FINDING THE OPTIMAL ATTACK ANGLE FOR HITTING A BASEBALL

by

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ABSTRACT

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Since the introduction of Statcast in 2015, there has been a growing popularity in baseball analytics on the fan and player sides. Statcast brought about the launch angle trend, and since Statcast's release, we have seen an annual 1° increase in launch angle for the last six to seven years. This study looks at the relationship between projected distance and attack angle in order to find the optimal attack angle for hitters. By using a bat sensor and making a batting cage in the garage, I was able to collect all of the data needed to make these conclusions. Following the data collection and entering all of the data into LoggerPro to generate graphs, it became clear the Optimal attack angle did not vary throughout the strike zone. From these graphs, it has been determined that the optimal attack angle for a line drive is between 5 and 5°, and 20 and 37° will likely result in a home run. The furthest hit balls will be the result of a swing with an attack angle of 29 to 32°.

Keywords: baseball, attack angle, projected distance, the physics of baseball, bat sensor

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BACKGROUND

This study focuses on the relationship between the swing plane, more commonly known as attack angle, and the projected distance of a baseball. As baseball analytics has grown in popularity over the last decade there has been a massive change in how players train. Launch angle has been a major focus for training hitters to hit more home runs. Ideally, hitters want to have a launch angle between 10-25° for a good, solid line drive. Since this trend in launch angle, players have been shifting their focus hitting the ball not only harder but also higher. Daniel Murphy, Washington Nationals slugger, increased his average launch angle from 11.1 to 16.6° from 2015 to 2016. This proved beneficial for him, as his batting average jumped from 0.281 to 0.347, in addition to 11 more home runs. Anthony Rendon, Murphy's teammate, also shared this focus on increasing launch angle, and his went from 10.6° in 2015 to 16.8°. As a result, his slugging percentage grew from .363 to .450. (Sheinin, 2017)

Trends prove that hitting the ball hard and high will result in more home runs, but how do you train launch angle? You don't. You can't. You can, however, train the hitter's swing plane. But what is the optimal attack angle to drive the ball? Does the optimal attack angle vary depending on where the ball is in the zone?

Growing up, all of my summers were spent at the ball field watching my brother and listening to the Cubs game on the way home. As my brother's baseball became more competitive and there were more games, I realized I better learn to understand this game because it isn't going anywhere anytime soon. As soon as I started to pay attention and understand it, I fell in love with the game. I started watching Cubs games and learned the player's names followed their stats. Since Statcast's release in 2015, the launch angle trend has always been something I have been curious and skeptical of.

SETUP

To find the answers to these questions, I knew I would need to have some sort of batting facility where I could make marks for the batter's feet, a tee, as well as a strike zone. This was also right at the beginning of a pandemic (April 2020), so I couldn't go to a hitting facility, and I couldn't go and spray paint a batting cage at the park by my house. Instead, I made a batting cage in my garage and had my brother use a bat sensor when he hit off the tee. Originally, I was planning on making a batting cage with 4 nets as the sides. On the net behind the tee, I would paint the strike zone as well as the 9 sub-zones, and move the tee so that the ball would be in that sub-zone and he would hit from there. A diagram of my original design can be found in **Figure 1**. After talking to my dad about this and how I was going to set it up, he told me we own a base that has markings for the vertical components of the strike zone, as demonstrated by **Figure 2**. Using this base allowed me to simplify the setup for this study.

In the garage, I installed a bike hanging system to hang a net. This allowed me to raise and lower the net so that the cars could still park in the garage and I wouldn't have to worry about taking all of the time to set up and clean up before and after collecting data each time. Then, I made marks on the garage floor with painter's tape to mark where the plate and Alex's feet went when he hit a ball into the net. I also used the tape to make marks on the adjustable base of the tee to mark the various heights in the strike zone.

DETERMINING CONSTRAINTS

I used a bat sensor (Diamond Kinetics SwingTracker) to collect the data. This sensor determines various metrics including impact momentum, exit velocity, power, attack angle, and projected distance. For the first week, I had Alex use the sensor and hit as he normally would so I could determine constraints for data collection. These constraints are necessary to ensure a high correlation when graphing the data in logger pro (Projected Distance vs Attack Angle). The set constraints can be found in **Table 1**.

DATA COLLECTION

Once all of the prep work was done, I was ready to start collecting data. To collect data, I positioned the tee to where it needed to be, and then Alex would hit with the bat sensor on the knob of his bat. At the end of a hitting session, I would go through and pick out the data I could use given the set constraints. This data was then stored in an Excel sheet as demonstrated in **Figure 3**.

Once I got 50 swings worth of data from a sub-zone, I transferred the attack angle and projected distance values into LoggerPro to graph these metrics. **Figures 5-14** and **Table 2** contain and present all of the data collected. There are graphs for each sub-zone, as well as one graph with all 450 data points plotted on it. **Table 2** contains the maximum points along the line of best fit from each of the graphs.

