This is an excerpt from the full Jet Propulsion Vehicle Design Report.

Experimental Data and Results

A sonar placed at the end of the track was used to collect position data over time. As such, in the raw data, the coordinates of position decrease as time increases because the vehicle gets closer to the sonar. There were a few sonar readings that indicated extraneous noise, potentially introduced by motion detected in the background of the vehicle. To mitigate this, we truncated those values and used linear interpolation to fill in the gaps, although this may have introduced some fluctuations. To better visualize the data, we remapped the position values such that x=0 corresponds to the first photogate. This means that the position values leading up to the first gate are negative and increase as the vehicle travels down the course.

During trials one and two, our vehicle veered too far to the side of the track, placing it out of the sonar's range. As a result, the position data for the last .352 seconds of trial one and .214 seconds of trial two before reaching the second photogate are derived from linearly interpolated values. In the recorded data, multiple gate-state changes occur due to the laser briefly reconnecting with the photogate while the vehicle body traverses the laser, either underneath the body or through the wheel spokes. This fact was taken into consideration when calculating the total time to traverse each photogate, Δt_{pg}.

Figure 9 (a): vehicle position relative to the first photogate, velocity, and acceleration as a function of time for trial 1

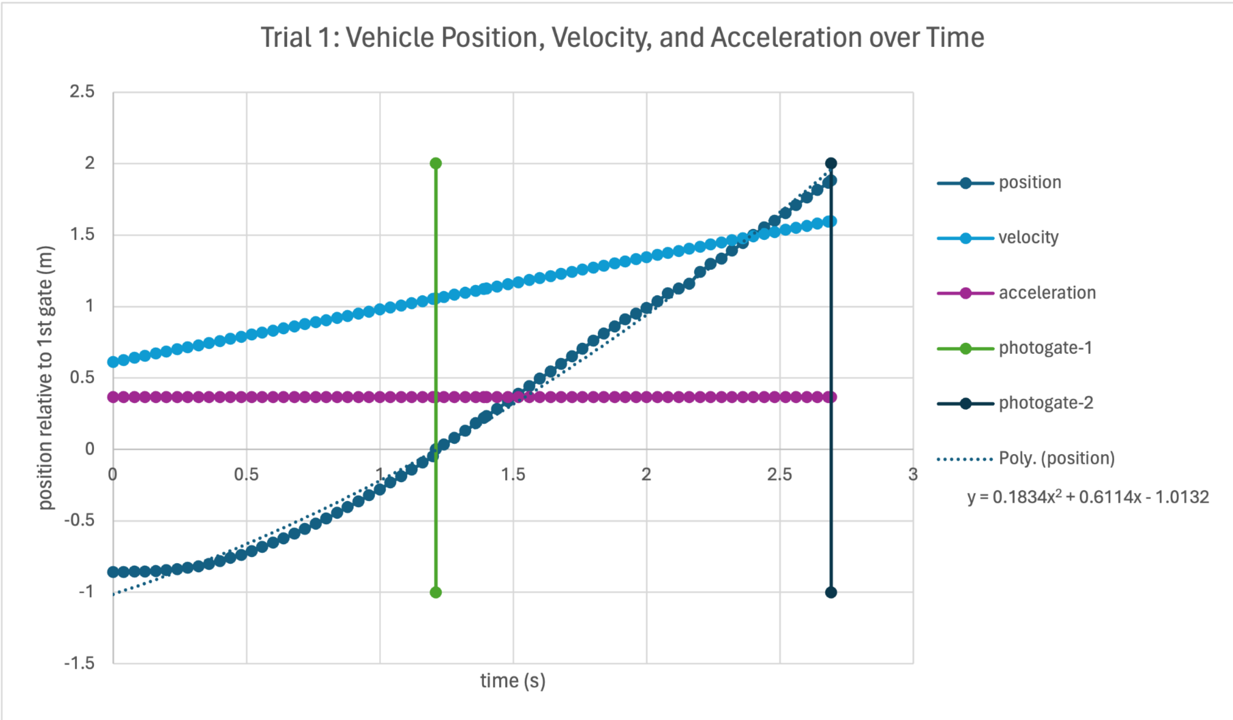


Figure 9 (b): vehicle position relative to the first photogate, velocity, and acceleration as a function of time for trial 2

