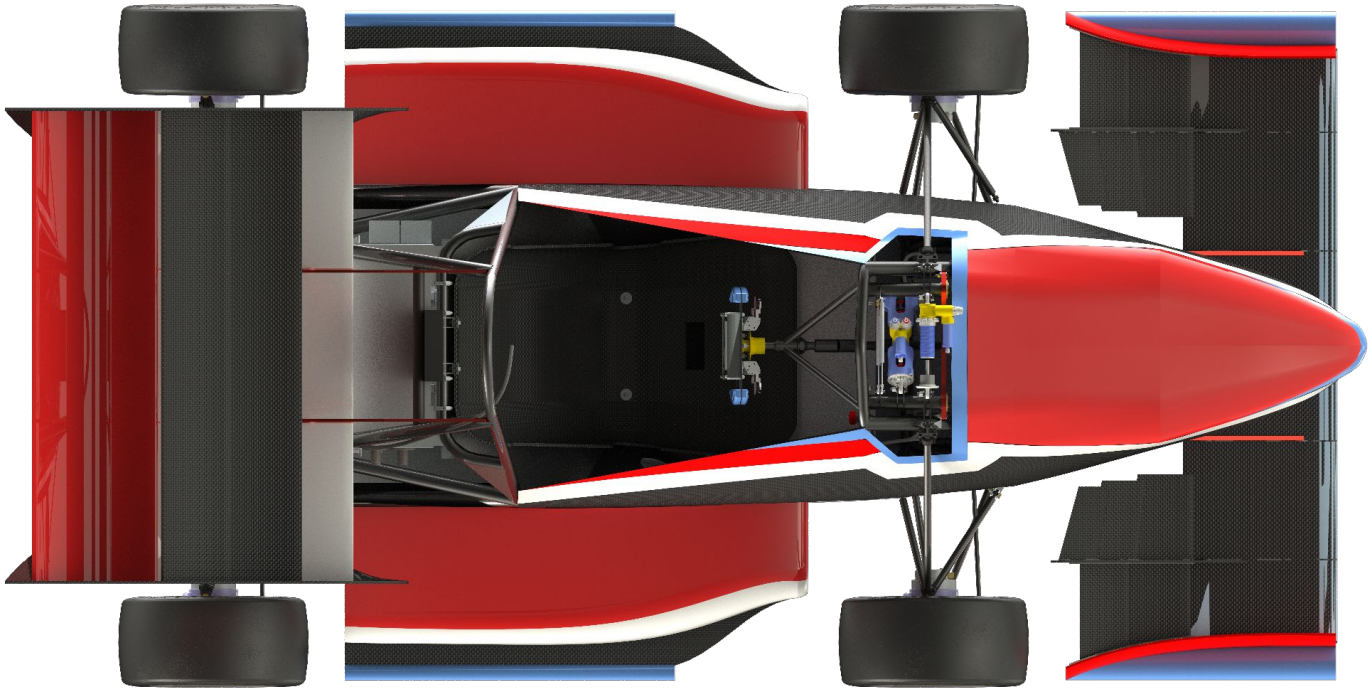
Vehicle Architecture and Systems Management



Design Binder

MY25 Exec

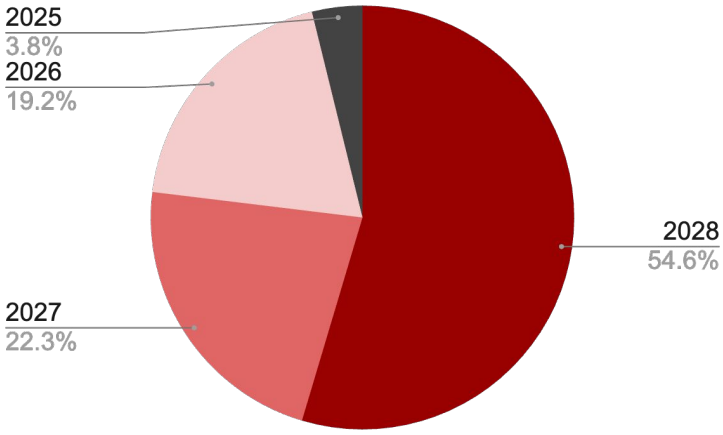
04/19

Table of Contents

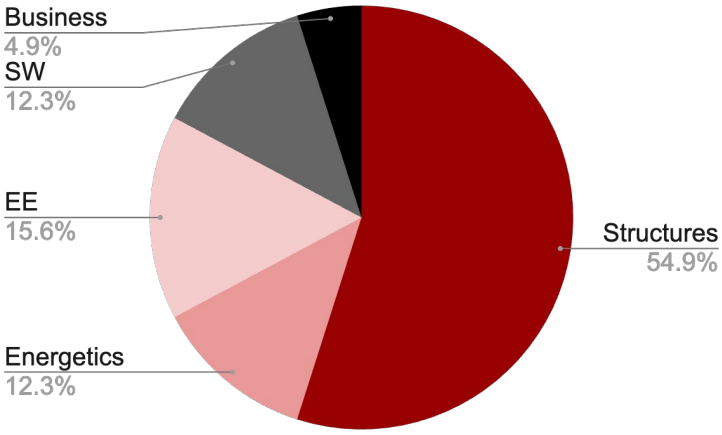
Team Structure

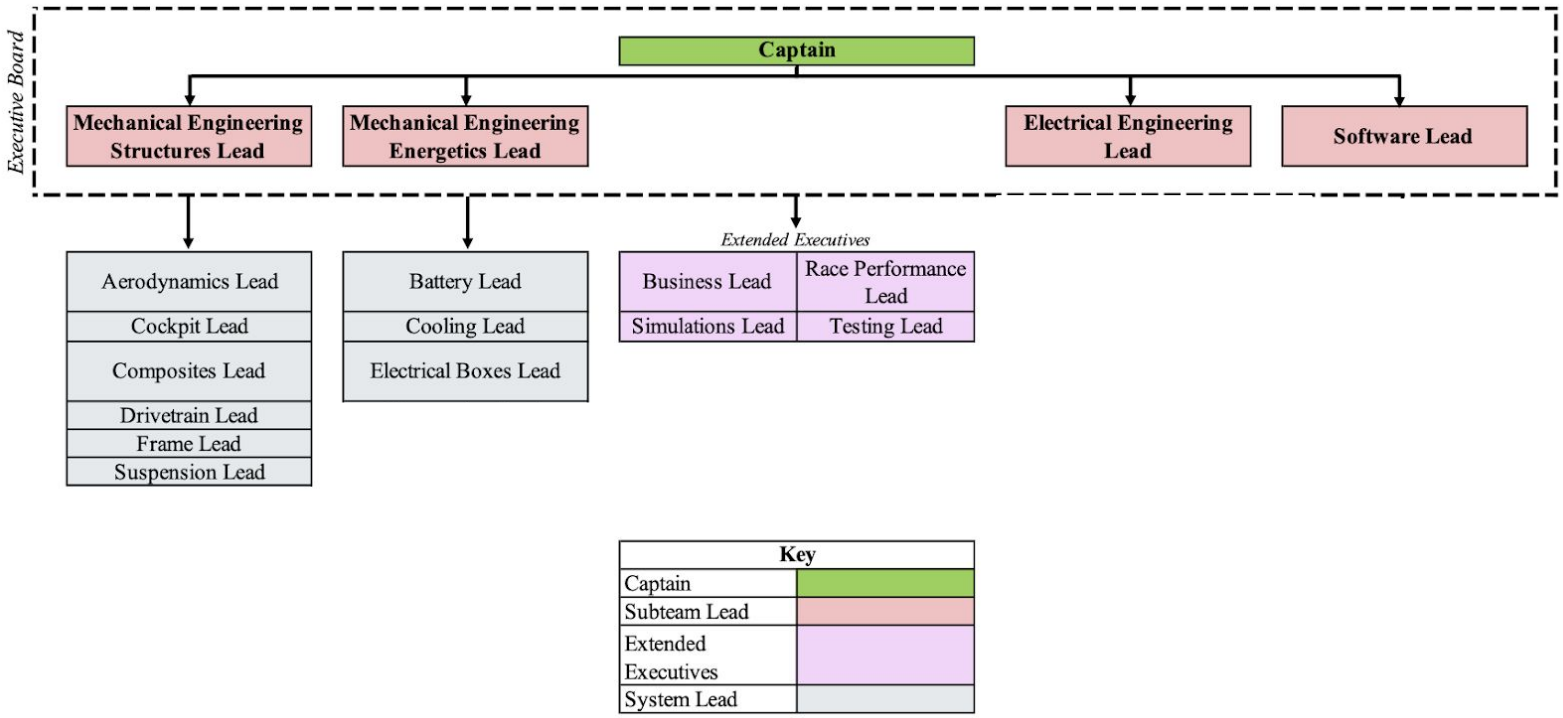
85 Total Members

Class Breakdown



Subteam Breakdown





Team Goals

Competition Finish: **Top 5 Overall at FSAE Michigan**

Dynamic Events:

Lap Sim with Car architecture + 10% margin:

- **Accel**: 3.555 + 0.355 = **3.91 s**
- **Skidpad**: 4.91 + .491 = **5.4**

Linear regression from historical Top 5 team performance

- **Autocross: 48.0s**
- **Endurance: 1600s**

Static Events:

