RIT Formula SAE Senior Design

Agenda

- Project Description
- Customer Needs
- Engineering Specifications
- Budget
- Risk Assessment
- Preliminary Testing Results
- Finalized Intake Design Details

Project Introduction

- As each competition passes, fuel efficiency and technical superiority becomes much more prevalent in competition scoring. To advance the RIT Formula SAE Racing Team in the engine subsystem, the variable intake system will prove to be innovative and technically competitive.

- Problem Statement: This senior design project will develop a variable intake system for the Formula SAE race car that will allow for increased fuel efficiency, design advancements and a greener methodology to produce more engine power.

Project Introduction

Project Scope:

1. Measure the fuel efficiency of the engine
2. Improve power and torque
3. Packaging the system with simplicity to allow for ease of installation and maintenance
4. Design and build for the non-professional, weekend and competition market

Work Breakdown

- FSAE Intake System
  - Project Manager
    - Scheduling (Kursten)
    - Meeting Planning (Kursten)
    - Documentation (Kursten)
  - Design Engineer
    - Final Intake Design (Dave)
    - Fluids/CFD Analysis (Dave)
  - Test Engineer
    - Design all Test Equipment (Matt)
    - Testing Schedule (Matt)
    - Testing and Tuning (Matt and Kursten)
  - Controls Engineer
    - Programming Motec (Dan)
    - Data Analysis of Motec Output (Dan)
  - Integration Engineer
    - Integrating intake into engine (Tom)
    - Wiring (Tom)

Customer Needs

Customer Need #	Importance	Description
		Volumetric Efficiency
CN1	4	Increased Air Inductance
		Fuel Efficiency
CN2	7	Optimized usage of race fuel
		Power/Torque
CN3	5	Increased HP Output
CN4	5	Increased Torque Output
		Drivability
CN5	6	Ease of length of change while driving
		Weight
CN6	3	No significant weight gain
		Reliability
CN7	7	Low maintenance
		Manufacturability
CN8	1	Simplistic
		Serviceability
CN9	2	Computer programming
CN10	2	Assembly
		Cost
CN11	0	Low cost

Importance: 10 = Highest Importance
0 = Lowest Importance

Specifications

Engr. Spec. #	Importance	Source	Specification (description)	Unit of Measure	Marginal Value	Ideal Value	Comments/Status
ES1	2	Weight	The overall weight of the system compared to non-adjustable	lbs	4.0	1.85	Current system 1.478 lbs
ES2	1	Performance	The reduction of lap times due to system performance	sec	1	2	Will vary depending on event
ES3	3	Fuel Economy	The impact this system has on fuel consumption	lbs/hr	0	-2	
ES4	7	anufacturing Tin	Time required to produce a working unit	days	20	10	
ES5	5	Current Draw	Current required by the system to operate	amps	5	1	
ES6	4	Actuation Time	Time required to change position	milliseconds	200	100	
ES8	5	Voltage Draw	Voltage required to produce a working system	volts	12	12	

Concept Screening

Concept Screening		
	2-Stroke	Infinitely
Selection Criteria		
Volumetric Efficiency		
Increased Air Inductance	+	+
Fuel Efficiency		
Optimized usage of race fuel	+	+
Power/Torque		
Increased HP Output	+	+
Increased Torque Output	+	+
Drivability		
Ease of length of change while driving	-	+
Weight		
No significant weight gain	0	0
Reliability		
Low maintenance	0	0
Manufacturability		
Simplistic	+	-
Serviceability		
Computer programming	+	-
Assembly	+	-
Cost		
Low cost	0	0
Sum +'s	7	5
Sum 0's	2	2
Sum -'s	1	3
Net Score	6	2
Rank	1	2

Based on the customer needs, the best intake system for the race car is the two-position as it allows for a greater number of benefits compared to an infinitely variable system given the time frame, tools and manufacturing capabilities available.