TROUBLESHOOTING

After about three months of collecting data, my brother got a minor elbow injury. To prevent him from worsening the injury, we paused data collection. Before the injury, I was on track to finish collecting data by late September/early October. Unfortunately, data collection could not resume until early October and wrapped up in March. Data collection took much longer than I originally anticipated due to many factors. Alex played basketball this Winter, so we could not hit with the sensor as frequently. In addition to not being able to hit as frequently, Alex got stronger, so he was hitting with fewer swings within my parameters and I had to get more swings from him to get the 50 swings for each subzone. At the start of the project, I was able to use data from about 15 of 20 swings and when we resumed I was able to use approximately 7 of 20 swings. These events slowed down data collection drastically. By the end of data collection, Alex had over 2,400 swings with the sensor.

RESULTS

All graphs and tables (**Figures 5-14 and Table 2**) of the data collected can be found in the references.

ANALYSIS

Line drives typically travel 220 to 260 feet, and anything beyond that is considered a home run. Pop-flys tend to be in the infield or barely in the grass of the outfield. When hitting off of the tee, Alex only hit about seven pop-flys, and none of these swings were within the constraints so they are not included in the data set. Alex hit plenty of ground balls during this study, and they never had a projected distance greater than 212 feet.

Low in the Zone

Figures 5-7 represent the graphs for balls that were hit low and away, low and middle, and low and inside within the strike zone. Between the graphs, there is not a lot of variation as far as the shape of the lines of best fits or the maximum points on the graph. Comparing the three graphs, the attack angle that yields the greatest projected distance varies by only 0.43°, and the maximum projected distance varies by 10 feet. For a batter who is considered a “home run hitter”, they should focus on training their swing to have an attack angle of about 20° to 37°. For a hitter like Alex, one who focuses on driving the ball into the gaps, they should train to obtain a consistent swing plane of about 5° to 16°. Anything between 0° and 5° will result in a bobbler, or possibly a bunt, that might get the player on base depending on the skill level of the defense.

Middle of the Zone

Figures 8-10 represent the graphs for balls that were hit middle and away, middle, and middle and inside within the strike zone. Between the graphs, there is not a lot of variation as far as the shape of the lines of best fits or the maximum points on the graph. Comparing the three mid-level sub-zone graphs, the attack angle that yields the greatest projected distance varies slightly more than it did the low sub-zones. There is a variation of 1.71° and an 8-foot difference in maximum potential difference. A possible explanation for this would be a difference in the consistency in power, impact momentum, and exit velocity. As far as what attack angle certain types of hitters should train for, those ranges remained roughly the same. Home run hitters should attack the ball at a 20 to 40° angle and maximum power to ensure the ball leaves the park. Line drive hitters should focus on an attack angle between about 7° and 19°. Swing planes below 7° are very unlikely to leave the infield unless the ball is hit with greater power.

High in the Zone

Figures 11-13 represent the graphs for balls that were hit high and away, high and middle, and high and inside within the strike zone. This set of graphs has more variation in attack angle and projected distance than the other two sub-zone levels. Comparing the three graphs, the attack angle that yields the greatest projected distance varies by 4.12°, and the maximum projected distance varies by 13 feet. The reason for the greater potential distances here is most likely because Alex was much stronger when collecting the data for these sub-zones, and so nearly all of the swings collected for this were on the higher side as far as power, impact momentum, and exit velocity. The range a certain hitter should focus on once again is consistent with the mid-level and lower sub-zones. Home runs hitters should continue to focus on hitting the ball with an attack angle of 20 to 40°, line drive hitters' swing plane should be about 5 to 15°, and anything from $0° \leq \theta < 5°$is most likely not going to leave the infield nor be a successful hit if the defense is of decent skill level.

The Entire Zone

Figure 14 graphs the projected distance vs the attack angle from all 450 collected swings during data collection. The varying colors and shapes are for the different sub-zones, but the line of best fit is for all 450 swings. The optimum attack angle for solid line drives is from 6° to 16°. For a home run hitter, their optimum attack angle is from 20 to 35°. Anything with an attack angle from $0° \leq \theta < 6°$is likely a ground ball that does not travel past the infield and will not result in a hit if the opposing defense fielding the ball is of average skill level.

CONCLUSIONS

Engineering Design Process

The engineering design process was essentially the structure used to plan and conduct the entire study. After determining I wanted to find the optimum attack angle for a hitter, I expanded my background knowledge on the topic to gain a better understanding of what I was looking for, as well as what I might need to conduct this project. From there, I came up with multiple plans for how this study should be conducted to find the answers I was searching for. I sought out feedback on my various plans and ended up finding a way to simplify my plans while increasing the accuracy and consistency of the results. I set up an area to complete this study and tested it for about a week to ensure it would work efficiently and accurately. Throughout the week I installed many changes to the design such as adding tape to the floor where the batter's feet go and where the base goes. To make it easier for a shorter person (such as myself) to put the net back, I took some old wire hangers and made a hook tool. This made it much easier for me to clean up the area after collecting data. Once data collection had begun, I kept a log of the data from swings that could be used and the date of those swings. In addition to the log kept in the Excel sheet (see **Figure 3**), I made a blog where I would post frequent updates regarding the status of the study. The blog posts can be found on my personal website, which is in the references, under "RESEARCH PROJECT". As I was collecting data, I was entering the data into LoggerPro to make the graphs, then analyzing and reflecting on the trends I was seeing. This continued through the end of the project. The engineering design process played a major role in how I conducted this study.

