OptimumLap for EV

Michal Podhradsky

Portland State University

Viking Motorsports

Motivation

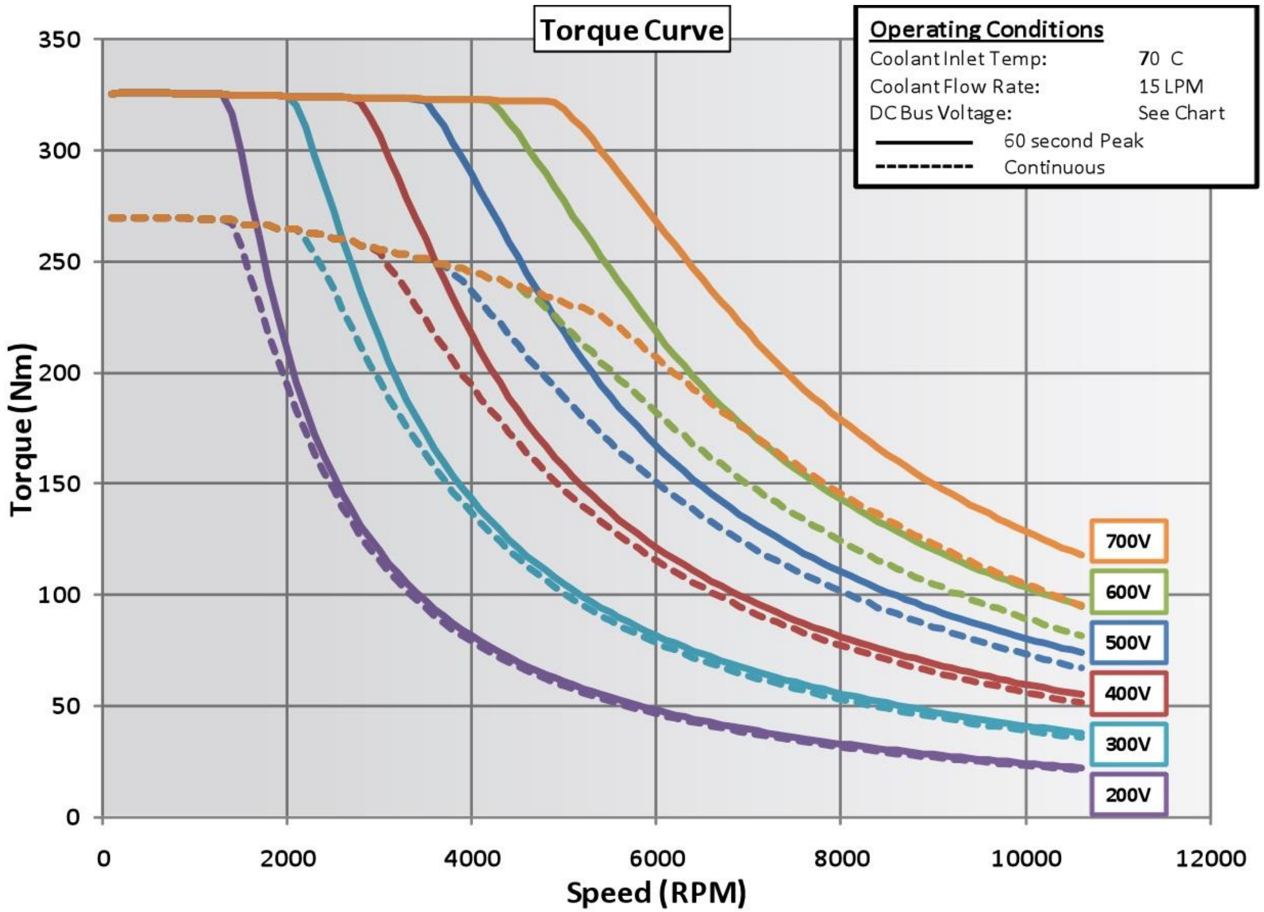
- Optimum Lap simulates behavior of the car on an arbitrary track
- Lot of data, including lap time, motor power at any given time, car speed, motor RPM, acceleration etc…
- Data can be exported as csv file
- For more details look at:
  - *OptimumLap for dummies (and EEs)*
  - *EV handbook*
- All project files are available at https://github.com/podhrmic/OptimumLap-VMS

Please feel free to try it yourself!

CURRENT CAR MODEL (EV)

Current car: Remy motor & 4 battery modules (200V)

- Remy motor has this torque characteristics:



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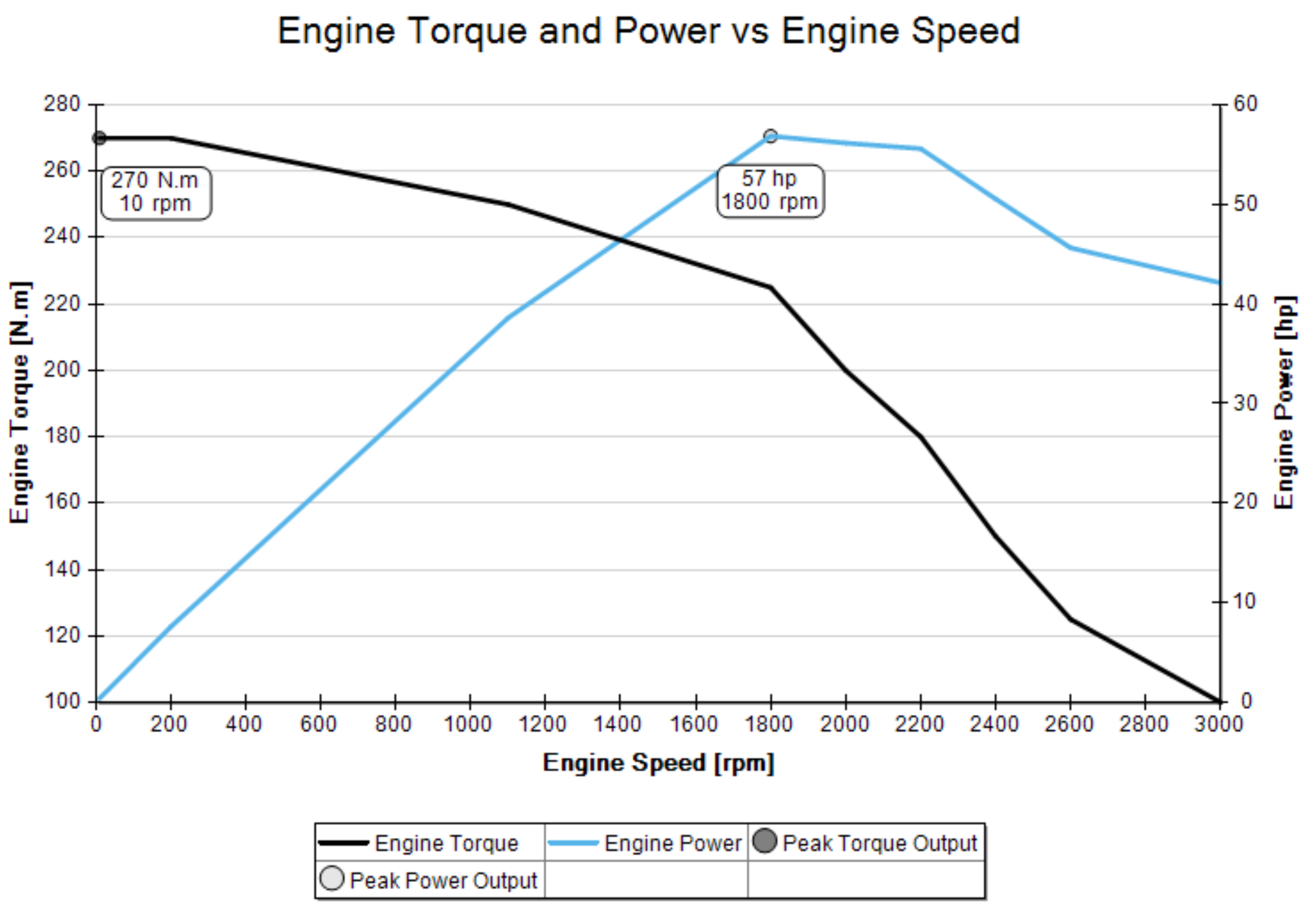
Current car: Remy motor & 4 battery modules (200V)