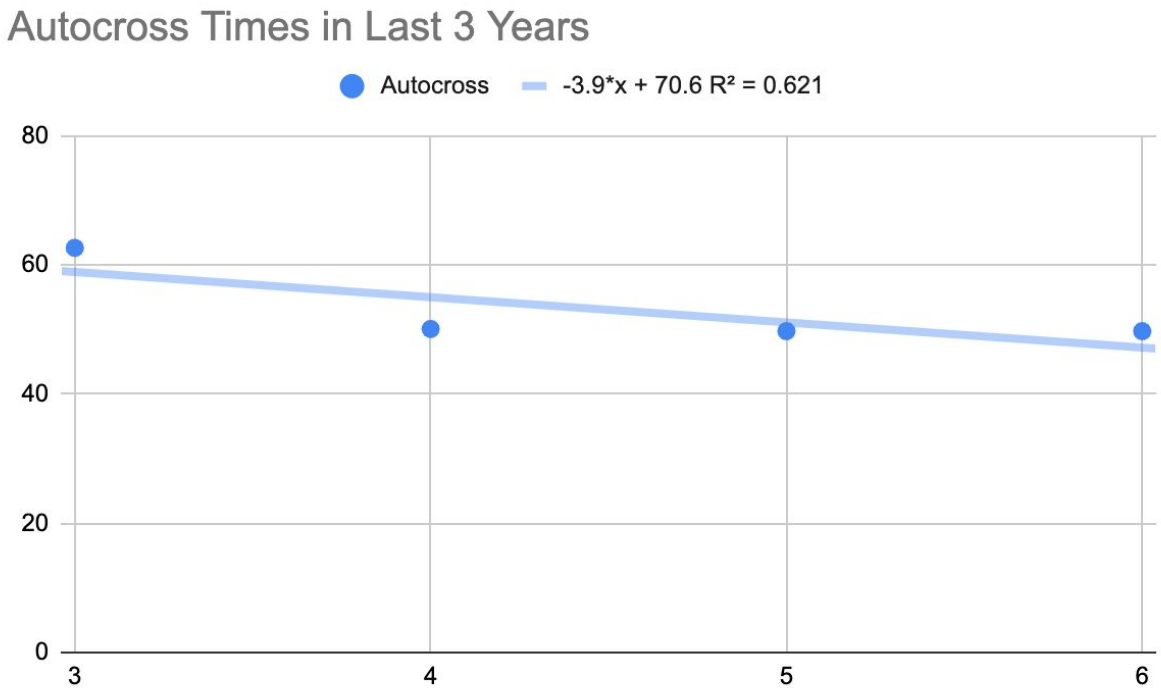
Winning Design Event at Hybrid

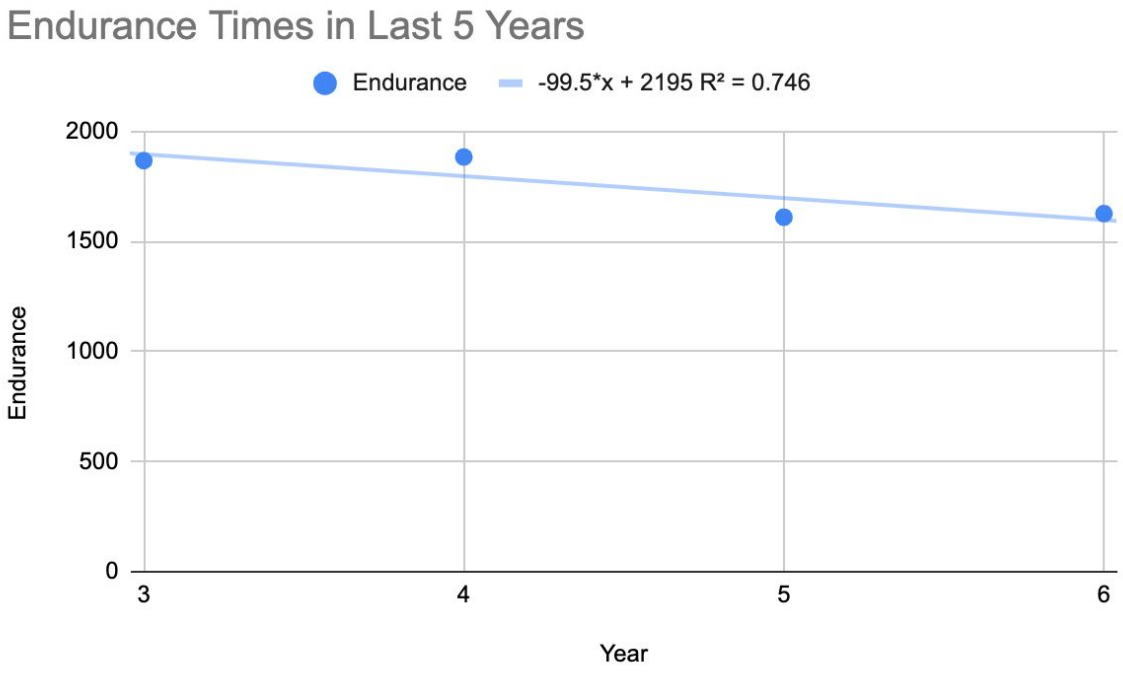
Design Finalist at Michigan (~110/150 p

Top 10 Cost Event (~77/100 points)

Business Finalist at Michigan (~67/75 p

Team Goals


Autocross Times in Last 3 Years
Autocross
-3.9*x + 70.6 R² = 0.621
80
60
40
20
0
3
4
5
6


Endurance Times in Last 5 Years
Endurance
-99.5*x + 2195 R² = 0.746
2000
1500
1000
500
0
Endurance
3
4
5
6
Year

Predicted 2025 FSAE Electric Performance

Team	#	Accel	Skidpad	AutoX	Endurance	Lap Count	Energy Used (kWh)	Accel (100)	Skidpad (75)	AutoX (125)	Endurance (275)	Efficiency (100)	Cost (100)	Design (150)	Presentation (75)	Penalties	Score (1000)
ETS	201	3.6	5.00	46.00	1473	22	5.0	100	44	125	250	61	84	110	58		832.196
Georgia Tech	210	3.6	4.70	46.78	1664	22	5.1	100	67	119	157	53	75	90	67		727.524
U. of Washington	203	3.6	4.60	50.44	1581	22	5.8	100	75	91	195	49	65	80	67		722.394
MIT	246	**4**	**5.40**	**48.00**	**1600**	22	5.0	71	21	109	186	56	77	110	67		697.067
RIT	204	4.14	5.17	50.00	1583	22	5.3	63	34	94	194	54	77	110	43		668.327
Wisconsin	252	4.72	5.22	47.71	1602	22	4.3	32	31	111	185	66	83	110	49		667.591
Montreal	238	4.16	5.21	49.52	1610	22	5.2	61	31	98	181	53	72	140	29		666.544
CMU	202	4.14	5.20	50.00	1580	22	5.0	63	32	94	195	57	51	75	62		628.934
San Jose	217	4.42	5.29	49.23	1609	22	100.0	47	27	100	182	0	84		61		500.173
Cornell	292	4.25	5.04	50.22	1872	22	2.4	56	42	93	78	100	76	95	67		607.148
Oregon State	247	4.07	5.07	48.86				67	40	103		-3	78	85	48		416.860
Cal Poly SLO	257	4.83	5.14	49.55				27	35	98		-3	77	135	47		416.744
UIUC	223	5.33	5.39	47.85				7	21	110		-3	74	135	67		411.969
UT - Arlington	209	5.06	5.24	48.24				17	29	107		-3	70	120	67		408.002
U-Toronto	205	4.34	5.39	51.98				51	21	81		-3	67	130	49		397.217
Pittsburgh	231	4.19	5.71	53.06				60	5	74		-3	76	125	46		382.529
Singapore	225	4.38	5.24	49.80				49	29	96		-3	61	100	47		379.489
Kennesaw State	206	4.89	5.50	49.69				24	16	97		-3	84	85	67		369.711
UC Davis	290	4.69	5.33	49.31				33	24	99		-3	84	75	46		358.810
Concordia	228	4.73	5.59	54.01				32	11	68		-3	84	80	64		336.217
Auburn	230	4.79	5.48	51.08				29	16	87		-3	81	65	47		322.254
U-Missouri	216	4.84	5.38	52.61				27	22	77		-3	71	70	51		314.202
UMichigan	250	4.485						43	0	0		-3	74	137	59		310.344
Laval	245	5.06	5.48	54.95				17	16	63		-3	84	80	48		305.492
Virginia Tech	208	4.39		53.89				48	0	69		-3	56	85	40		296.459
McGill	233							0	0	0		-3	77	150	67		290.588
British Columbia	214	5.42	5.62	56.30				5	9	55		-3	78	70	60		274.373
Texas A&M	232	5.456	6.05	50.10				5	4	94		-3	65	95	10		268.680
Columbia	263	4.91	5.73	59.44				24	5	39		-3	74	85	36		259.290

Team Goals Cont.

Reliability:

- Testing Metrics:
  - **5 Representative Endurances** with no faults or failures
  - **10 Representative Accels**, timed
  - **5 Representative Skidpads,** timed
  - **10 Representative Autocrosses,** timed
  - Successful Brakes and Rain tests

- **Over 200 km of intentional testing**
- Rigorous Testing documentation
  - Preflight and Inflight checklists

- Onboard telemetry to track:
  - Battery Power Draw
  - Motor, Inverter, Battery Temperature
  - Motor torque and speed
  - Suspension shock pot data