Budget

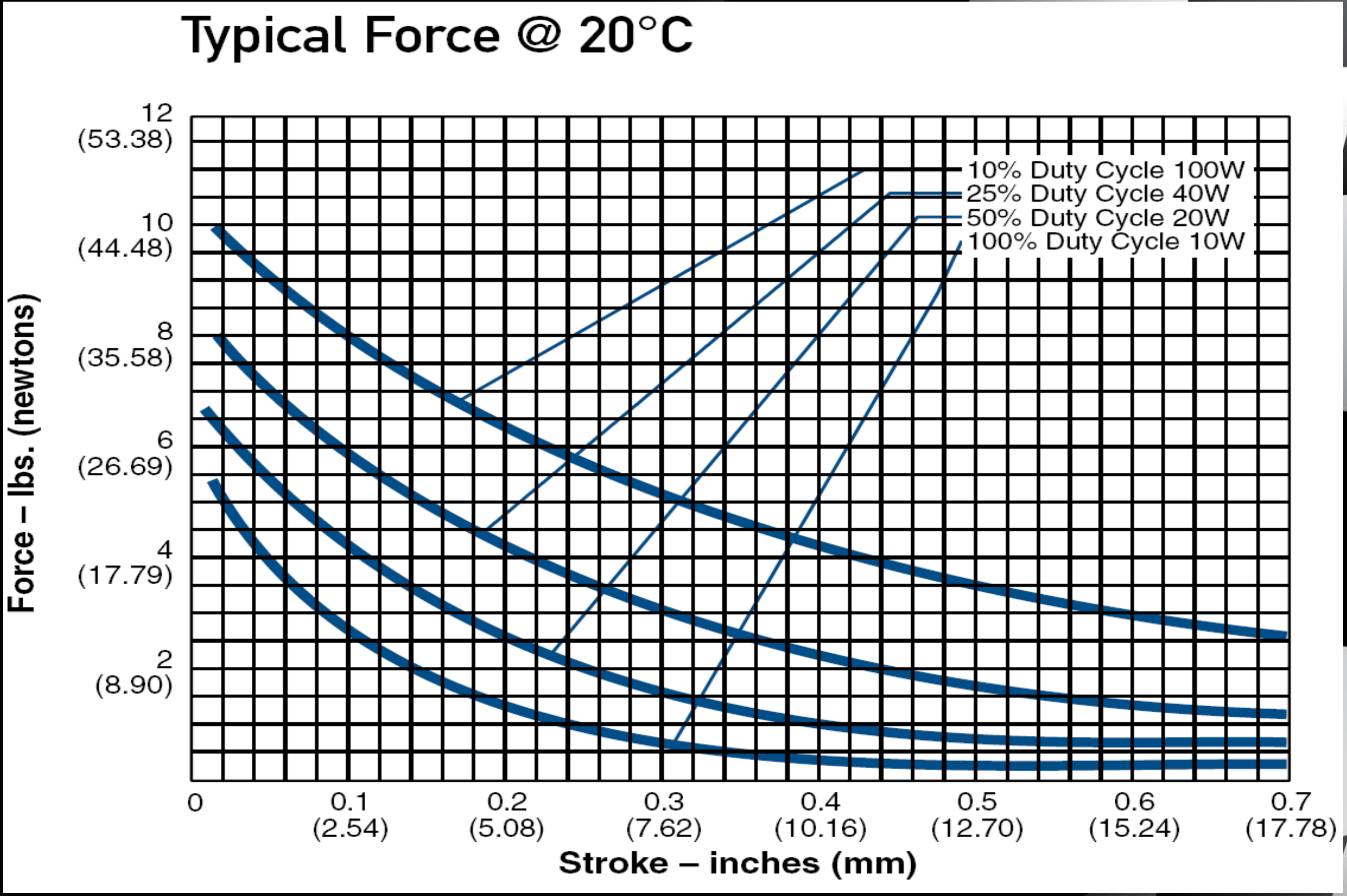
Product	Manufacturer	Part Number	Unit Price	Quantity	Total Price	Comments
			Testing and Verification			
Testing Materials						
93 Octane Fuel	-	-	$ 3.00	20	$ 60.00	gallons
100 Octane Fuel	-	-	$ 6.00	20	$ 120.00	gallons
Tires	Competition Tire East	D2696	$ 180.00	4	$ 720.00	Goodyear Tires
Miscellaneous Dyno Materials	-	-	-	-	-	
Thermocouples	Omega	KMQSS-062U-6	$ 26.00	8	$ 208.00	
			Manufacturing and Assembly			
Electric Actuation						
Electric Solenoid	Allied Electronics	Ledex 195204-230	$ 19.97	3	$ 59.91	2 for testing, 1 for manufacturing
Extension Spring	McMaster-Carr	9657K33	$ 6.86	1	$ 6.86	Package of 12
Pneumatic Actuation						
Three Way Solenoid	Skinner	3131BBN1EN00RRT1J1C1	$ 57.50	2	$ 115.00	Three Way Valve
Pneumatic Cylinder	Bimba	010.5-NRBNT	$ 20.15	2	$ 40.30	Single Acting .5" Stroke, non rotating, 7/16 bore
Pressure Regulator	Parker	14R110C	$ 18.99	1	$ 18.99	
System Materials						
Aluminum Plate	McMaster Carr	8975K439	$ 10.94	2	$ 21.88	Size: 0.25 x 6 x 12, for Base Flange
Aluminum Tube	McMaster Carr	89965K123	$ 18.18	1	$ 18.18	Size: 1.5 x 0.035 x 36, for Static Runners
Aluminum Sheet	McMaster Carr	89015K14	$ 12.63	1	$ 12.63	Size: 0.050 x 12 x 12, for Plenum Shell
Aluminum Sheet	McMaster Carr	89015K18	$ 26.29	1	$ 26.29	Size: 0.125 x 12 x 12, for Plenum Base
ABS Plastic Rod	McMaster Carr	8587K52	$ 57.57	1	$ 57.57	Size: 3 Round x 12, for Diverter
ABS Plastic Rod	McMaster Carr	8587K49	$ 22.53	2	$ 45.06	Size: 2 Round x 12, for Dynamic Runners
Miscellaneous System Materials						
Air Filter	K&N Filters	RU-0981	$ 29.99	1	$ 29.99	Size: 2 Round x 12, for Dynamic Runners
			Total		$ 1,391.26	
			Maximum Total		$ 1,500.00	
			Balance		$ 108.74	

(light purple)	Purchased
(orange)	To Be Purchased
(red)	To Be Returned

Risks

Please see handout for list

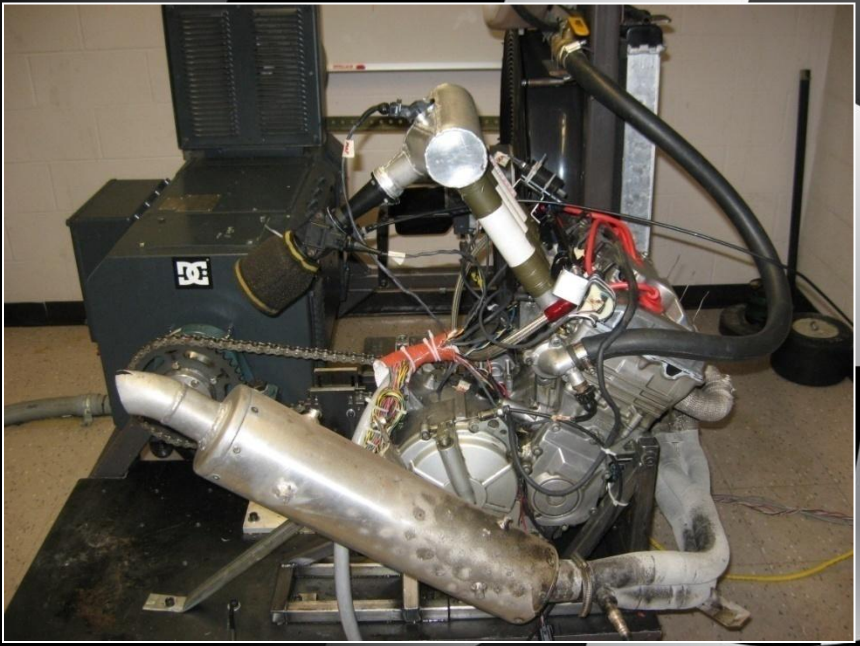
Solenoid Force Curve



Testing Equipment

Test Equipment available
Machine shop equipment
DC Dynamometer
Chassis Dynamometer
Honda CBR 600 test engine
RIT FSAE race car
Electronic test equipment
Computers

Test Equipment needed but not available
Advanced Vehicle based data acquisition system (DAQ)