- In OptimumLap:



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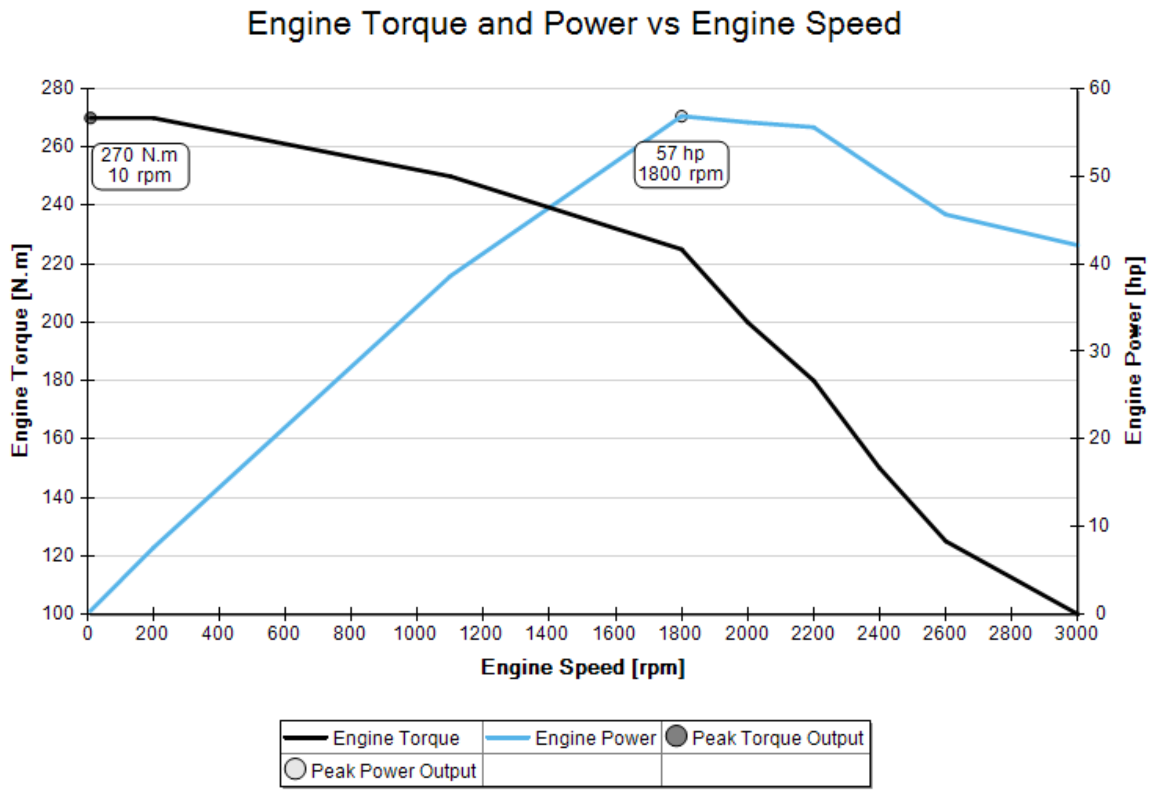
Current car: Remy motor & 4 battery modules (200V)

- Note that Nominal voltage is actually 177V, so the actual torque will be lower than in the datasheet, but we can ignore that for now
- We also know that the max RPM we can get with our controller is about 2500 RPM, so we input only relevant data points (up to 3000 RPM)
- A quick sanity check - the power profile of the motor should match the power profile from the datasheet



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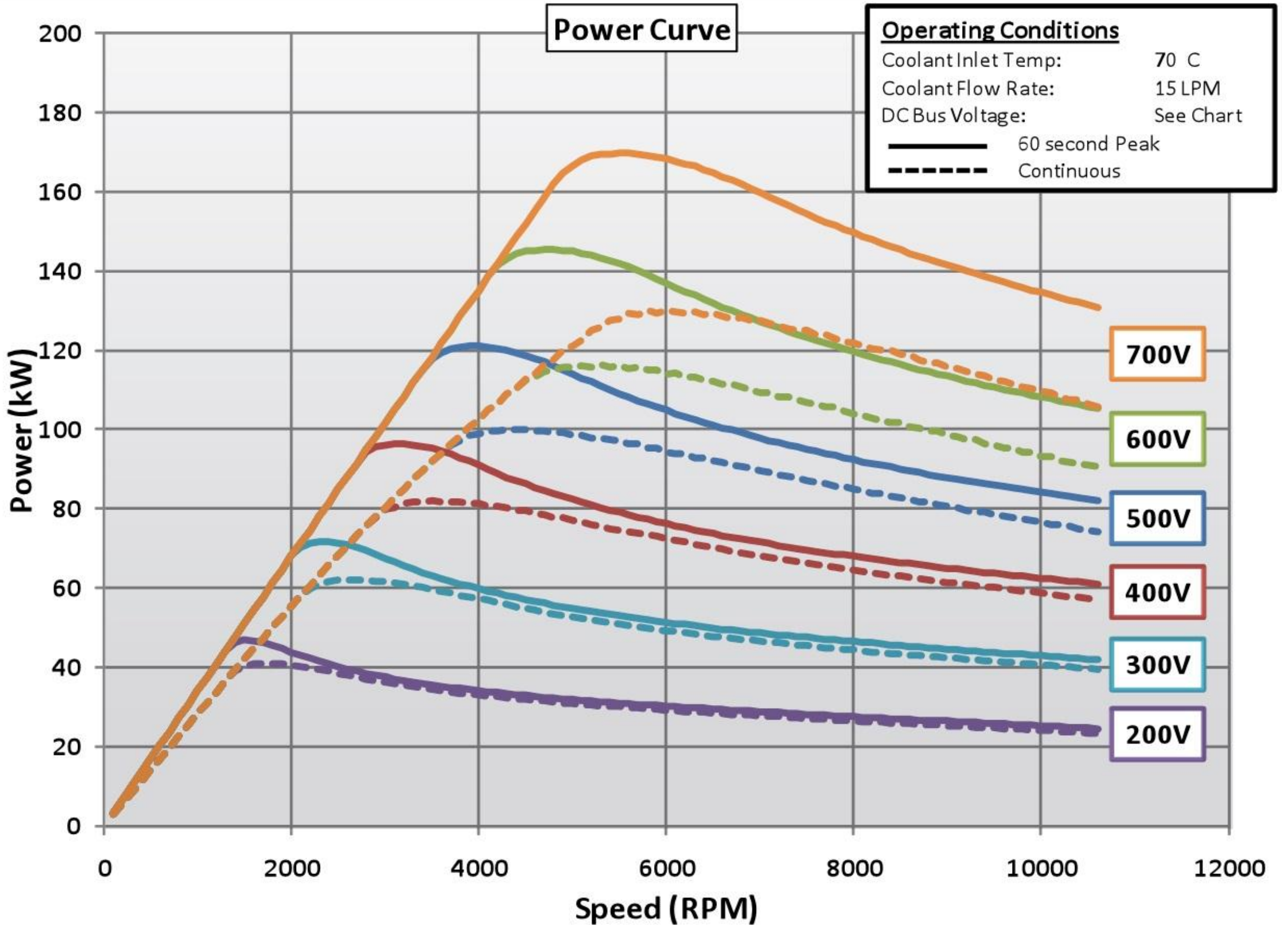
Current car: Remy motor & 4 battery modules (200V)

