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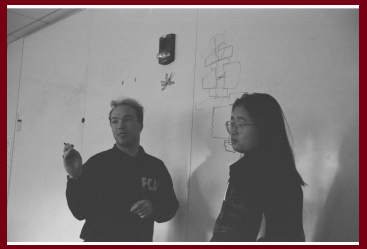
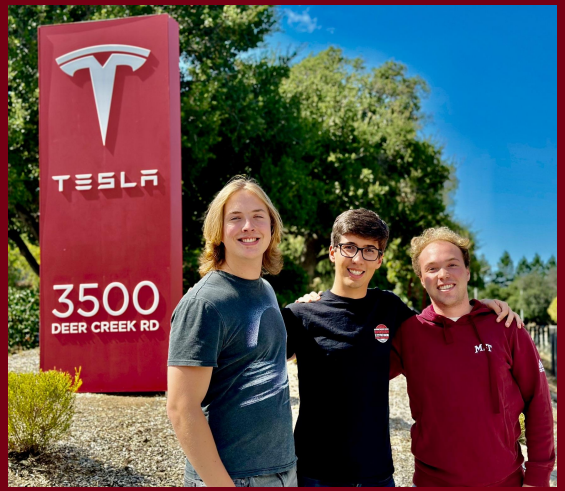
Aaron Becker - Background and Experience

Fall 2023





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Background, Portfolio & GitHub

Currently a junior at MIT, Mechanical Engineering major & CS minor.

https://ambecker.com
https://github.com/aaroexxt

Please visit my portfolio for additional background on my previous experiences and projects.
My GitHub has much of the source code and design files from projects, as well as the website itself!

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Previous Work Experience

Tesla Motors - 2022

Power Electronics Mechanical team - design of production-ready parts for PW3 assembly line

Thermal modelling and analysis for component validation in reflow

Powerwall 3 Team - Tesla's innovative Energy products

No additional publicly available pictures due to NDA

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Previous Work Experience

Rain Aerospace - 2020/2021

No additional publicly available pictures due to NDA

Design and implementation of practical avionics for flight vehicle in 6 weeks. Ground & vibration test campaign completed during internship

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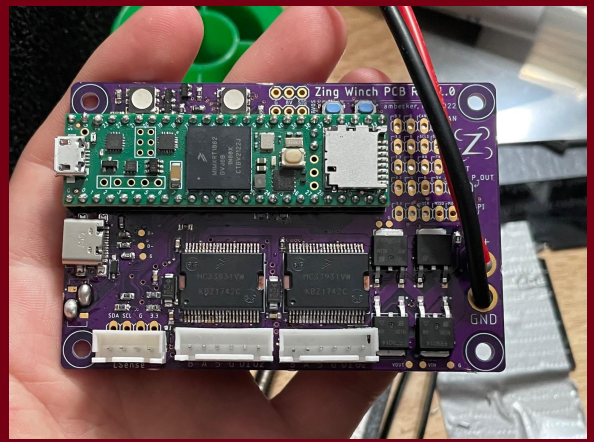
Previous Work Experience

Zing Drones - 2021

Initial design of drone delivery system

Thermal model for motors

Remote activation, custom PCB




```
//Motor parameters, from Pololu
//TODO update these for 10:1 motor and test again on drone
mParams_s mParams = {
  .ratedVoltage = 12.0, //V
  .noLoadRPM = 1600.0, //RPM
  .noLoadCurrent = 200.0, //mA
  .stallTorque = 3.0, //kg-cm
  .stallCurrent = 5500.0, //mA
  .mass = 0.19, //kg
  .gearRatio = 6.3 //ratio
};

//Slope of torque vs current
float torqueVsCurrentSlope = (mParams.stallTorque*0.0980665)/mParams.stallCurrent; //torque (N/m) per current (mA)

//Current at high side of motor driver, mA
#define DRIVER_SENSE_CURRENT_POINTS 6
float DRIVER_SENSE_CURRENT_MOTOR[6] = {
  0.0,
  300.0,
  500.0,
  1500.0,
  3000.0,
  6000.0
};

//Current at measure resistor, mA
float DRIVER_SENSE_CURRENT_MEASURE[ ] = {
  0.05,
  0.75,
  1.56,
  4.28,
  8.57,
  17.15
};
```

No additional publicly available pictures due to NDA

```
***
or efficiency and simple thermal model calculation
er in = I*V (current * voltage)
er out = T*w (torque * angular velocity)

 = Pout + Pthermal
we know thermal power, we can estimate motor temperature in the following way.

les in = Pthermal * time
or temp = (Joules in / (mass * specific heat capacity)) + initial temp
**/

at motor_powerIN = (motor_current / 1000.0) * supplyVoltageAverage;
at motor_powerOUT = (motor_torque * motor_angularVelocity);

at motor_powerThermal = motor_powerIN - motor_powerOUT;
(motor_powerThermal < 0) {
otor_powerThermal = 0;


at dt = (millis() - lastThermalSampleTime) / 1000.0;
at deltaTempPowerLoss = (motor_powerThermal * dt) / (COPPER_MASS_KG * COPPER_SPECIFIC_HEAT_CAPACITY);

at deltaTempNewton = -NEWTON_COOLING_CONSTANT * (motorTemp - TEMP_AMBIENT_CELSIUS) * dt;

orTemp += deltaTempPowerLoss;
orTemp += deltaTempNewton;

(motorTemp >= (MOTOR_ALARM_TEMP*MOTOR_ALARM_DERATING_FACTOR)) {
LAG_motor_alarm = true;
//Disable motor controllers
igitalWrite(MOTOR_1_EN_PIN, LOW);
igitalWrite(MOTOR_2_EN_PIN, LOW);
lse if (FLAG_motor_alarm && motorTemp < (MOTOR_ALARM_TEMP*MOTOR_ALARM_DERATING_FACTOR)-MOTOR_REENABLE_TEMP_DROP_BELOW_THRESHOLD
LAG_motor_alarm = false;
//Enable motor controllers
igitalWrite(MOTOR_1_EN_PIN, HIGH);
igitalWrite(MOTOR_2_EN_PIN, HIGH);
```

