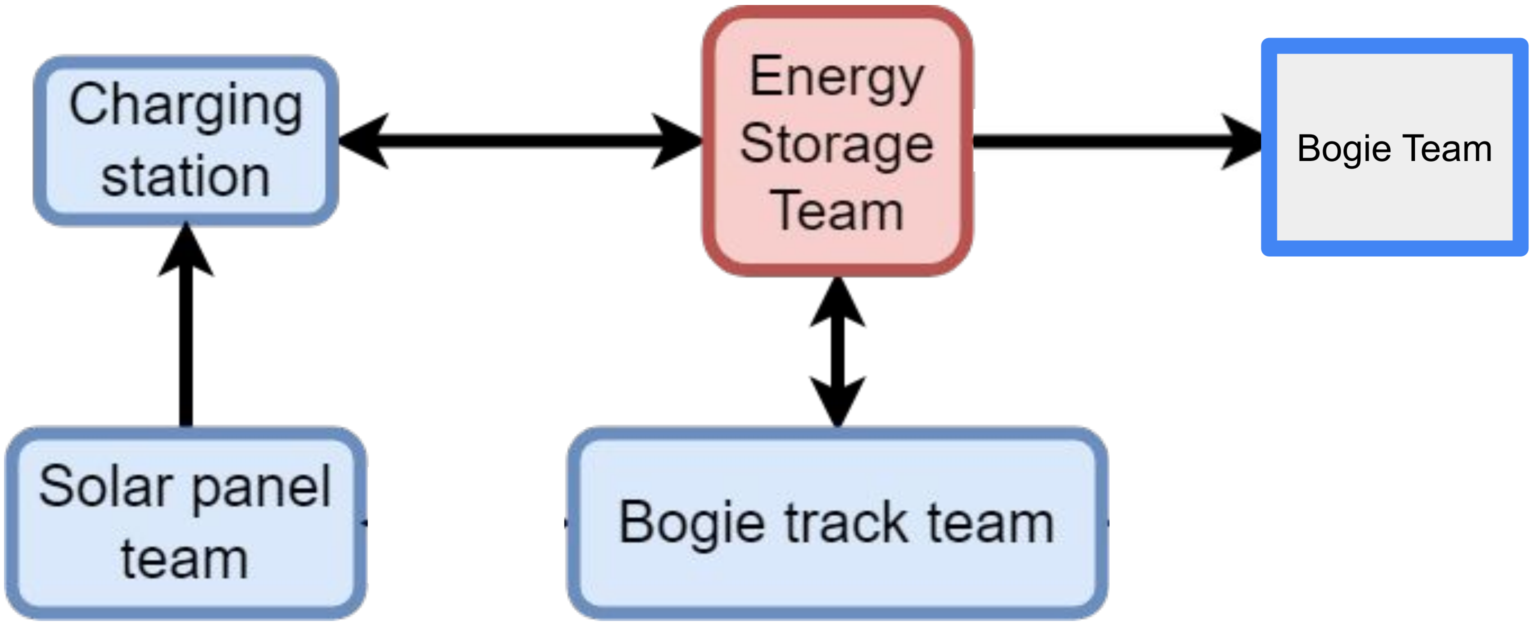
We are working with the Bogie Team in order to design the carbon brush-based third rail system





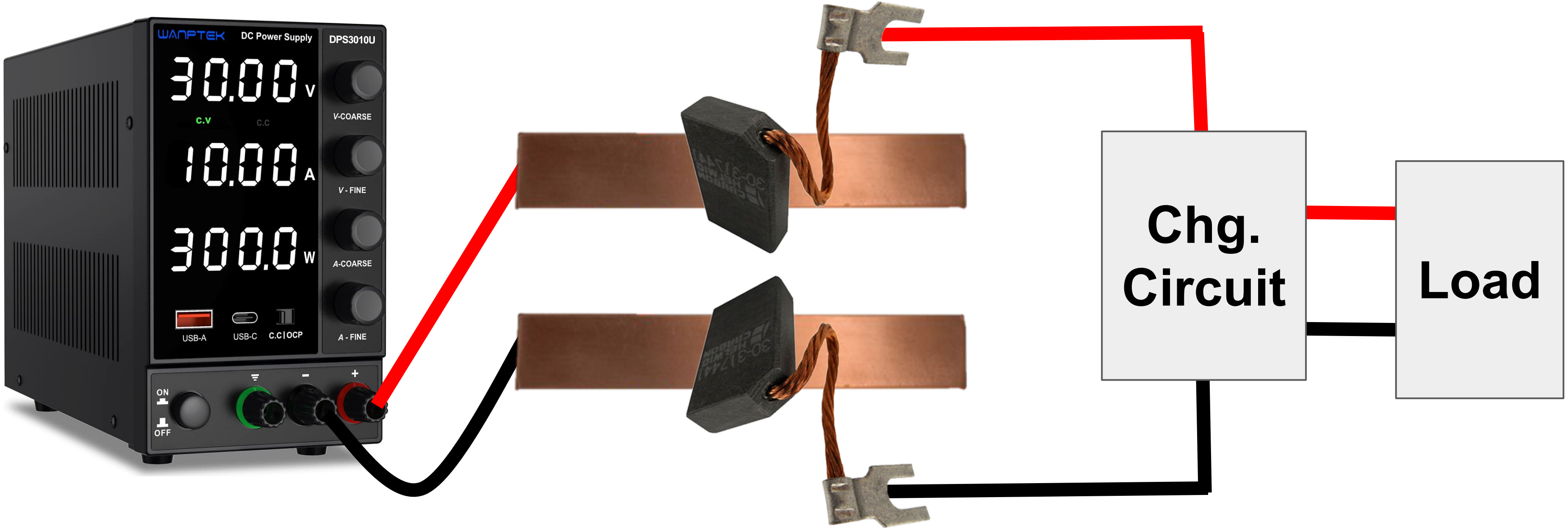
Anton Loeb

Our team is dependent on a handful of people, while also being counted on to complete our section of the project.



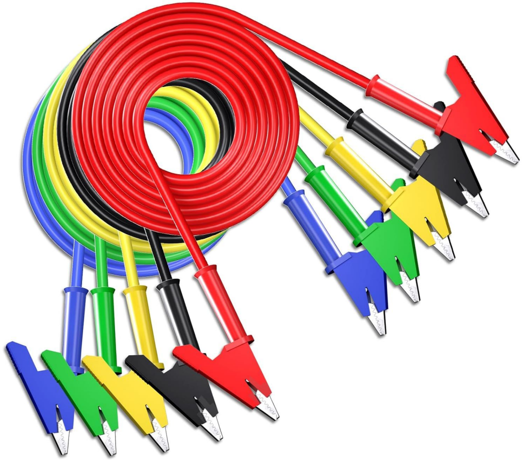
Anton Loeb

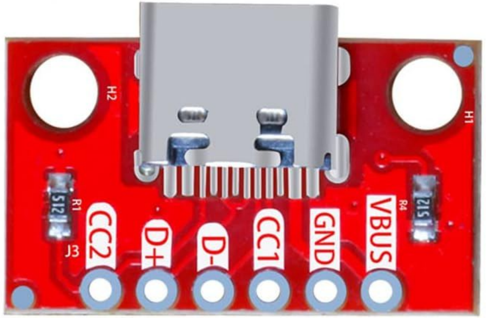
In order to test our design before integrating it with the other teams' components, we will use a simulated load and power supply.



Anton Loeb

In terms of budgeting, most of our expenses has been on quality of life materials and reducing technical limitations





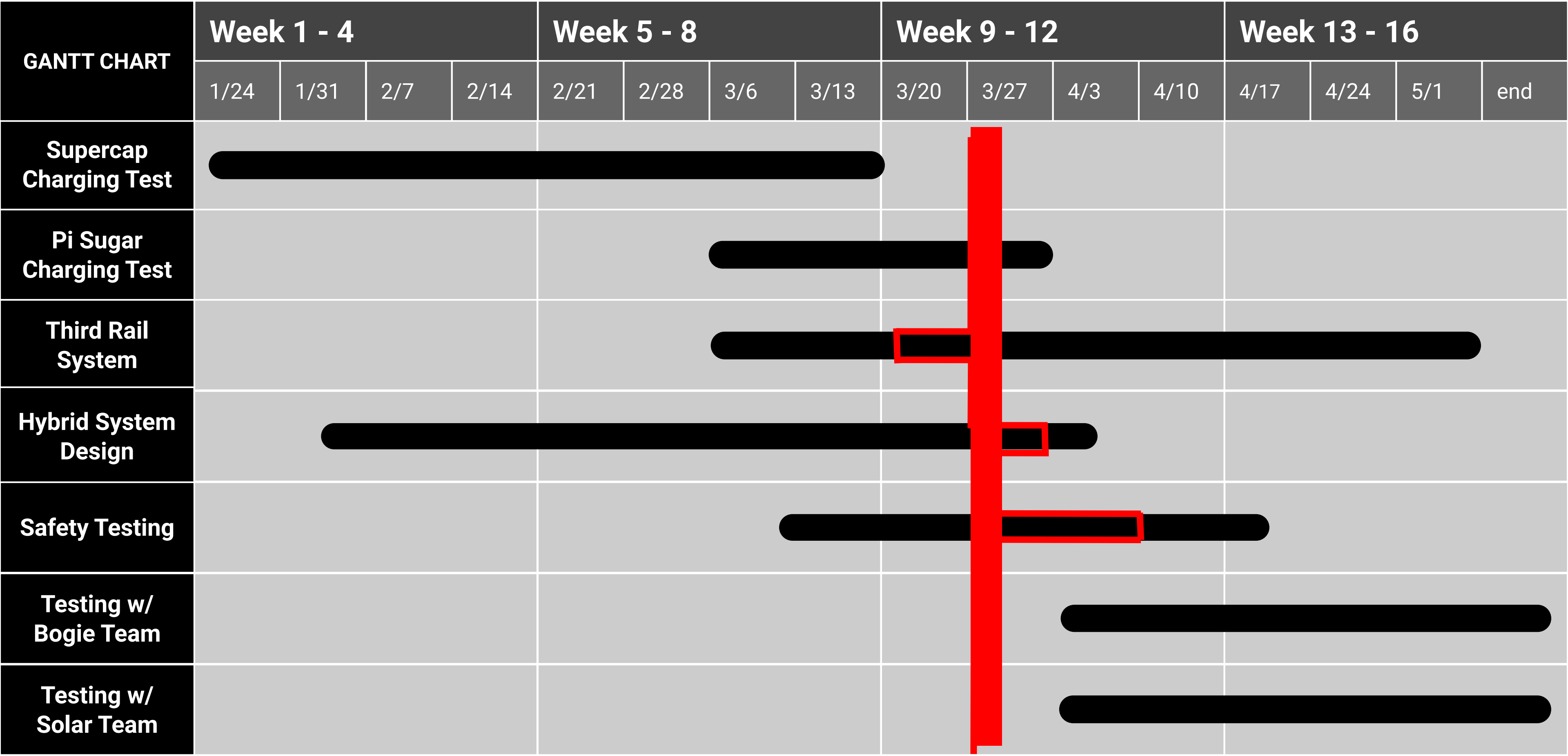
Anton Loeb

We have managed to remain within our budget and don't plan on making many future expenditures

Part Name	Part No.	Source	Price
Maxwell Supercapacitors	BCAP0350 P270 S18	SPARTAN SUPERWAY Rise Above	**$ ~**
Lithium-ion rechargeable cell	INR18650-25R	SPARTAN SUPERWAY Rise Above	**$ ~**
Lithium Battery Charging and Protection Board	TP4056	amazon	**$8.99**
Pi Zero/Pi Sugar	Pi Sugar 3	amazon	**$69.99**
Misc. Expenditures	Power supply alligator clips, heatsink, resistor, etc.	amazon	**$122.67**
		Total ≈	**$202**