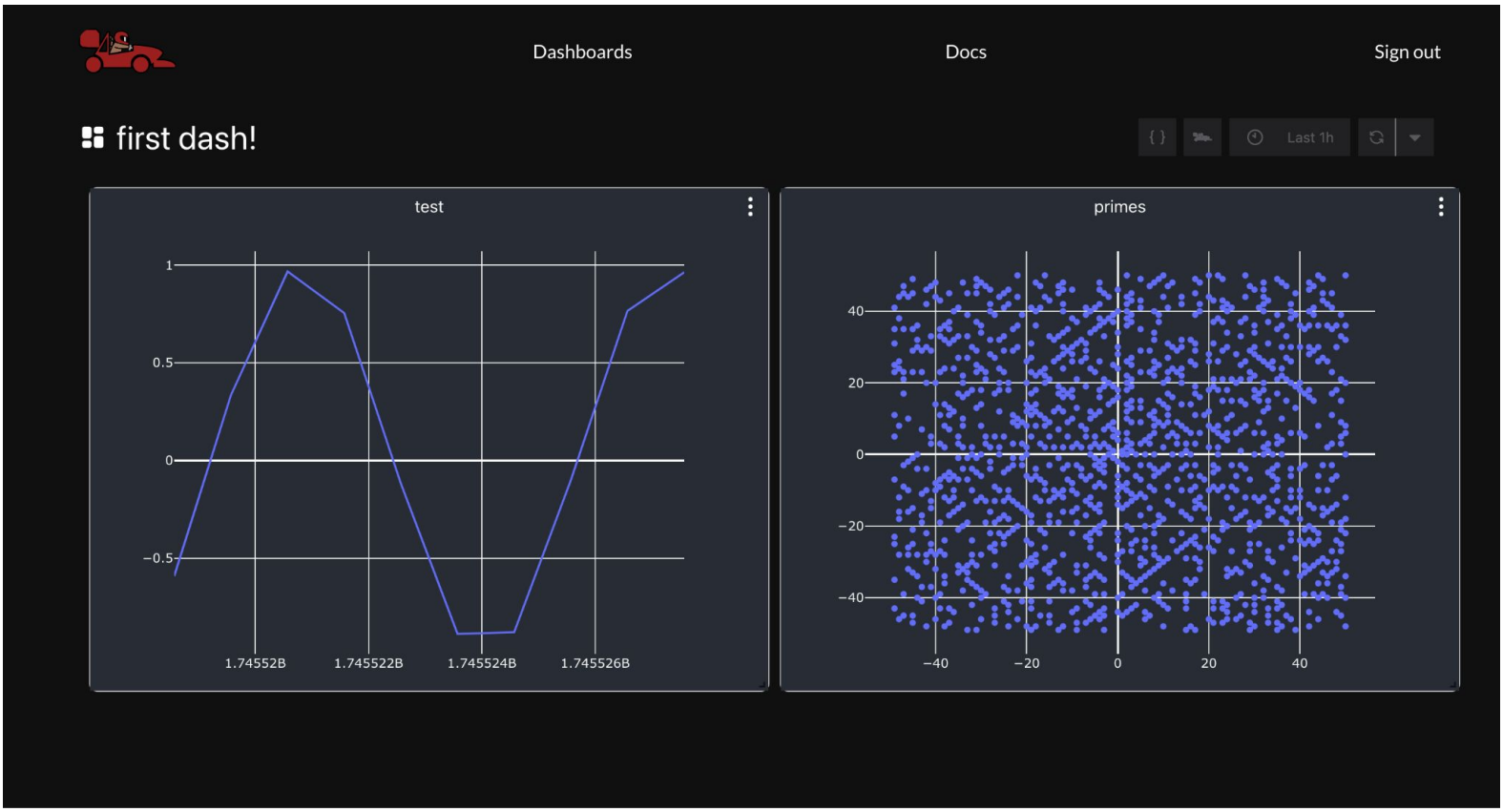
Preflight Checklist

Before car leaves jacks

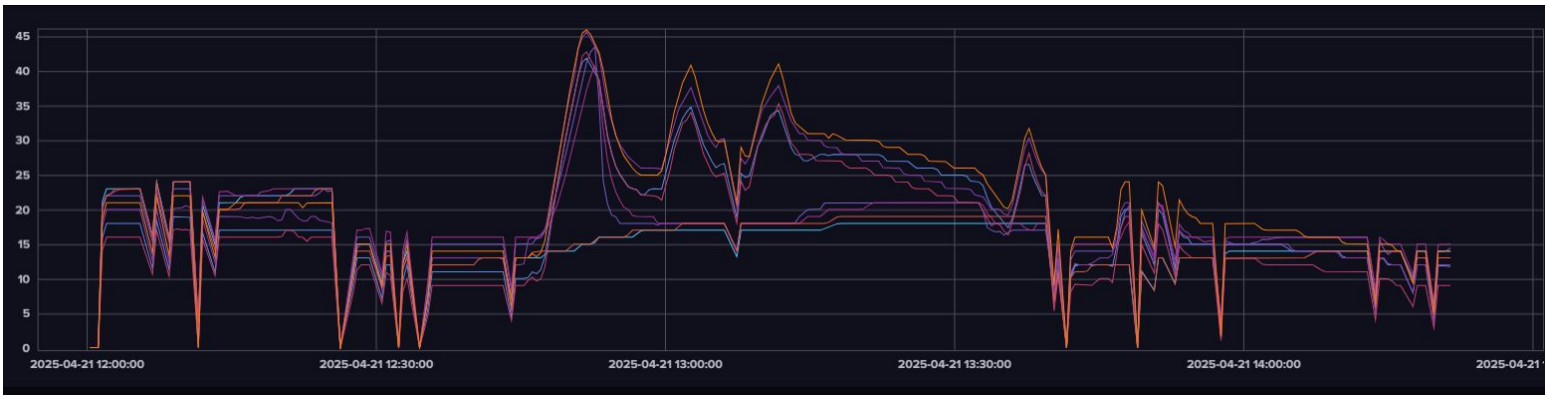
	Item to check	Sign Off
1.1	**Vehicle is Ready**	
1.1	HV battery is charged	
1.2	BMS cable is plugged back into battery, HVD is plugged in	
1.3	LV battery is charged (record voltage)	
1.4	Back-up LV battery is charged (record voltage)	
1.5	Area around vehicle is clear	
2	**Vehicle Safety Checks - Mechanical**	
2.1	**General Mechanical Checks**	
2.1.1	Brake pedal is tight	
2.1.2	Accel pedal is tight	
2.1.3	Check wheels by shaking rims (shouldn't wiggle much)	
2.1.4	Reservoirs are full	
2.1.5	Steering has full range of travel	
2.1.6	Brake overtravel switch is flipped in the correct direction	
2.2	**Powertrain**	
2.2.1	Lug nuts on + tight on all 4 wheels	
2.2.2	No leaks in brake line	
2.2.3	Brake pads are good, rotors aren't rubbing	
2.2.4	Brake rotors are secure	
2.2.5	Halfshaft rubber boots are tight/not loose	
2.2.6	Chain is tensioned (~0.25" travel when poked)	
2.2.7	Chain is greased	
2.2.8	Motor nut is tight	
2.2.9	Cooling loop is full, bled, and no leaks	
2.2.10	Catch can is empty	
2.3	**Chassis**	

Telemetry

Custom Data Acquisition Website

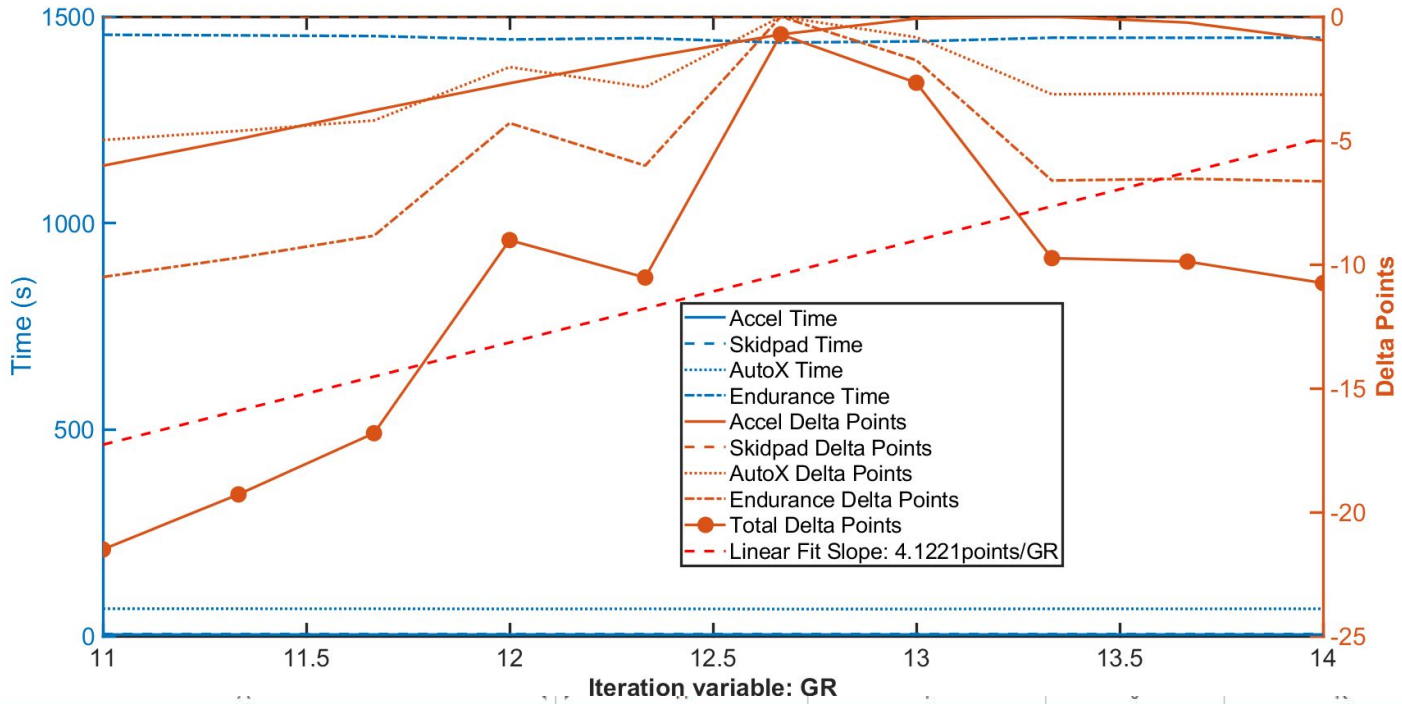


Live Motor, Battery, Inverter Temperature Dashboard



Simulations

4WD Justification + Motor Selection

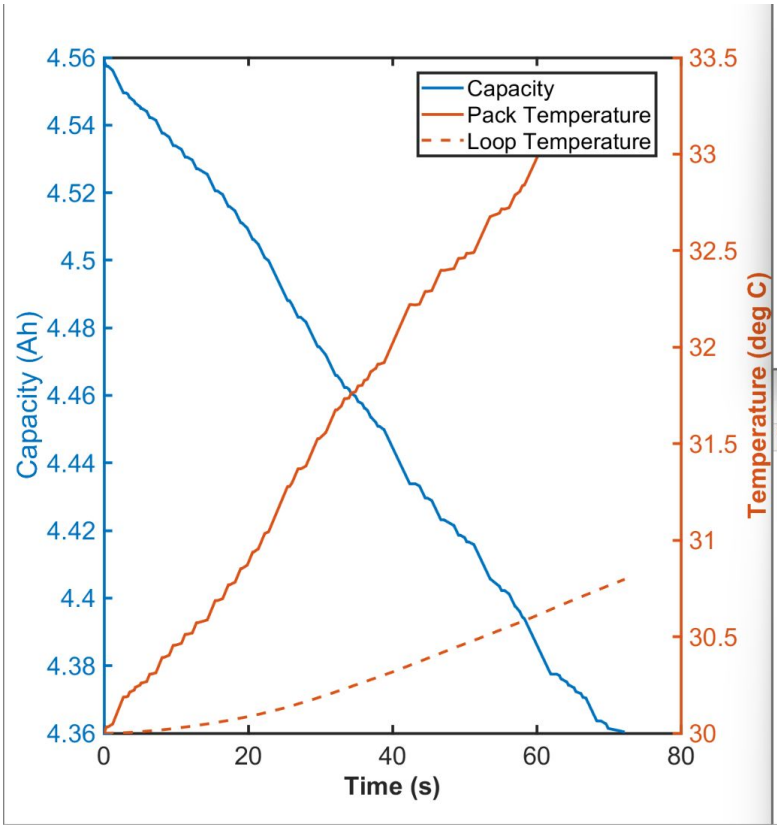


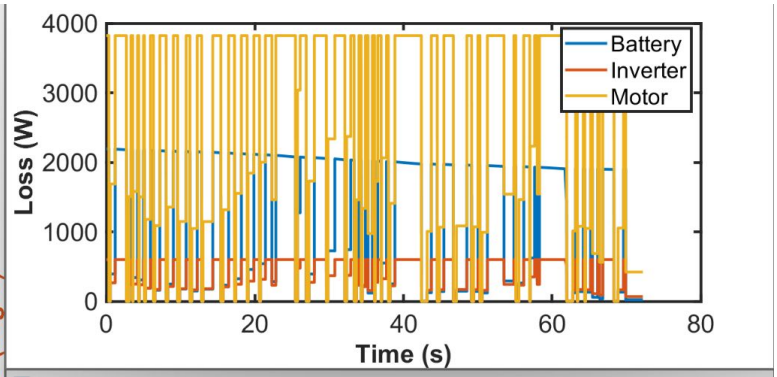
Motor:	Accel (s):	Skidpad (s):	Lap (s):	Endurance (s):
Fischer TI085-052-070-04B7S-07S04BE2	3.508	4.8502	65.1054	1432.3197
DHX Hawk40/K40	3.518	4.8715	65.6044	1443.297
DHX Hawk20/K20	3.87	4.8431	67.2682	1479.9014
Parker GVM142-050G	4.09	4.8767	68.5478	1508.0526
Parker GVM142-050K	3.809	4.8767	67.3389	1481.4554
Moog AFW505E	3.78	4.8562	65.1585	1433.4872
AMK DD5-14-10-POW-18600-B5 (600V)	3.598	4.8125	65.3188	1437.0129
AMK DD5-14-10-POW-18600-B5 (400V)	3.806	4.8125	66.7349	1468.1684