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Personal Projects - Summary

Multidisciplinary engineer with background in mechanical, electrical engineering and systems integration

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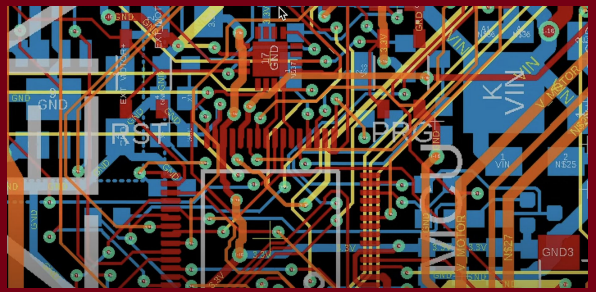
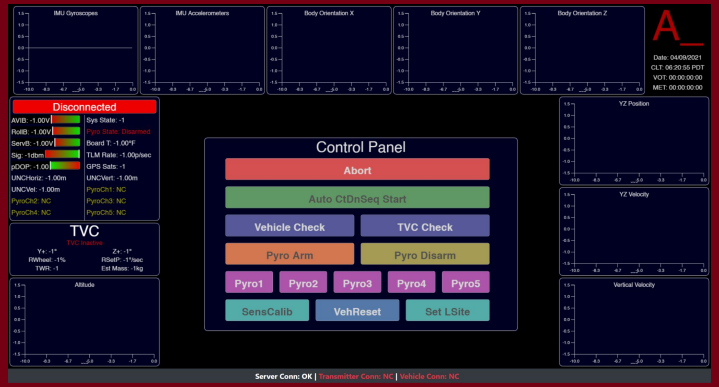
Personal Project Focus - ZENITH

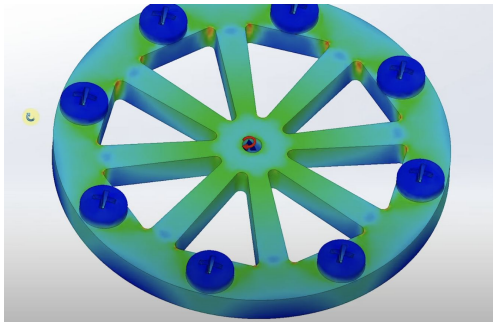
Thrust Vector Control at the model scale; design and development of guidance computer, thrust vector control mount



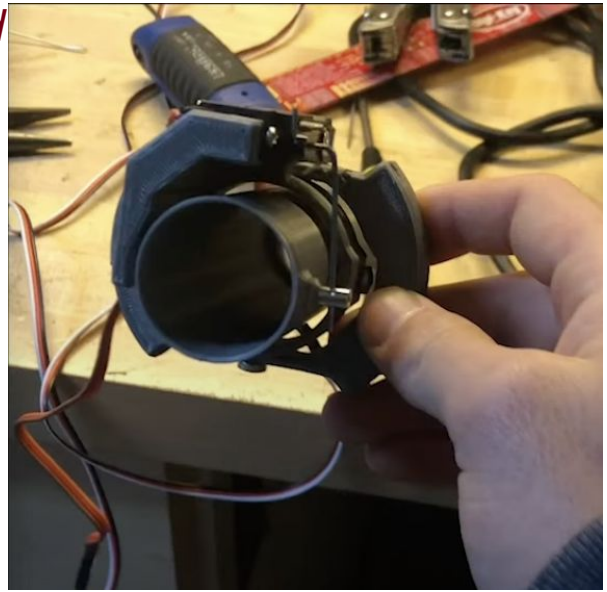


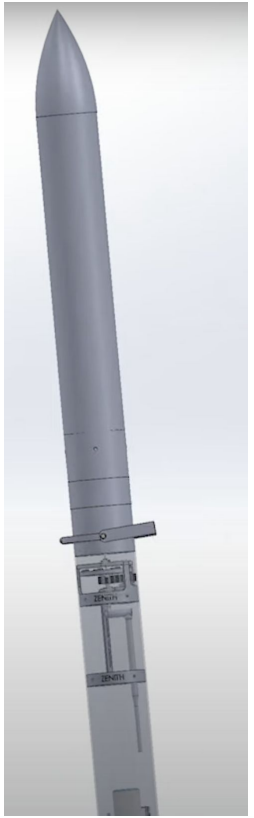
Personal Project Focus - ZENITH 2

Mechanical and Electrical Focus, with strong software background - Kalman recursive state estimation