Testing

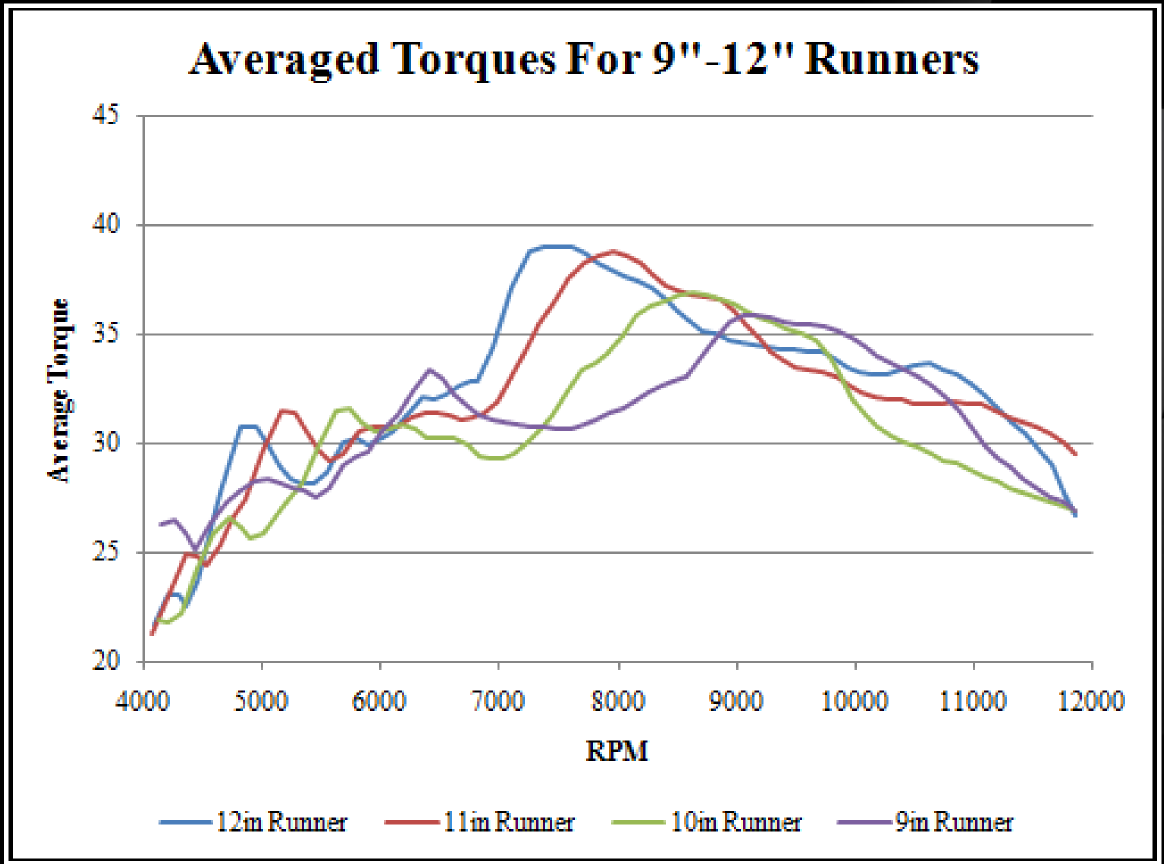
<u>Sub-System Breakdown</u>

- ***Mechanical System***
- The mechanical system is comprised of the sliding interface that allows the change in runner length and the plenum that the runners interact with. This system must allow for the desired change in length, not leak, maintain desired plenum volume, and comply with the FSAE rulebook.
- ***Actuation System***
- The actuation system will move the mechanical system based on inputs from the control system. Actuation speed is critical for this application as transient times must be kept under 100ms. This system must also be able to gauge the system's location.
- ***Control System***
- The controls for this system will be fully integrated into the engine control unit (ECU) for the vehicle. Using inputs such as RPM, throttle position, manifold pressure and current runner length the control system will output a desired runner length to be achieved by the actuation system.
- ***Supporting Systems***
- The variable intake will interface with the engine on one end and a throttle/ restrictor assembly on the other. Sufficient information on the flow characteristics of the throttle/ restrictor assembly will be needed to design and tune this system.
- The electrical requirements of the actuation system will be provided by the vehicle's stator. There is a limited amount of power available from this system, which must be taken into account.

Current Draw Analysis

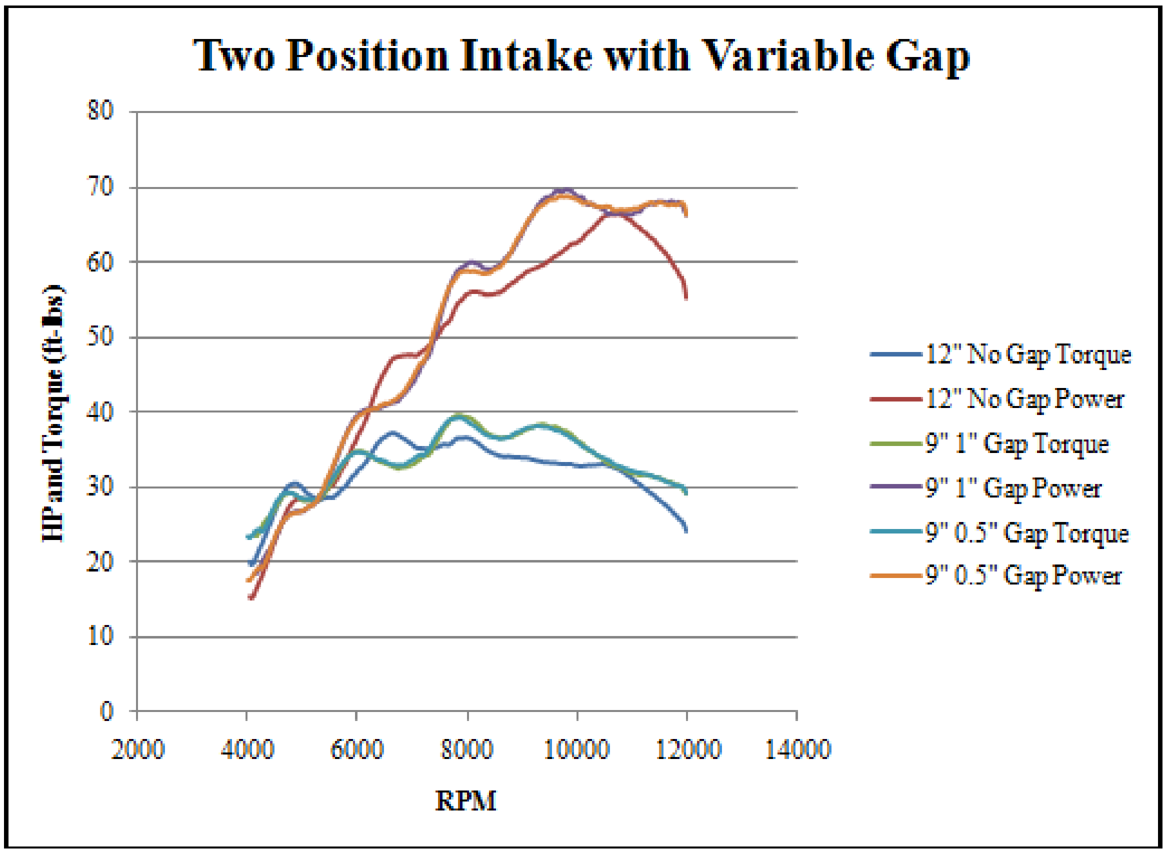
Component	Max Limits (A)	Duty Cycle	Average (A)
Motec and Sensors	2.5	1	2.5
MW Power	6	1	6
Dash	2	1	2
Brake Light	0.5	0.2	0.1
Fuel Pump	5.4	1	5.4
Fan	7.4	1	7.4
Shift Solenoids	0.5	0.2	0.1
TCMX	1	1	1
Wheel Speed Sensors	0.8	1	0.8
Intake Actuation System	**0.5**	**0.5**	**0.25**
Totals	26.6	7.9	25.55