Roman Ortiz

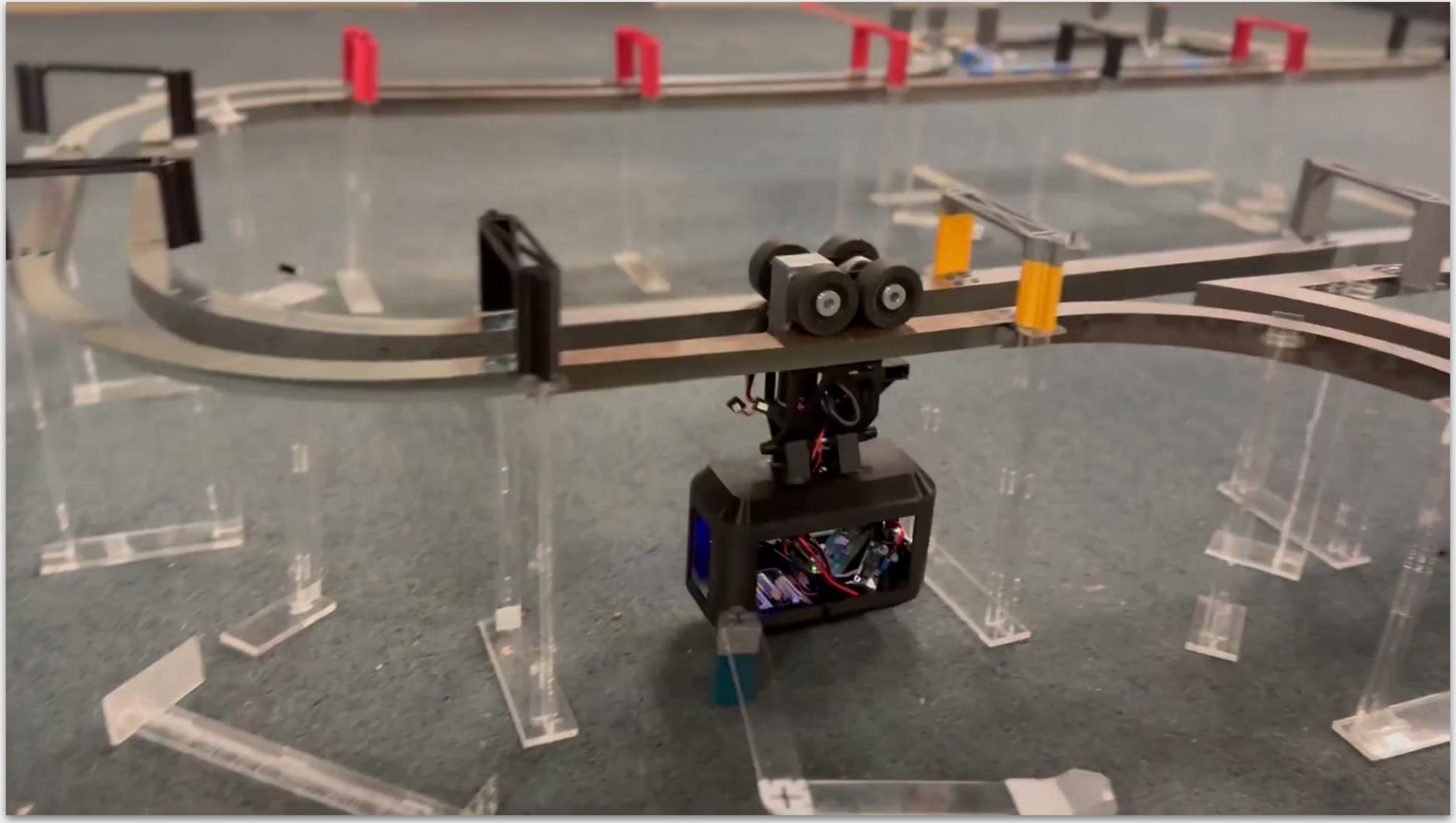
Despite some design changes, we are on schedule



Patrick Chiu

To conclude, we have successfully developed a Hybrid Battery-Supercapacitor System & Implement the 3rd Rail

Thank you for listening, any questions?



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[18] Boyle, D., & Associates Engineering Service Group. (2018). Automated Transit Network- Feasibility Study. http://www.advancedtransit.org/wp-content/uploads/2018/10/20180904-GPATS-ATN-Feasibility-Study.pdf

The TP4056 is a complete constant-current/constant-voltage linear charger for single cell lithium-ion batteries. Its SOP package and low external component count make the TP4056 ideally suited for portable applications. Furthermore, the TP4056 can work within USB and wall adapter.
No blocking diode is required due to the internal PMOSFET architecture and have prevent to negative Charge Current Circuit. Thermal feedback regulates the charge current to limit the die temperature during high power operation or high ambient temperature. The charge voltage is fixed at 4.2V, and the charge current can be programmed externally with a single resistor. The TP4056 automatically terminates the charge cycle when the charge current drops to 1/10th the programmed value after the final float voltage is reached.
TP4056 Other features include current monitor, under voltage lockout, automatic recharge and two status pin to indicate charge termination and the presence of an input voltage.

FEATURES

- Programmable Charge Current Up to 1000mA
- No MOSFET, Sense Resistor or Blocking Diode Required
- Complete Linear Charger in SOP-8 Package for Single Cell Lithium-Ion Batteries
- Constant-Current/Constant-Voltage
- Charges Single Cell Li-Ion Batteries Directly from USB Port
- Preset 4.2V Charge Voltage with 1.5% Accuracy
- Automatic Recharge
- two Charge Status Output Pins
- C/10 Charge Termination
- 2.9V Trickle Charge Threshold (TP4056)
- Soft-Start Limits Inrush Current
- Available Radiator in 8-Lead SOP Package, the Radiator need connect GND or impending

ABSOLUTE MAXIMUM RATINGS

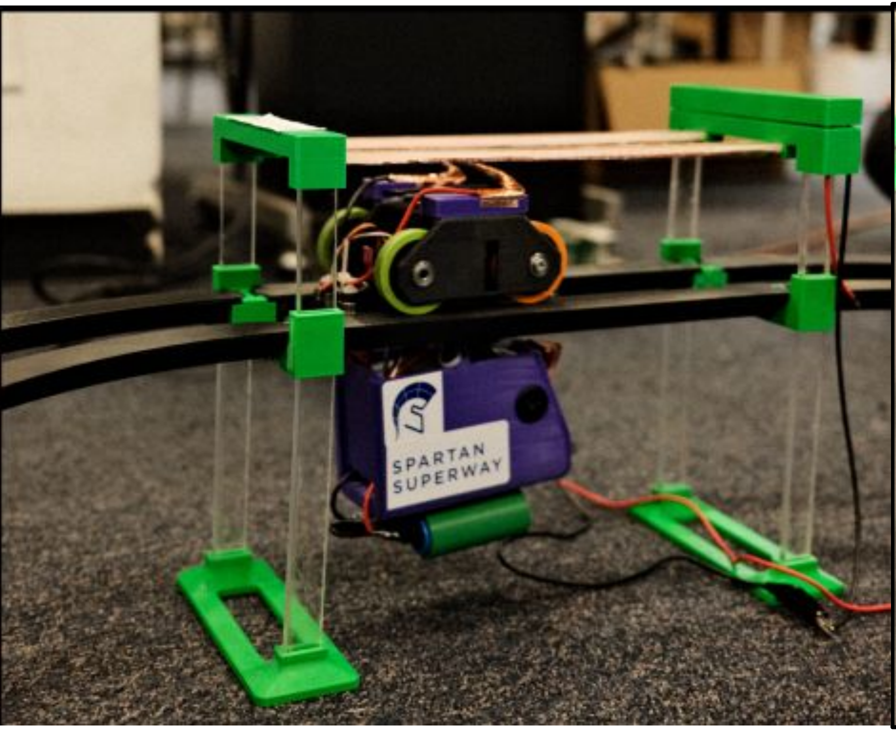
- Input Supply Voltage(V_{CC})：-0.3V～8V
- TEMP：-0.3V～10V
- CE：-0.3V～10V
- BAT Short-Circuit Duration：Continuous
- BAT Pin Current：1200mA
- PROG Pin Current：1200uA
- Maximum Junction Temperature：145℃
- Operating Ambient Temperature Range：-40℃～85℃
- Lead Temp.(Soldering, 10sec)：260℃

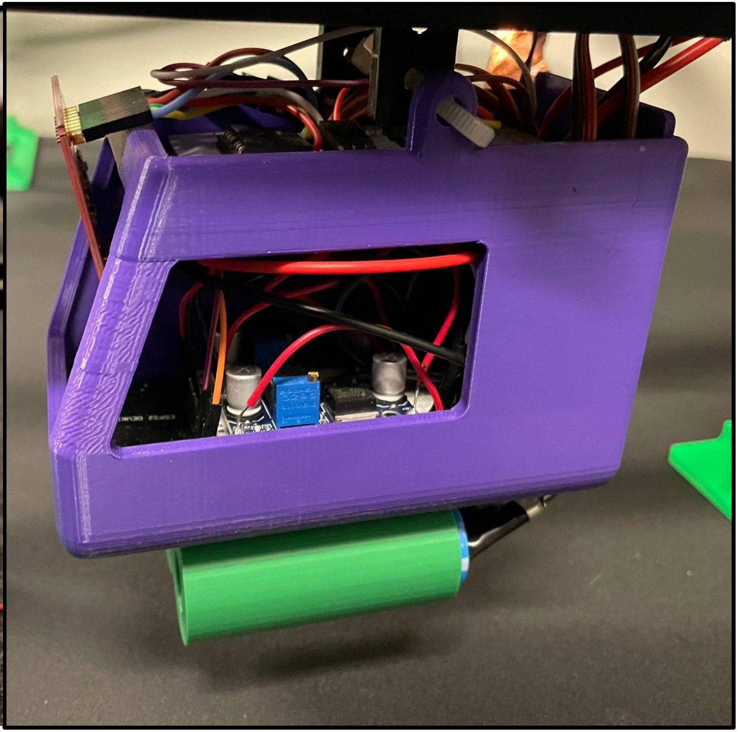
APPLICATIONS

- Cellular Telephones, PDAs, GPS
- Charging Docks and Cradles
- Digital Still Cameras, Portable Devices
- USB Bus-Powered Chargers,Chargers

Complete Charge Cycle (1000mAh Battery)

We need an energy storage system that can continuously output 18W of power to meet the demand!





[10]

Nyalah Payne

Key changes from the initial design will be implemented to meet our needs

General Specifications for the Bogie	Previous Design	New Design
Charge Time:	Less than 30 min	Less than 1 minute
Operational Time:	45 minutes	10 minutes
Power Storage Source:	Supercapacitors	Supercapacitors & Lithium Ion Battery

Nyalah Payne

To avoid melting plastic of the thin wire, we will use 16 gauge or thicker wire

In terms of scheduling, we are on track with our progress

TASK TITLE	TASK OWNER	START DATE	DUE DATE	PCT OF TASK COMPLETE
Research (Vortex 3)				
Prepare for meeting with Ping Hsu	Patrick	1/24/24	1/31/24	100%
Prepare for meeting with Ping Hsu	Roman	1/24/24	1/31/24	100%
Prepare for meeting with Ping Hsu	Nyalah	1/24/24	1/31/24	100%
Prepare for meeting with Ping Hsu	Michael	1/24/24	1/31/24	100%
Prepare for meeting with Ping Hsu	Anton	1/24/24	1/31/24	100%
Design Development (Vortex 3)				
Integrate charging circuit w/ Super cap	Patrick	1/31/24	2/14/24	100%
Integrate charging circuit w/ Super cap	Roman	1/31/24	2/14/24	100%
Get appropriate capacitors/resistors for charging circuit	Nyalah	1/31/24	2/14/24	100%
Develop third rail design	Michael	1/31/24	2/14/24	40%
Develop third rail design	Anton	1/31/24	2/14/24	40%
Design Testing (Vortex 3)				
Test supercap voltages	Patrick	2/7/24	2/21/24	100%
Test charging circuit outputs	Roman	2/7/24	2/21/24	100%
Measure voltage output of supercap & help w/ integration	Nyalah	2/7/24	2/21/24	100%
Test input voltages/currents w/ charging circuit	Michael	2/7/24	2/21/24	100%
Test input voltages/currents w/ charging circuit	Anton	2/7/24	2/21/24	100%

Patrick Chiu

In terms of scheduling forecast, our anticipated challenge will be finishing the third rail design

