Department of
MECHANICAL ENGINEERING
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Formula SAE Active Aerodynamics

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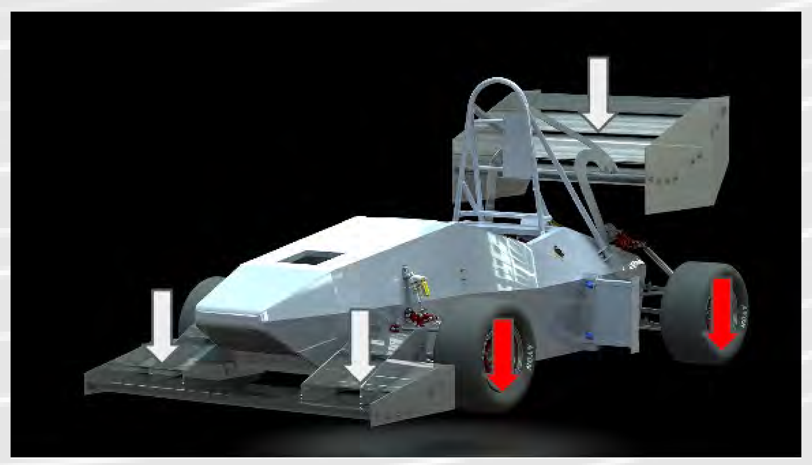
Introduction

Formula SAE is an international collegiate competition in which student teams are tasked to construct a small scale open wheel race car, which will compete against hundreds of other teams every summer. During this competition, a single second can separate dozens of teams.



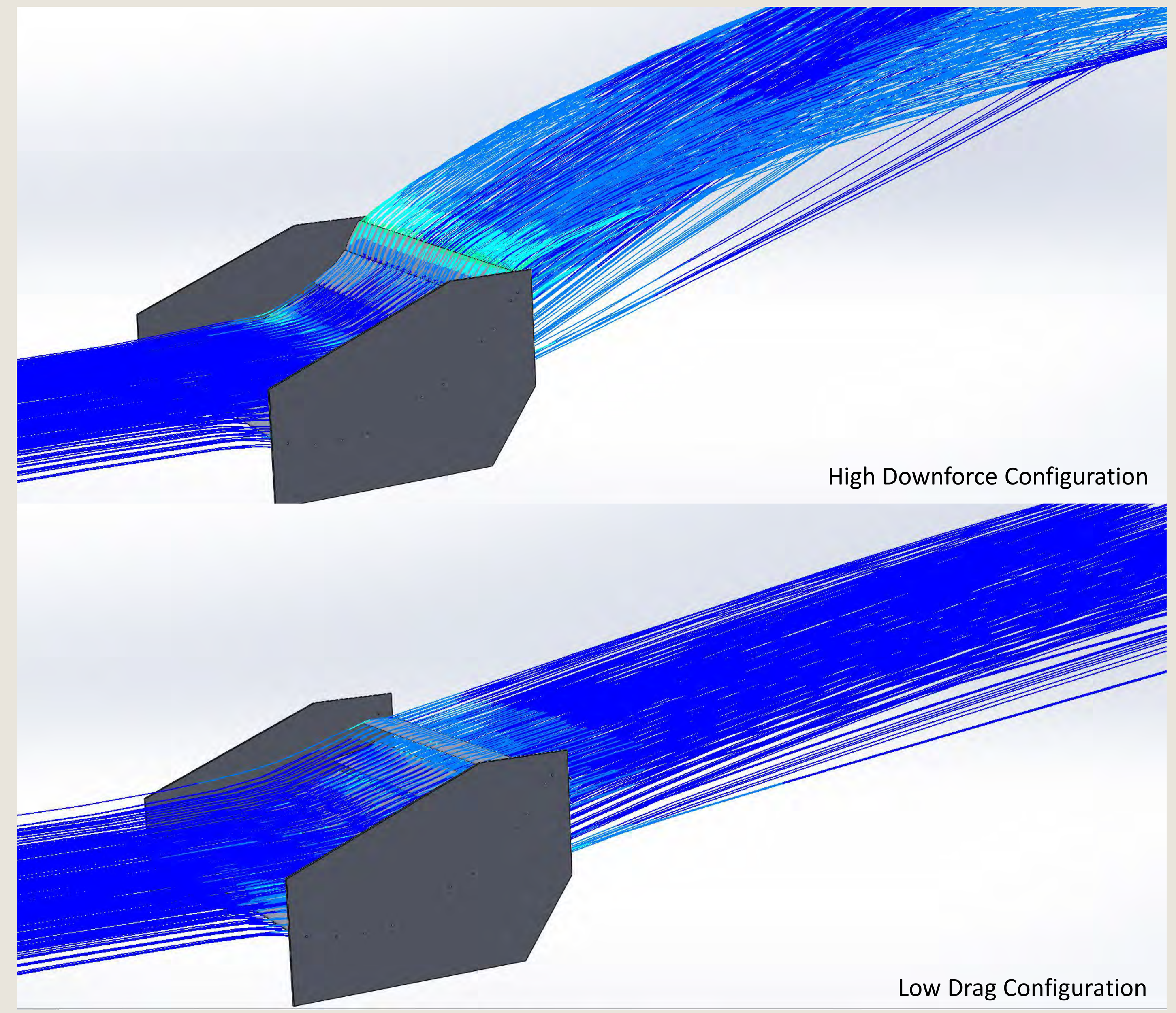
A well designed aerodynamics package that reduces the time it takes to complete a turn by just a fraction of a second can sum to this difference. By directing air upward, an aerodynamics package generates downforce on the car, pressing the tires into the ground and allowing the car to carry more speed into turns.