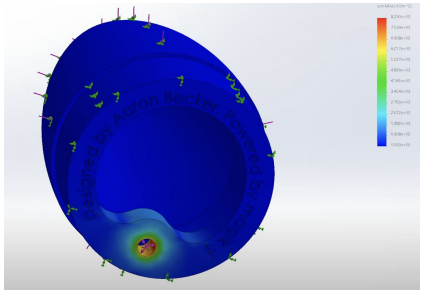


Roll flywheel and motor controller integrated



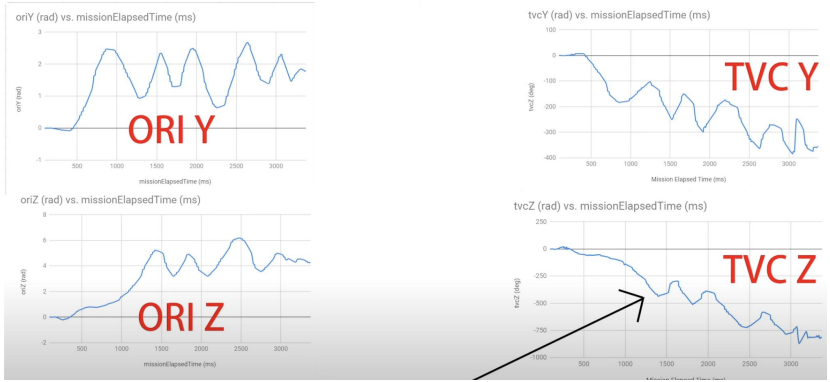


FEM performed on custom nosecone for tear-out of threads

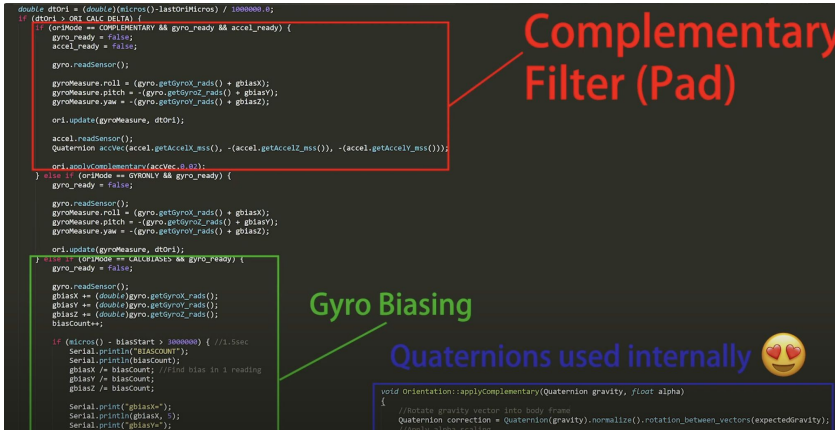


Personal Project Focus - ZENITH 3

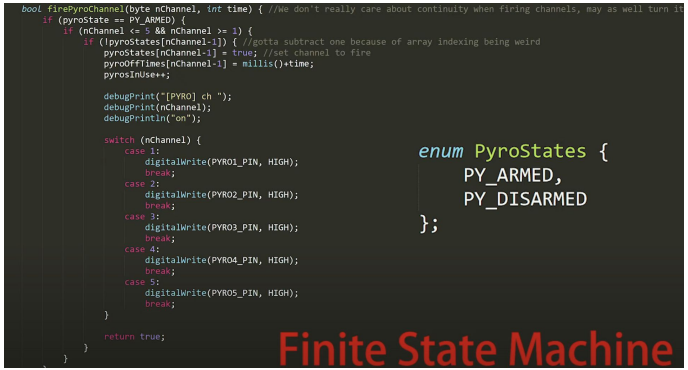
Software and background - C++



Datalogging for debugging and optimization of control parameters



Complementary filter for accel/gyro fusion in flight
Kalman state estimator to fuse GPS and inertial data



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FSAE

Practical, hands-on design experience - CAD, FEM, bolted joint analysis, statics, vibration and structures
Read on!

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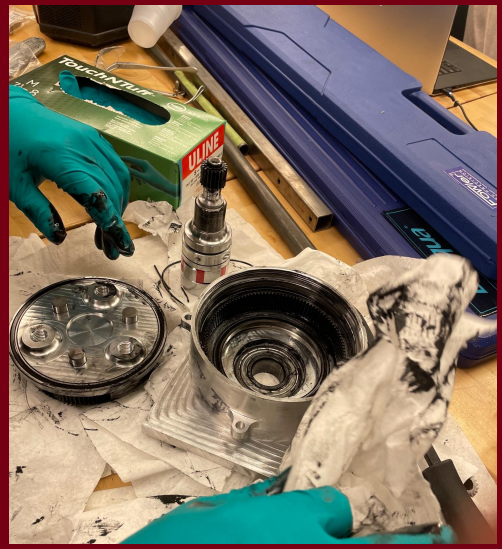
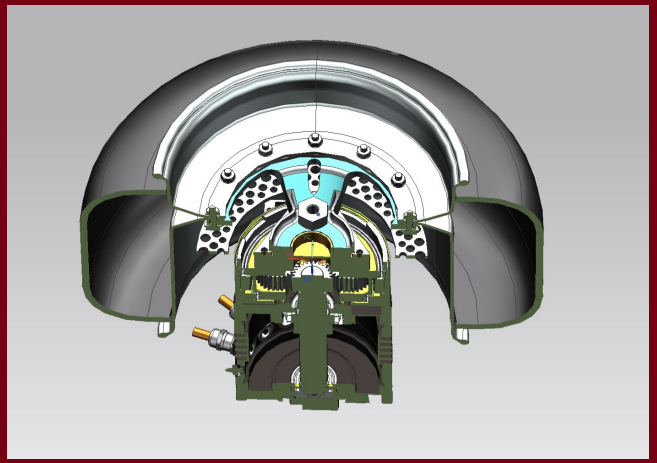
FSAE - Years