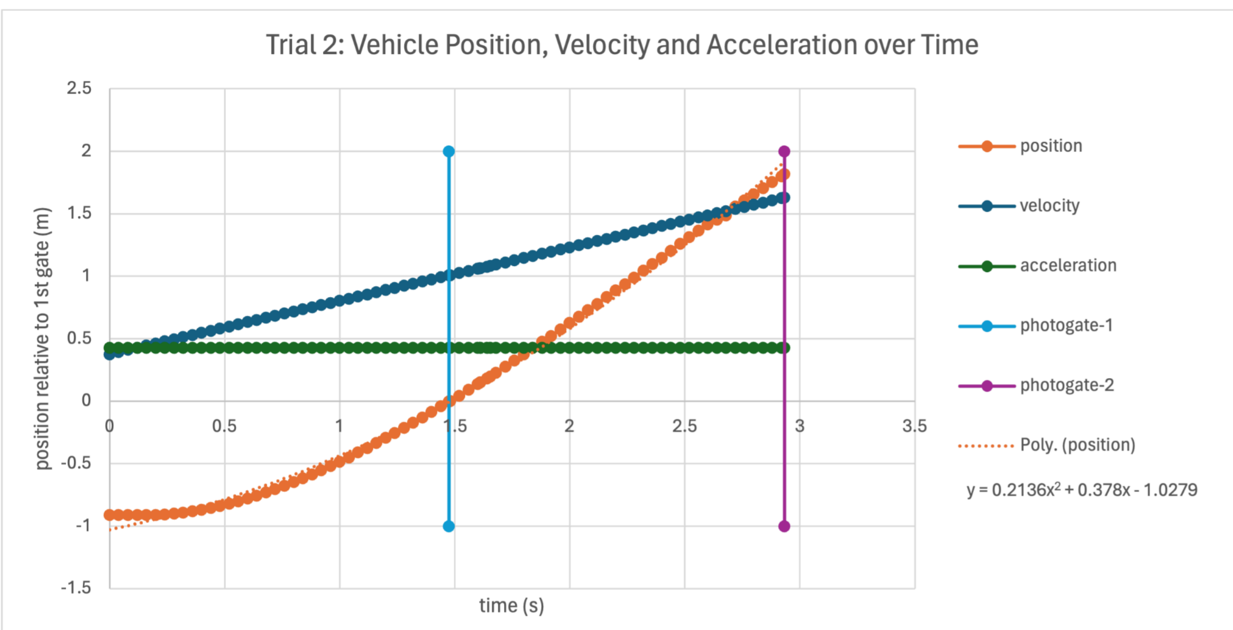
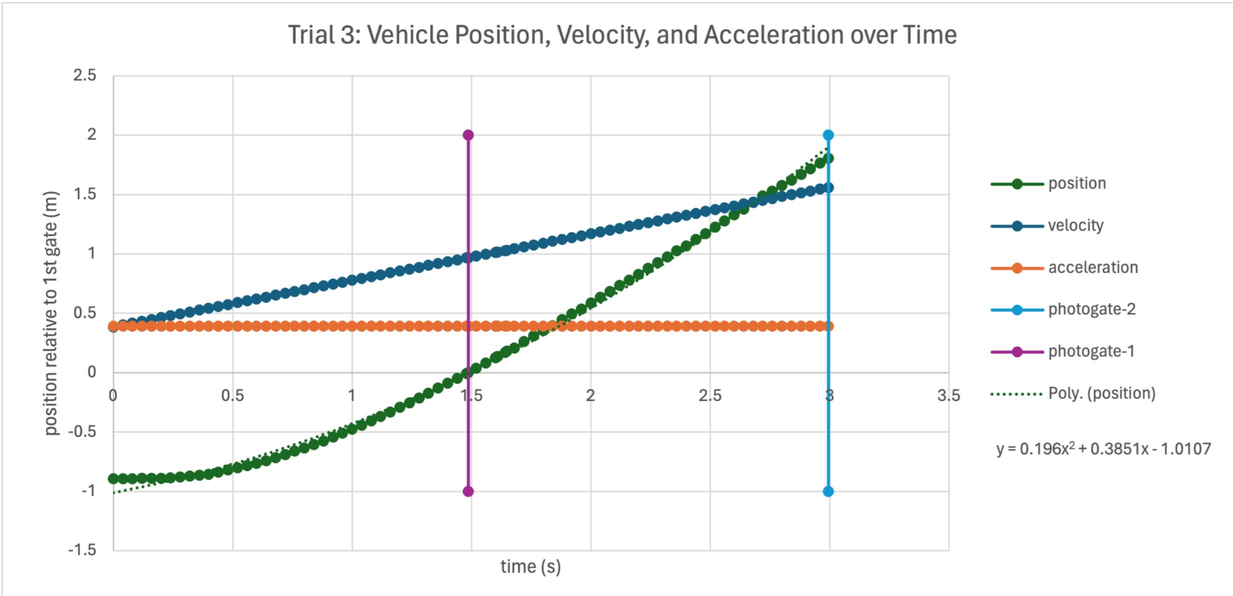