- And it does (again look at 200V curve), 40kw is ~53hp



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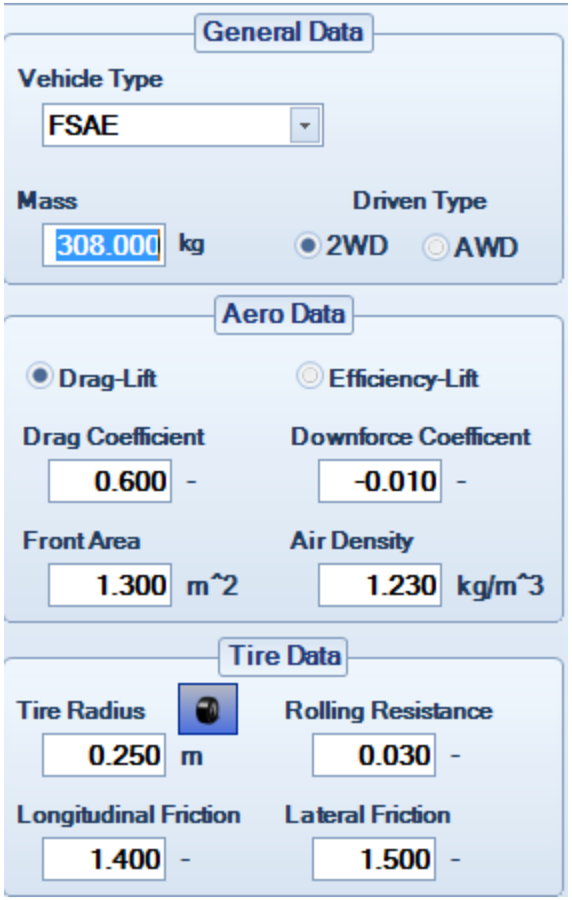
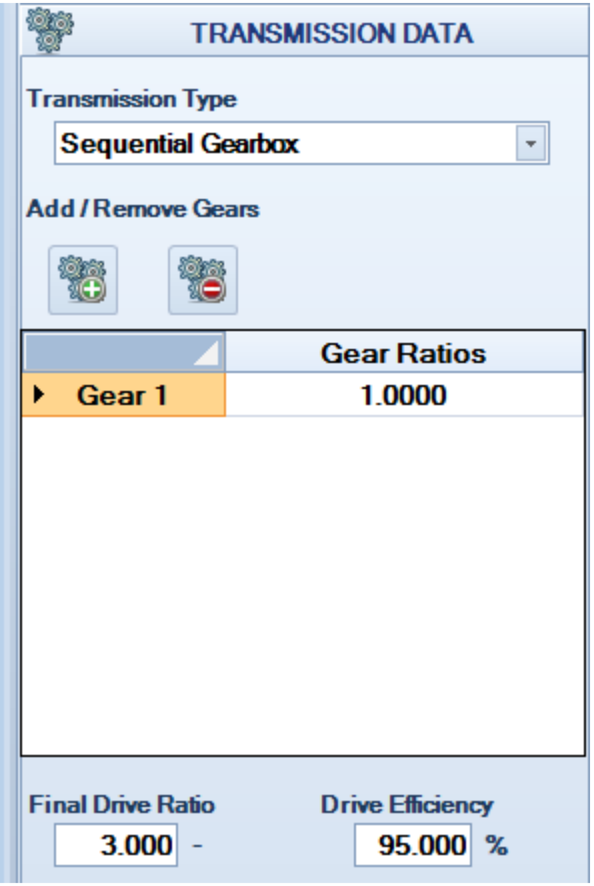
Current car: Remy motor & 4 battery modules (200V)

- Car weight: 308 kg (measured)
- Aero and tire data taken from default *FSAE No Aero* model from http://share.optimumg.com/vehicles/?page=2
- Thermal efficiency 97% (default)



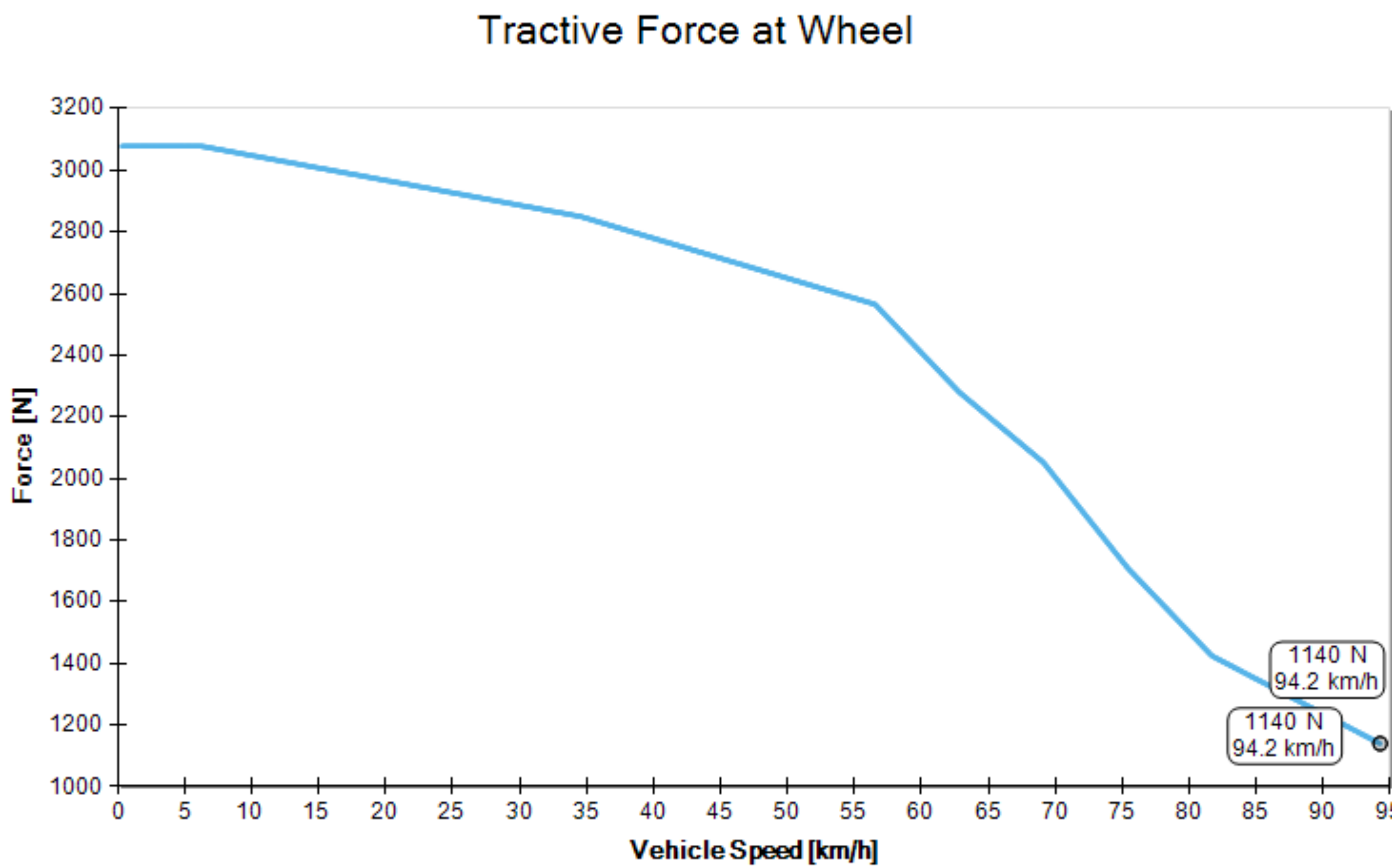
Current car: Remy motor & 4 battery modules (200V)

- Only one gear, ratio 1
- Final drive ratio: 1:3
  - gives max speed of 95kmh
- Drive efficiency 95% (default)



Current car: Remy motor & 4 battery modules (200V)