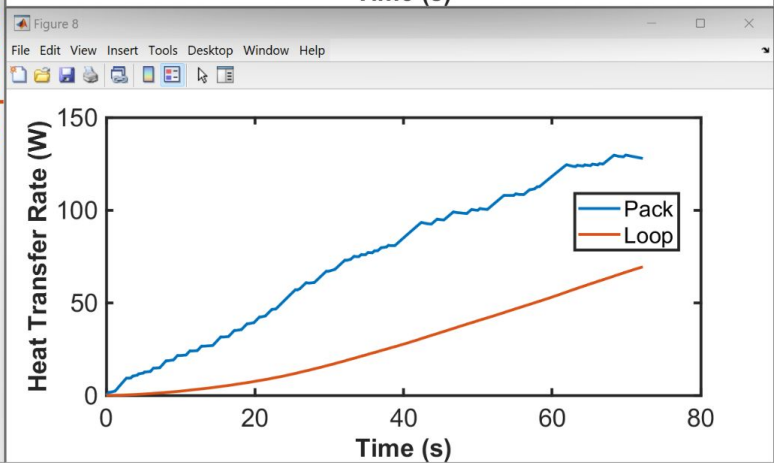
Motor:	Power (W):	Gearbox (Stages):	Voltage (V):	OD (in):	Length (in):	Total Mass (kg):	Cost ($):	Total Cost($):	Feasibility (rank):	Performance (rank):
Fischer TI085-052-070-04B7S-07S04BE2	35,366	2	600	4.72	5.49	10.53	2873	11492	4	1
DHX Hawk40/K40	66,240	1	400	5.25	6.5	13.7	4200	16800	3	4
DHX Hawk20/K20	18,400	1	400	5.25	5.44	9.5	3200	12800	2	5
Parker GVM142-050G	14,000	1	400	5.59	8.72	14.5	1882	7528	7	7
Parker GVM142-050K	29,000	1	400	5.59	8.72	14.5	1882	7528	6	6
Moog AFW505E	54,797	1	600	3.74	10.16	11.4	0	0	5	2
AMK DD5-14-10-POW-18600-B5	36,000	2	600	4.28	5	8.55	See AMK Pricing	See AMK Pricing	1	3

Simulations

Battery Sizing

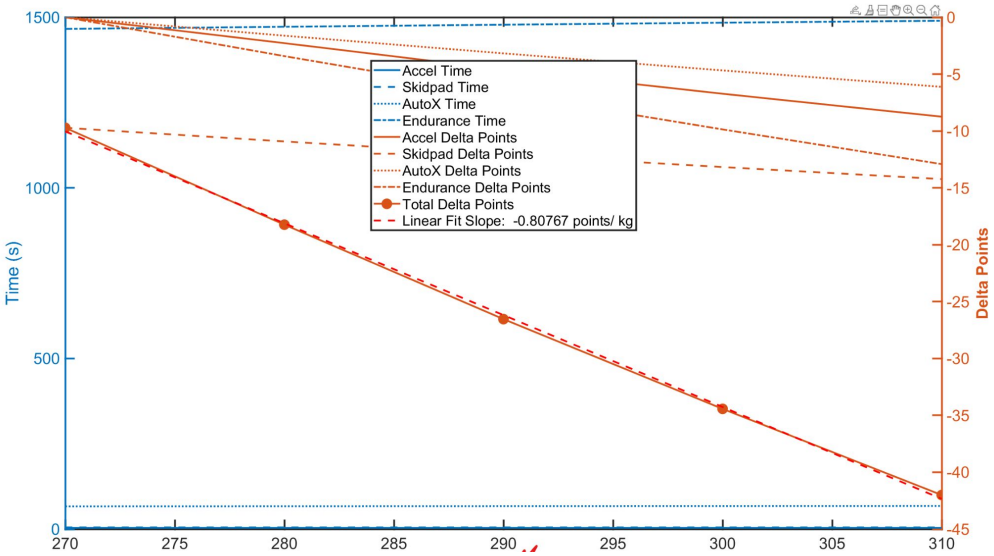






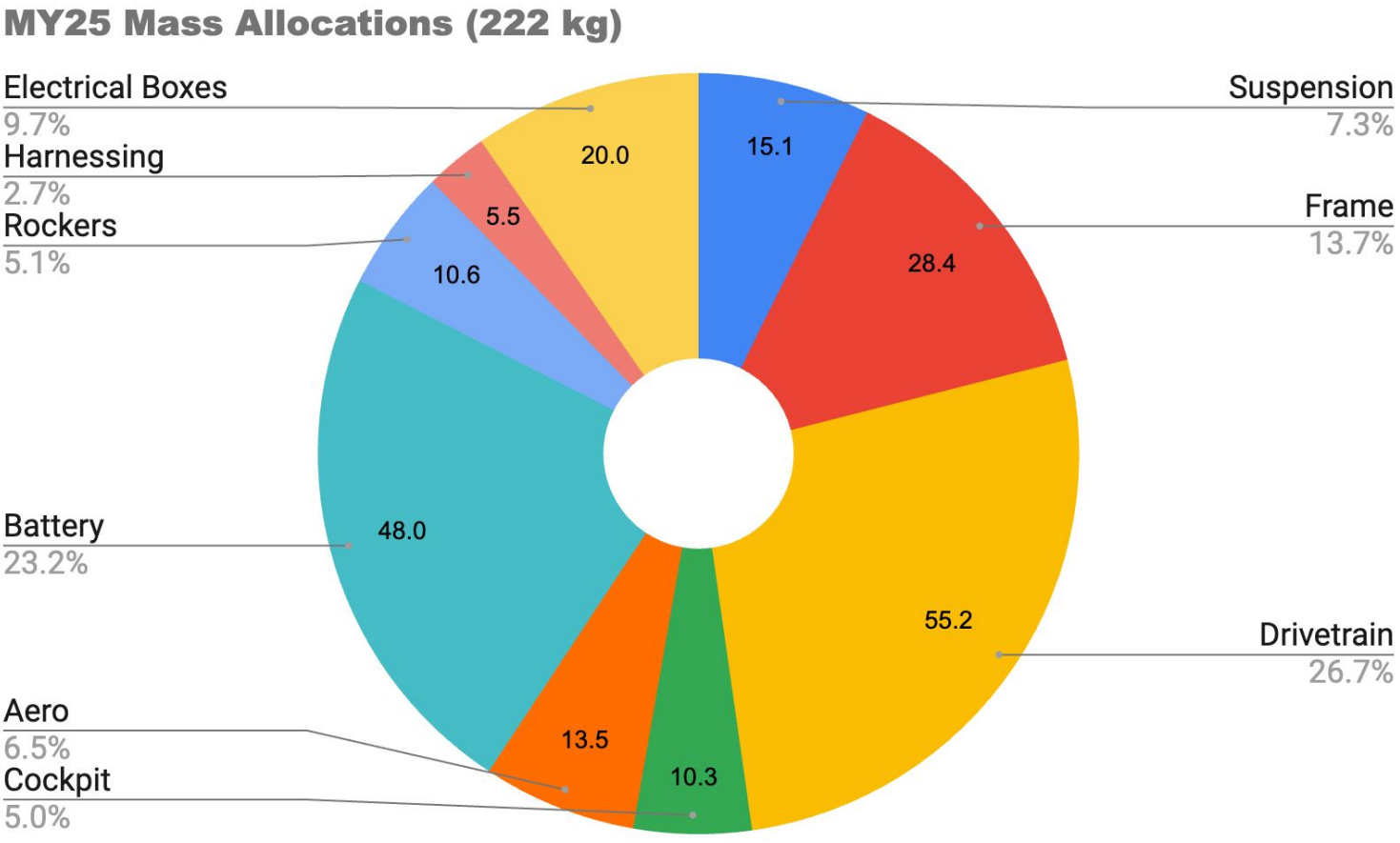
Simulations Cont.

Car Parameter Sensitivities



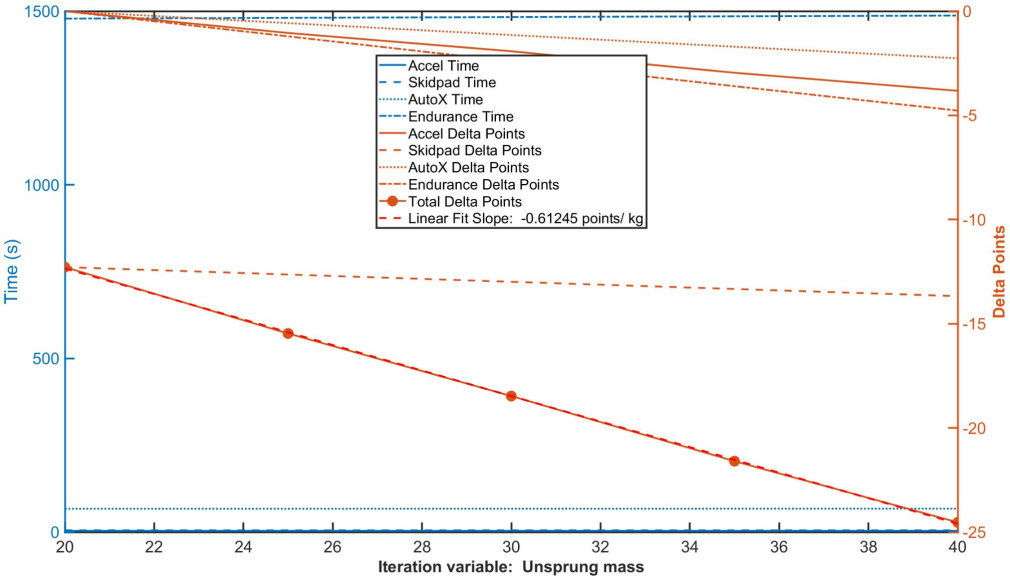
Sprung Mass (kg)

Sprung Mass
Actual: 222 kg

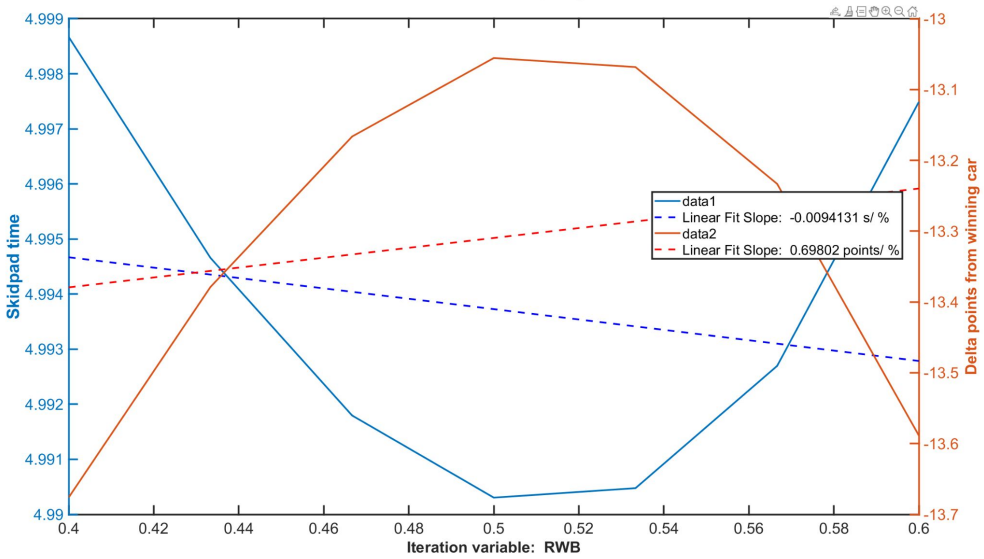


Simulations Cont.