Findings

After comparing all of the data and graphs side by side, I concluded the optimal attack angle depends on what kind of hitter you are, as well as what those angles are based on that. I also determined that there is no clear, significant evidence to prove the optimum swing plane changes depending on where the ball is within the strike zone. This means that hitters should train to have the same attack angle whether the ball being hit is high and inside or low and away. Home runs are the result of a strong swing with an attack angle of about 20° to 35°. The furthest hit balls will be the result of a swing with an attack angle of 29 to 32°. For someone who is not necessarily built to be a powerhouse home run hitting machine, they should focus on hitting with an attack angle of about 5 to 15° to have a greater chance at getting on base from a hit in games. An attack angle from $0° \leq \theta < 5°$ will most likely be a blooper or a bunt that does not leave the infield. In most cases, if there is decent defense fielding the ball, the batter will get out.

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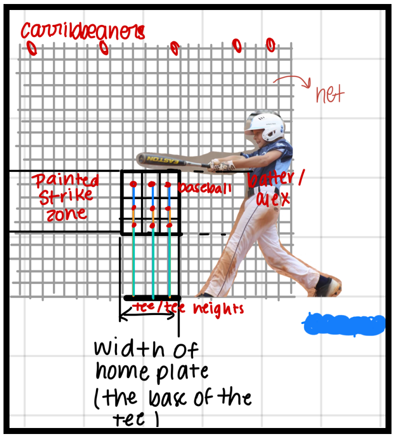


Figure 1

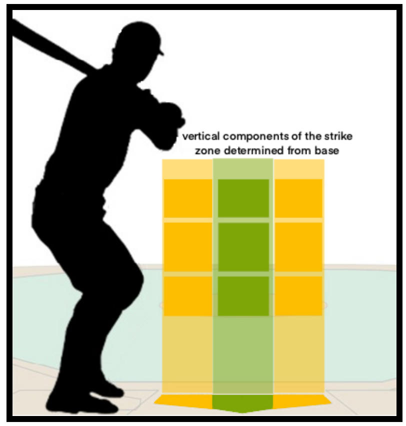
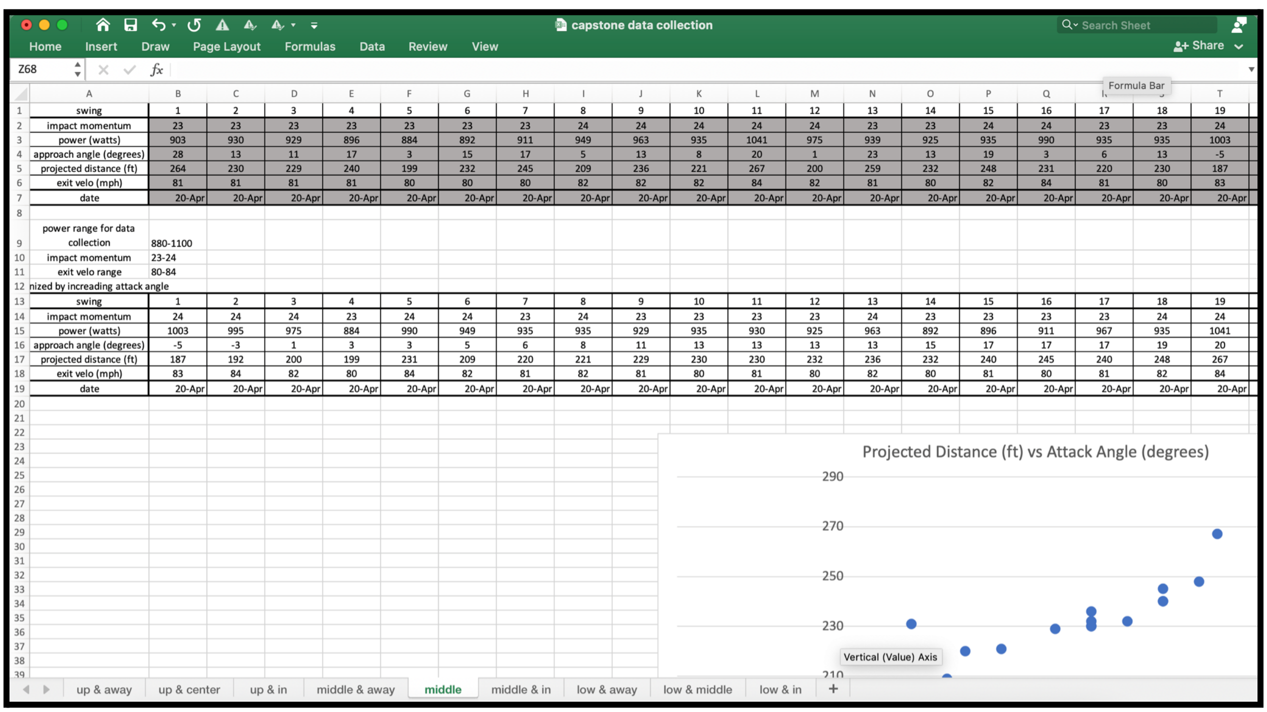