Third rail / State machine integrations (Vortex 4)				
Test Supercap charging times	Patrick	2/21/24	3/6/24	0%
Look into third rail contact fabrication	Roman	2/21/24	3/6/24	0%
Integrate state machine designs	Nyalah	2/21/24	3/6/24	20%
Integrate state machine designs	Michael	2/21/24	3/6/24	20%
Test third rail block obtained from core team	Anton	2/21/24	3/6/24	0%
Testing! (Vortex 4)				
Test Supercapacitor discharging/charging values	Patrick	3/6/24	3/20/24	0%
Test input power into Supercapacitor charging circuit & whole system	Roman	3/6/24	3/20/24	0%
Monitor battery charging/discharging	Nyalah	3/6/24	3/20/24	0%
Monitor battery charging/discharging	Michael	3/6/24	3/20/24	0%
Monitor the motor that'll be powered by the Battery	Anton	3/6/24	3/20/24	0%
Design Prototyping (Vortex 4)				
Implement new design changes based on previous feedback	Patrick	3/20/24	4/3/24	0%
Implement new design changes based on previous feedback	Roman	3/20/24	4/3/24	0%
Implement new design changes based on previous feedback	Nyalah	3/20/24	4/3/24	0%
Implement new design changes based on previous feedback	Michael	3/20/24	4/3/24	0%
Implement new design changes based on previous feedback	Anton	3/20/24	4/3/24	0%
Research (Vortex 5)				
Look into issues w/ previous design	Patrick	4/3/24	4/17/24	0%
Look into issues w/ previous design	Roman	4/3/24	4/17/24	0%
Look into issues w/ previous design	Nyalah	4/3/24	4/17/24	0%

Patrick Chiu

Power consumption are to be determined by the motor testing

Actual operating power = Voltage * Current

Depending on the motor, we are choosing between PiSugar or 18650 lithium ion batteries

Using the Maxwell 350F supercapacitor allows us to charge with higher current quickly and safely

Pi Zero & Pi Sugar Specifications

Pi Zero Electrical Specs

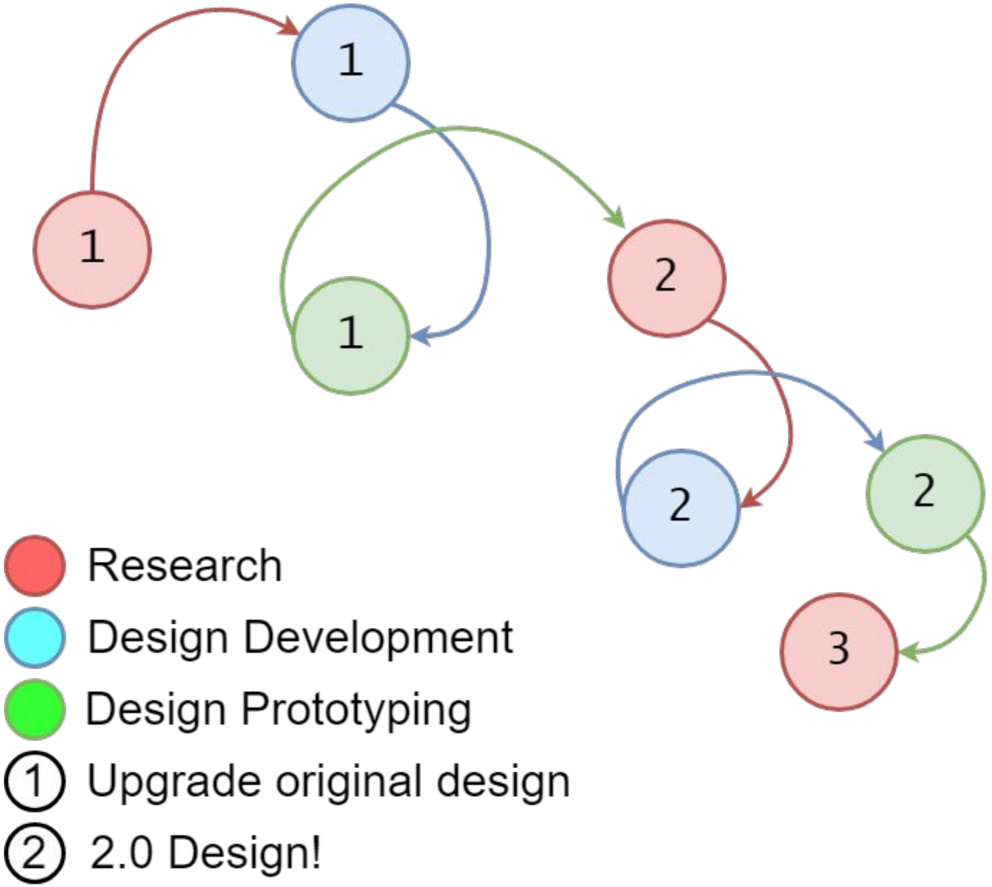
Specifications Pi Zero	Max Current	Voltage
GPIO Pin	16mA	3.3V to 5V
Overall Syst.	120 mA	3.3V to 5V

*Also, as a point of reference, when you power off a Raspberry Pi (any model), it typically uses 20-30 mA (0.1W) until you physically disconnect the power.

Pi Sugar 3 Electrical Specs

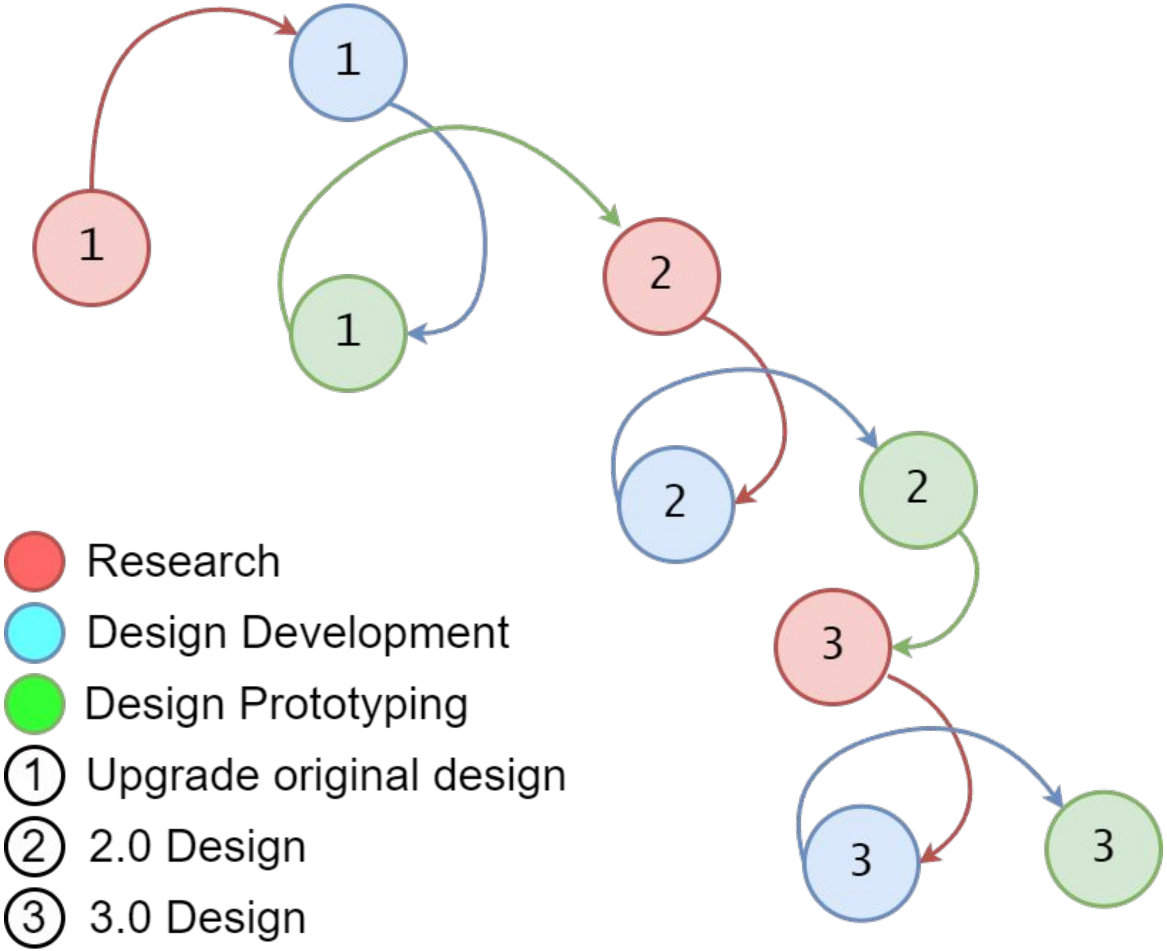
Electrical Specifications	PiSugar 3
Input	5V-3Amax
Output	5V-2.5Amax
Battery capacity	1200mah
Communication interface	0x75/0x32 address
Size of PCB	65mmX30mm