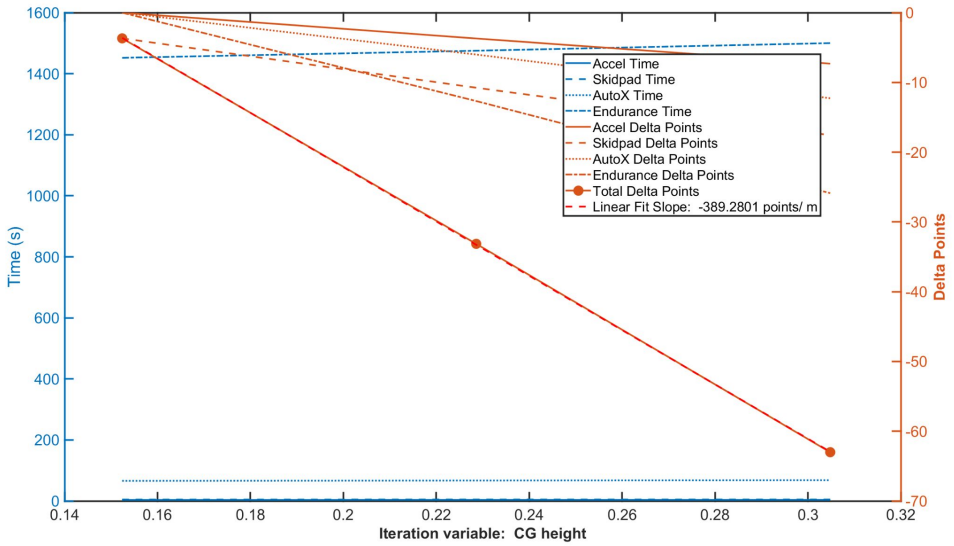
Car Parameter Sensitivities



Unsprung Mass
Actual: 50 kg



RWB
Goal: 51%
Actual: 51%

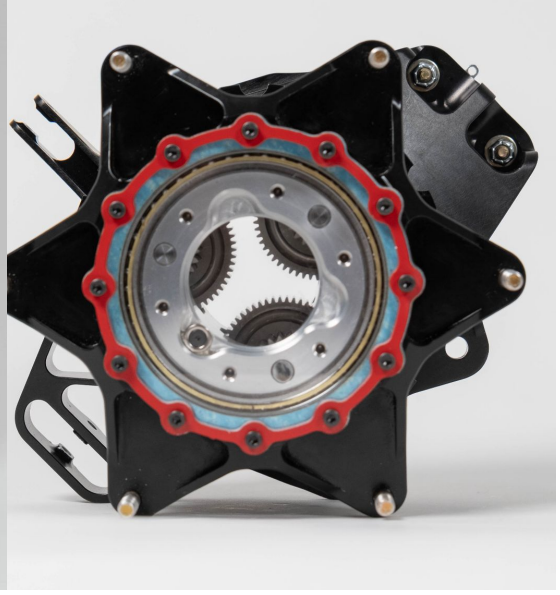


CG Height
Goal: 10in
Actual: 9.92in

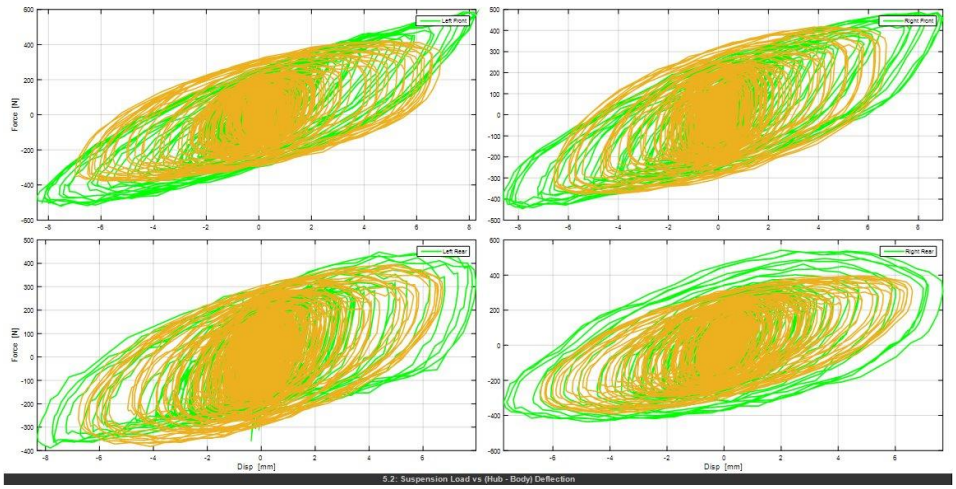
Architecture

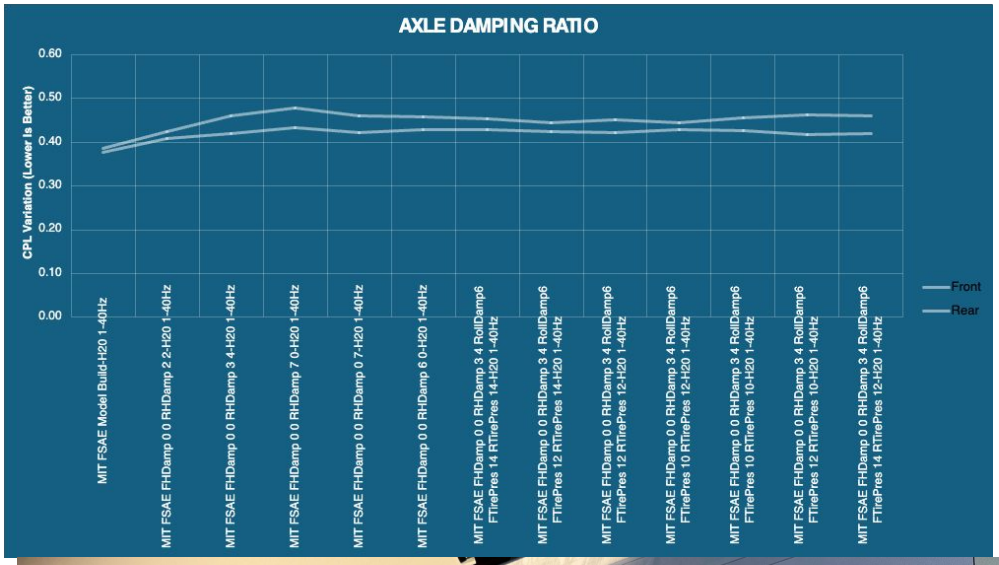
Structures:

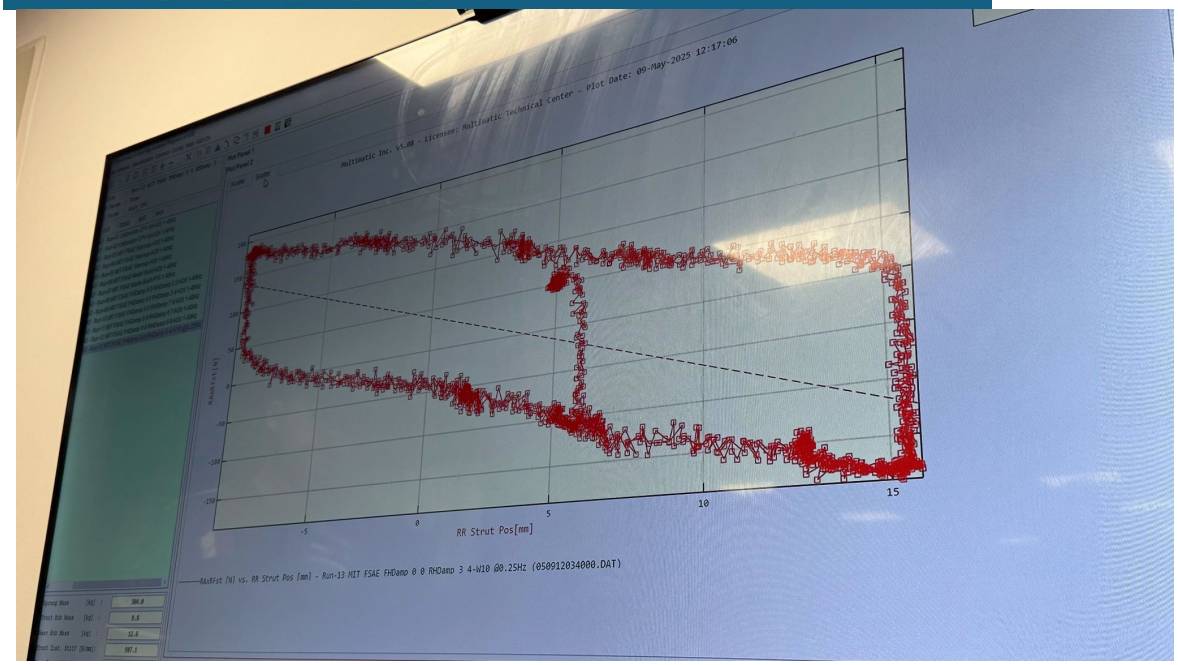
- Custom In-hub compound planetary gearboxes
- Decoupled Roll-Heave Suspension, sponsored by Multimatic
- Mass: 215 kg
  - Composites R&D