Figure 2

Power (Watts)	880 - 1100 watts
Impact Momentum (kg*m/sec)	23 - 24 kg*m/sec
Exit Velocity (mph)	80 - 84 mph

Table 1



capstone data collection

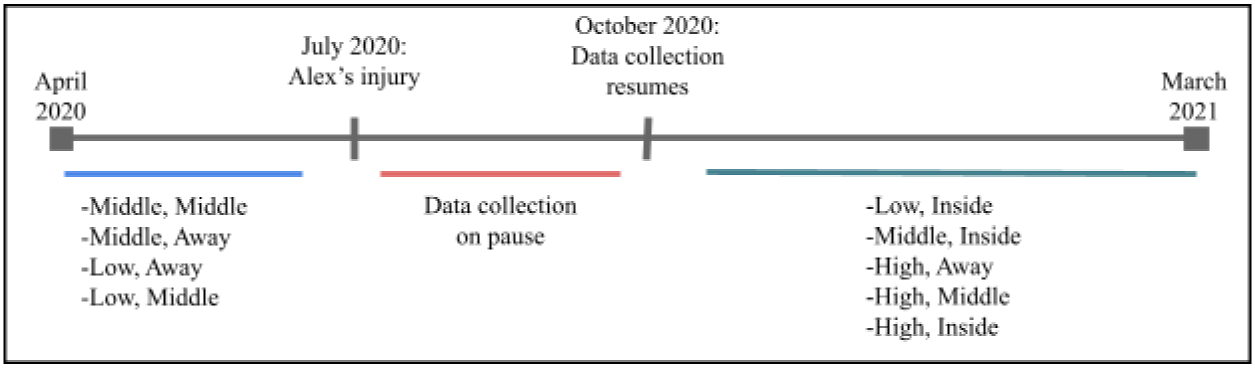
swing	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
impact momentum	23	23	23	23	23	23	23	24	24	24	24	24	23	23	24	24	23	23	24
power (watts)	903	930	929	896	884	892	911	949	963	935	1041	975	939	925	935	990	935	935	1003
approach angle (degrees)	28	13	11	17	3	15	17	5	13	8	20	1	23	13	19	3	6	13	-5
projected distance (ft)	264	230	229	240	199	232	245	209	236	221	267	200	259	232	248	231	220	230	187
exit velo (mph)	81	81	81	81	80	80	80	82	82	82	84	82	81	80	82	84	81	80	83
date	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr

power range for data collection	880-1100
impact momentum	23-24
exit velo range	80-84

nized by increading attack angle

swing	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
impact momentum	24	24	24	23	24	24	23	24	23	23	23	23	24	23	23	23	23	24	24
power (watts)	1003	995	975	884	990	949	935	935	929	935	930	925	963	892	896	911	967	935	1041
approach angle (degrees)	-5	-3	1	3	3	5	6	8	11	13	13	13	13	15	17	17	17	19	20
projected distance (ft)	187	192	200	199	231	209	220	221	229	230	230	232	236	232	240	245	240	248	267
exit velo (mph)	83	84	82	80	84	82	81	82	81	80	81	80	82	80	81	80	81	82	84
date	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr	20-Apr