2023 - Powertrain Lead
2022 - Front Powertrain Team
2021 - Brakes and Mechanical Team





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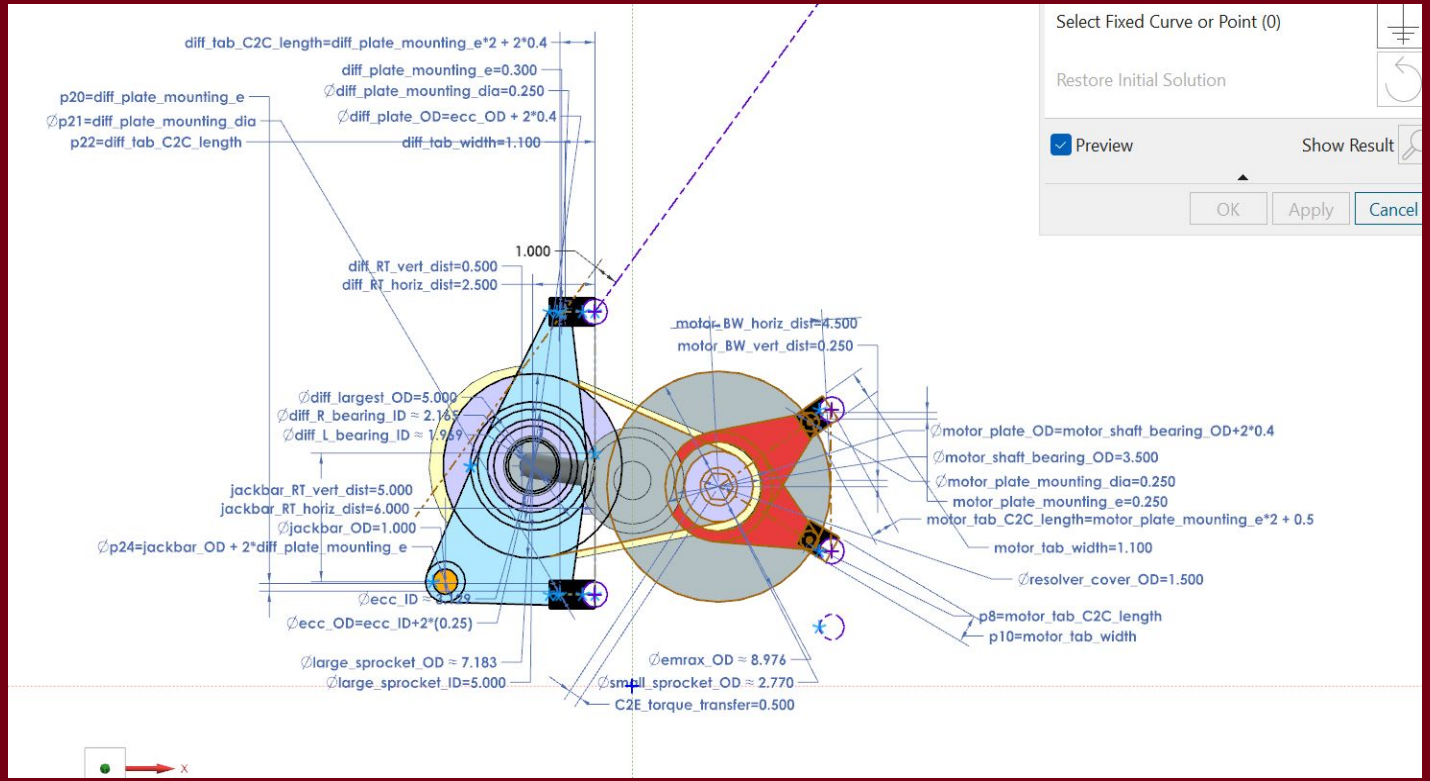
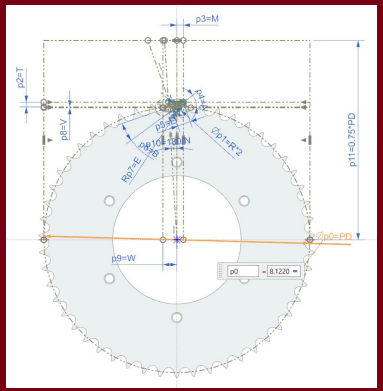
FSAE - CAD (NX)



