

# Rubric and Methodology for Aerodynamic Experiment using Load Cells

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**Note:** Along with the rubric components, also include Objective(s) and Theory.

## I. Rubric Components

Component	Details	Weight (%)
Experimental Setup	Proper mounting, alignment, calibration of load cells	15%
Instrumentation & Data Acquisition	Arduino integration, sampling rate, wiring, data reliability	15%
Data Processing	Raw force conversion, filtering, tare removal	15%
Aerodynamic Coefficient Calculation	CL, CD, use of dynamic pressure, projected area	20%
Plotting & Trends	CD vs CL, Cl/Cd vs $\alpha$ behavior with angle of attack, stall point	10%
Sensitivity & Uncertainty	Repeatability, standard deviation, error propagation, sensor accuracy	15%
Interpretation & Discussion	Coherence with expected trends, NACA data matching, flow physics explanation	10%

## II. Experimental Methodology

### 1. Setup & Coordinate System:

- Two perpendicular load cells: Drag (horizontal), Lift (vertical)

- Airfoil: NACA 4318 mounted on a sting balance or internal frame
- Arduino reads voltage (use HX711 for strain gauge cells)

## 2. Tare Removal (Zeroing Baseline):

Before turning on flow:

```
long tareLift = analogRead(liftPin);
long tareDrag = analogRead(dragPin);
```

Then during data acquisition:

```
liftCorrected = analogRead(liftPin) - tareLift;
dragCorrected = analogRead(dragPin) - tareDrag;
```

## 3. Force to Newton Conversion:

Use calibration from known weights (linear fit):

$$\text{Voltage\_out} = a \times \text{Force} + b \rightarrow \text{Force} = (\text{Voltage\_out} - b)/a$$

## III. Aerodynamic Coefficient Computation

Let:

- L = Lift (N), D = Drag (N)
- $q = 0.5 * \rho * U^2$  (Dynamic Pressure)
- S = Projected area = chord  $\times$  span

Then:

$$CL = L / (qS), CD = D / (qS)$$

## IV. Uncertainty & Sensitivity Analysis

### A. Standard Deviation:

### B. Propagation of Uncertainty:

### C. Sensitivity to Angle of Attack:

Plot CL vs  $\alpha$ , compute  $dCL/d\alpha$  in linear region

D. Repeatability Check:  
Perform multiple runs, compare standard deviation of CL, CD

## V. Recommended Plots

- CL vs  $\alpha$
- CD vs  $\alpha$
- CD vs CL (drag polar)
- Cl/Cd vs  $\alpha$
- Tare stability (voltage vs time at zero flow)
- Error bars from uncertainty analysis

## VI. Additional Tips

- Use median filtering or moving average for Arduino data smoothing
- Calibrate with known weights before experiment
- Ensure wind tunnel blockage ratio <10%
- Save Arduino data in .csv for MATLAB/Python analysis