Figure 3



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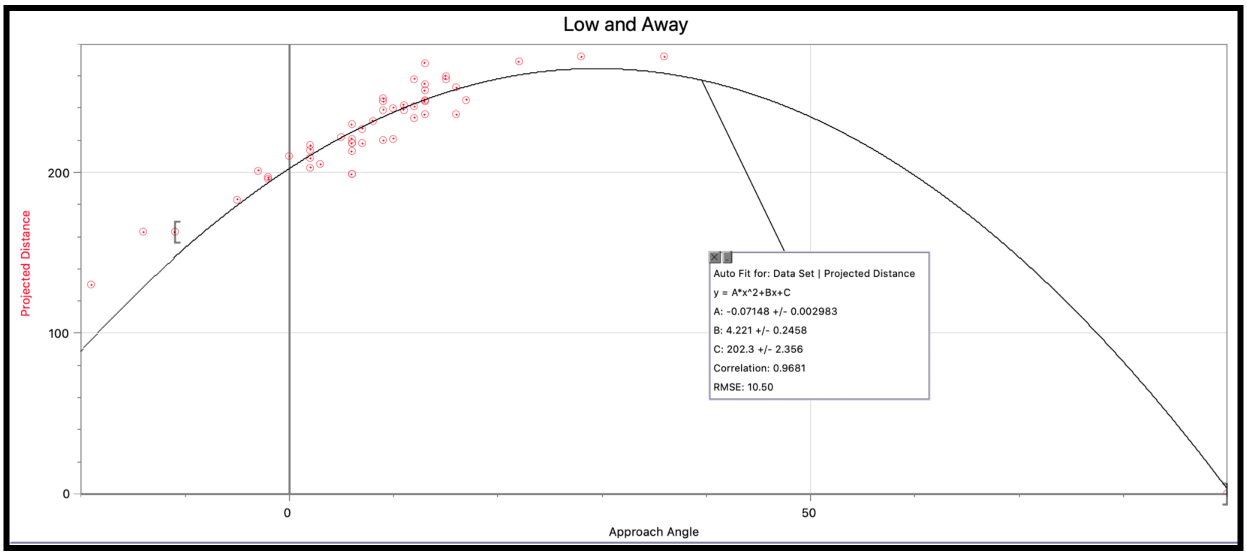

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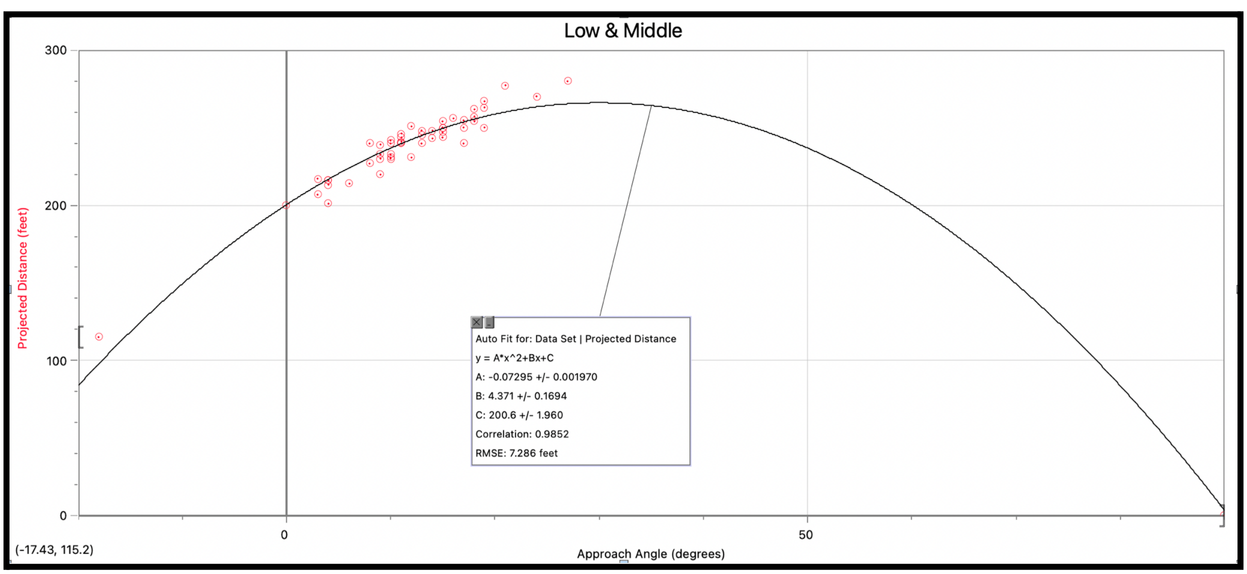

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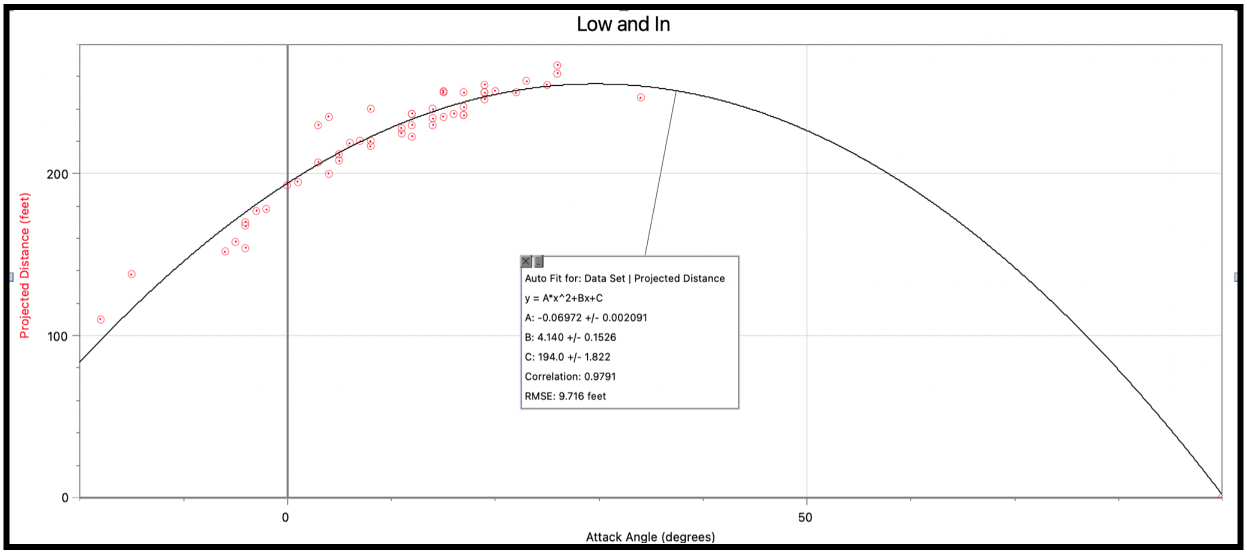