- Looks reasonable, lower at higher speed



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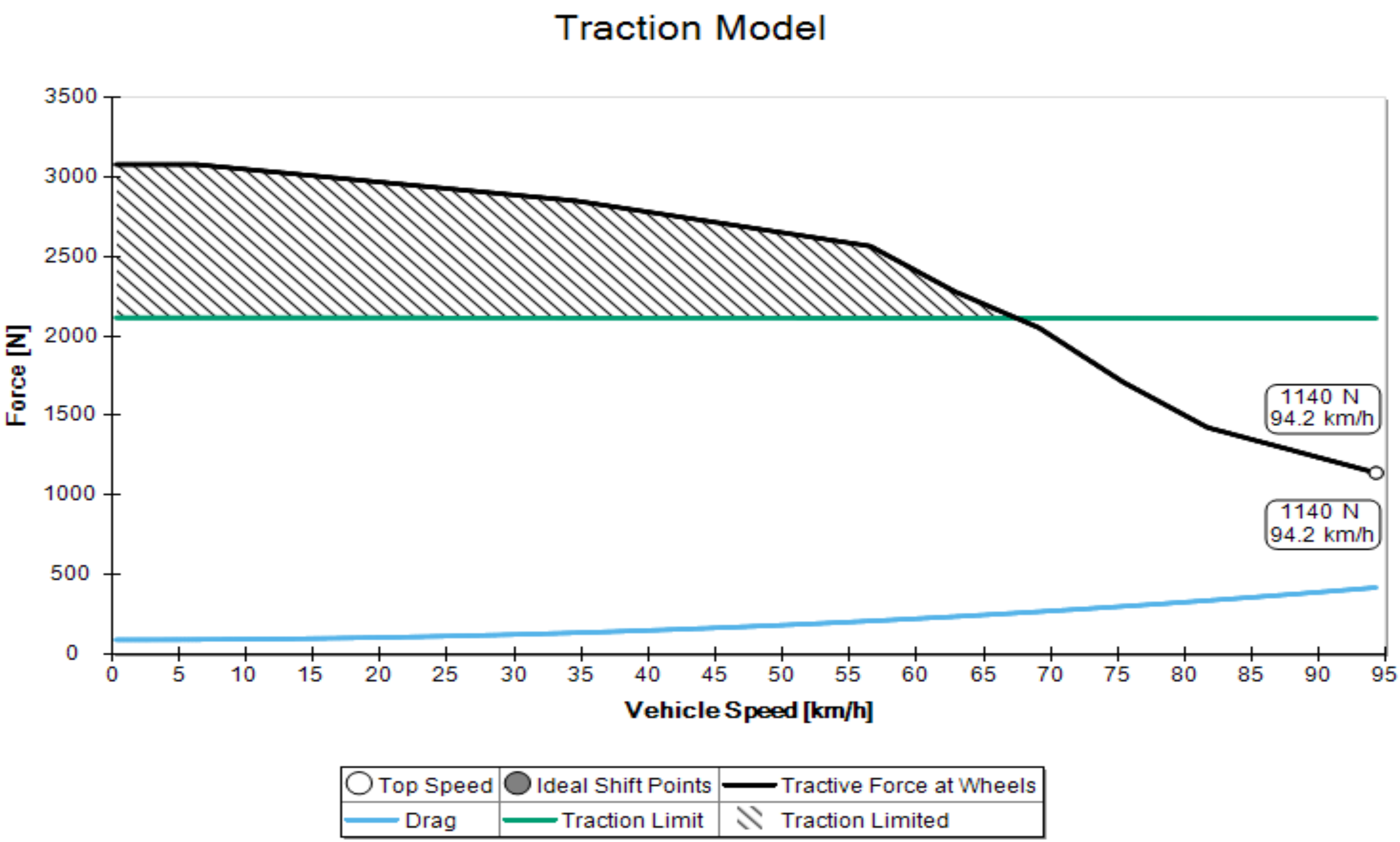
Current car: Remy motor & 4 battery modules (200V)

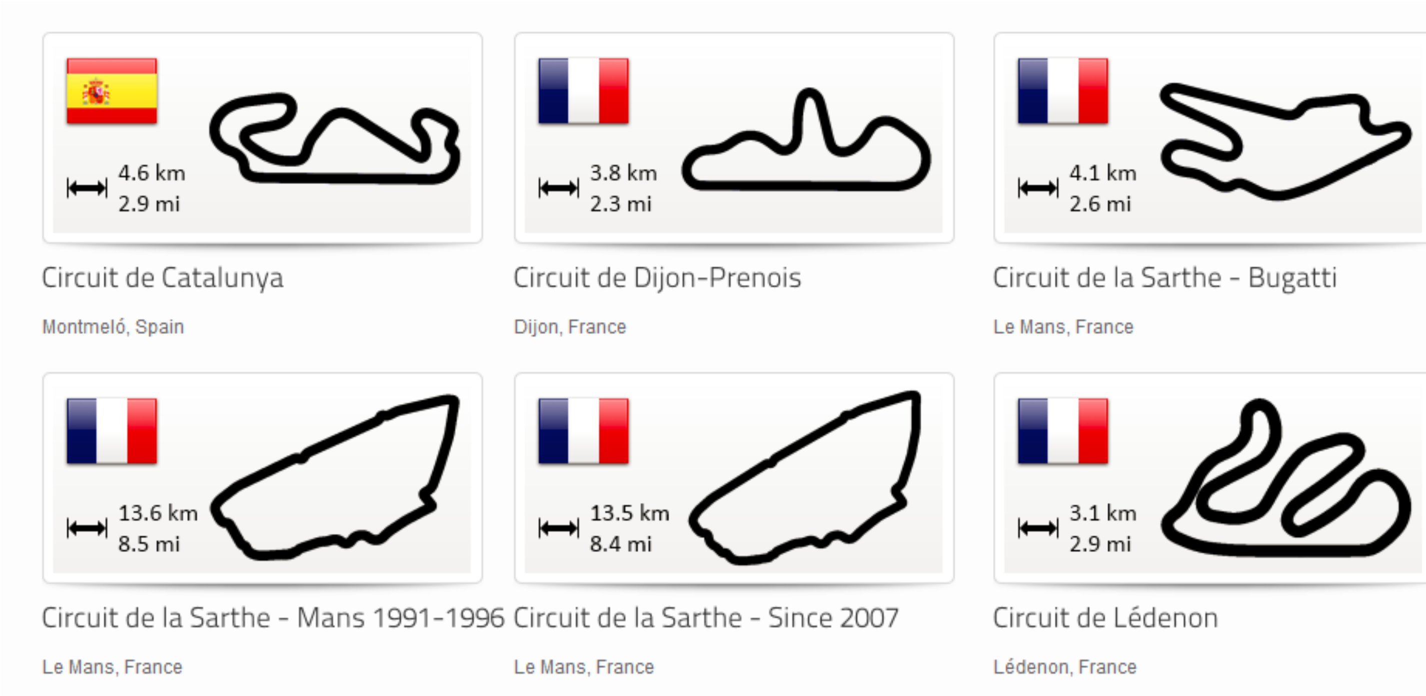
- Somehow reasonable too



Current car: Questions

- Are the values all somewhat reasonable?
- Max speed?
- Acceleration?
- Tractive force?
- Air drag and roll coefficients?

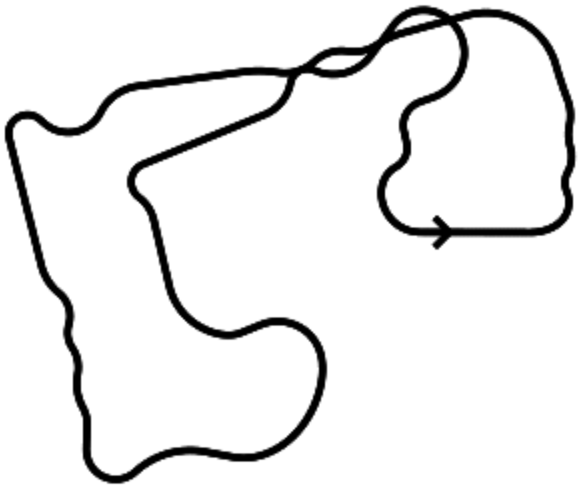
If so, lets go a step further.