4-post Testing



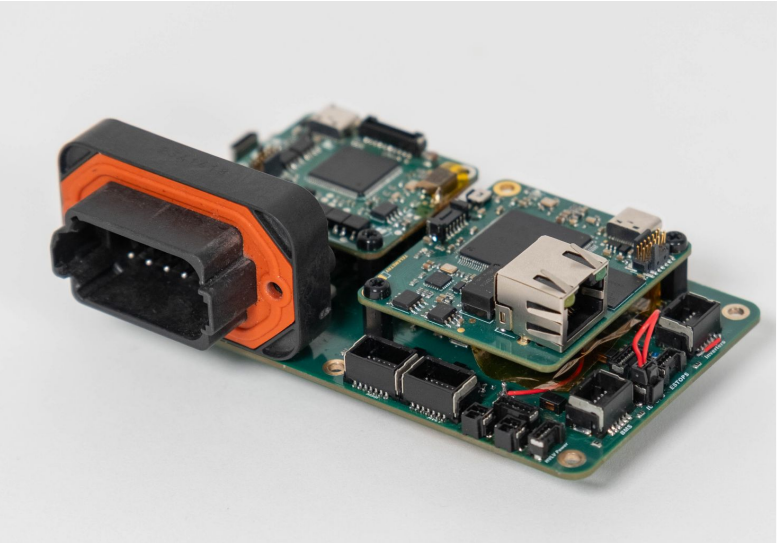


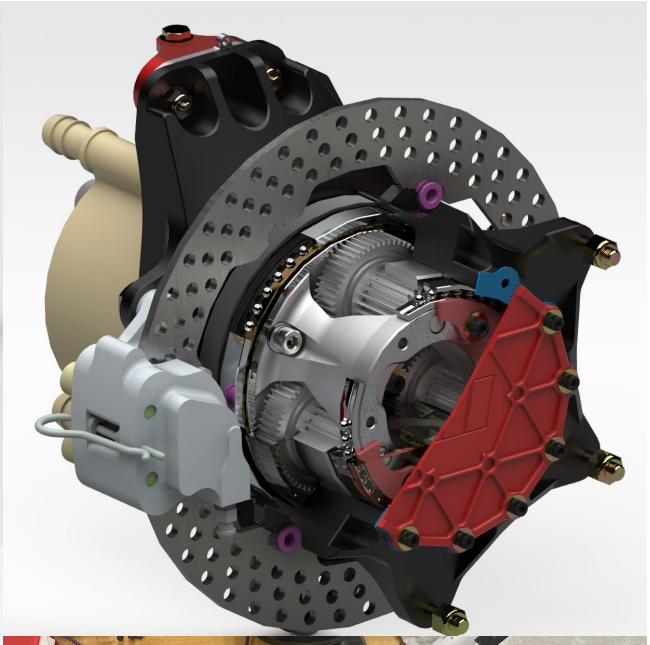


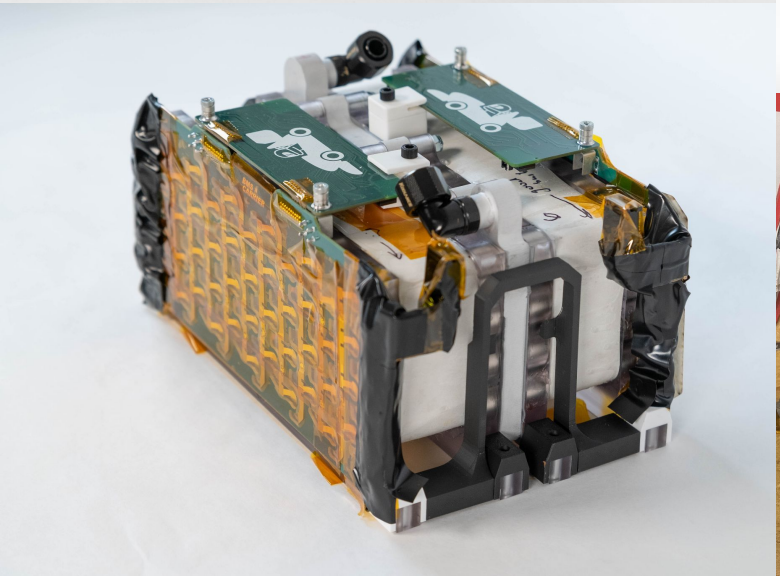
Architecture

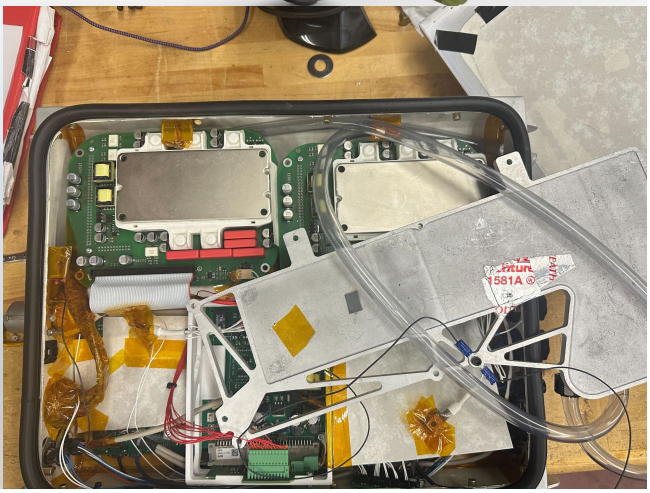
Tractive System and Firmware:

- 4x AMKMotion Formula Student Motor + Inverter kit
- 600V Water-cooled battery + inverter loop
- Water-cooled motor loop
- Fully custom Low Voltage System





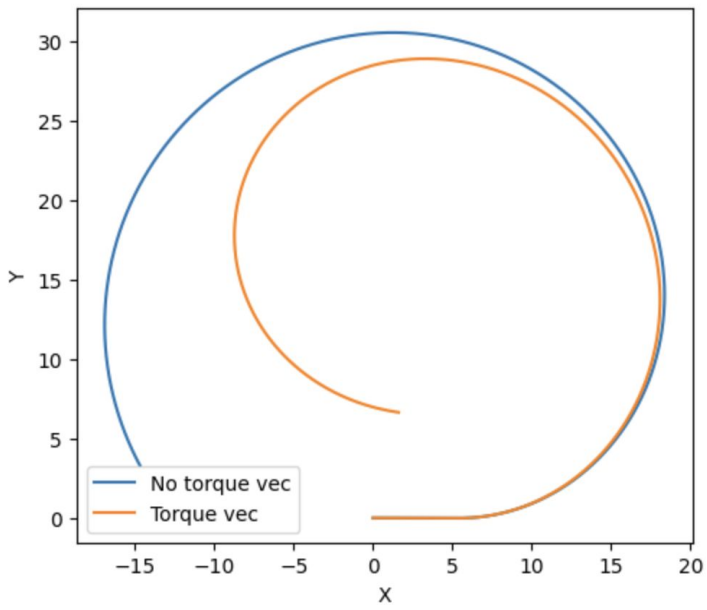




Architecture

Controls:

- Steering encoder and IMU to capture steering angle and yaw rate data
- 4WD torque vectoring PID loop to optimize yaw rate



Design Cycle Process

DRDR	CoDR	DR1	DR2	MaDR/Test Plans
Design Requirements Design Review Defining Design requirements from: - Budget - Timeline - Rules - Load Cases - Optimization Sims - Interfaces	**Concept Design Review** Presenting possible concepts which do/don't satisfy design requirements Selecting a concept you want to go with Building out a timeline for said concept	**MVP Design of selected concept** Full analysis for critical elements Packages/interfaces with systems smoothly No critical issues Major risks and remaining to do highlighted	**Ready for deployment, manufacturing, assembly** End of design phase - "freeze"	Plans, timelines for manufacturing, testing, assembly

Milestone	Deadline	Actual Date Hlt
LV EE Bench	2/1	3/20
Rolling	2/14	3/21
HV EE Bench w/ PSU	2/14	3/21
HV EE Bench w/ Battery	2/21	3/22
Stands Test	3/08	3/23
Roman	3/08	3/24
Shakedown	3/12	4/21

Summer:

- System level DRDR and CoDRs
- Finalize justifying team goals

Fall:

- System + subsystem DR1 and DR2
- MY24 Fall Testing + Wind Tunnel Testing
- Finalize car design and analysis
- Scrutineering
- Document Submission

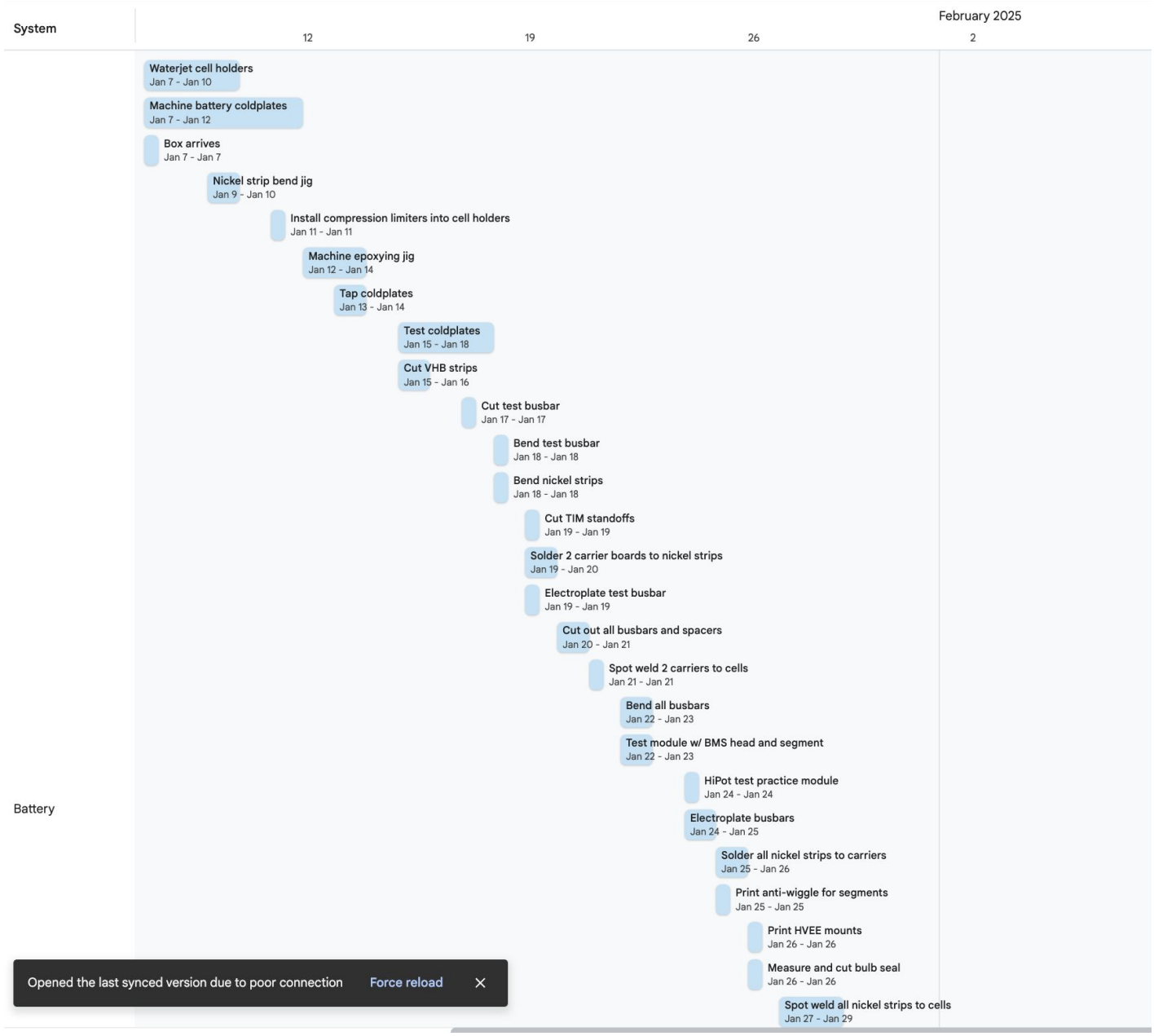
Winter:

- IAP Manufacturing Sprint
- Subscale/Unit Tests
- Static Event preparation

Spring:

- Full Car Testing
- Controls and Telemetry Testing
- Mock inspections
- Driver Training