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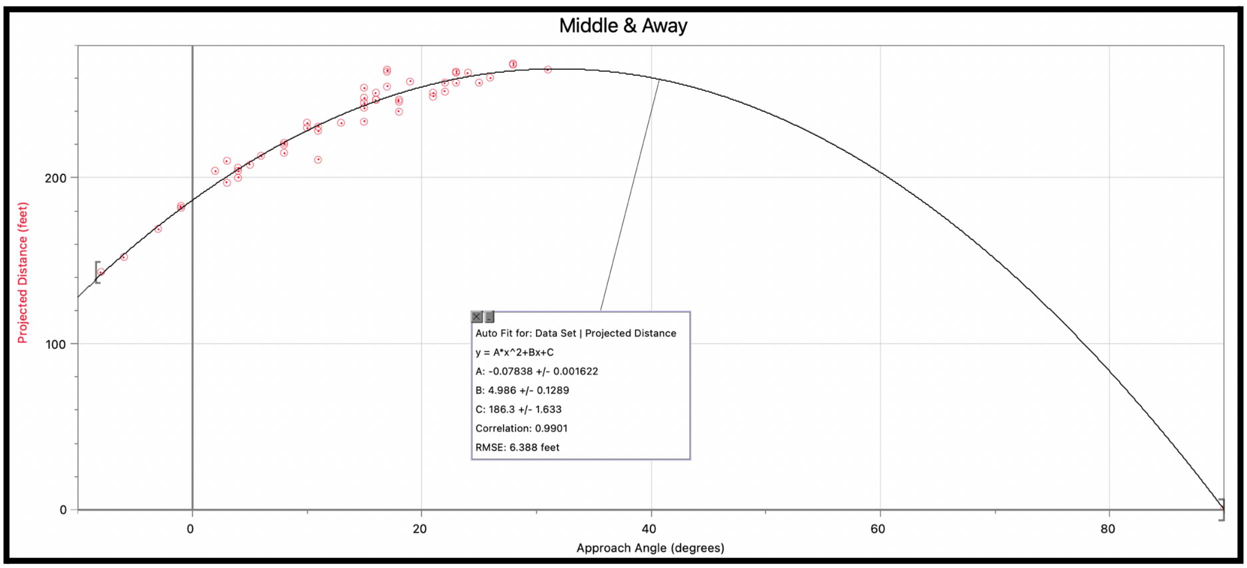

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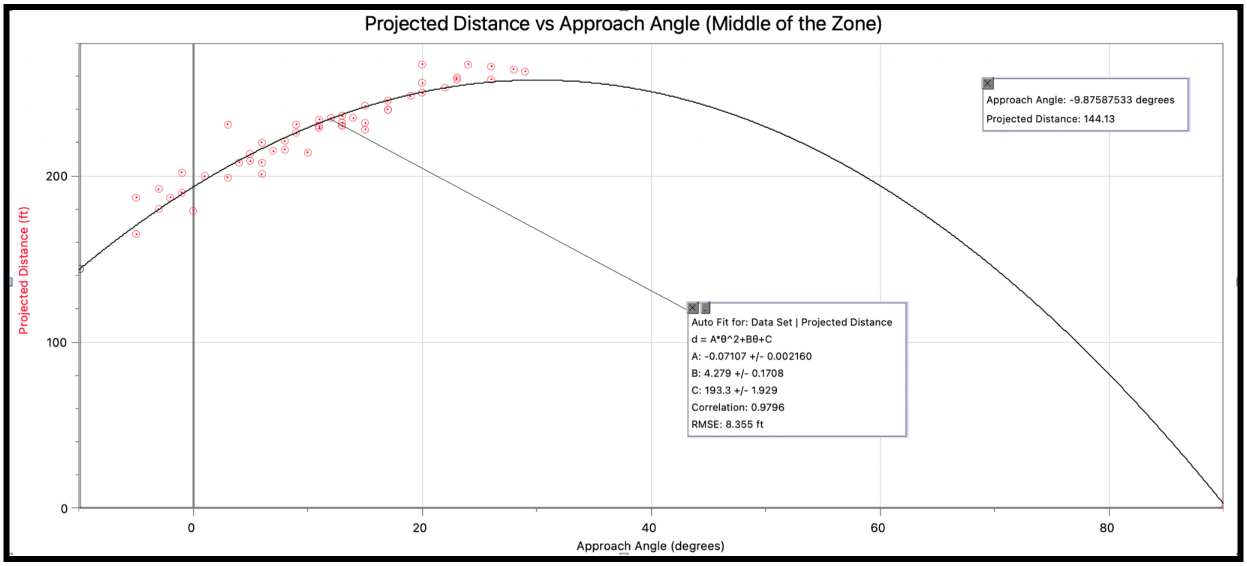