Figure 9 (c): vehicle position relative to the first photogate, velocity, and acceleration as a function of time for trial 3



In figures 9a, 9b, and 9c, the position, velocity, and acceleration data for each trial are shown with respect to time. The velocity and acceleration equations were derived using the first and second derivatives respectively based on the best fit curve for the position data. The derivations are shown below.

Trial 1:

$$x(t) = .1834t^2 + .6114t - 1.0132$$
$$x'(t) = v(t) = .3668t + .6114$$
$$v'(t) = a(t) = .3668$$

Trial 2:

$$x(t) = 0.2136t^2 + 0.378t - 1.0279$$
$$x'(t) = v(t) = 0.4272t + .378$$
$$v'(t) = a(t) = .4272$$

Trial 3:

$$x(t) = .196t^2 + .3851t - 1.0107$$
$$x'(t) = v(t) = .392t + .3851$$
$$v'(t) = a(t) = .392$$

Using Δt_{pg} and the total length of the vehicle, $L_v = .2$m, we can calculate the instantaneous velocity (V_{inst}) at both the start and finish photogates using equation 10. These results are shown in figure 10.

$$V_{inst} = L_v / \Delta t_{pg} \tag{10}$$

Figure 10: time to traverse each gate and corresponding instantaneous velocity

gate	Δt_{pg} (time to traverse gate) (s)	V_{inst} (m/s)
trial 1, gate 1	0.178283	1.12181195
trial 1, gate 2	0.187673	1.0656834
trial 2, gate 1	0.178912	1.117868
trial 2, gate 2	0.198642	1.00683642
trial 3, gate 1	0.162557	1.23033767
trial 3, gate 2	0.173746	1.15110564

The calculated V_{inst} in figure 10 and the velocity equation as a function of time are close but deviate slightly. For example, V_{inst} at trial 1, gate 1 is approximately 1.12 m/s whereas $v(0) = 0.9782$ m/s for trial 1. This discrepancy could be due to the fact that the position curve is not a perfect fit for the scatter plot, and therefore the derivative of the function (velocity), is not completely accurate.

$$V_{avg} = \Delta x / \Delta t_{total} \tag{11}$$

$$a_{avg} = V_{inst} / \Delta t_{total} \quad (12)$$

To estimate the average velocity of the vehicle during the time trial, we used equation 11 where Δx is the distance between photogates. To estimate the average acceleration (a_{avg}), we used the formula shown in equation 12.

The calculated average acceleration is greater than that derived in the equation. This may be due to the fact that this average calculation only considers the data points between gates, whereas the equations utilize position values before the first gate. The acceleration is positive, which means that our vehicle was accelerating between photogates. The average velocity and acceleration for each trial is shown in figure 11.

Figure 11: average velocity and average acceleration of vehicle between photogates

trial	Δt_{total}(s)	Δx (m)	V_{avg} (m/s)	a_{avg} (m/s^2)
trial 1	1.480047	1.88067805	1.270688056	0.86075231
trial 2	1.458441	1.81894401	1.247183817	0.85180083
trial 3	1.509175	1.80436417	1.195596382	0.78898845
averages	**1.48 s**	**1.833 m**	**1.2378 m/s**	**.83386 m/s2**

The average force imparted on the vehicle between photogates is calculated using equation 13.

$$\Sigma F_{avg} = (mass) \times a_{avg} \quad (13)$$

Taking our calculated values of acceleration for each of the three trials we can find the average force by dividing by the number of trials. This was slightly less than the theoretical force .129 N.

$$\Sigma F_{avg} = (.133\, kg) * (.83386\, m/s^2) = .111\, N$$

To estimate the total work done on the vehicle between photogates, we used equation 14.

$$W = F_{avg} \times \Delta x \tag{14}$$

The total work done on the vehicle between photogates is .203 Joules.

$$W = .111\,N \ * \ 1.833m = .203J$$

To estimate the power of the vehicle between photogates as work per unit time, we used equation 15.

$$P = W / \Delta t_{total} \tag{15}$$

The power of the vehicle between photogates is .137 W.

$$P = .203J / 1.48s =.137J/s =.137W$$