4.6 km
2.9 mi
Circuit de Catalunya
Montmeló, Spain
3.8 km
2.3 mi
Circuit de Dijon-Prenois
Dijon, France
4.1 km
2.6 mi
Circuit de la Sarthe - Bugatti
Le Mans, France
13.6 km
8.5 mi
Circuit de la Sarthe - Mans 1991-1996
Le Mans, France
13.5 km
8.4 mi
Circuit de la Sarthe - Since 2007
Le Mans, France
3.1 km
2.9 mi
Circuit de Lédenon
Lédenon, France

TRACKS

Track: FSAE Endurance, Lincoln, Nebraska 2012

- We are most concerned about endurance for EV



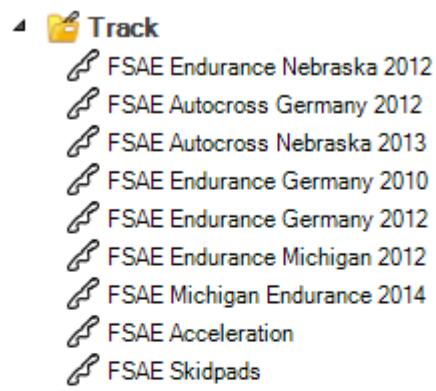
Track: FSAE Endurance, Lincoln, Nebraska 2012

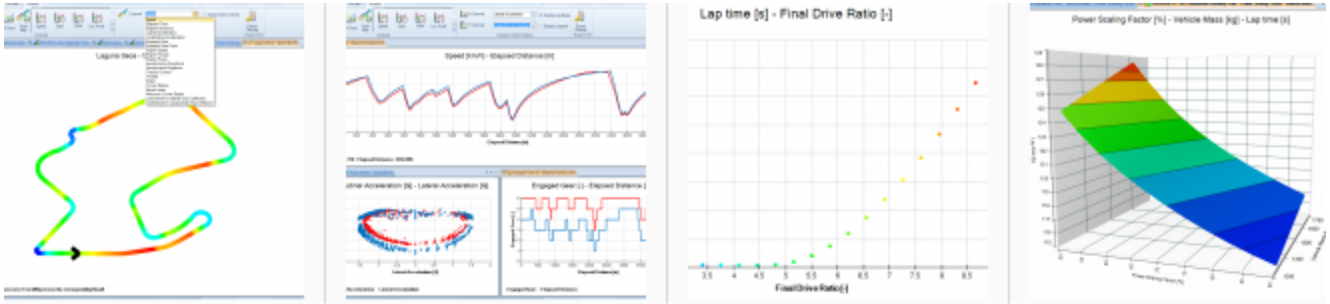
- Track report:

	Statistic	Value
	Total Track Length	1169.8 m
	Percent Left Corners	42.36 %
	Percent Right Corners	28.01 %
	Percent Straights	29.63 %
	Average Corner Radius	24.43 m
	Minimum Corner Radius	8.1 m
	Longest Straight	61.6 m

Track: FSAE Endurance, Lincoln, Nebraska 2012

- Endurance is ~22 km total, so around 18 rounds of the current track
- Also available acceleration, skidpads and autocross tracks





SIMULATION

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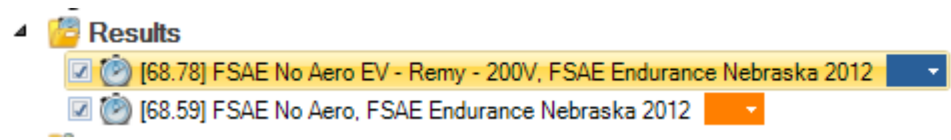
Simulation

- Simulated lap for current EV and for default FSAE No Aero model (for comparison)
- The lap times are very similar:
  - (difference 0.2 s)



- EV with Remy motor produces more torque, but IC car has more hp
- EV has lower RPM than IC (2000 RPM vs 11000 RPM)
- The speed of both cars is quite similar, hence very similar time

Lets look at the results.

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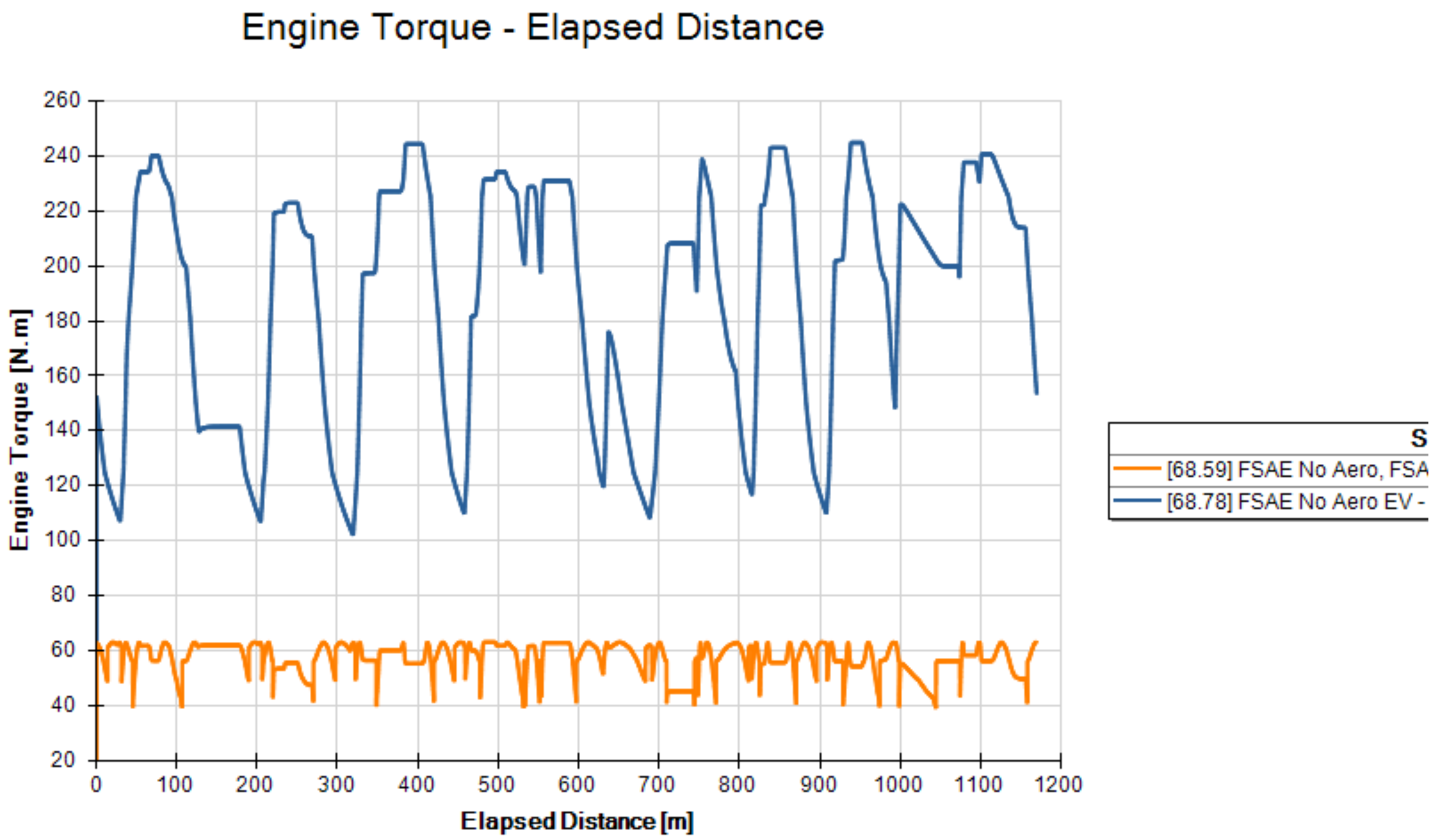
Simulation: Engine Torque