This is a recap of our previous design vortex



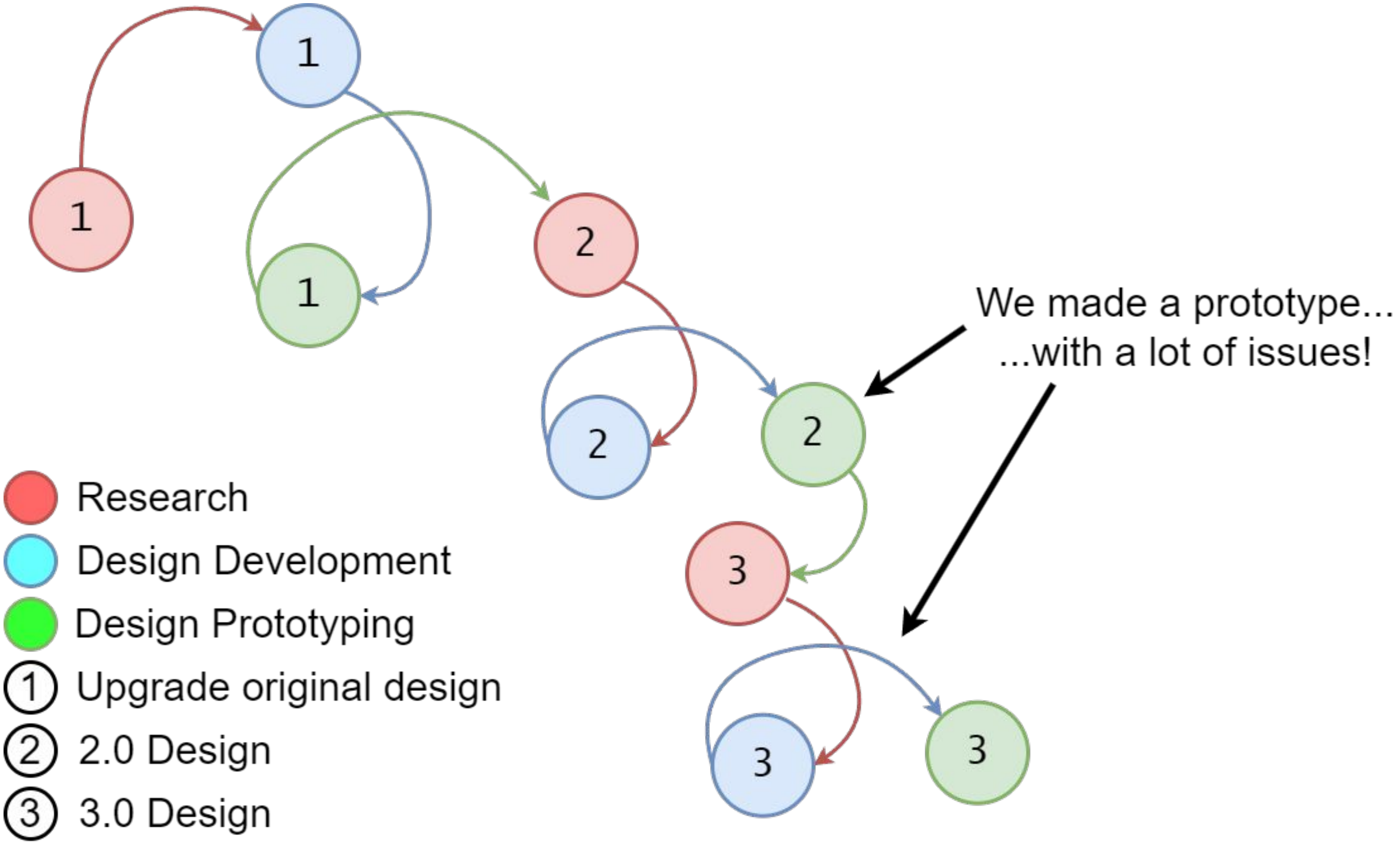
Michael
Korens

Here is where we are now

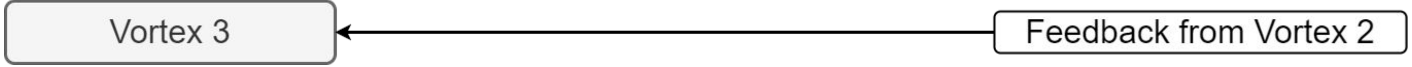


Michael
Korens

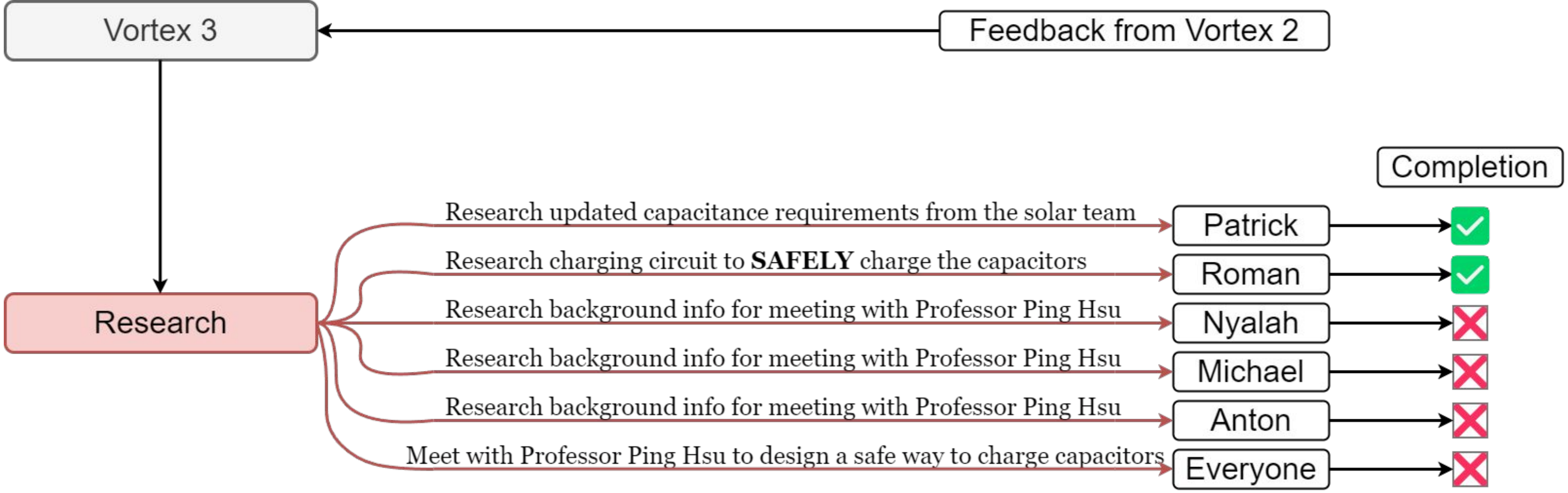
Here is where we are now



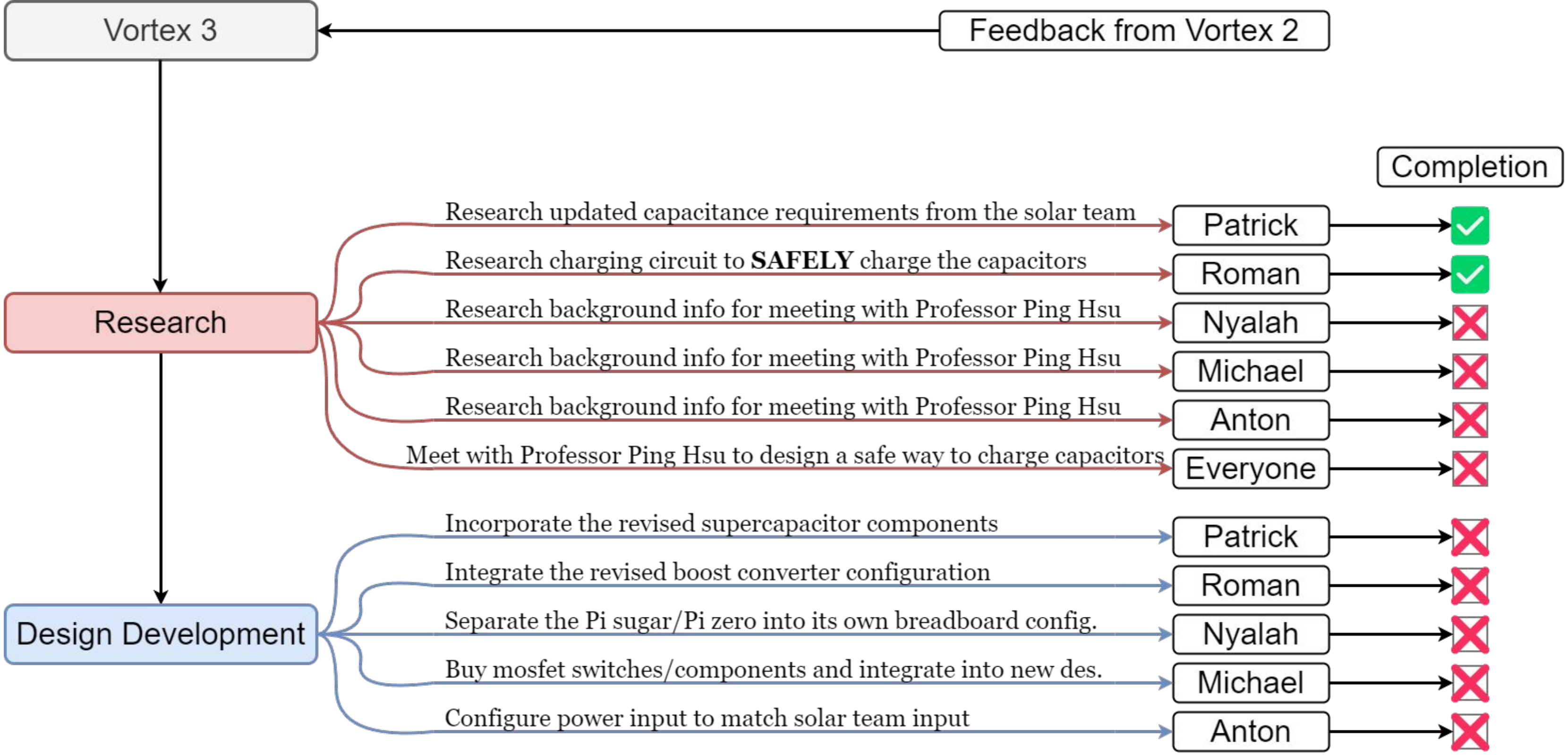
Michael
Korens



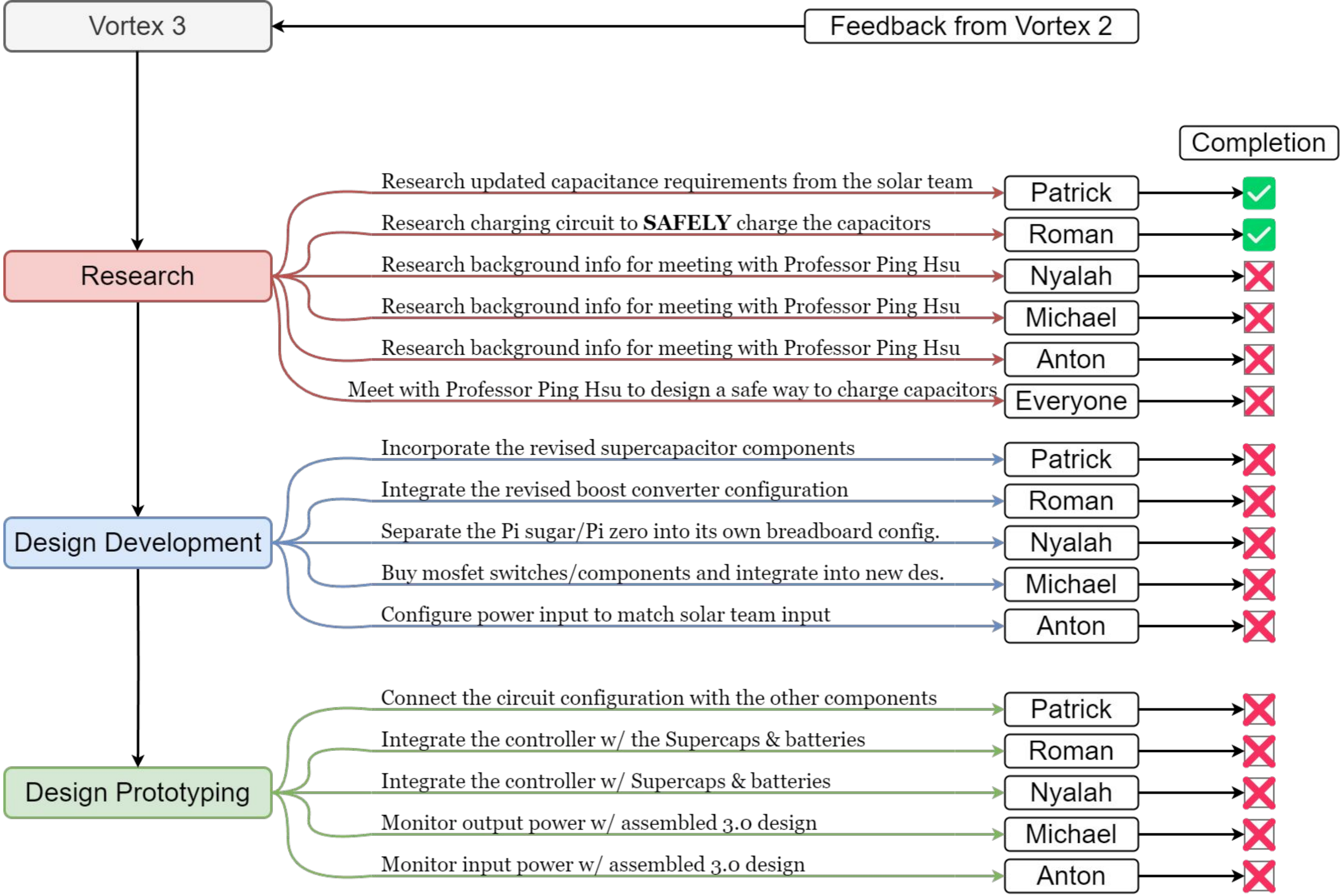
Michael
Korens



Michael Korens



Michael Korens



Michael Korens

The estimated energy consumption is 9.30 Joules through 8 meter of track

$$E(t_s) = \frac{1}{\bar{\eta}} \left\{ (1-R) n_t \frac{M_V V_L^2}{2} + \frac{1}{2} \rho C_D A_V \left[(V_L^2 + \langle V_w^2 \rangle) D_s - \frac{V_L^4}{2a_m} \right] + n_T M_V \left[C_1 D_s + C_2 V_L (D_s - \frac{V_L^2}{3a_m}) + gz \right] \right\} + n_T P_{aux} t_s$$