Preliminary Testing Results



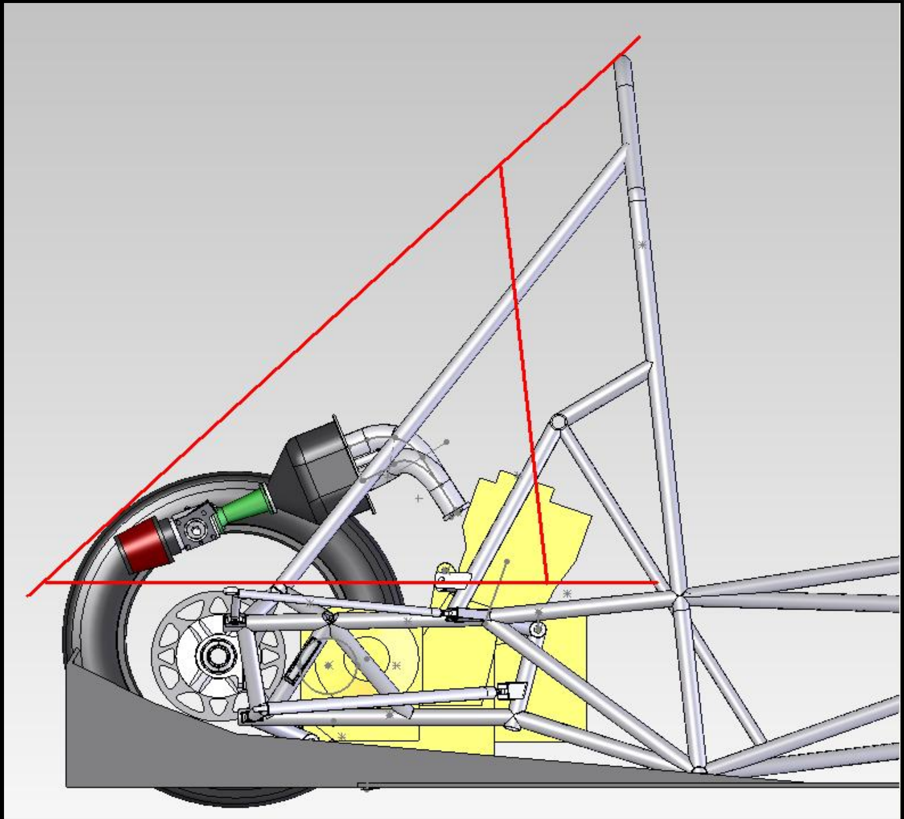
To find the runner lengths that achieved the best possible torque and horsepower, we modified a previous intake into our first prototype so that the runner length was adjustable. Testing was performed at inch increments from 6” through 12”. As you can see from the graph above, the best resulting lengths are 12”, 11” and 9”. Using this data, a second prototype was created.

Preliminary Testing Results



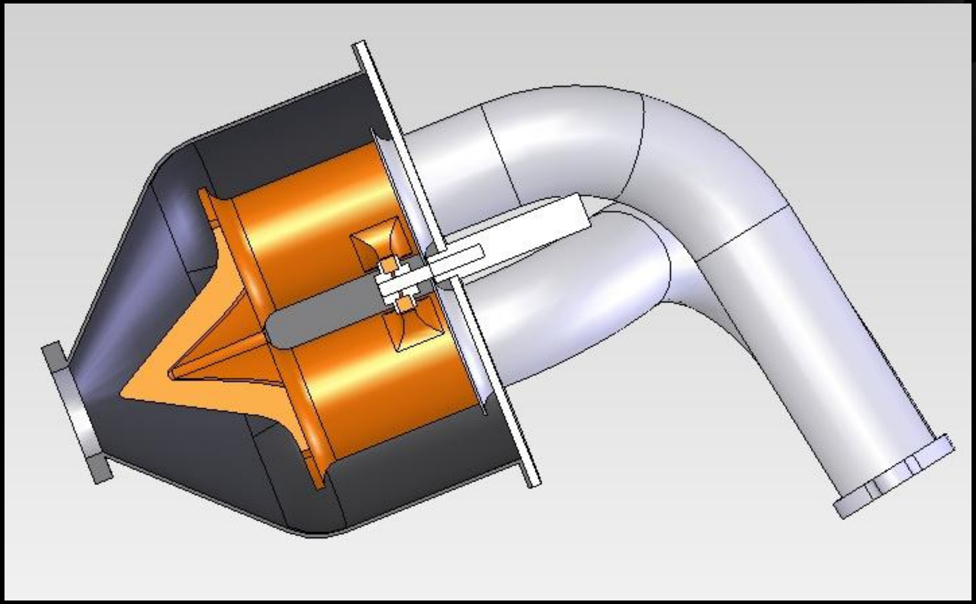
To mimic a two position system with the desired torque and horsepower peaks, we modified an existing plenum to fit the extending runners with an adjustable gap. When the intake was in long mode, the gap was closed and the total runner length was 12 inches. When the intake was in short mode, the gap was open and the total runner length was 9 inches. The open gap length was tested a multiple length in order to determine differences in yielding horsepower and torque. As a result, the optimal gap length to be used in the final design is 0.5 inches.