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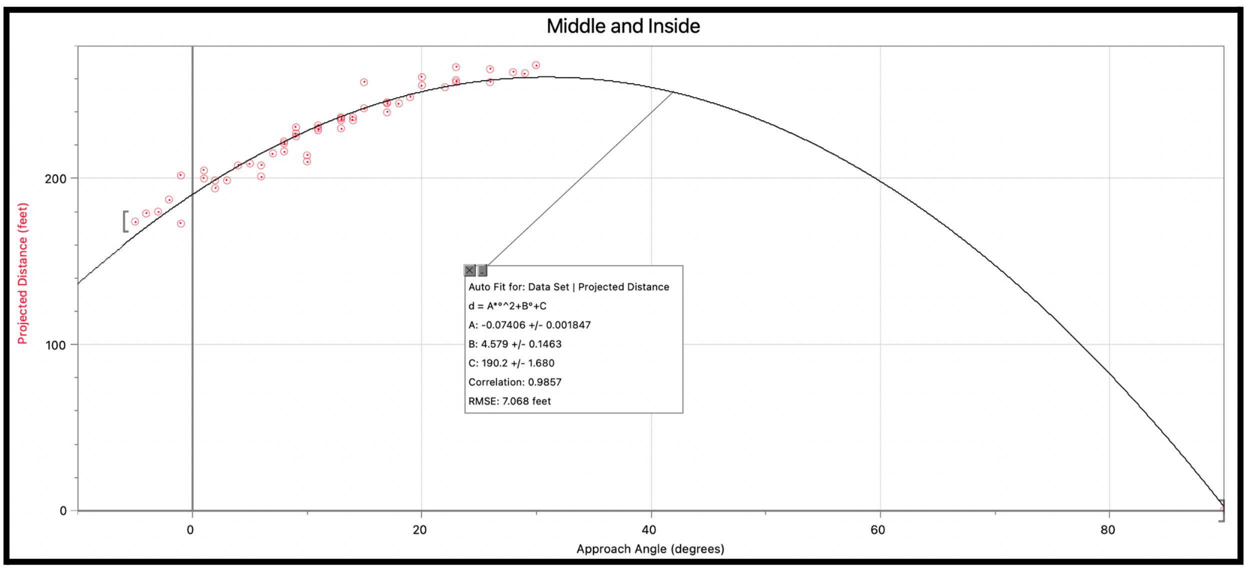

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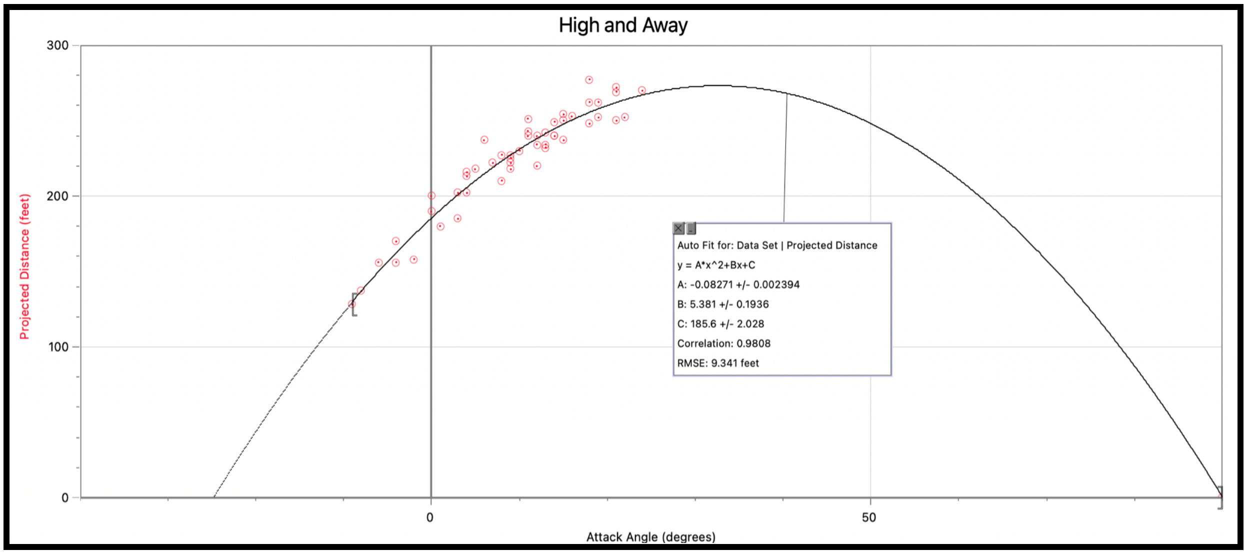