<u>Ideal Energy per vehicle</u>

Energy required:	9.30 J
Average trip time:	35.0 seconds
Average power:	0.266 W

Patrick Chiu

Additional assumptions are made using current track design and previous year data

```
n_bar = 0.80  #  average efficiency of the electric motor
g = 9.81  # acceleration due to gravity, m/s^2
a_m = 0.25*g  # maximum acceleration for seated passengers
J1 = a_m  # jerk starting from rest
J2 = a_m  # jerk approaching line speed
R_regen = 0  # regenerative braking recovery efficiency
n_t = 1  # number of vehicles in a 'train'
M_v = 1 # vehicle + bogie mass, kg
W_v = M_v*g  # weight of vehicle and bogie
```

$$E(t_s) = \frac{1}{\bar{\eta}}\left\{(1-R)n_t\frac{M_V V_L^2}{2} + \frac{1}{2}\rho C_D A_V\left[(V_L^2 + \langle V_w^2\rangle)D_s - \frac{V_L^4}{2a_m}\right] + n_T M_V\left[C_1 D_s + C_2 V_L\left(D_s - \frac{V_L^2}{3a_m}\right) + gz\right]\right\} + n_T P_{aux} t_s$$

Patrick Chiu

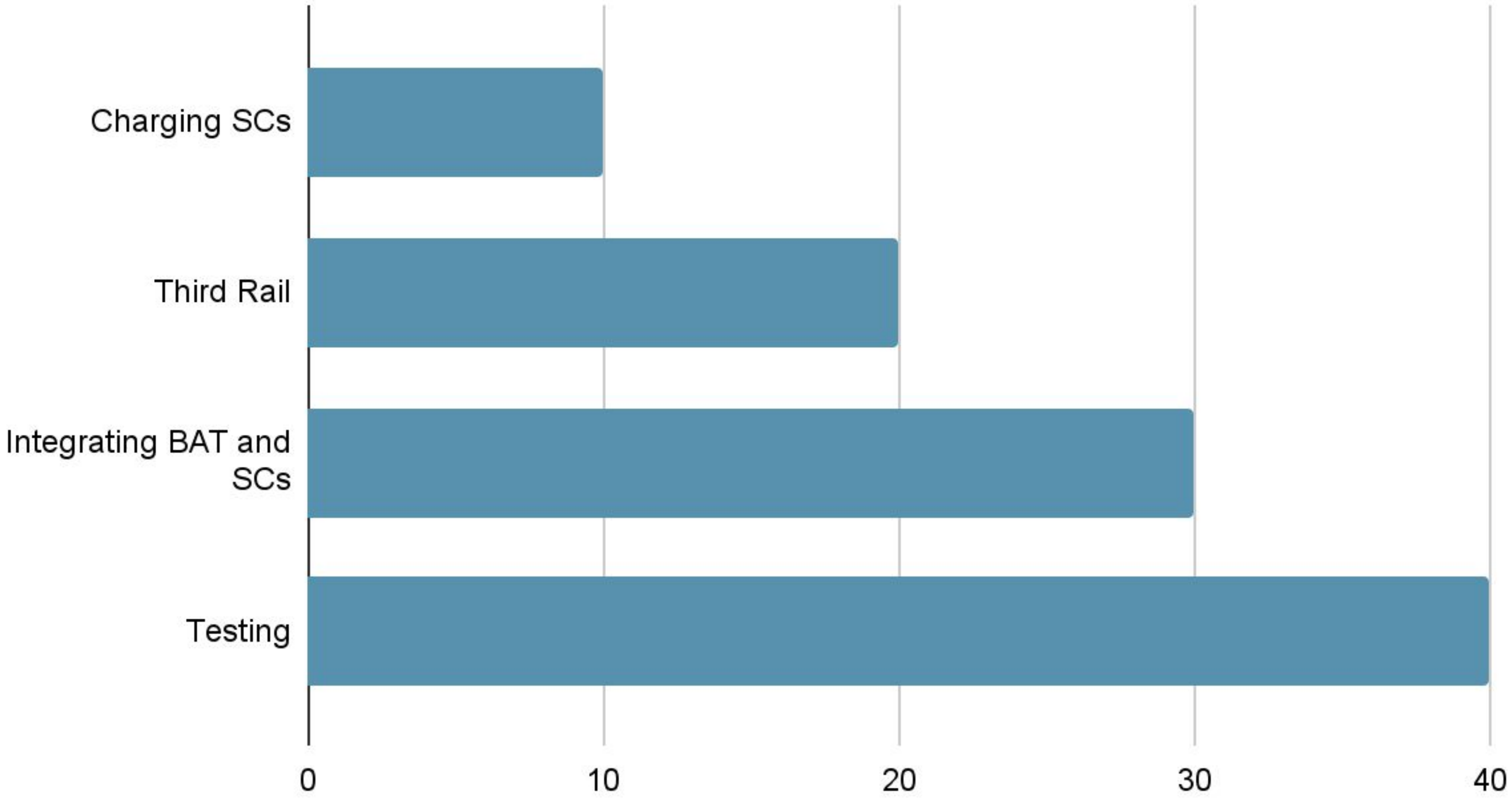
Additional assumptions are made using current track design and previous year data

```
V_l = 0.2826 # line speed, m/s
V_w = 5 # average wind speed, m/s
rho = 1.275  # density of air, kg/m^3
C_d = 0.51  # coefficient of drag (0.42 for a solid hemisphere)
A_v = 0.02  # frontal area of a vehicle, m^2
D_s = 8  # distance between stations, m
R_wheel = (1.75/2)*0.0254 # Radius of wheel (assuming 12 in. diameter), m
f1 = 0.057  # Coefficient of rolling resistance, in.:
# Cast iron on steel = 0.021 in; Polyurethane on steel = 0.03 - 0.057 in.
f1=f1*0.0254 # Coefficient of rolling resistance, m
```

$$E(t_s) = \frac{1}{\bar{\eta}}\left\{(1-R)n_t\frac{M_V V_L^2}{2} + \frac{1}{2}\rho C_D A_V\left[(V_L^2 + \langle V_w^2\rangle)D_s - \frac{V_L^4}{2a_m}\right] + n_T M_V\left[C_1 D_s + C_2 V_L\left(D_s - \frac{V_L^2}{3a_m}\right) + gz\right]\right\} + n_T P_{aux} t_s$$

Patrick Chiu

Gantt Chart


Charging SCs
Third Rail
Integrating BAT and SCs
Testing
0
10
20
30
40

Additional assumptions are made using current track design and previous year data

```
C1 = Fsr(M_v,R_wheel,f1)/M_v  # static roll resist per unit mass, N/kg)
C2 = 0.0004935  # dyn roll resistance (depends on velocity). N/(kg-m/s)
z = 0.10  # elevation change from start to the end of the trip, m
P_aux = 0.0  # auxilliary power, W (see Wikipedia for auto air con)
f_unk = 1.0  # extra factor for collector shoe and switching wheel drag
t_d = 5.5  # dwell time in station, s
```

$$E(t_s) = \frac{1}{\bar{\eta}}\left\{(1-R)n_t\frac{M_V V_L^2}{2} + \frac{1}{2}\rho C_D A_V\left[(V_L^2 + \langle V_w^2\rangle)D_s - \frac{V_L^4}{2a_m}\right] + n_T M_V\left[C_1 D_s + C_2 V_L(D_s - \frac{V_L^2}{3a_m}) + gz\right]\right\} + n_T P_{aux} t_s$$

Patrick Chiu

Energy loss is not significant due to the constrained environment condition and small scale

```
KE loss = 4.99e-02 J ---> 0.5%
Air drag loss = 1.63e+00 J ---> 17.5%
Rolling resistance loss = 6.39e+00 J ---> 68.7%
Elevation loss = 1.23e+00 J ---> 13.2%
Aux power loss 0.00e+00 J ---> 0.0%
```

Ideal charging power is 7 times larger than operating power based on the operating time and dwell time

Operating Time ≈ 35 seconds

Dwell Time ≈ 5 seconds

Operating/ Dwell Time Ratio = 7

The ideal and actual energy and power calculations are significantly different

Ideal:	Actual:
Energy = 9.3J	Energy = 650J
Operating power = 1.86W	Operating Power = 18W
Charging power = 0.266W	Charging power = 126W
	(6V, 3A)

Energy = Power * Time

Patrick Chiu

These are our detailed energy and power calculations

Operating:	**Charging:**
Operating Energy = Operating Power * Operating Time =	Actual Charging Power = Actual Energy / Dwell Time =
18W * 34.5 seconds = 621 J	621 J / 5.10 seconds = 122 W
Actual operating power = Voltage * Current =	Ideal Charging Power = Ideal Energy / Dwell Time =
6 Volts * 3 Amps = 18 Watts	9.3 J / 5.1 seconds = 1.82 W
Ideal operating power = Ideal Energy / Operating Time =	
9.3J / 34.5 seconds = 0.269 W	

Energy = Power * Time

Patrick Chiu

All combinations of the SCs below store enough energy for either ideal or actual energy consumption

Capacitance (F)	Total Energy Stored (J)	Available Energy (J)
500	5467.5	2467.5
3000	32805	14805
5000	54675	24675
325	3553.875	1603.875

>650J

$$E = 0.5 * C * (V_{eq}^2 - V_{motor}^2)$$

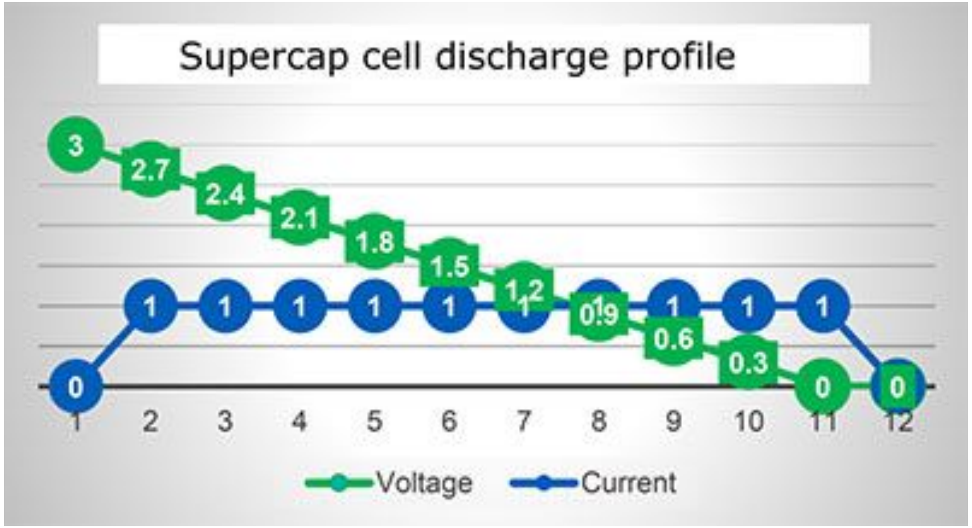
where

V_{eq}=8.1V

V_{motor}=6V

Patrick Chiu

SCs will power the motor, and Li-Ion battery will power microcontroller for stability