Parametric CAD in Siemens NX - same software SpaceX uses I believe

Spreadsheet-driven dimensions



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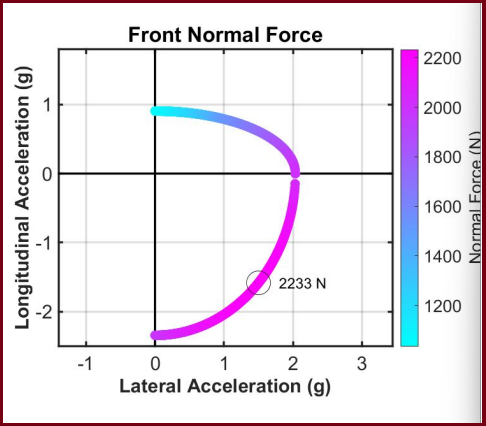
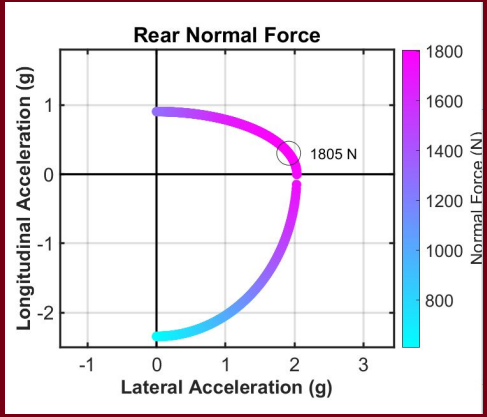
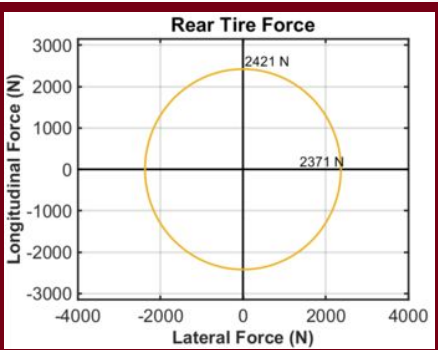
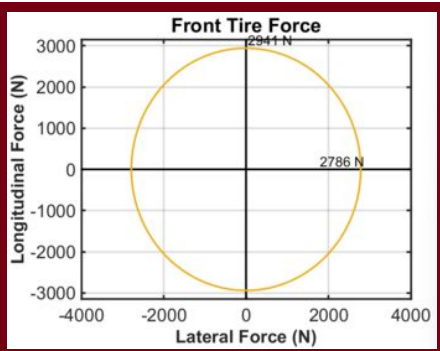
FSAE - Sizing

(credit: Claudius Tewari, Jeremy Noel, Rebecca McCabe, myself)









Force per tire derived from simulation data validated against previous cars

*Yields **nominal contact patch** loading*

Nominal Contact Patch Loading

X = Long Y = Lat Z = Norm	Front	Rear
X +	0.0 kN	2.0 kN
X -	2.0 kN	1.8 kN
Y +	3.3 kN	3.4 kN
Y -	3.3 kN	3.4 kN
Z +	2.3 kN	2.3 kN
Z -	0.5 kN	0.9 kN
M_y +	425 Nm	205 Nm

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FSAE - Spreadsheet Design (credit: Hezekiah Pendley, myself)

Assuming SAE Grade 8

Office Online Frame

Inputs:

Value Name:	Value:	Units	Value	Units
Tensile Strength:	1034	[Mpa]	1034000000	[Pa]
Shear Strength:	620.4	[Mpa]	620400000	[Pa]
Factor of Safety:	1.5	n/a		

General Car Forces

	Rear				Front			
Force Name:	Value	Units	Value	Units	Value	Units	Value	Units
Max Lateral(+/-)	3.4	[kN]	3400	[N]	3.3	[kN]	3300	[N]
Max Longitudinal	2	[kN]	2000	[N]	2	[kN]	2000	[N]
??	-1.8	[kN]	-1800	[N]				
Max Normal	2.3	[kN]	2300	[N]	2.3	[kN]	2300	[N]
Max Bump	3	[kN]	3000	[N]	3	[kN]	3000	[N]

Input Forces

Symbol	Value	Units	Descr.	Source
Fr_T_Brake	425	Nm	Front Brake Moment (M_y+)	Sam
Re_T_Brake	205	Nm	Rear Brake Moment (M_y+)	Sam
T_Tie_Rod	100	Nm	Tie Rod Moment (M_y+)	Suspension
T_UBJ	x	Nm	Upper Ball Joint Moment (M_y+)	Suspension
T_LBJ	x	Nm	Lower Ball Joint Moment (M_y+)	Suspension

7075-T6 Material Inputs

Symbol	Value	Units	Converted Val.	Units2	Description	Source
T_Yield	58	ksi	399910000	Pa	Tension Yield	MMPDS
S_Yield	36	ksi	248220000	Pa	Shear Yield	MMPDS
Br_Yield (e	114	ksi	786030000	Pa	Bearing Yield	MMPDS
FoS	1.5	n/a	1.50	n/a	Factor of Safety	Powertrain

Derived Forces

Symbol	Value	Units	Descr.	Source
FF_Caliper	1257.83	N	Force at the Front Brake Caliper	Derived
FR_Caliper	2578.55	N	Force at the Rear Brake Caliper	Derived
F_Tie_Rod	1238.44	N	Force at Tie Rod	Derived
F_UBJ	x	N	Force at Upper Ball Joint	Derived
F_LBJ	x	N	Force at Lower Ball Joint	Derived