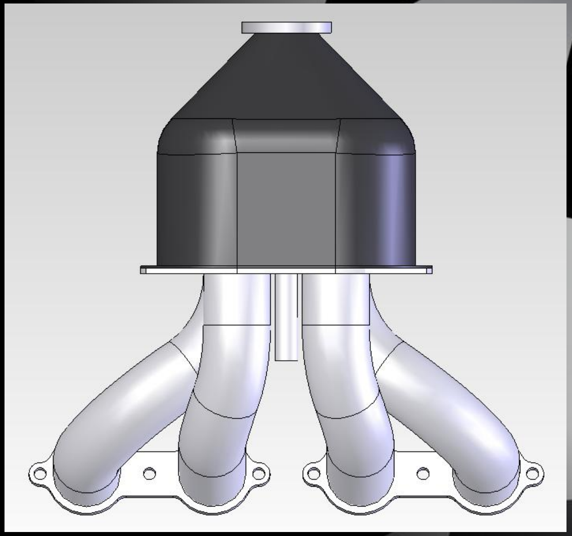
Finalized Intake Design



Packaging: The geometry of the chassis, as well as the governing rulebook, defines the packaging area for the intake system. The intake must lie within the area outlined below.

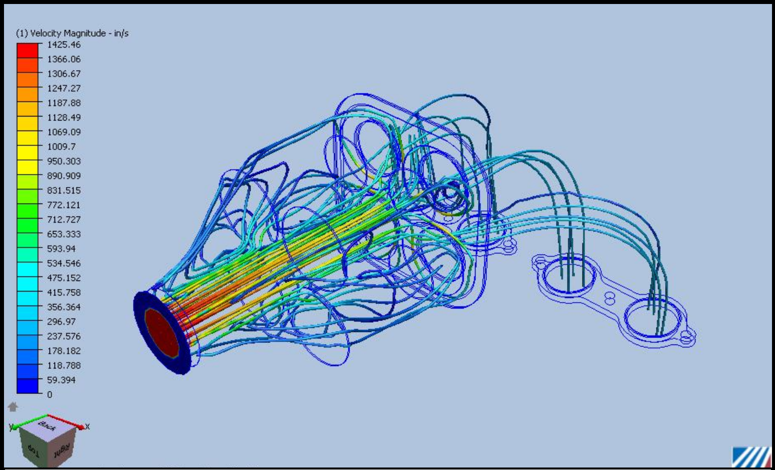
Finalized Intake Design



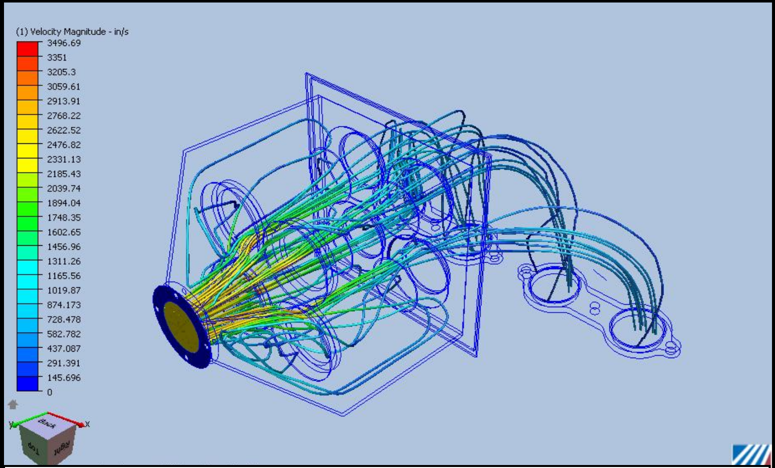


Finalized Intake Design

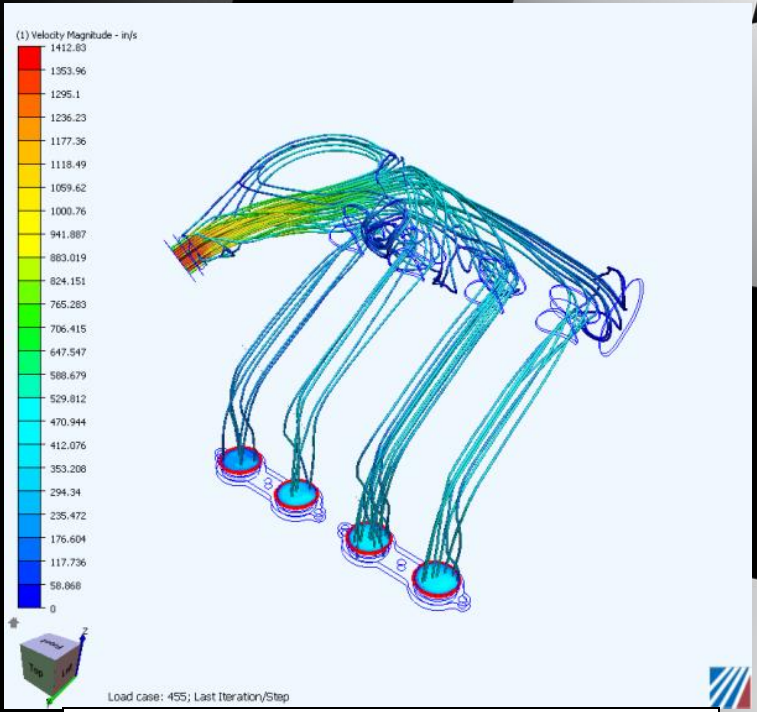
CFD Analysis



Intake System without Spike to Direct Flow into Runners

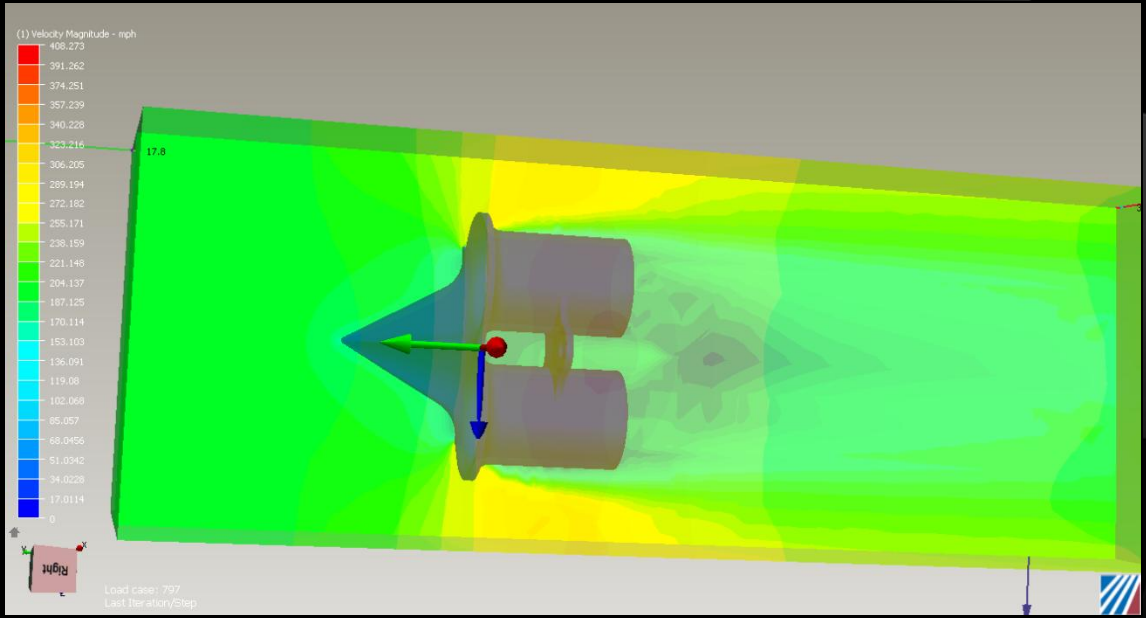


Intake System with Spike to Direct Flow into Runners