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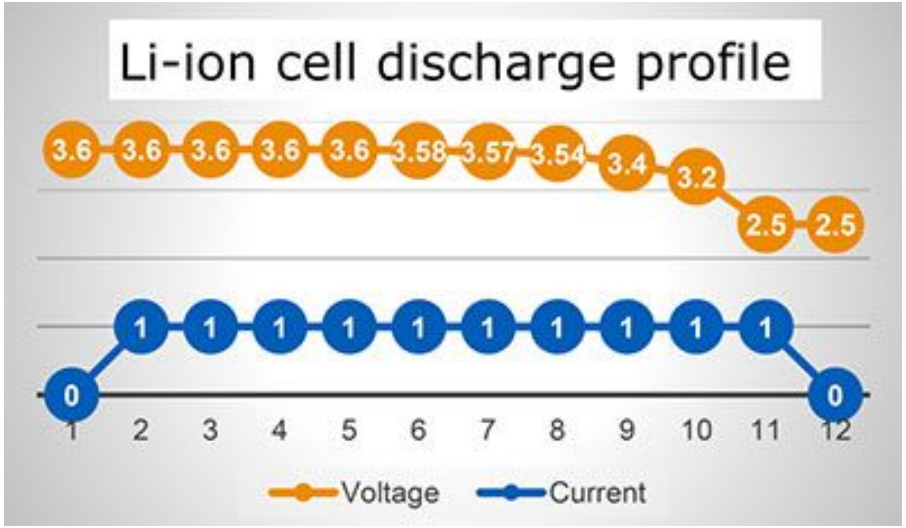
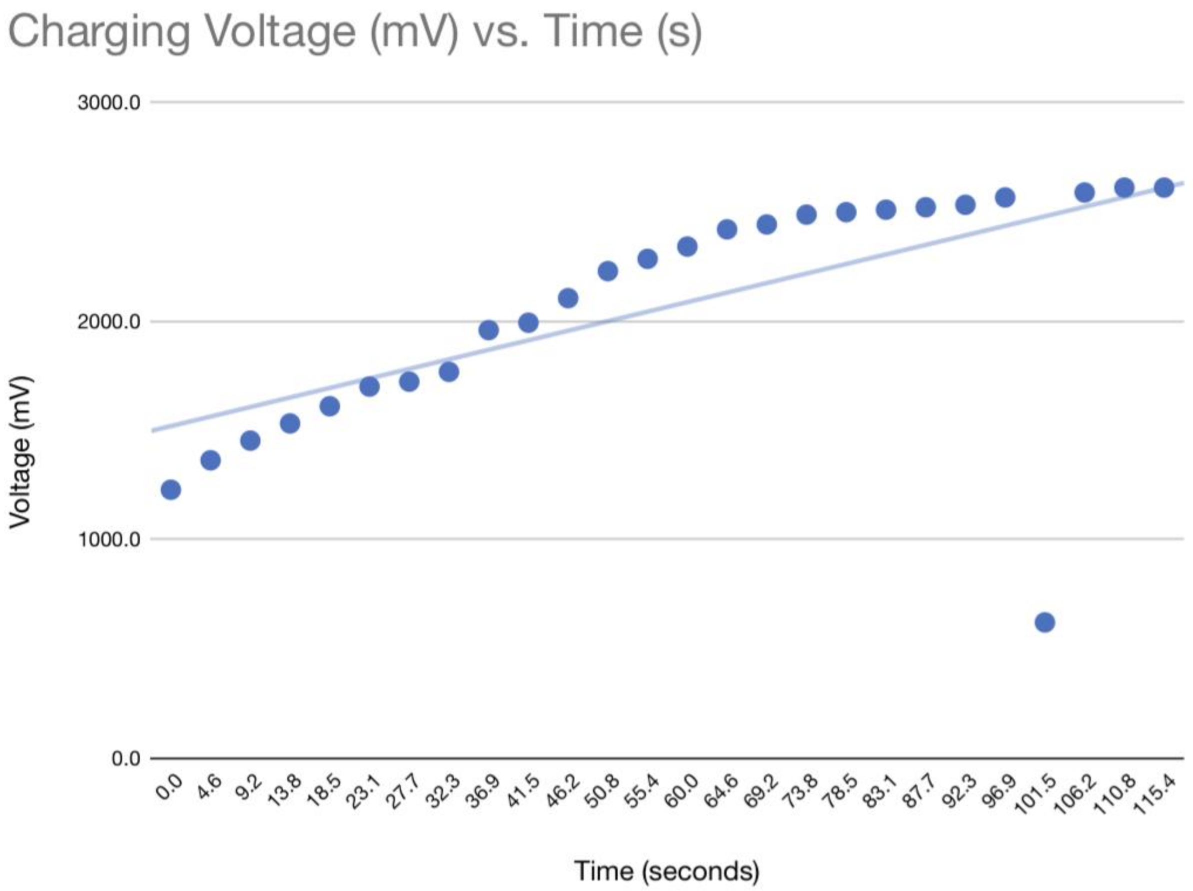


[14]

Patrick Chiu

Actual testing charging time is about 2 min



Charging time and required energy in offline station can be estimated with the following equation and future test data

$$P = I * V$$

$$= I^2 * ESR$$

where

P is the power delivered in SCs

I is the charging current

V is the charging voltage

ESR is the equivalent series resistance

$$E = P * t$$

$$= I * V * t$$

$$= I^2 * ESR * t$$

where

E is the energy delivered to SCs

Patrick Chiu

The heat dissipate in charging capacitor is critical to minimize the charging time and maximize the charging current

$$P = I^2 * (ESR)$$
$$\Delta T = P / G$$

where

P is the power dissipate from the capacitor
I is the continuous current
ESR is the equivalent series resistance
ΔT is the rise of capacitor temperature
G is the heat conductivity in °C/W

Supercapacitors stores energy different than lithium ion battery

$$E = \frac{1}{2}CV^2$$

E = 0.5 * (166.6F) * $(8.1V)^2$
E = 5465.3J

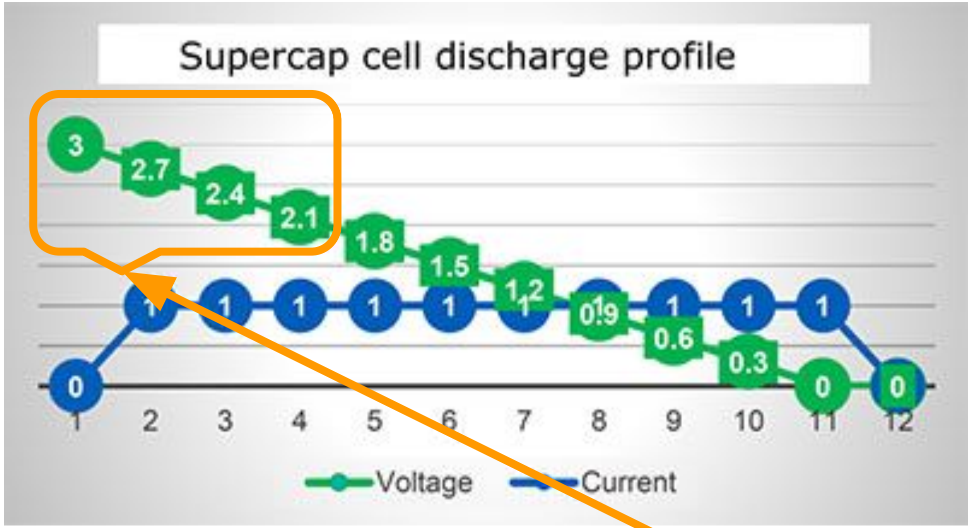
Supercapacitor

$$P = IV$$
$$P = (5000\,mAh) \times (3.7\,V)$$
$$P = 18,500\,mWh \times 3.6\,\frac{J}{mWh}$$
$$E = 66,600\,J$$

Li-ion Battery

Patrick Chiu

Supercapacitors stores less energy than lithium ion battery



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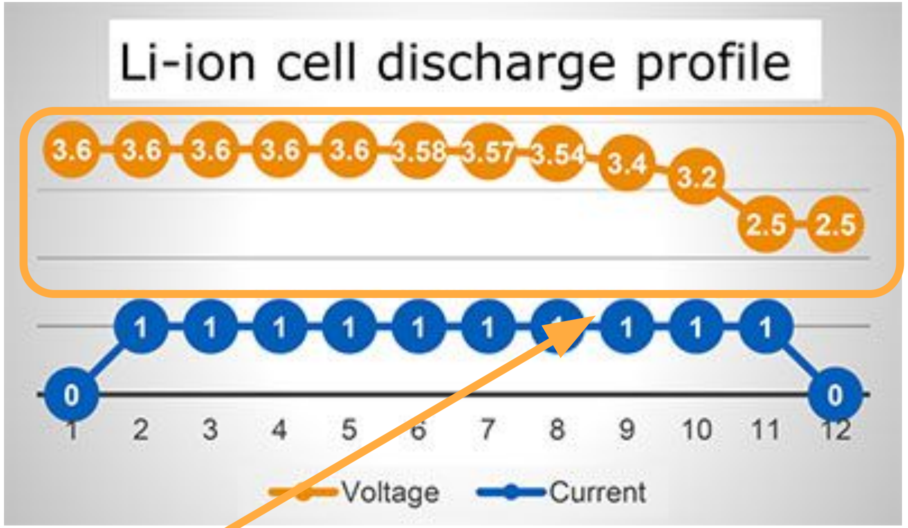
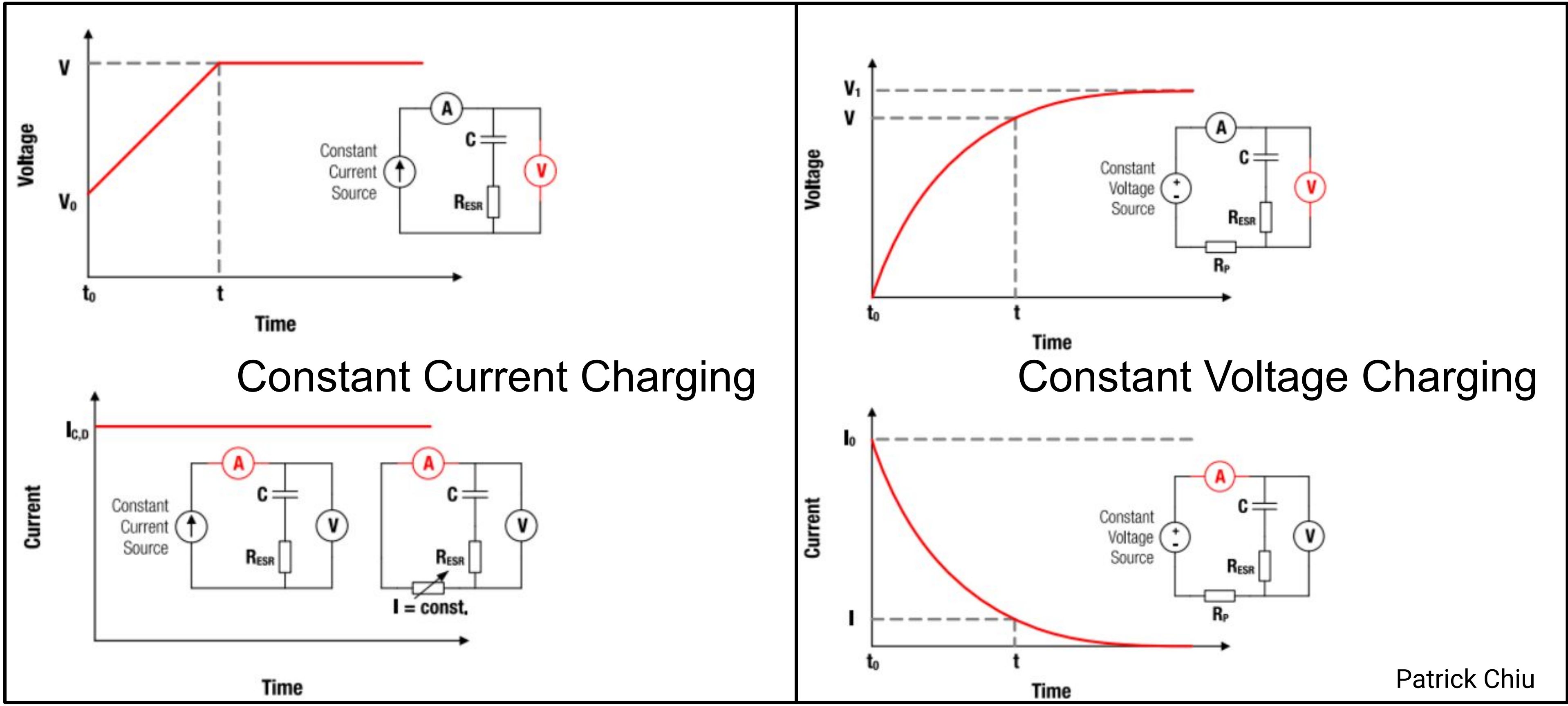


[14]