Dimensions

Symbol	Value	Units	Value	Units	Description	Source
Bolt_CR	3.13	in	0.0795	m	Caliper Bolt Circle Radius	CAD
Bolt_OD	0.3125	in	0.00794	m	Caliper Bolt Outer Diameter	CAD
C_Tab_t	0.2	in	0.00508	m	Caliper Tab Thickness	CAD
Tab_OD	0.625	in	0.0159	m	Caliper Tab Outer Diameter	CAD
TR_Dist	3.179	in	0.08075	m	Tie Rod Distance	CAD
TR_Bolt_C	0.1875	in	0.004763	m	Tie Rod Bolt Outer Diameter	CAD
TR_Tab_t	0.1	in	0.00254	m	Tie Rod Tab Thickness	CAD
TR_Tab_O	0.375	in	0.009525	m	Tie Rod Outer Diameter	CAD

Margins

Margins	Failure Mode	Component	Feature
3.632072625	Tearout	Front Upright	Toe Tie Rod
8.264145249	Tension	Front Upright	Toe Tie Rod
6.645987924	Bearing	Front Upright	Toe Tie Rod
4.187221939	Tearout	Rear Upright	Toe Tie Rod
9.374443878	Tension	Rear Upright	Toe Tie Rod
7.562352001	Bearing	Rear Upright	Toe Tie Rod
2.22411535	Tearout	Rear Upright	UBJ
4.504587183	Tension	Rear Upright	UBJ
17.87287034	Bearing	Rear Upright	UBJ
1.660969869	Tearout	Rear Upright	Camber bracket upright attachment
3.543119289	Tension	Rear Upright	Camber bracket upright attachment
11.82977726	Bearing	Rear Upright	Camber bracket upright attachment

*Material allowables from **MMPDS-20**, formulae derived from **Shigley's, Roark's, Machinery's Handbook***

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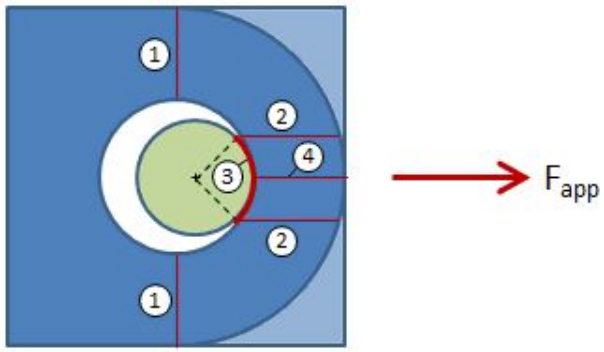
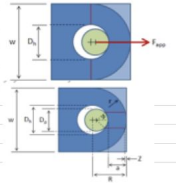
FSAE - Bolted Joint Analysis (credit: Hezekiah Pendley, myself)



Sizing done with Air Force method/first principles

1) *Tension failure across net section*
2) *Shear failure along two planes*
3) *Hoop tension failure*
4) *Out of plane buckling*

Shear Forces/Shear stresses			
Name of Output	Value	Units	Description/Note
Front Toe Rod			
Bearing failure:			
Min thickness:	0.20762523	mm	thickness of plate
	0.008174222	in	1.4316
Chosen Thickness	0.125	in	
	3.175	mm	
Tension failure:			
Lug OD	6.0810	mm	
	0.2394	in	
Shear Failure:			
Lug OD	6.9295	mm	
	0.2728	in	0.824
Chosen OD	0.8250	in	
	20.955	mm	
Rear Toe Rod			
Bearing failure:			
Min thickness:	0.185404664	mm	
	0.007299396	in	
Chosen Thickness	0.125	in	
	3.175	mm	
Tension failure:			
Lug OD	5.9902	mm	
	0.2358	in	
Shear Failure:			
Lug OD	6.7479	mm	
Lug OD	0.2657	in	
Chosen OD	0.8250	in	
	20.955	mm	