Timeline

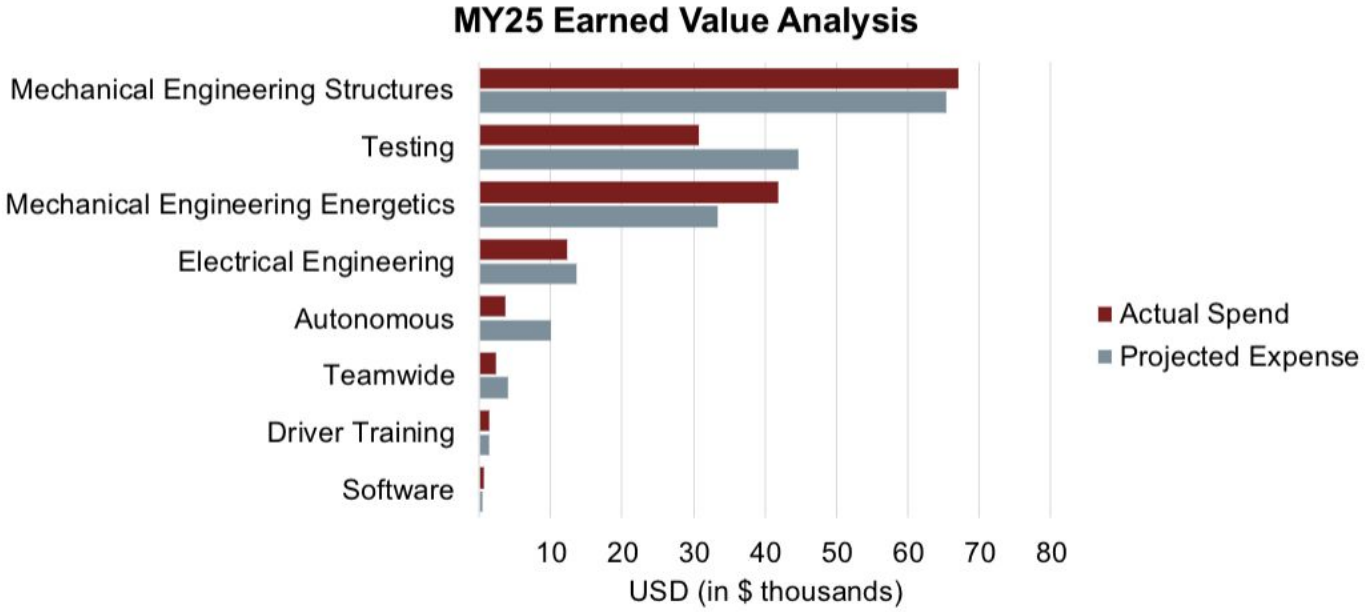

System
February 2025
12
19
26
2
Waterjet cell holders
Jan 7 - Jan 10
Machine battery coldplates
Jan 7 - Jan 12
Box arrives
Jan 7 - Jan 7
Nickel strip bend jig
Jan 9 - Jan 10
Install compression limiters into cell holders
Jan 11 - Jan 11
Machine epoxying jig
Jan 12 - Jan 14
Tap coldplates
Jan 13 - Jan 14
Test coldplates
Jan 15 - Jan 18
Cut VHB strips
Jan 15 - Jan 16
Cut test busbar
Jan 17 - Jan 17
Bend test busbar
Jan 18 - Jan 18
Bend nickel strips
Jan 18 - Jan 18
Cut TIM standoffs
Jan 19 - Jan 19
Solder 2 carrier boards to nickel strips
Jan 19 - Jan 20
Electroplate test busbar
Jan 19 - Jan 19
Cut out all busbars and spacers
Jan 20 - Jan 21
Spot weld 2 carriers to cells
Jan 21 - Jan 21
Bend all busbars
Jan 22 - Jan 23
Test module w/ BMS head and segment
Jan 22 - Jan 23
HiPot test practice module
Jan 24 - Jan 24
Electroplate busbars
Jan 24 - Jan 25
Solder all nickel strips to carriers
Jan 25 - Jan 26
Print anti-wiggle for segments
Jan 25 - Jan 25
Print HVEE mounts
Jan 26 - Jan 26
Measure and cut bulb seal
Jan 26 - Jan 26
Spot weld all nickel strips to cells
Jan 27 - Jan 29
Battery
Opened the last synced version due to poor connection
Force reload

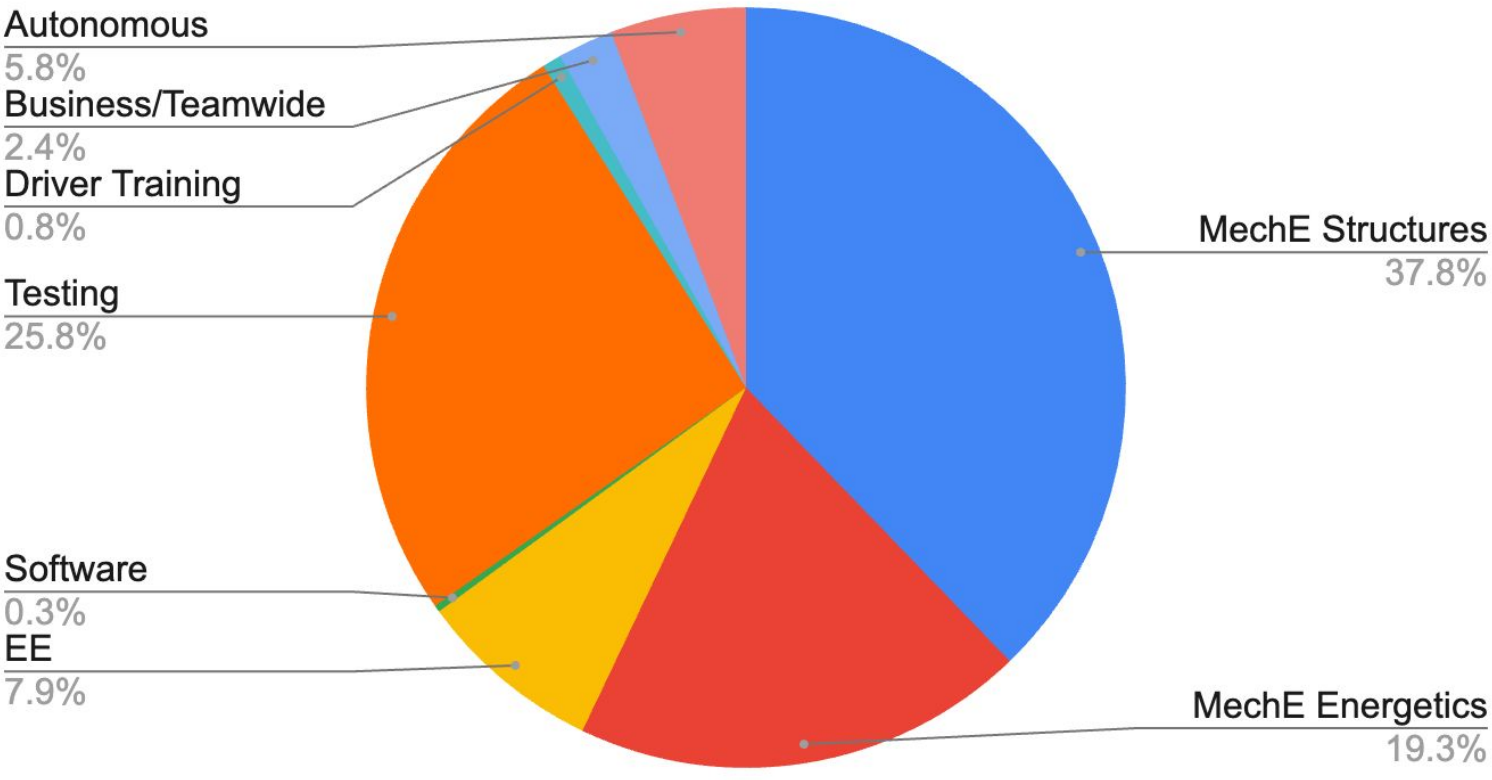
timeline_2

	Column 1	Date	Priority	SubTeam	System	Status	Notes
2	System Leads Assigned	June 19		Team	Team	Done	
8	Architecture DR	July 21		Team	Team	Done	Battery shape, Aero Elements, RWB, CG Height, Mass allocation, Ride Height, Wheelbase + Track Width, Suspensio
11	HV Electronics DR	July 27		EE	HV Electro...	Done	
12	VCU/megaLV DR	July 27		EE	VCU/Mega...	Done	
13	Prepreg Sponsor	July 27		Structures	Composites	Done	Amelia/Trevor talking with Specialty Materials. Currently progressing with figuring out sponsorship terms
21	Board Architecture DR	August 7		EE	EE	Done	
24	sensor node rewrite DR	August 10		SW	Software	Done	
28	VCU/megaLV Schematic	August 24		EE	VCU/Mega...	Done	
33	HV Electronics Schematic	September 14		EE	HV Electro...	Done	
39	Motor Inverter Spin	September 21		EE	EE	Done	
40	MegaLV Software Done, begin testing on N	September 21		SW	Software	Done	
43	**Hybrid Registration**	September 26		Team	Team	Done	Done
44	HV Electronics Layout	September 28		EE	HV Electro...	Done	
53	VCU/megaLV Layout	October 7		EE	VCU/Mega...	Done	VCU done, LVBatt
54	Inboard Sus Packaging	October 9		Structures	Suspension	Done	Driven by frame DR1
57	Torque Vectoring DR	October 16		SW	Controls	Done	
58	Motor inverter spin with Theo's code	October 16		SW	Software	Done	
60	LV Harnessing Sent Out	October 18		Energetics	Harnessing	Done	
65	Backplane Layout	October 20		EE	EE	Done	
67	HV Electronics Sendout	October 21		EE	HV Electro...	Done	
68	VCU/megaLV Sendout	October 21		EE	VCU/Mega...	Done	
69	Backplane Sendout	October 21		EE	EE	Done	
70	Hybrid ESF 1 Ready for Review	October 22		EE	Team	Done	
76	Hybrid ESF 1 Submission	October 28		EE	Team	Done	20 Bonus points if approved 30 days before due date. 10 points if approved 15 days before due date
77	Power Limiting DR	October 28		SW	Controls	Done	
83	Hybrid SES Submitted	November 1		Structures	Structures	Done	20 bonus points if approved before Nov 15: https://www.formula-hybrid.org/deadlines
99	Sus Links CoDR	November 9		Structures	Suspension	Done	
102	Steering Wheel DR1	November 10		Structures	Cockpit	Done	
104	CF Box go/no go	November 10		Structures	Composites	Done	
122	Frame VR3 BOM, Jigging Order, Coping Ord	November 29		Structures	Frame	Done	
123	Frame Scrutineered	November 29		Structures	Frame	Done	Needs to be done before sending out
127	Final HV Electronics Sendout	November 30		EE	HV Electro...		