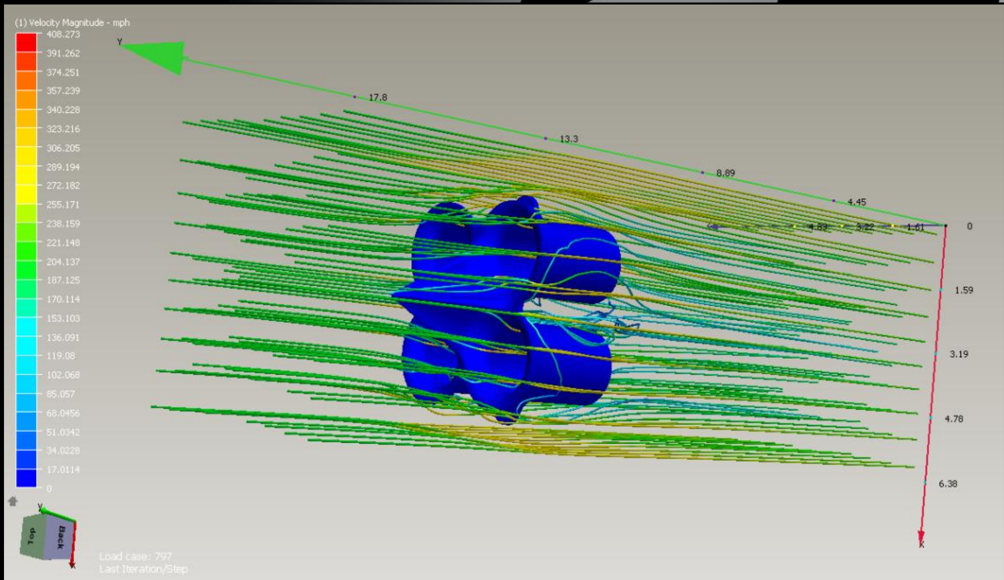


Previous Design

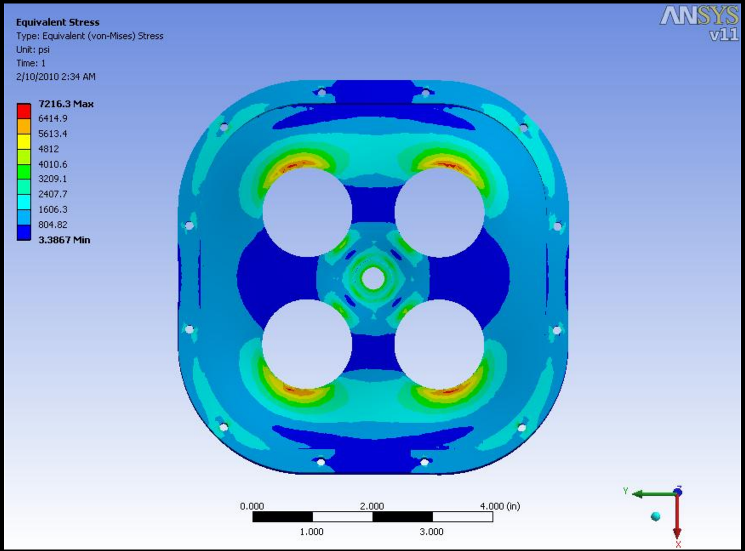
Finalized Intake Design

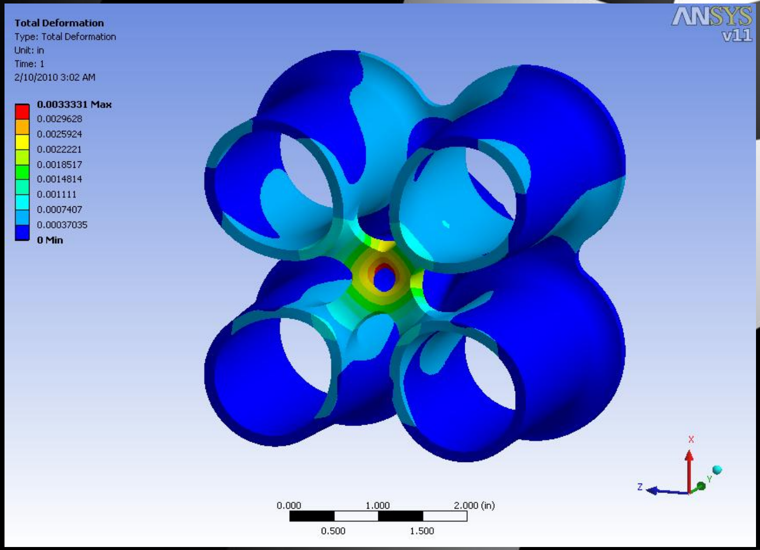


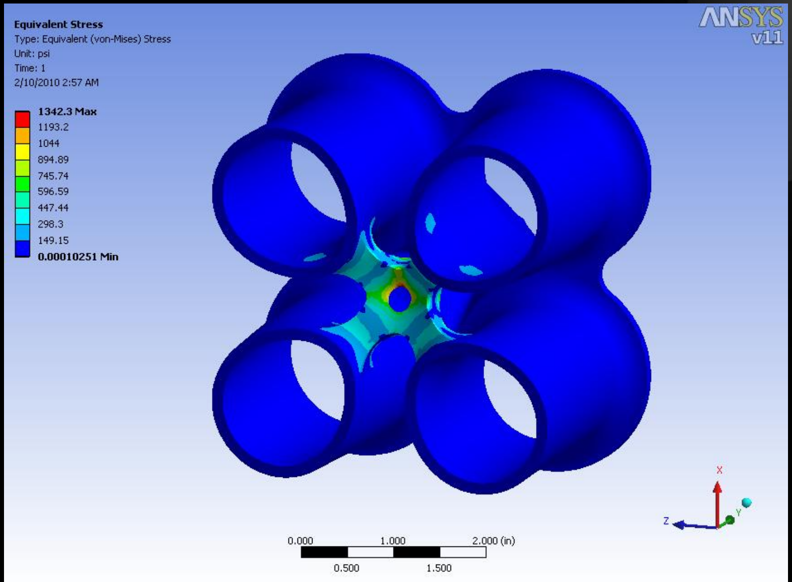
CFD Analysis



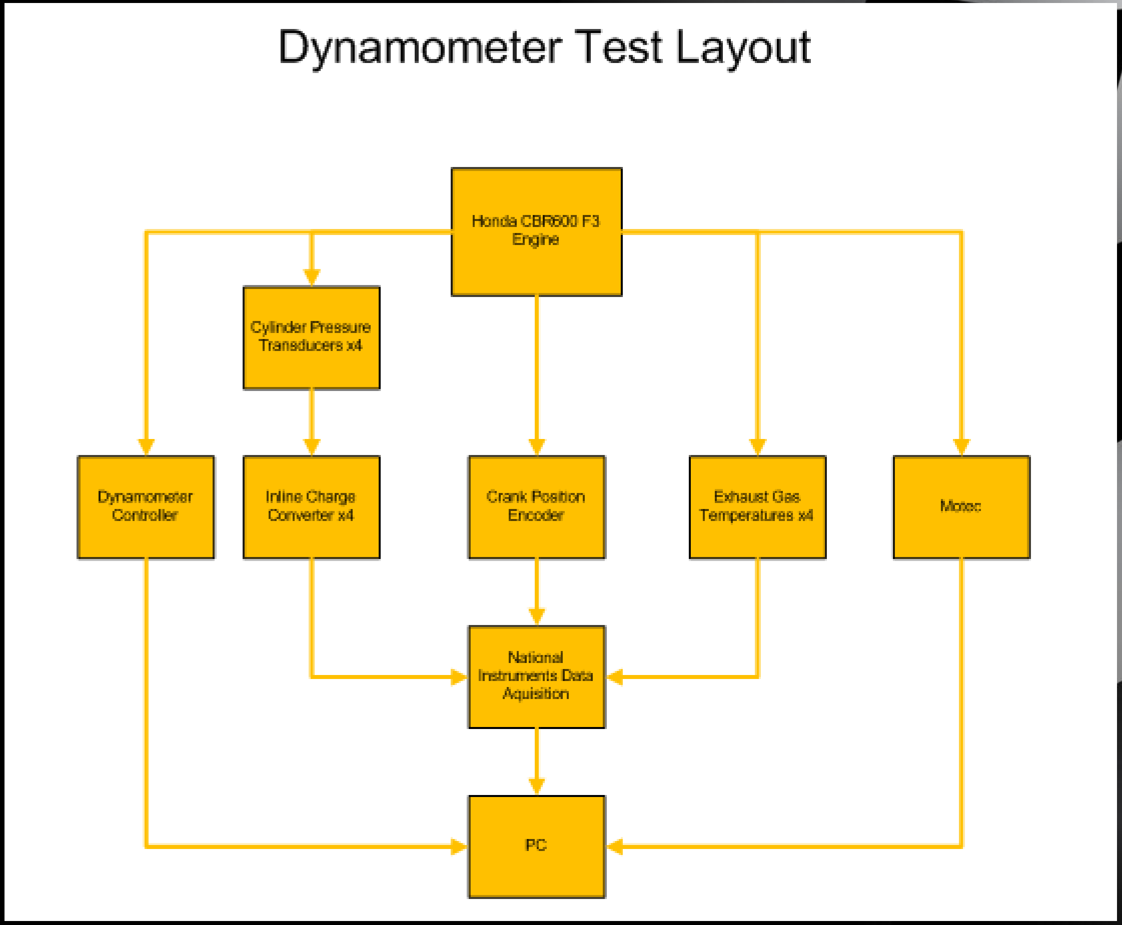
Finalized Intake Design



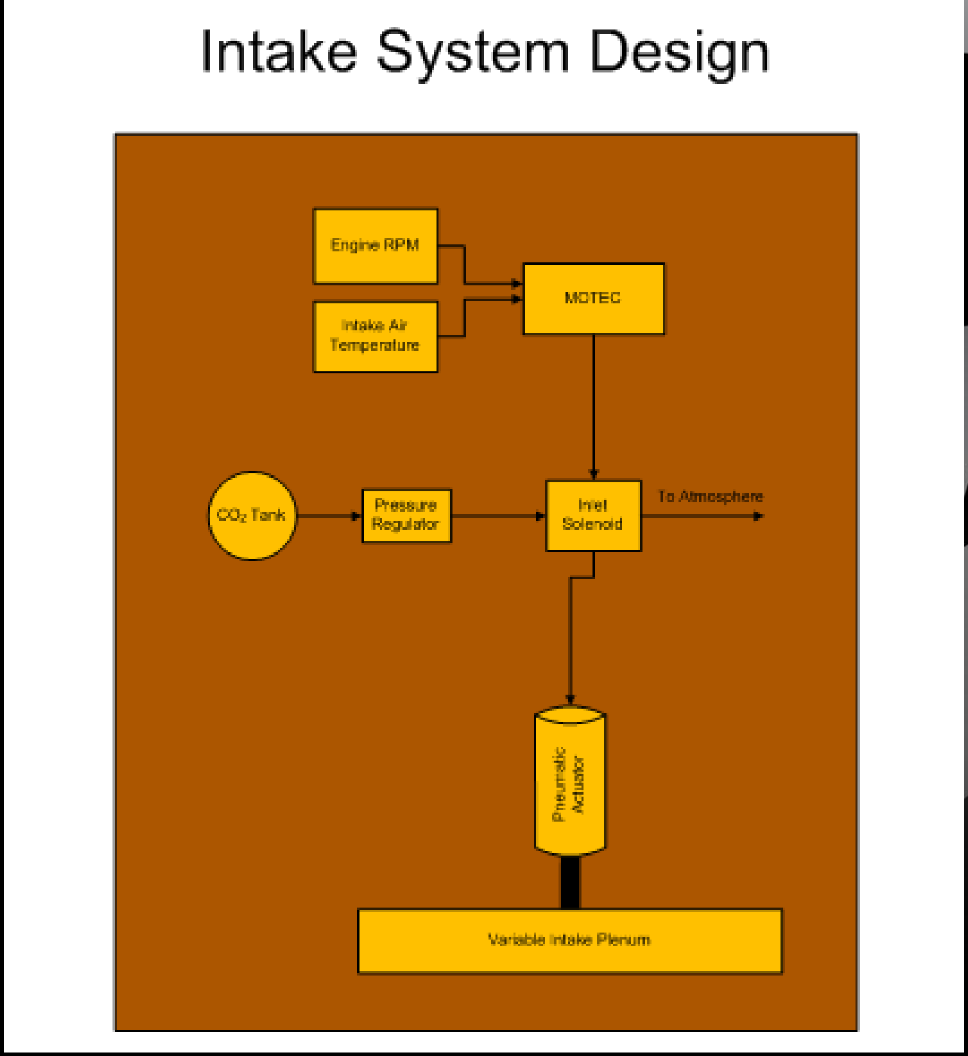




Electrical Integration and Assembly



Electrical Integration and Assembly



Intake Actuation Map

Aux Table 8

TP % \ RPM	0	8000	8250	8500	8750	9000	12000
100.0	0	0	0	0	50	100	100
90.0	0	0	0	0	50	100	100
80.0	0	0	0	0	50	100	100
70.0	0	0	0	0	50	100	100