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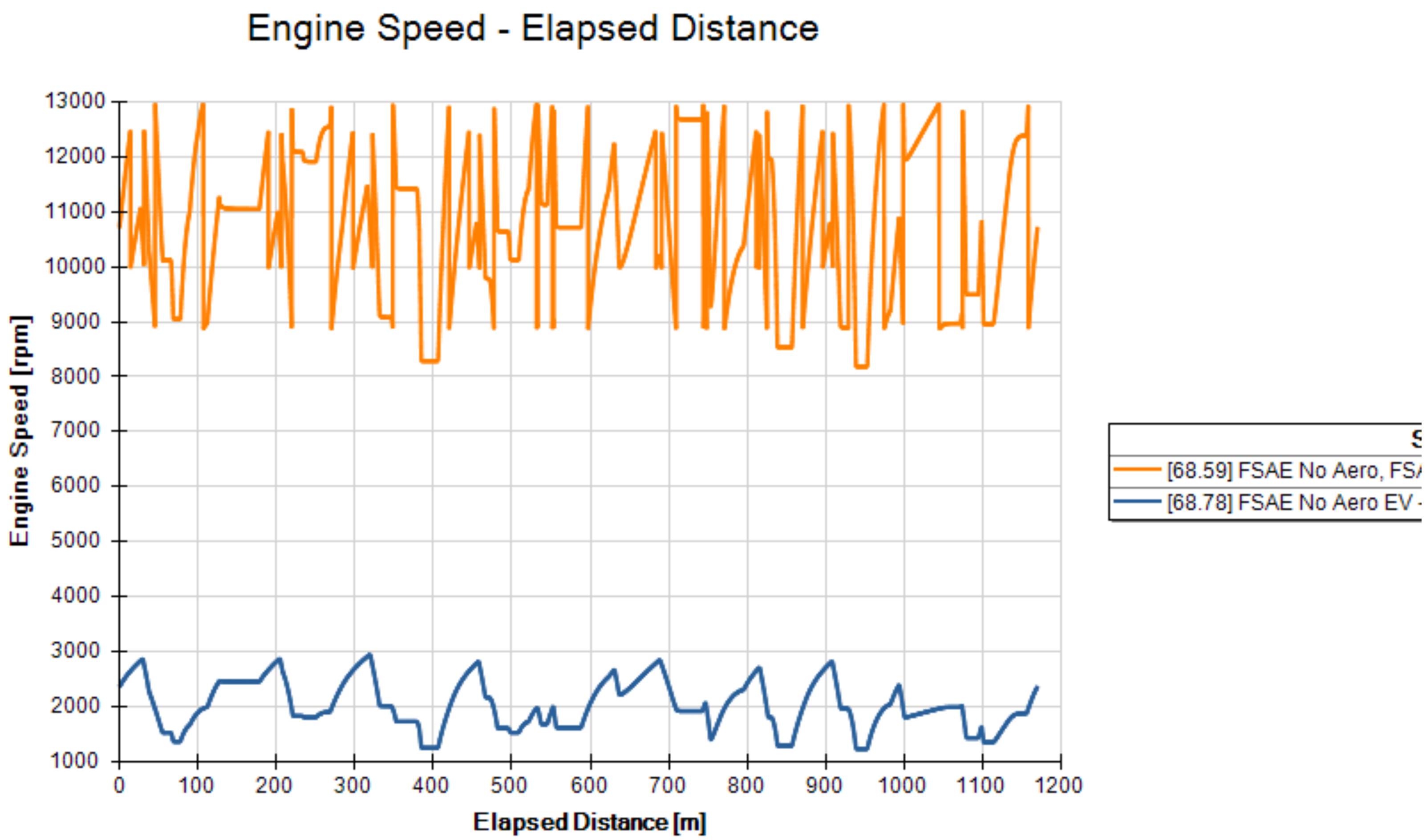
Simulation: Engine RPM



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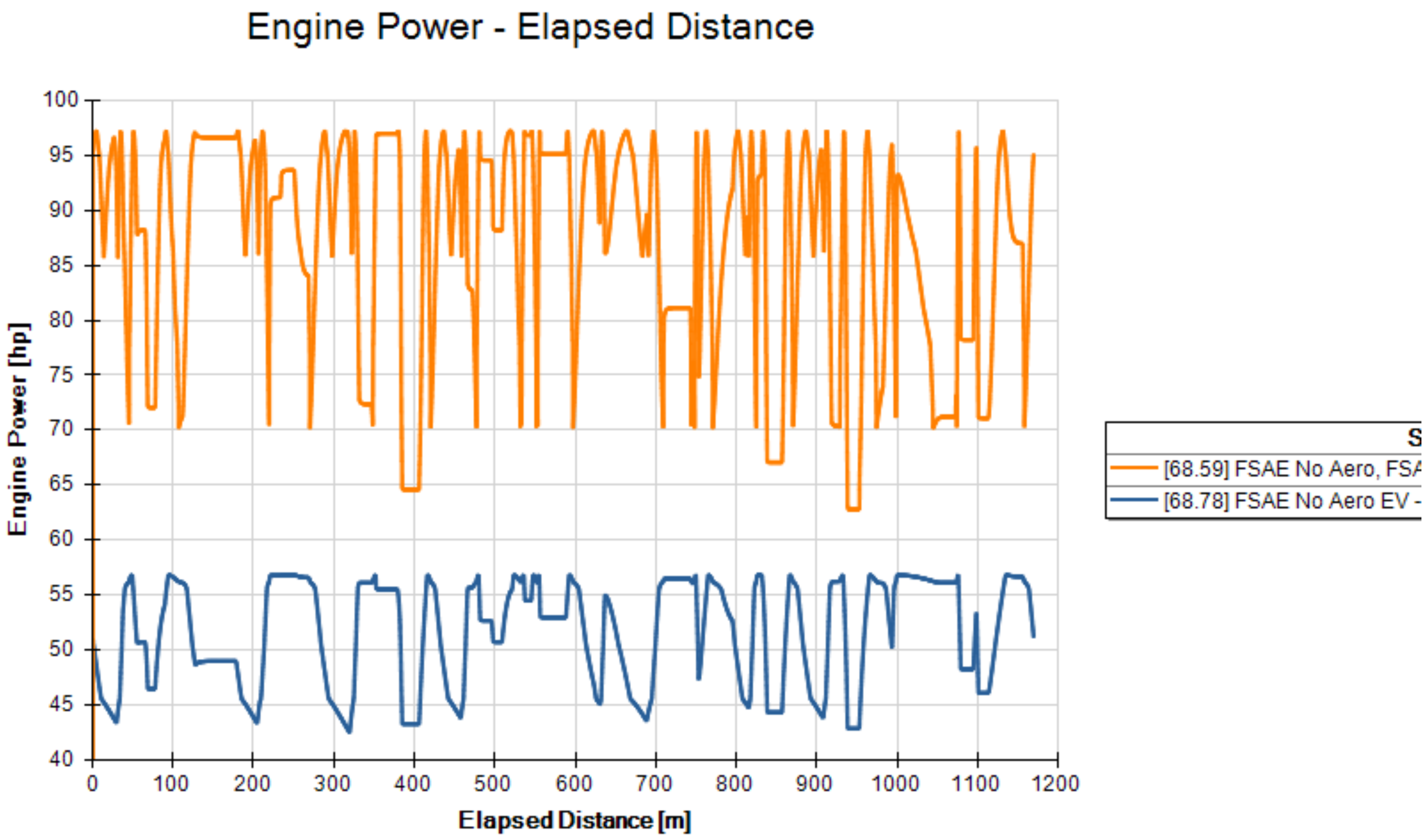
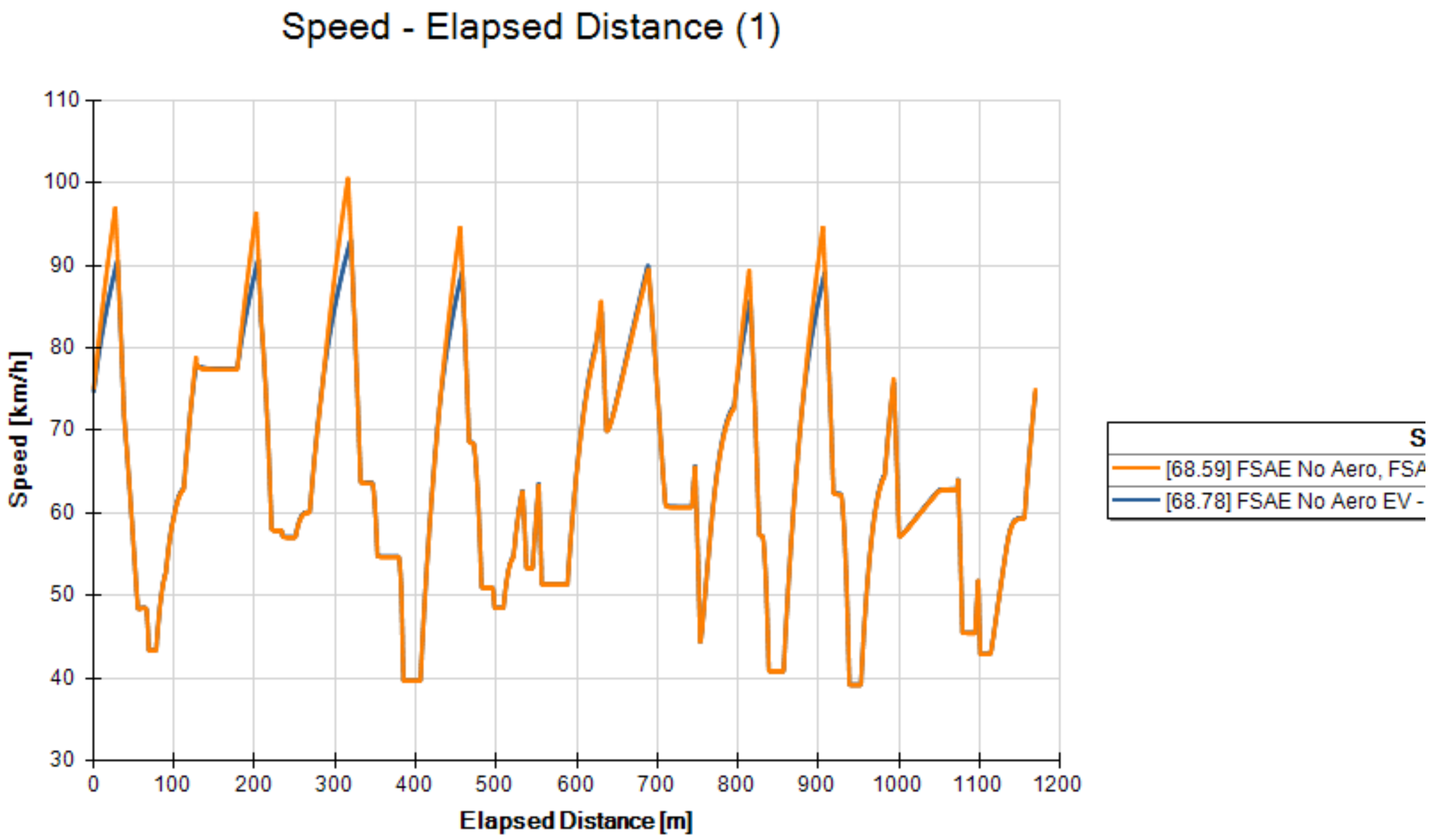
Simulation: Engine Power



