# Introduction

This document details the vision, purpose, requirements, and design of a car-mounted trio of load cells for measuring lift, drag, and moment in place of a wind tunnel substitute. As the development of Crash-Sat continues the needs for an intelligent airframe design and controls system grows. A very important part of these facets is the detailed understanding of dynamics and static aerodynamic behavior. Proper flight coefficients must be determined for modelling a robust controls system and loading profiles must be tested to ensure the structural integrity during the pitching phase; simply to name a couple of examples.

After trade studying aerodynamic analysis options such as CFD, wind tunnels, and numerical solutions; a conclusion was made that these options, though useful in their own way, are not an adequate replacement for the accessibility and direct approach of a real world model under real aerodynamic loading. Additionally the procurement of a wind tunnel for more controlled testing is seen as an unnecessary expensive endeavor. Thus a car-mounted system will be created for testing aerodynamic loading under real aerodynamic effects.

This car mounted system will allow for near 1:1 sized models to be tested in a semi-controlled environment with near immediate availability, barring weather and excessive wind. The design will focus on measurement accuracy and user convenience. Special attention will be given to structural integrity and safety in both the design and testing procedures to ensure the vehicle in use remains road legal and does not pose a threat to any other drivers on the road.

# Requirements

Below in Table 1 is a list of system level requirements to be following in the design process. Table 1 is a representation of the requirements at the time of writing and more up to date requirements may be present elsewhere.

**Table 1: Requirements list**

|  |  |  |
| --- | --- | --- |
| Req. ID | Description | Priority |
| SYS-1 | The structure must be able to form a non-destructive mount to the roof, or equivalent surface, of a typical American sedan. | Medium |
| SYS-2 | The primary structure and car mounting interface must be able to withstand up to 10 pounds of lift, and 30 pounds of drag, with damage to the vehicle. | High |
| SYS-3 | The structure must be shown by some calculation or off-road test to be resilient to eddy current resonance from speeds of 0 to 80 MPH. | High |
| SYS-4 | Any and all use of the test rig must not intrude on illegal actions by use of the vehicle. | High |
| SYS-5 | Test rig shall use 3 linear load cells of adequate measurement range and resolution to measure lift, drag, and moment body forces with +/- 2% accuracy for all body forces. | Medium |
| SYS-6 | Test structure and mounting mechanism must be able to withstand 10 MPH sudden braking and 1 G turns. | Medium |
| SYS-7 | Load cells must have locally mounted digital amplifiers and DAQs with a serial bus to share on-the-fly updates to a laptop inside the vehicle. | Low |
| SYS-8 | An airspeed pitot tube will be included for accurate airspeed measurements and this measurement will be displayed live to the driver for accurate speed control. | Low |

# Design

The design begins by selecting a mounting location on the vehicle. For the sake of airflow symmetry and to avoid intruding on neighboring lanes and roadside obstacles, only candidates on the car’s centerline will be considered. 3 primary locations are considered:

1. Top of car
   1. Pros: Highest measurement accuracy, steady and straight airflow, no view obstructions, clear of car in case of catastrophic failure, easy access during testing.
   2. Cons: no great mounting points unless car has skylight or convertible roof, streamline compression means higher than freestream ambient pressure.
2. Front of car
   1. Pros: High measurement accuracy, symmetric airflow, little disturbance by car, lots of mounting points with removal of hood.
   2. Cons: Driver view obstruction, airflow deflects upwards slightly, requires hood removal.
3. Above the trunk
   1. Pros: Decent accuracy, all sedans have a good trunk, trunk can be stored in back seat during testing.
   2. Cons: trunk removal required, turbulent airflow at low speeds, no rear lights means not street legal, rear view obstruction.

Diagram

Description automatically generated

**Figure 1: Simple car streamlines [1]**

The roof of the car will be used to avoid visual obstruction of the driver and because the streamlines are very steady and uniform.

Next a baseline design must be selected. Aerodynamics models are usually mounted by the rear or the belly. A neutral design will be created so both methods can be used. 3 Load cells are required in order to measure lift drag and inherent moment of the model. A basic model is shown below.

# References

[1] Research Gate: “Comparison of Linear Vortex Panel Method and Finite Volume Method for Calculation of Generated Lift in Potential Flow Over Two-Dimensional Car Bodies” (<https://www.researchgate.net/figure/Streamlines-and-flow-patterns-around-the-car_fig1_347309635>)