
IX. DESIGN ROBUSTNESS

DESIGN OF EXPERIMENTS TO TEST PAINTBALL GUN ACCURACY

We, as well as our customers, are very concerned with paintball marker accuracy. In order to ensure the highest amount of accuracy on our marker, we found it critical to create a design of experiments to test the factors which contribute to the accuracy of the paintball marker. In order to determine a design of experiments to test for paintball gun accuracy, we first identified a set of control factors which we attributed to paintball accuracy and a set of noise factors. Control factors that we are able to adjust on the marker which relate to the marker's overall accuracy were determined to be: Barrel Shape, Barrel Length, Air Pressure and Spring Velocity. Noise factors which contribute in the variation of marker accuracy include: Playing Temperature, Paintball Type, and Barrel Lubricant Type.

The contributing control and noise factors are listed below at their various levels being investigated, with the level in the current design underlined for each factor.

Control Factors	Level 1	Level 2	Level 3
Barrel Shape	“S” Curve	<u>Straight</u>	Open Mouth
Barrel Length	6 in	<u>8 in</u>	10 in
Air Pressure	<u>600 psi</u>	900 psi	1200 psi
Spring Velocity	low	<u>medium</u>	high

Noise Factors	Level 1	Level 2	Level 3
Temperature	40 F	<u>60 F</u>	80 F
Paintball Type	Brand A	<u>Brand B</u>	Brand C
Lubricant	Oil	Chalk	<u>Synthetic</u>

Upon determining the levels for each of the control and noise factors it was necessary to choose a DOE matrix that would accommodate 4 control factors at three levels. The L9 array suits this application perfectly allowing us to perform 9 experiments to represent the 81 experiments.

Column Number and Assigned Factors

Test Number	Barrel Shape	Barrel Length	Air Pressure	Spring Velocity
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

The control factors are then given an assign location in the L9 matrix based on the complexity of a change in the DOE. The L9 matrix below shows their placement in the L9 array as well as the levels that will be tested for each experiment in the balance L9 array.

Finally we would complete the experiment at the assigned test factor levels. The marker would be set up using a 4 point laser site on a target to make sure the barrel center was located and perpendicular to the target area set-up at 25 feet away from the marker. At this point 5 shots would be fired and their distance away from the target center would be recorded and then later analyzed using ANOVA.

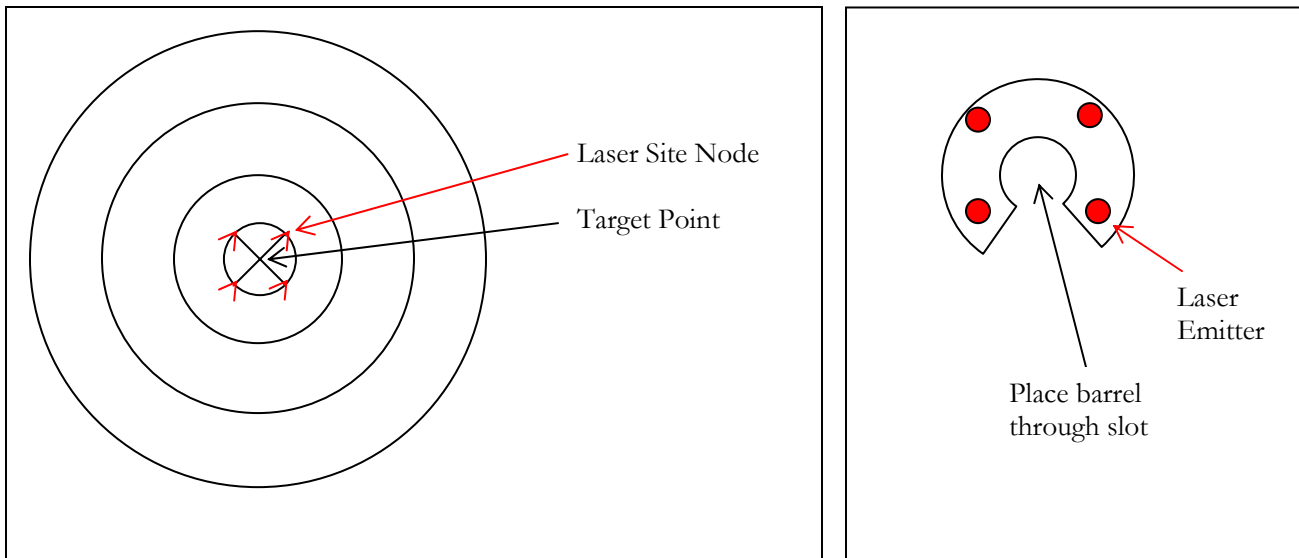


Figure10: Target Set-Up

Marker Set-Up

Using ANOVA, we would be able to analyze the mean effects of each factor and determine the contribution each factor plays in the markers accuracy. After determining the optimal factor settings we could then select the design in which the factor were set to optimize the markers accuracy as we try to minimize the distance between the target and the actual shot. To do this we would first compute the signal to noise ratio on each of the five data points for each test, then we would be able to compute the factor effects and plot them. After computing the error degrees of freedom and error variance, seeing the error degrees of freedom is zero, we could then pool the bottom half of the control factors (the two out of four factors with least influence) as error. Finally we could perform Analysis of Variance (ANOVA) to show factor effects, sum of squares, mean squares, F-factor. For each factor, we could compute the % contribution which is defined as $\% \text{ contribution due to a factor } i = (\text{sum of the squares due to factor } i) / (\text{total sum of squares due to all factors}) \text{ times } 100$. For each control factor, assuming the nominal values given we could determine the optimum level for each control factor on the basis of ANOVA and estimate the improvement of optimal solution over nominal performance.