Simulation: Car speed



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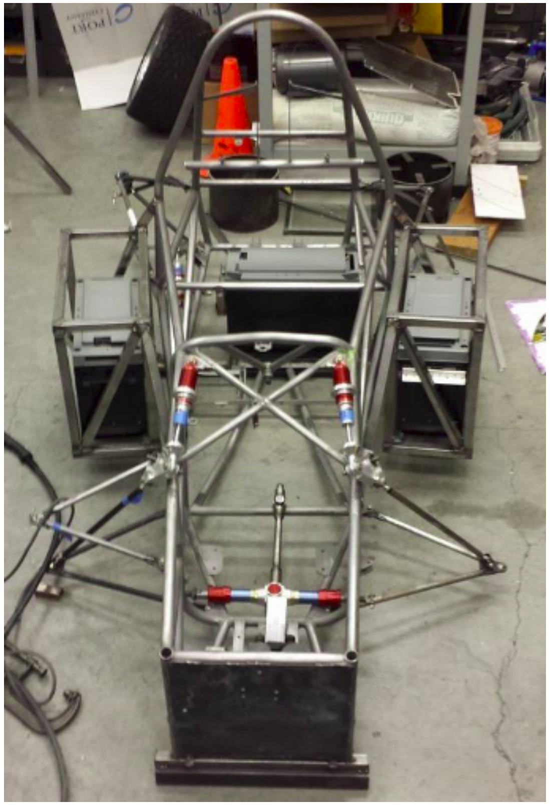
Simulation Results

- So even though EV is heavier and has less powerful motor, it can keep up with the IC car pretty well - so we can expect similar lap time
- That is because EV motor produces more torque, and has very hard gear ratio (lot of torque on drivetrain)

What about the current consumption and battery capacity?



ANALYSIS

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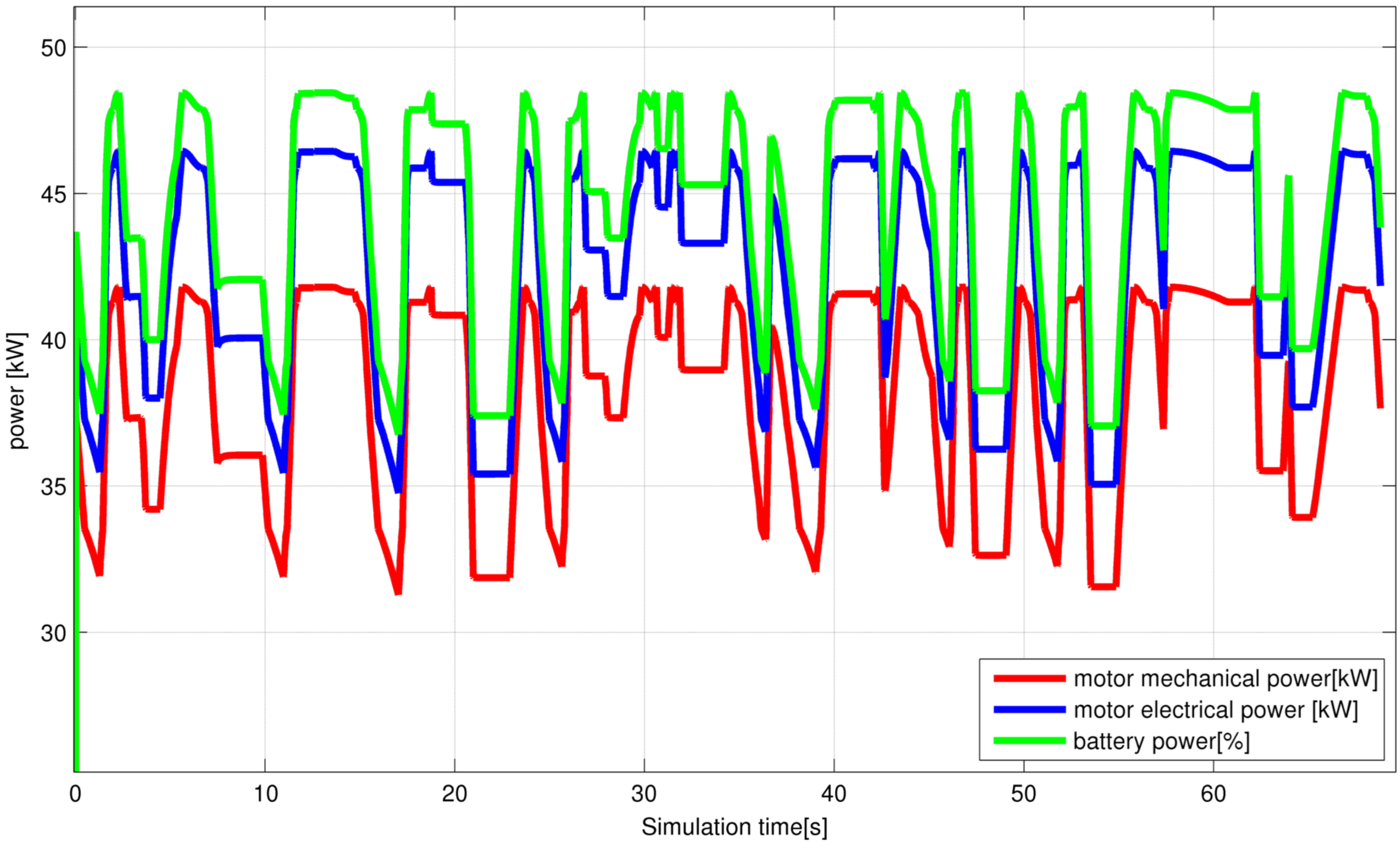
Analysis