60.0	0	0	0	0	50	100	100
50.0	0	0	0	0	50	100	100
40.0	0	0	0	0	50	100	100
30.0	0	0	0	0	50	100	100
20.0	0	0	0	0	50	100	100
10.0	0	0	0	0	50	100	100
0.0	0	0	0	0	50	100	100

Auxiliary Out 8 - Aux Table

Parameter	Value
PWM / Switched	1
Output Mode	0
Polarity	1
Frequency	10
Minimum Duty Cycle	0
Maximum Duty Cycle	100
Hysteresis	1

Hysteresis

Hysteresis when in Switched mode

The interpolated table value will affect the output as follows:

0 : Hysteresis Off

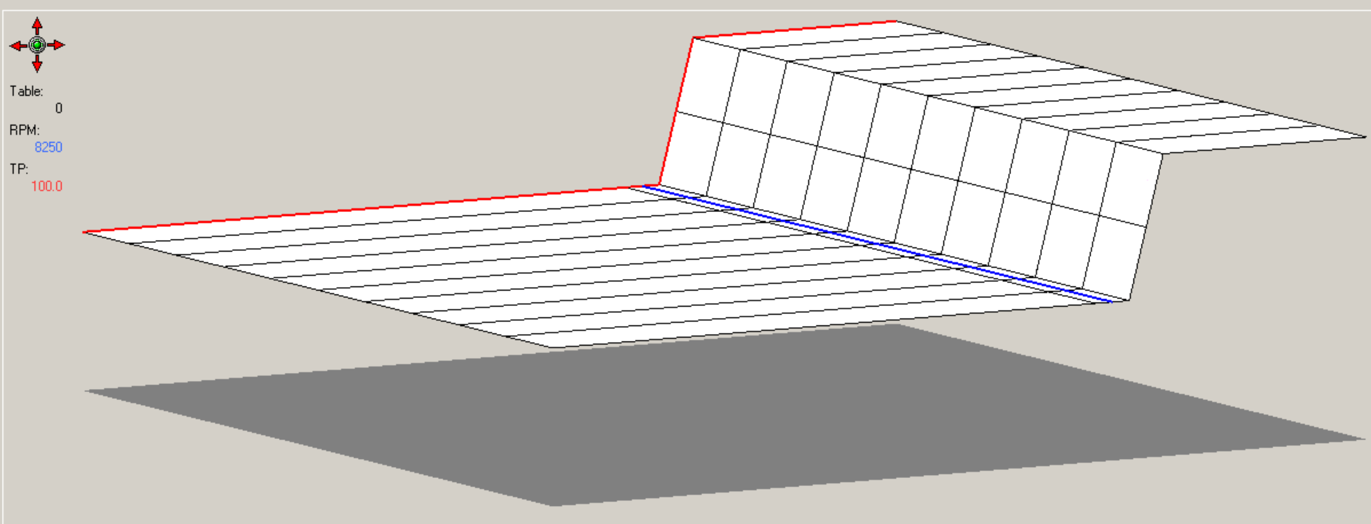
< 50 % : output off
>= 50% : output on

1 : Hysteresis On

0% (or less) : output off
100% (or more) : output on

Output is initially off if between 0 and 100%

Aux Out8 Duty Cycle (%)



Next Steps…Manufacturing

Rapid Prototyping

Composites

Aluminum

Next Steps…Dynamometer and Car Testing

Senior Design Team MSD II Tasks	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10
Finish Assembling Final Intake System										
Tune and Test Final Intake System on Dyno										
Integrate Intake System onto Race Car										
On Car Testing										
Prepare for Customer Review and Verification										
Work with Customer to Exemplify Final Intake Performance Capabilites										

Questions?