Available Energy

Patrick Chiu

Constant current charging takes significantly less time



Constant Current Charging

Constant Voltage Charging

Patrick Chiu

Constant charging takes significantly less time

$$t = (V - V_0) \times \frac{C}{I_C}$$

Constant Current Charging

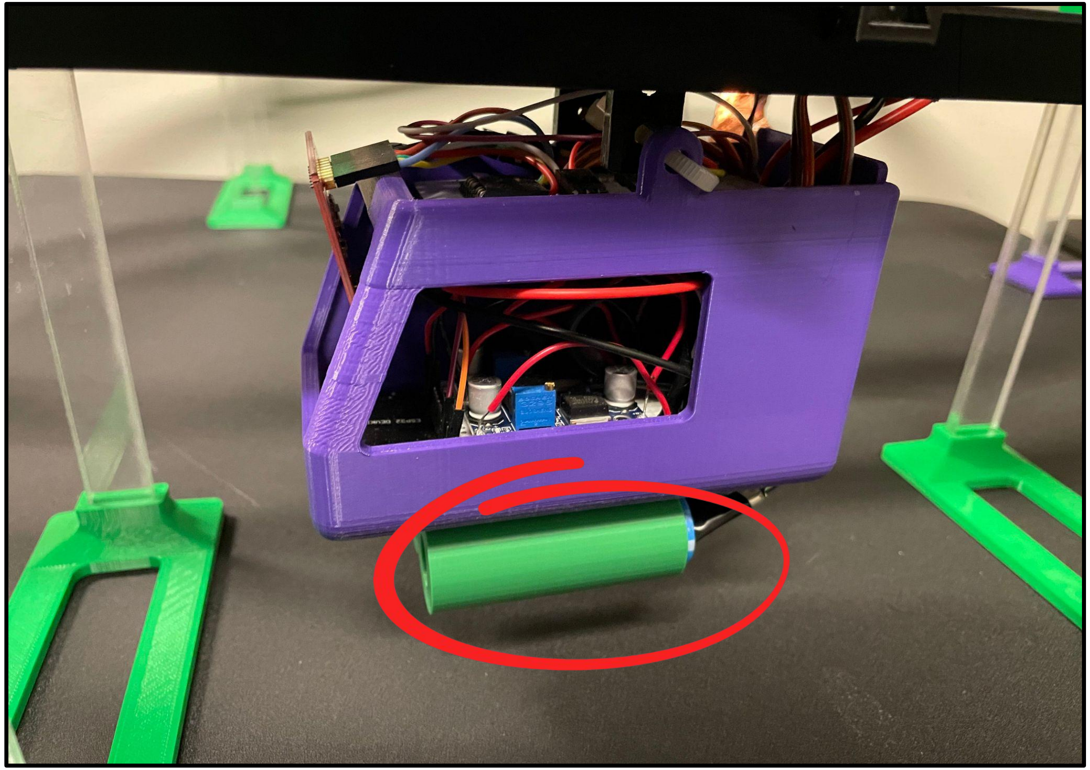
$$t = \ln\left(\frac{V_1}{V_1 - V}\right) \cdot (R_{ESR} + R_P) \cdot C$$

Constant Voltage Charging

where $R_{ESR}+R_P = (V_1/I_{max})$

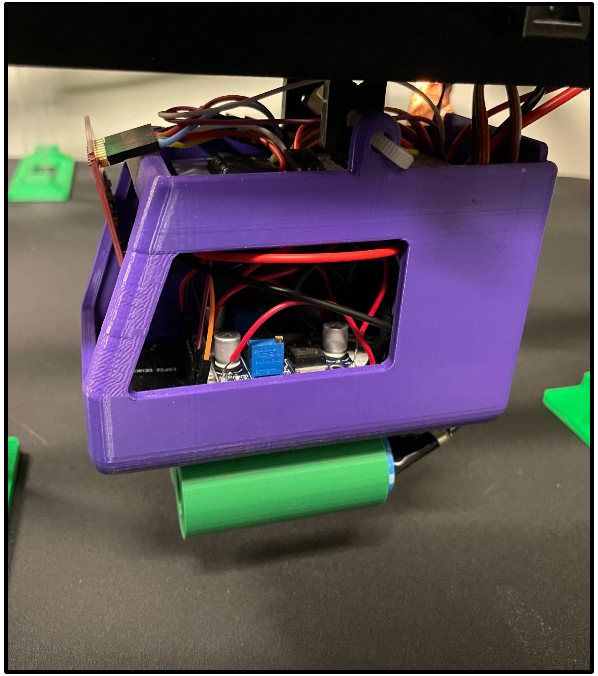
Patrick Chiu

Our energy storage and charging mechanisms relies heavily on supercapacitors



Roman Ortiz

Supercapacitors require less energy from storage units, take up less weight, and have an increased energy density efficiency

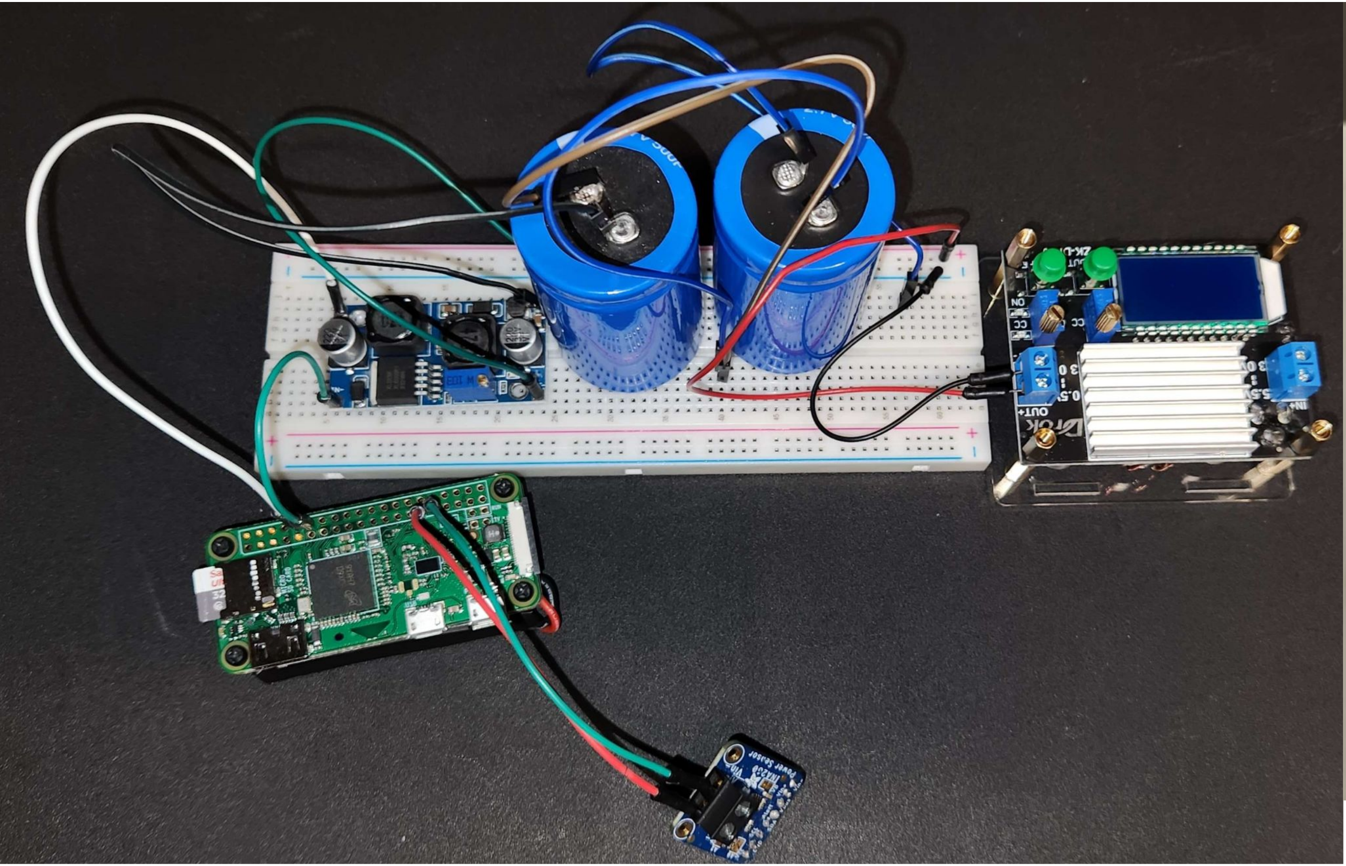


[3]

[10]

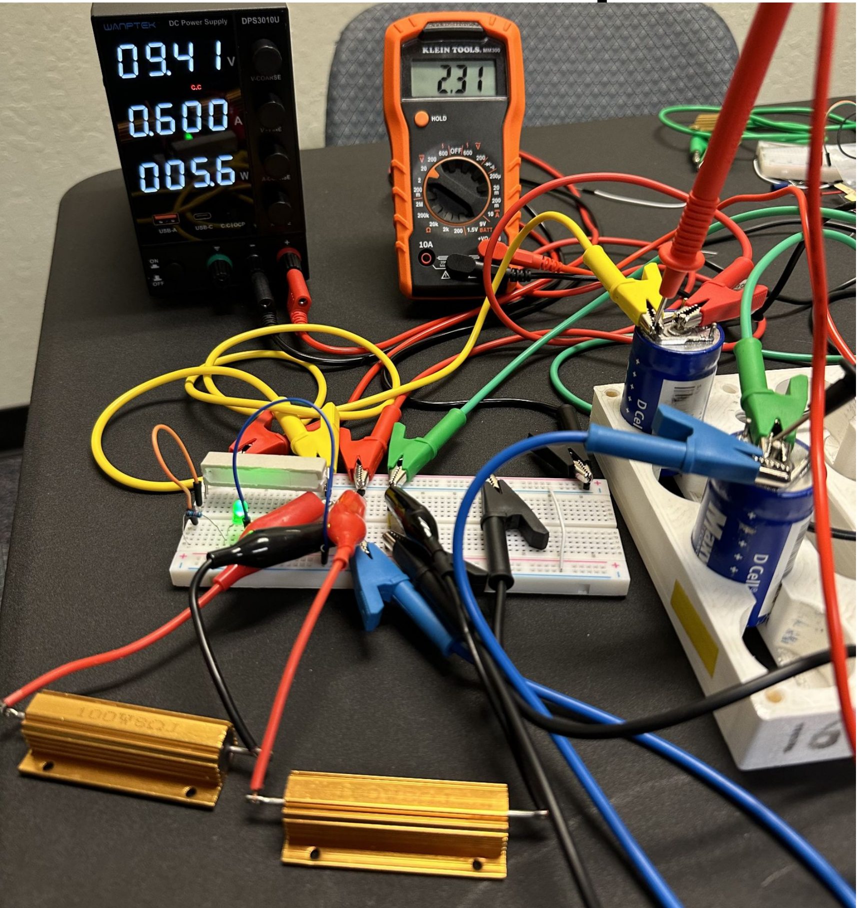
Michael Korens

We encountered a series of problem from our circuit testing and equipment limitation



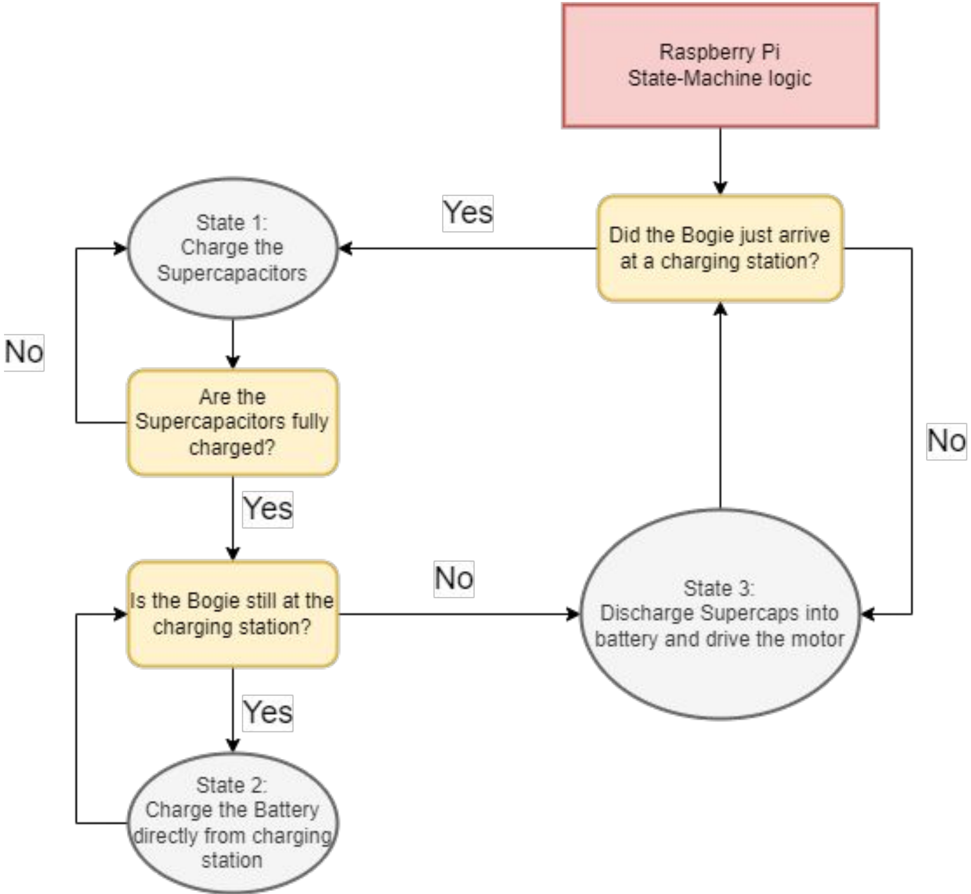
Patrick Chiu

The implementation of the electrical diagram has proven successful based upon our testing after upgrades