Budget

We budgeted and raised $173,000 through 5 active funding channels





Budget Tracking

MechE Energetics		**$33,400.00**	**$41,914.32**	**125.49%**	**-$**
	MechE Energetics: General Subteam	$500.00	$554.66	110.93%	
	Energetics: Battery	$16,800.00	$19,268.64	114.69%	
	Energetics: Cooling	$3,500.00	$5,723.78	163.54%	
	Energetics: EE Boxes	$1,100.00	$2,800.61	254.60%	
	Energetics: Harnessing	$11,500.00	$13,566.63	117.97%	
EE		**$13,650.00**	**$12,276.68**	**89.94%**	
	EE: General Subteam	$1,450.00	$9,014.01	621.66%	
	EE: BMS/Battery	$6,750.00	$559.47	8.29%	
	EE: CSB/Charger	$1,000.00	$579.20	57.92%	
	EE: Dash	$350.00	$105.12	30.03%	
	EE: HVLV	$1,000.00	$600.24	60.02%	
	EE: International Fees from PCB's	$50.00	$76.27	152.54%	
	EE: LVBatt	$650.00	$876.27	134.81%	
	EE: RSP	$200.00	$0.00	0.00%	
	EE: Sensor Node	$1,500.00	$274.23	18.28%	
	EE: VCU	$700.00	$191.87	27.41%	
Software		**$500.00**	**$591.00**	**118.20%**	
	Software: General Subteam	$500.00	$591.00	118.20%	
Autonomous		**$10,000.00**	**$3,670.48**	**36.70%**	
	Autonomous: General Subteam	$10,000.00	$3,670.48	36.70%	
Testing		**$44,600.00**	**$30,800.08**	**69.06%**	
	Testing: General Subteam	$200.00	$7,412.73	3706.37%	
	Testing: Comp Food/Gas	$10,000.00	$0.00	0.00%	
	Testing: Comp Vehicle Rentals	$500.00	$0.00	0.00%	
	Testing: Hybrid Housing	$5,000.00	$5,000.00	100.00%	
	Testing: Michigan Housing	$11,000.00	$11,000.00	100.00%	
	Testing: MY24 Maintenance	$500.00	$0.00	0.00%	
	Testing: Trip Gas	$2,000.00	$135.15	6.76%	
	Testing: Trip Food	$3,600.00	$0.00	0.00%	
	Testing: Vehicle Rental	$7,200.00	$2,652.20	36.84%	
	Testing: Registration Fees	$4,600.00	$4,600.00	100.00%	
Driver Training		**$1,400.00**	**$1,343.50**	**95.96%**	
	Driver: Sim PC	$1,000.00	$1,323.25	132.33%	
	Driver: Sim VR	$300.00	$20.25	6.75%	
	Driver: Software	$100.00	$0.00	0.00%	
Business/Teamwide		**$4,090.00**	**$2,244.00**	**54.87%**	
	Business: AWS Data	$20.00	$1.56	**7.80%**	
	Business: Google Cloud Data	$20.00	$17.33	**86.65%**	
	Business: Livery	$1,000.00	$0.00	**0.00%**	
	Business: Media	$200.00	$23.90	**11.95%**	
	Team: Shipping	$500.00	$1,369.39	**273.88%**	

Sponsors

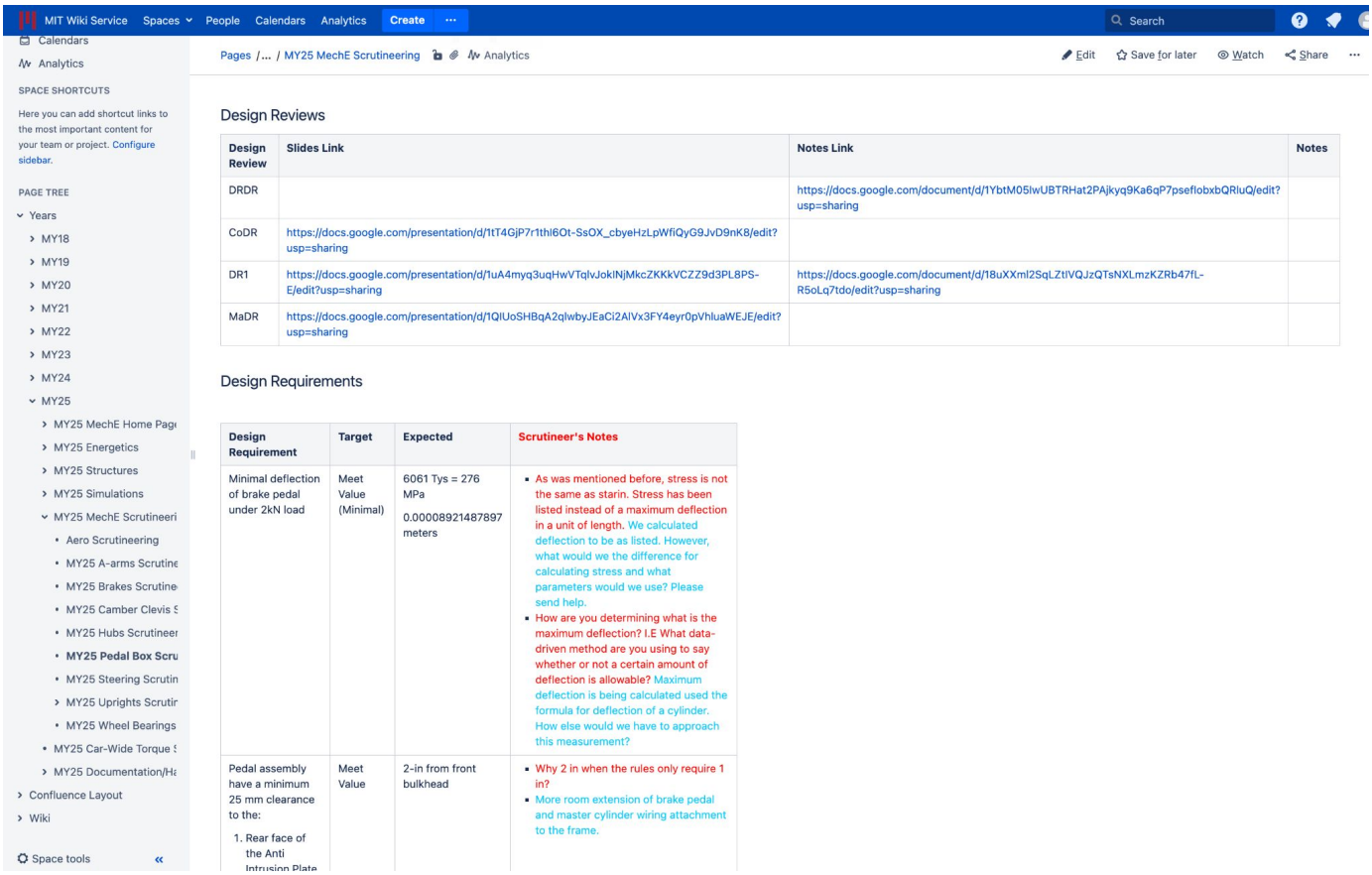
MIT MOTORSPORTS	Affiliate $1,000+	Bronze $2,500+	Silver $5,000+	Gold $10,000+	Titanium $15,000+	Carbon $20,000+
Invitation to Team Events	•	•	•	•	•	•
Logo on Website + Sponsor Banners	•	•	•	•	•	•
Logo on Team Apparel		•	•	•	•	•
Logo on Car		Small	Medium	Large	X-Large	Wing
Social Media Features			1x	2x	3x	4x
Access to Team Resume Book			•	•	•	•
Networking Event with Team				•	•	•
Team Attendance at Sponsor's Event*					•	•
Title Benefits (Team Dinner, Car Access, etc.)						•

*In collaboration with MIT's Edgerton Center

New Website

Risk Management

Rigorous Scrutineering and Technical Inspection process from alumni



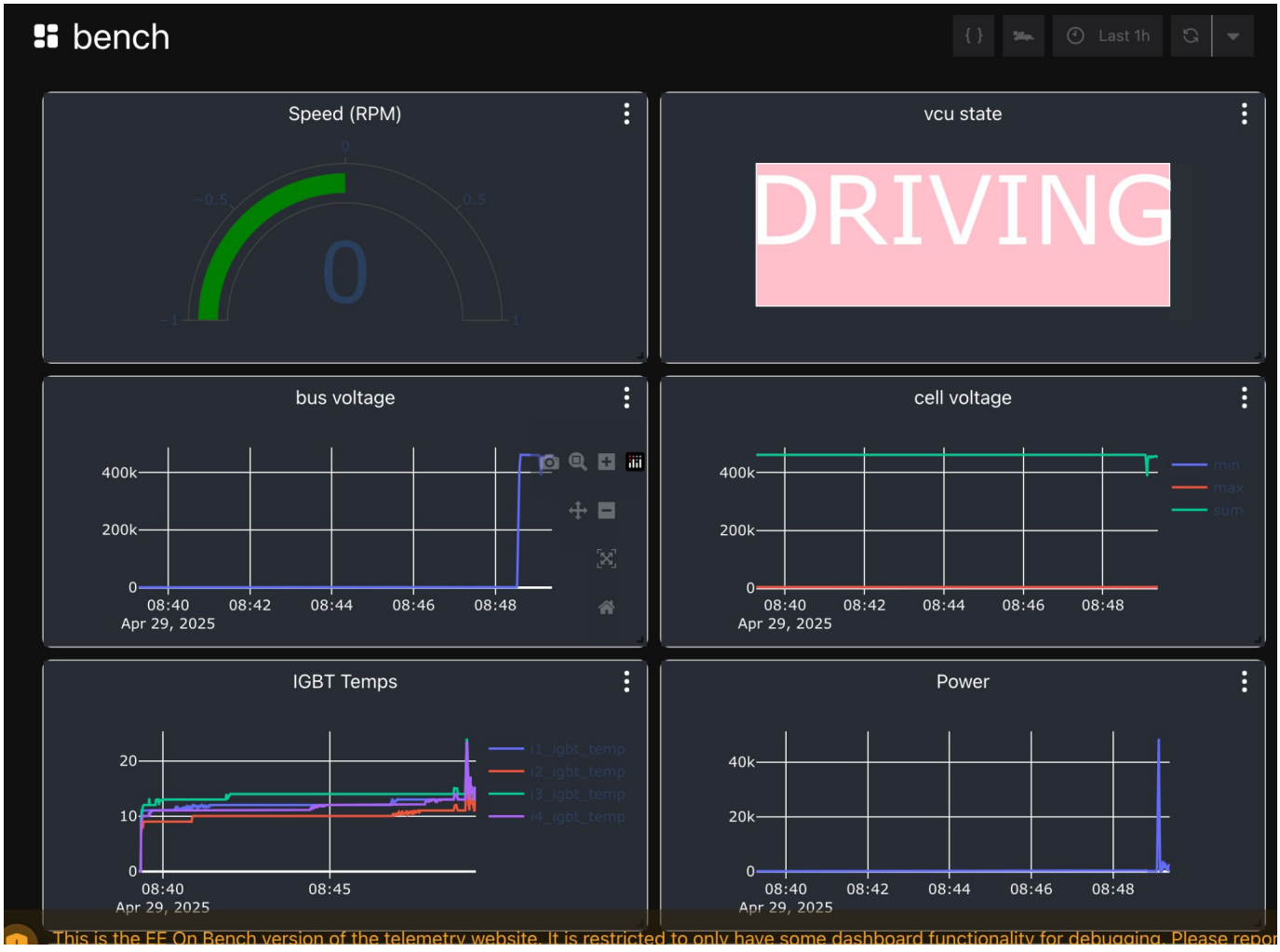
Go/no go dates, build gates

- Boron CF battery box

Testing and Validation

Over 200km run:

- 5 Representative Endurances
  - Live telemetry to monitor temperatures, speeds, and bus voltage throughout the run
- > 10 Accel Runs
- > 10 Skid Pad Runs
  - Sweeping suspension set up, controls tuning
- > 10 hours of autocross driver training



Resources

- Include here anything that you referenced in the slides
  - Research papers, articles, books, someone else's data, ect.