$$MoS = \frac{\sigma_Y}{FoS \cdot \sigma_{VM}} - 1$$

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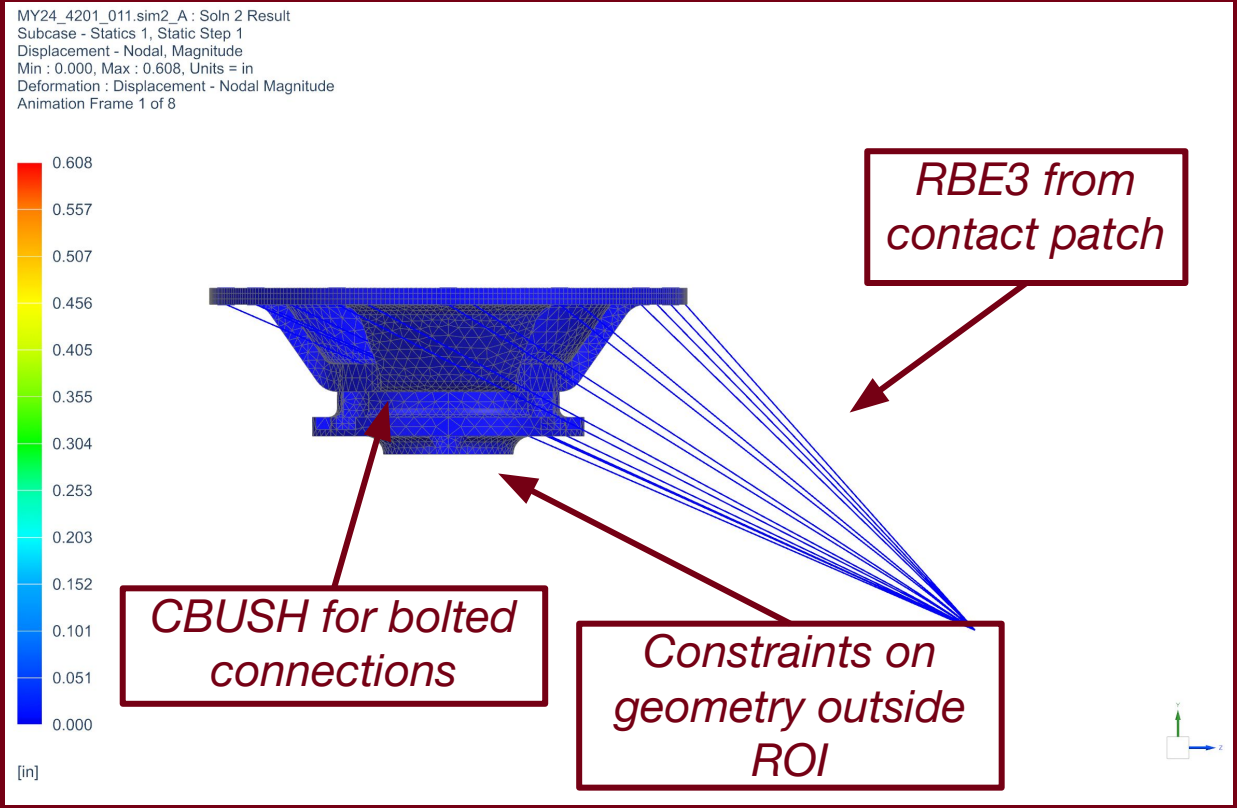
FSAE - FEM

(credit: Levi Gershon, Ander Jurs, myself)



Joint Parameters		
Max Preload	12,313	*lbf*
Nominal Preload	39,606	*N*
Minimum Preload	23,217	*N*
Assembly Axial Stiffness	301,871	N/mm
Bolt Axial Stiffness	378,804	N/mm
Grip Axial Stiffness	1,486,360	N/mm
Parallel Stiffness	1,865,164	N/mm
Huth Shear Stiffness	115,624	N/mm

*Bolt analysis done with **in-house calculator** that yields stiffnesses*
***RBE3** models forces from contact patch*
***CBUSH** elements used to model bolts (stiffness from calculator)*
***CHEXA** and standard tetrahedral elements to model geometry*

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FSAE - Bolt Analysis (credit: Levi Gershon)

*Bolt analysis done with **in-house calculator** that yields stiffnesses (shear and tensile) + margins*
Full bolt stackup modelled
Similar to SpaceX internal calculator?
Tool was not made by me, internal team resource - familiar with use

Inputs

Joint Overview	
Joint Type	Nut
Bolt Selection	Data Set
Nut Selection	Data Set

Limit Loads		
Tensile Force	5000	N
Shear Force	2000	N

Bolt Inputs		
Thread Type	Unified Fine	
Bolt Selection	5/16 - 24	
Bolt Diameter	0.313	in
Bolt Material	SAE Grade 8	
Bolt Pitch	24.00	tpi
Bolt Torque	272	in-lbf
Unthreaded Length	0.000	in
Effective Head Diameter	0.469	in

Joint Stackup			
Flange	*Thickness*	*Unit*	*Material*
1	0.065	mm	Aluminum 7075-T6
2	0.105	in	Steel 4130 Annealed
		in	

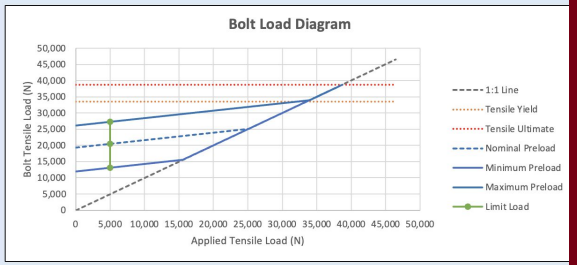
Nut Inputs		
Nut Grade	SAE Grade 8	
Nut Type	Regular / Distorted Thread	
Nut Height	0.266	in
Washer Height	0.063	in
N/A	0.500	in
Insert External Pitch	13.00	tpi
N/A	400	MPa
N/A	600	MPa

Generic Parameters		
Preload Uncertainty	35%	N/A
Lubricated	NO	N/A
Friction Carries Shear	NO	N/A
Edge to Diameter Ratio (E/D)	1.5	N/A

Outputs

Bolt Margins		
Bolt Combined	0.169	Yield
Bolt Combined	0.292	Ultimate
Bolt Tensile	0.244	Yield
Bolt Tensile	0.427	Ultimate
Bolt Shear	5.089	Yield
Bolt Shear	4.854	Ultimate
Bolt Thread Shear	0.165	Ultimate
Seperation Margin	1.160	N/A
Slip Margin	-0.609	N/A