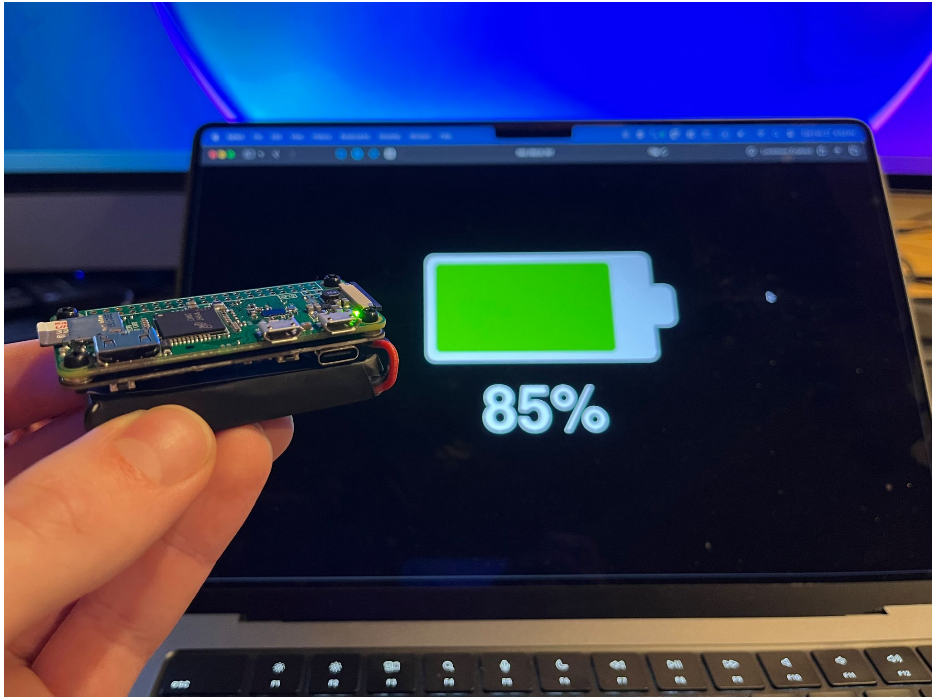
Patrick Chiu

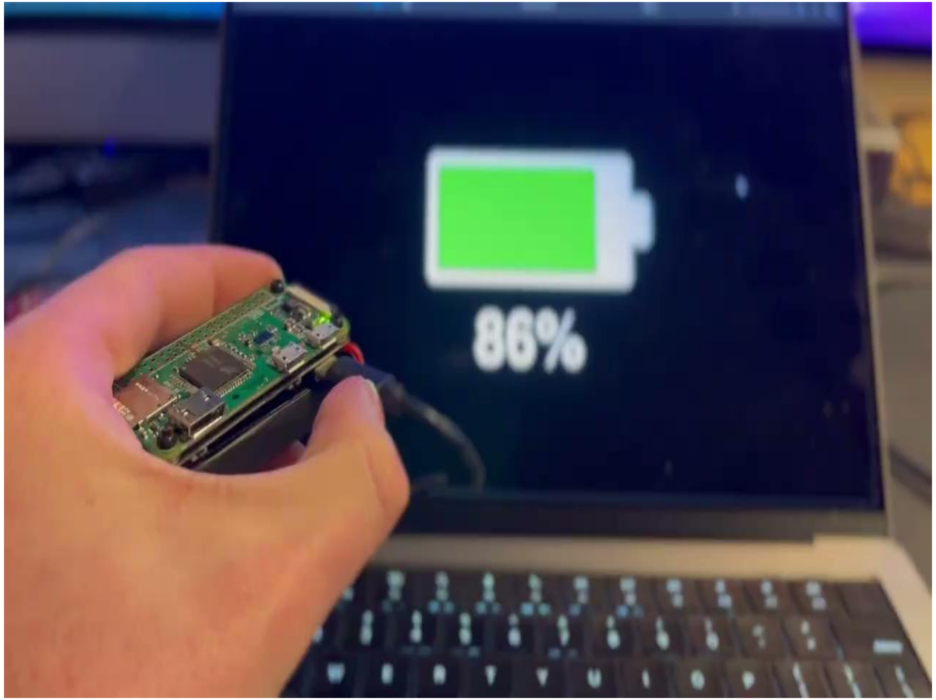
The last major addition that we need is a state-machine system powered by the Pi (to increase energy efficiency)



Michael Korens

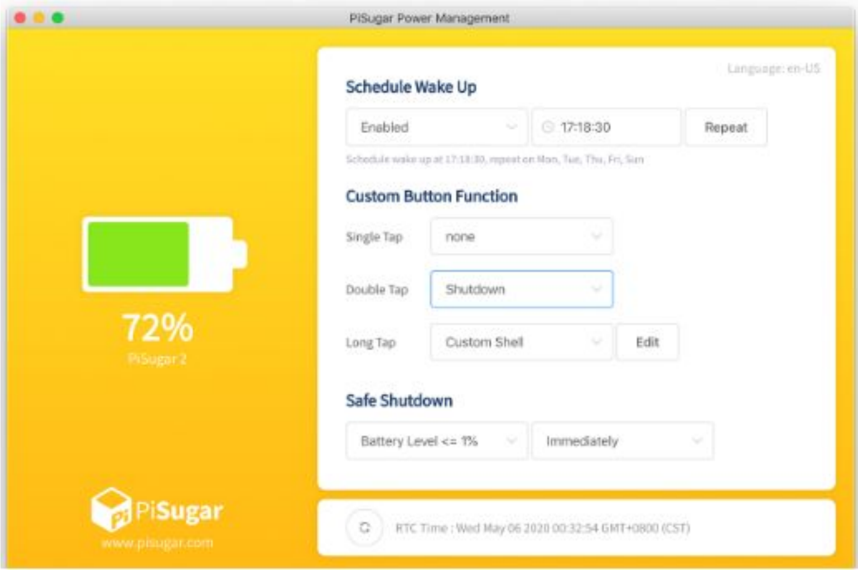
A Pi Zero with Pi Sugar will replace the ESP 32 and act as the charging system controller and monitoring system





Anton Loeb

Pi Zero allows for simplified remote monitoring and code execution



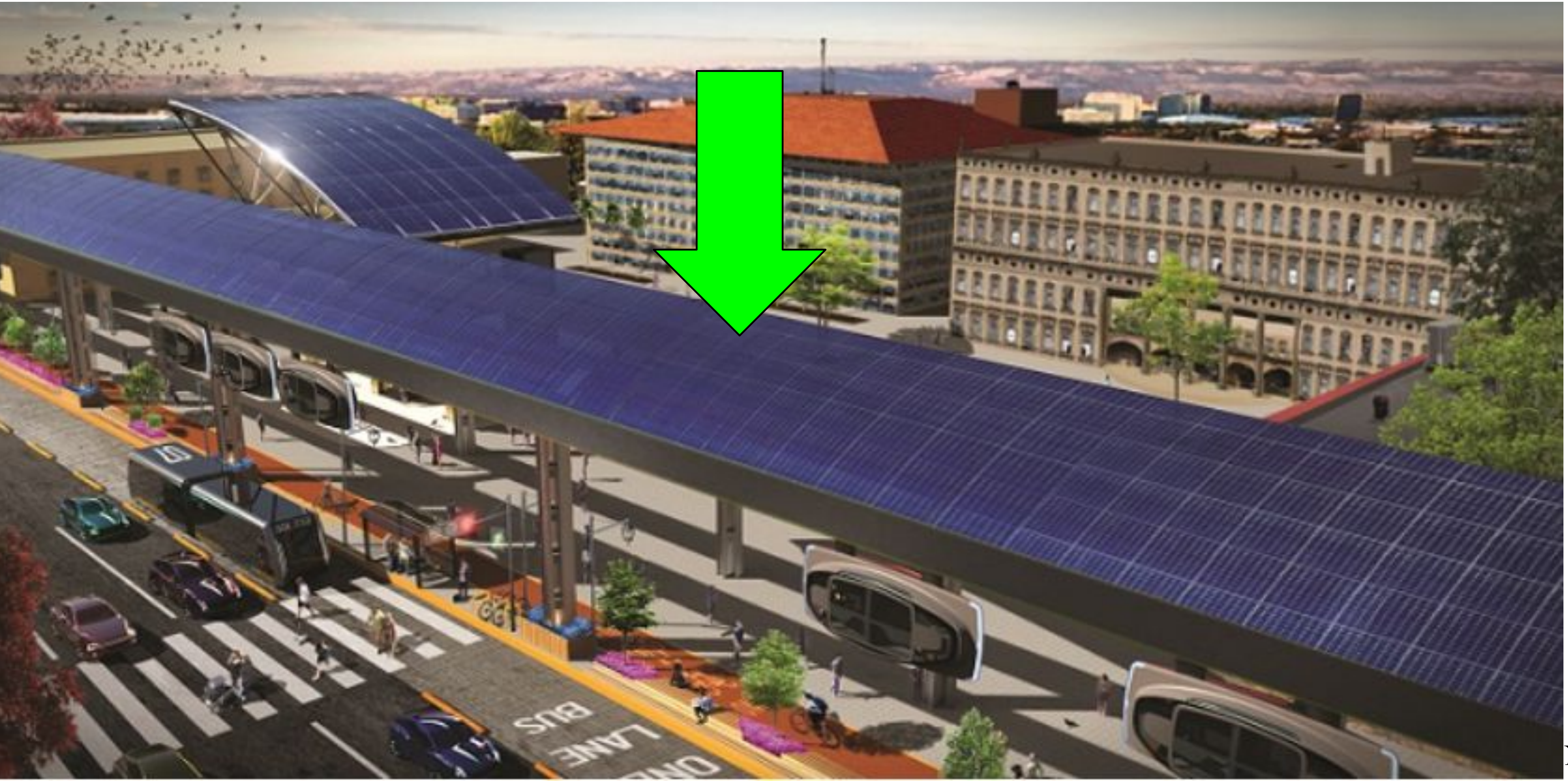
Anton Loeb

The Spartan Superway (SSW) is a solar-powered automated transit network system that reduces GHGs and improves efficiency of transportation for passengers

[9]

Nyalah Payne

A unique feature of the SSW is that it gathers energy from a canopy of solar panels above its guideways which will power the offline stations



[9]

Nyalah Payne

The goal is that the SSW will have vehicles (Bogies) suspended from an elevated network of guideways that can carry 4-6 people

[9]

Nyalah Payne

Stored energy/ charging energy is sufficient to run bogie up to 32 seconds

Stored Energy			
Supercapacitor	Available Energy	0.24 Wh	880 J
PiSugar	Stored Energy	4.4 Wh	15840 J
Lithium Ion Battery	Stored Energy	9.25 Wh	33300 J

Run Time	
Energy/Power=Time	880J / 27W = 32 sec

Patrick Chiu

Constant current charges significantly faster than constant voltage

Capacitance (F)	CC Charging Time (s)	CV Charging Time (s)
500	700	3645
3000	420	2187
5000	438	2278
325	5	24

CC/CV Time Ratio
= 19.2%

Patrick Chiu