Engineering Project Proposal  
Temple University - Technical Communication – 2023 Fall  
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DRAFT

Abstract

# Executive Summary

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# Problem Analysis

## Overview of problem and its significance

Automobile racing is a sport that has grown to be the pinnacle of automotive engineering and design. To be competitive in motorsports, teams must develop setup packages that optimize the performance of their racing car for each track they visit. The setup consists of simulating, testing, and tuning a wide variety of parameters on the racecar that affect mechanical grip and aerodynamic efficiency. Often, the most successful teams have a combination of the best drivers and best setups.

In contemporary motorsports, racing teams take advantage of sophisticated testing rigs and computer simulations to test many setup parameters before they arrive at the racetrack. The main methods for simulating racing setups are driver in loop (DiL) simulations and computer simulations. DiL simulators attempt to recreate the physical environment and variables of a racetrack and car which the driver can then test in real time. The amount of data collected is greater than what is collected solely at the racetrack but is still limited by the amount of time it takes to complete laps. Computer simulations are significantly faster and can be done behind the scenes. Often, 100,000+ laps of data can be collected in the time it takes to complete a few thousand laps with DiL simulations.

The way simulations are used by racing teams depends on the accuracy of the simulation method. Mainly, racing and data engineers are looking to correlate small aerodynamic or mechanical setup changes to performance differences. The complexity of aerodynamic modelling in particular poses a challenge, even for the highly sophisticated CFD models that exist. The various models used have tradeoffs between accuracy, time, and cost for specific parameters.

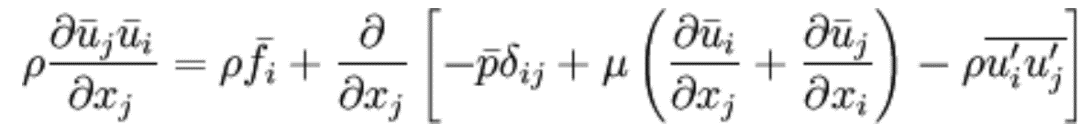
Having the most efficient method to prepare vehicle setups and testing procedures gives the highest probability of creating a successful driver/car pairing.

I need to have a more clearly defined problem. Not clear what my problem is. It has something to do with racecar setups and CFD.

## STEM fundamentals of problem

The majority of racing simulation problems stem from tradeoffs in CFD models. For the sake of making engineering progress, it is important to know why contemporary simulations cannot be faster, more accurate, and more cost effective all at the same time.

(22) RANS stands for Reynolds Averaged Navier Stokes equations which are a set of partial differential equations that describe viscous fluids. Approximations of flow turbulence attributes must be made and then solutions to the equations can be found.



The NS equations are written above. In summary: change in average fluid momentum leading to unsteadiness in average flow (turbulence?) = average body force + isotropic stress leading to average pressure field, + viscous stresses + Reynolds stress.

The Reynolds decomposition is what is used to figure out the RANS equations. Essentially, the flow variable (like u, maybe others) is separated into the time averaged component of the variable (u bar) and the fluctuating component of the variable (u'). It becomes u(x,t) = u bar(x) + u'(x,t) where x is the 3D position vector. Other flow parameters are density, velocity, pressure, and more.

(19) The most important challenges with modern CFD are in modelling the turbulence. There are two main approaches: showing as much detail as computationally possible or finding the most accurate overall effect on the flow behavior… the latter being more common. Applications involving complex and aggressive geometry tend to have the least success.

Modelling turbulence is extremely challenging as it is the most complicated type of fluid motion. To model the flow predictions, a mesh is created. The higher the detail, the higher the number of points that define the mesh. When running simulations, the computer is essentially mathematically calculating changes that occur to each point. Even for analysis on small specimens, a detailed recreation of turbulent fluid can require 10^9 to 10^12 points. This is because turbulence features such as eddies can be as small as 100 pico-m. Fluid motion happens fast, at a high frequency, so computer simulations need to also replicate that to accurately depict the interactions happening in flow.

Parameters that can effect CFD modeling:

* mathematical models
* Reynolds number
* eddy viscosity
* kinetic energy
* Fluid dynamics
* CFD
* Vehicle dynamics
* Vibrations

I need to find information that helps link the science behind CFD/setup and how it is used to my problem.

## Lessons from prior responses to the problem

## Project objectives and constraints

# Candidate Solutions

## Scope of solutions considered

To be competitive in today’s motor races, teams must have the most dialed in vehicle for the track they are at. There are a variety of ways to improve the performance of a race car ranging from tweaking the initial design to trial and error at the racetrack. Most teams will choose to tune the suspension and aerodynamic balance of their cars since they will make the largest impact on performance.

Track testing is a fundamental part of tuning a race car. Essentially, small adjustments are made to vehicle parameters. The car is driven for stints and then driver feedback and data are compared. This method of testing is very reliable as it tests actual components and conditions that will be in use. However, track testing is typically limited in time which results in limited data collection. Achieving a highly optimized racing setup would take an exorbitant amount of time and resources. To adjust parameters that don’t have adjustable parts or to test new concepts, an entirely new component or system might need to be designed and fabricated. This can cost lots of time and funding.

A shaker rig is a mechanical testing apparatus that simulates the bumps, etc. encountered in a racetrack lap and applies them directly to a race car chassis. The shaker rig works by attaching hydraulic actuators to various parts of the race car. For example, a 7-post shaker rig has one platform for each tire to sit on and then a mount for 3 locations along the car's length.

Computer simulations

## Explanation of candidate solutions

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A race car on a track

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Figure 1. Ayrton Senna racing for McLaren

## Comparative assessment of candidate solutions

Table 1. 3x3 Table Example

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# Project Recommendations

## Proposed solution

## Design and implementation challenges

## Anticipated project outcomes and impacts

# Glossary

# References

## Additional sources consulted