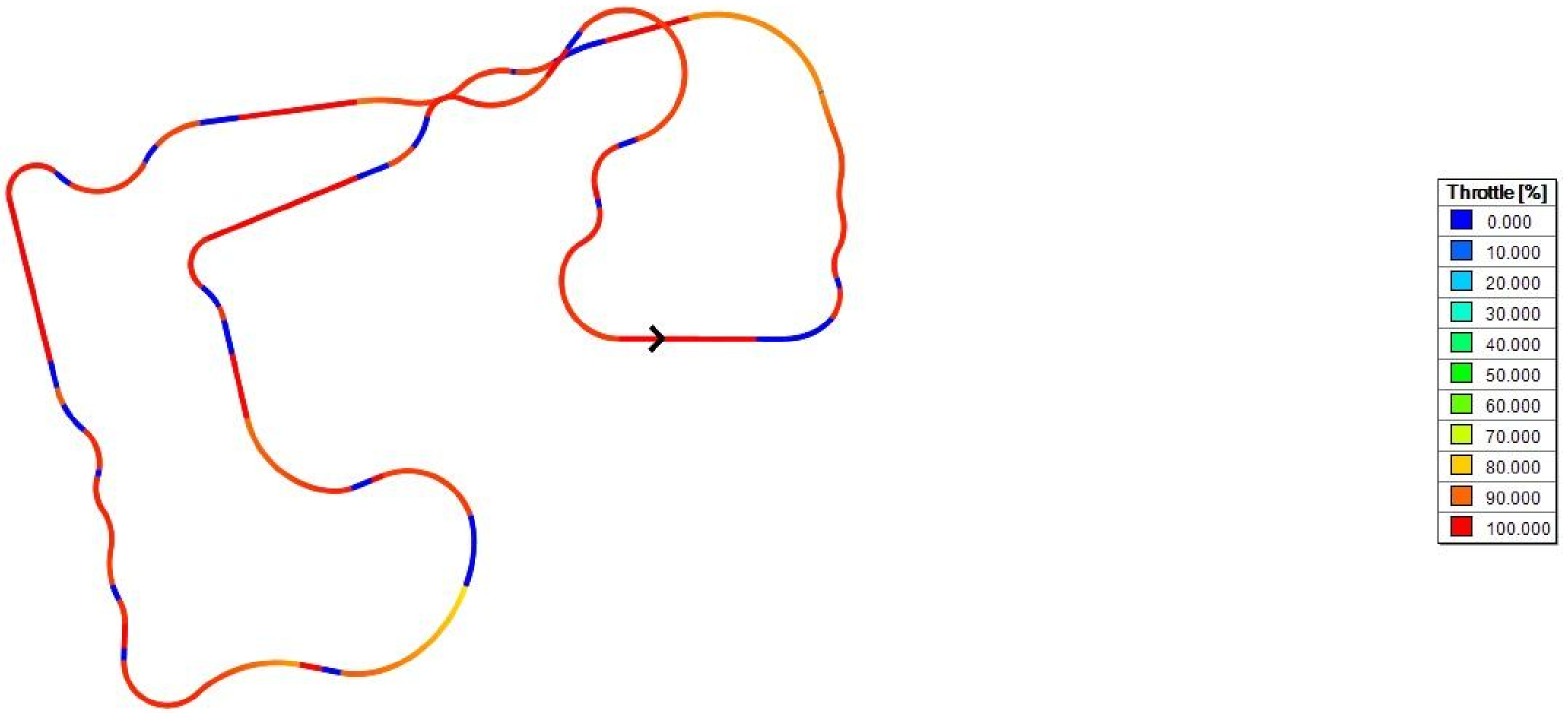
- We know the produced mechanical motor power at any given point (*Pme*)
- Electrical motor power is: *Pe = Pme / motor_efficiency [kW]*
- Motor efficiency greatly varies (from 74% to 97%) and depends on RPM and produced torque. But for now we can assume it to be 90%
- The battery power is: *Pb = Pe/inverter_efficiency [kW]*
- Inverter efficiency also varies a bit, so for simplicity we can assume constant losses of 2kw. The equation then will be *Pb = Pe + 2 [kW]*
- We know the system voltage (it depends on state of charge and in this case varies from 120 to 200V), we use the nominal system voltage of 177V (12 cells x 4 battery packs x 3.7 V nominal voltage)
- Knowing the voltage, we know the current: *Ibat = Pb/Vdc [A]*
- Integrating the current we get the charge needed to finish one lap

Analysis: Power output



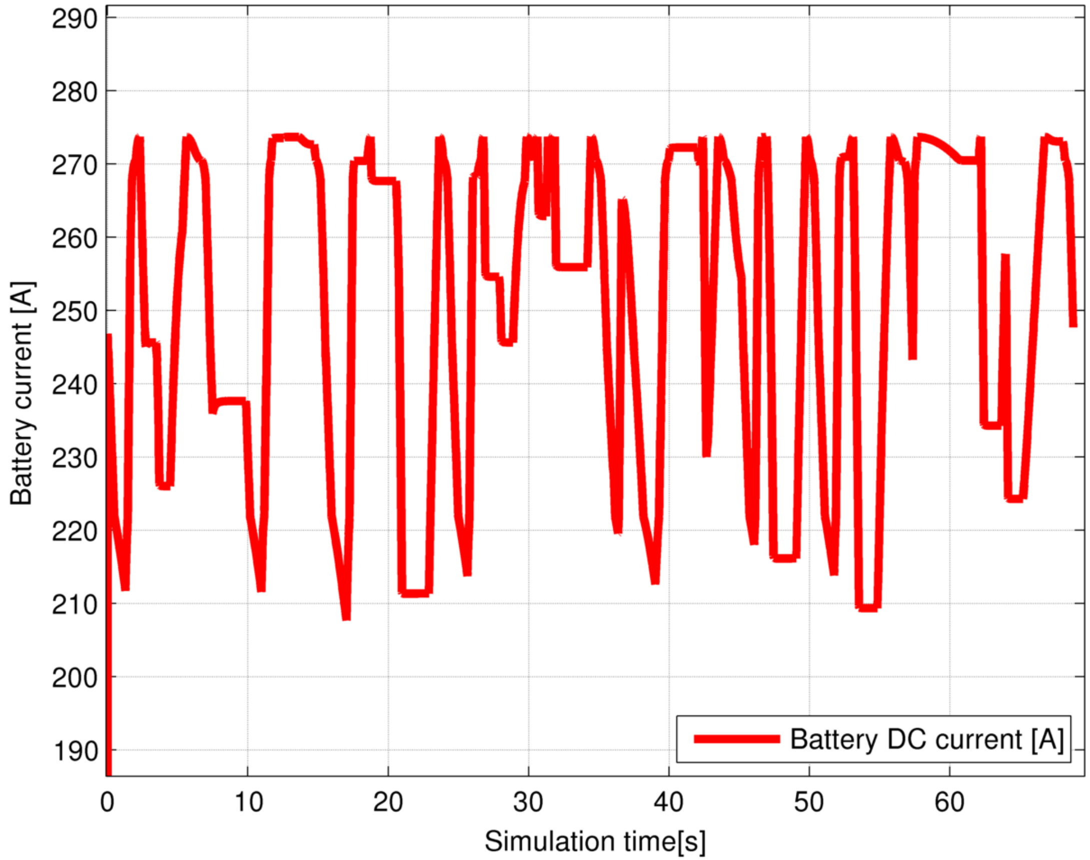
Analysis: a side note

- Note that EV doesn't consume power if the motor is free-spinning (i.e. not producing torque), like during braking or regen
- From the track simulation, we use throttle either at 100% or 0% (brake)
- So we integrate current only when throttle > 10% (to get more precise estimation)



Analysis: current consumption

- The integration is done in MATLAB and described in *OptimumLap for Dummies (and EEs)*
- Here is the final plot of DC battery current



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Analysis: endurance

- The current peaks up to **275[A]** (that is OK and within the limit batteries can provide)
- Average current consumption is around **210[A]**
- We have **32[Ah]** in the battery packs, so it means if we discharge it at **250 [A]**, the battery will last for **32/210*60 = 9.1 minutes** (roughly 8 laps)

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SUMMARY

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Summary

- If we want to keep up pace with conventional IC car (no aero, not optimized), we have to discharge batteries at high rate
- In that case, endurance will be a problem because we don’t have enough “juice”
- Lighter car seems to be beneficial, because less power is needed for acceleration

NEXT STEPS

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Next steps

1. Simulate different combination of motors and batteries (the models are already there) and see what lap time we can get
2. Calculate endurance with less powerful motors and see the difference
3. Tamper max produced torque, so the consumption is lower and see how does it compromise the performance

Comments are welcome!