Problem Statement

This project addresses the problem of parasitic drag caused by fixed wings on the aerodynamics package. These wings provide desirable downforce during periods of limited traction (cornering and braking). However, they create unwanted drag during straight sections, reducing the top speed of the vehicle. By modifying the existing fixed wings and converting them into a set of powered adjustable flaps, the aero package is able to alter its geometry during the race. This provides an opportunity to change the forces produced by the aero package on-the-fly.

Design Metrics

#	Metric	Unit	Marginal Range	Ideal Value	Importance
1	Cornering ability	G-force	0.05 - 0.1	>0.1	5
3	Device weight	kg	<4	<3	5
4	Actuator power use	Watt	5-25	<20W	5
5	Total cost	$USD	300-500	<400	4
6	Minimum uptime	min	10-30	>30	4
7	Driver learning curve	min	1-5	1	4
8	Avg. maintenance time	min	<5	<1	3
9	Installation time	min	1-5	<1	3
10	Installation workers	people	1-3	<2	3
11	Aesthetic ranking	SUBJ	3-5	5	3

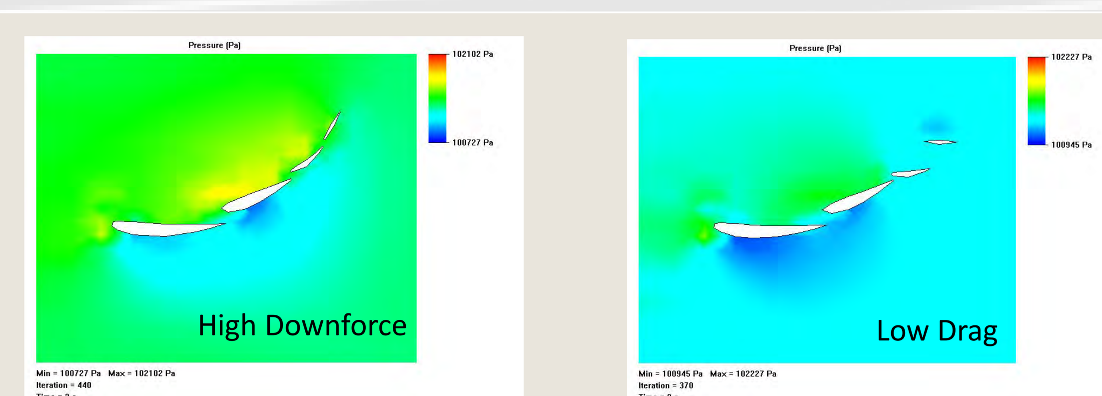


Computational Analysis

The team chose to apply the active aero system to the rear wing, as it has an inferior lift to drag ratio compared to the front wing. Of the four elements on the wing, the two rearmost elements were chosen to be active. We used CFD software to perform an optimization of 100 design iterations to find ideal configurations for maximum downforce and minimum drag. The wing elements move between these two configurations during operation of the aerodynamic system.

The rear wing now produces **22%** more downforce in corners and **75%** less drag in straightaways.

Configuration	Element 3 (deg)	Element 4 (deg)	Downforce (N)	Drag (N)
Passive (old)	36.73	45.89	136.815	310.8505
High Downforce	10	0	170.4275	363.432
Low Drag	40	60	62.9695	141.6695



Illustrations of pressures acting on active aero configurations

Construction

Weight is minimized by constructing the aero package out of carbon fibre composites where possible. The wing elements are made from polystyrene foam core wrapped in a layer of carbon fiber weave, with PLA plastic ribs laminated to either end. The ribs connect the wing elements to both the carbon fiber endplates and a linkage that connects the active flaps to the actuator, which is mounted on the vehicle chassis.


Close-up of carbon fiber weave


Actuator System mockup, showing all pneumatic components.

The actuator that powers the system is a pneumatic piston, which was chosen for its high force output and low energy consumption. It is able to move the wing elements between either configuration within the design goal of one second, and can withstand aerodynamic forces at the car's top speed of 60 mph.

Control System

The flaps automatically actuate between the high downforce and low drag configurations to provide the car with increased downforce or decreased drag depending on the vehicle's needs. By increasing downforce, the vehicle is capable of maintaining higher speeds in corners, while decreasing drag allows the vehicle to obtain higher speeds during straight sections.

A microcontroller uses accelerator and brake input to determine the flap configuration. When the driver applies the brakes, the high downforce configuration is applied. When the accelerator is pressed down fully, the low drag configuration is applied.

Acknowledgement

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