Nut Margins		
Internal Thread Shear	0.633	Ultimate
N/A	N/A	Ultimate
N/A	N/A	Ultimate



Flange Specific Margins			
Failure Mode	*Margin*	*Flange Number*	Type
Shear Out	-0.916	1	Yield
Shear Out	-0.918	1	Ultimate
Frustum Bearing	0.304	2	Yield
Frustum Bearing	0.588	2	Ultimate
Pin Bearing	-0.891	1	Yield
Pin Bearing	-0.887	1	Ultimate
Hoop / Tension	-0.854	1	Yield
Hoop / Tension	-0.858	1	Ultimate

Joint Parameters		
Max Preload	5,883	lbf
Nominal Preload	19,372	N
Minimum Preload	11,948	N
Assembly Axial Stiffness	1,243,121	N/mm
Bolt Axial Stiffness	1,614,215	N/mm
Grip Axial Stiffness	5,407,436	N/mm
Parallel Stiffness	7,021,651	N/mm
Huth Shear Stiffness	4,284	N/mm

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FSAE - Tab Analysis (credit: Levi Gershon, Keiji Imai)

*Tab analysis done with **in-house calculator** that yields stresses (von mises - can compare to tensile allowable)*
Inputs are tab styles and geometry

Case Specific Loads

Tensile Load:	4000 N	See figure 2
Vertical Shear Load:	1500 N	See figure 2
Horizontal Shear Load:	200 N	See figure 2
Torsional Moment:	0 Nmm	See figure 2
Vertical Moment:	0 Nmm	See figure 2
Horizontal Moment:	0 Nmm	See figure 2

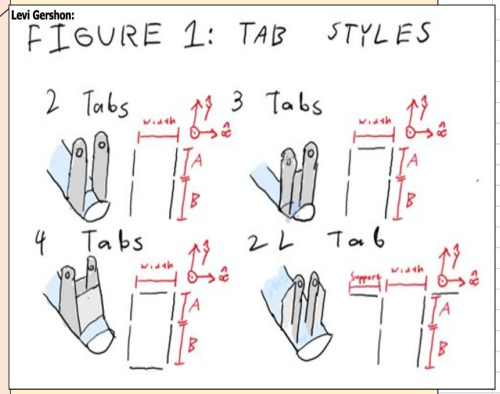
Geometry

Plate Thickness:	0.1 in	Sheet metal gauge used for tab
Length:	1.000 in	Distance from bolt center to tube
Width:	0.800 in	See figure 1
Height A:	0.500 in	See figure 1
Height B:	0.500 in	See figure 1
Support Width:	0.000 in	See figure 1, if 2L style
Tab End Diameter:	0.400 in	See figure 1
Bead Size:	0.049 in	Confirm with welder if changed

Material Parameters

Tab Tensile Yield:	360 MPa	4130 Steel Plate, MATWEB annealed
Tab Bearing, Yield:	619 MPa	Ratioed to the above, MMPDS for ratio, 2 E/D

Levi Gershon:

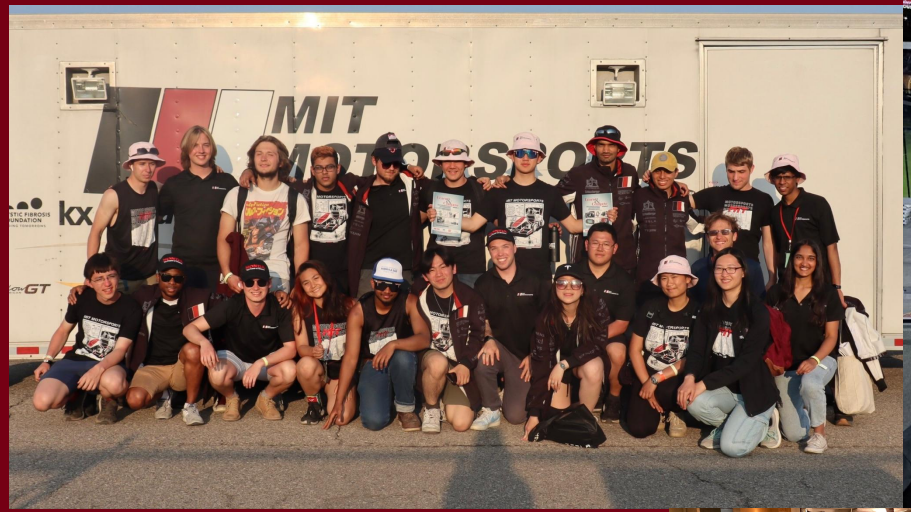


Outputs

Bolt Margins		
Beam Stress	152.93	*MPa*
Beam Von Mises	0.57	N/A
Weld Stress	307.88	*MPa*
Weld Von Mises	-0.15	N/A

Massachusetts Institute of Technology

Teams and Leadership



2023 - FSAE Hybrid / Michigan - Powertrain Lead

2021 - Flight Club

2019 - **FRC Robotics World Champions** - Mechanical Co-Lead

Thank you for viewing!
Please contact me at ambecker@mit.edu.