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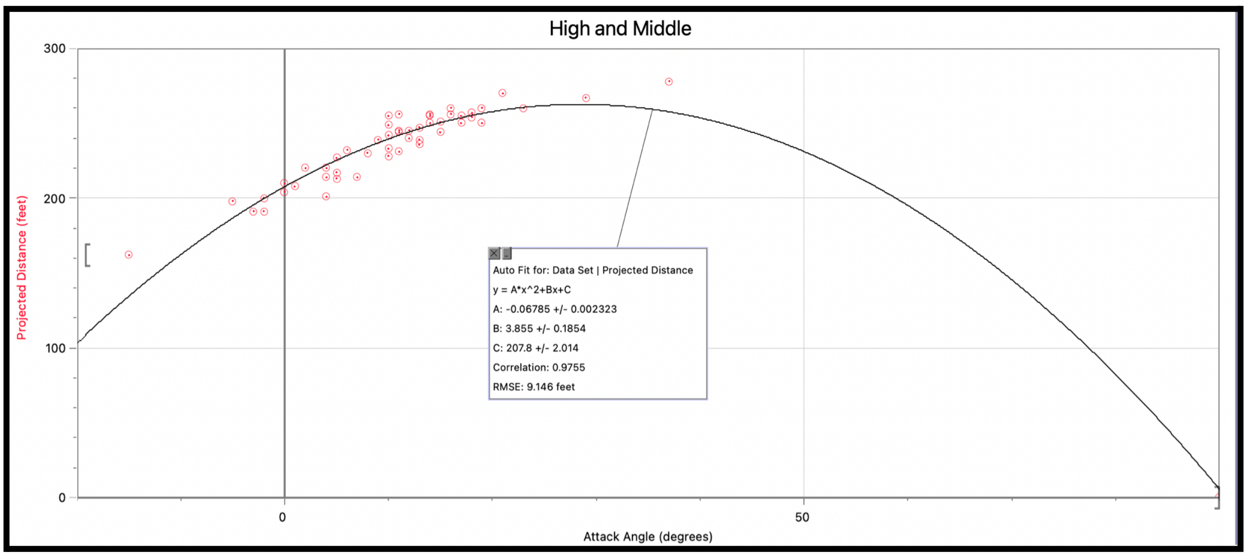

Figure 12

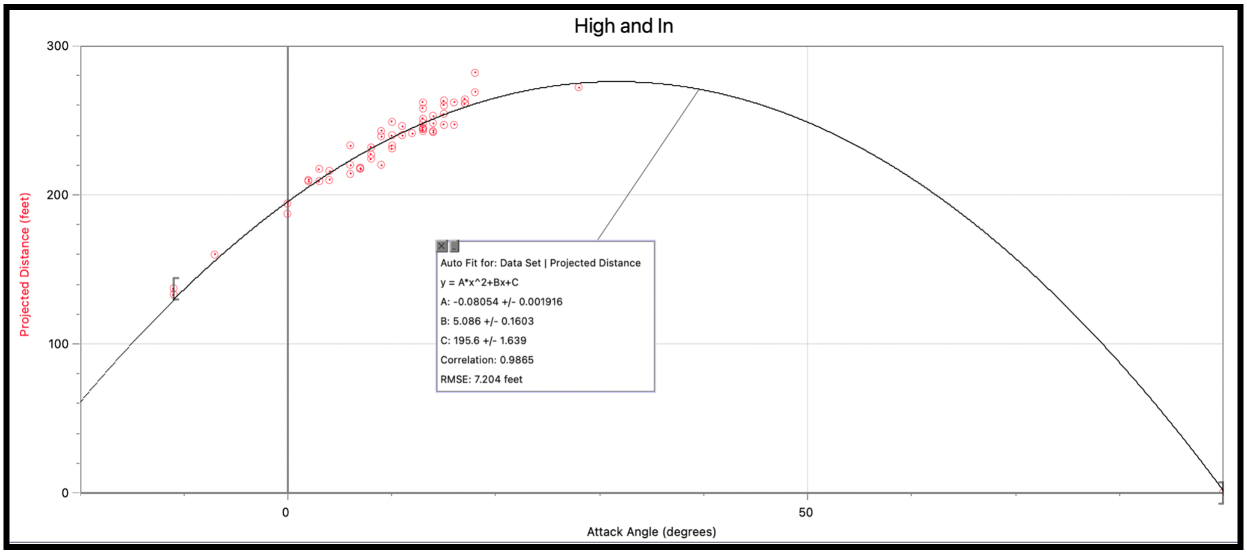

Figure 13

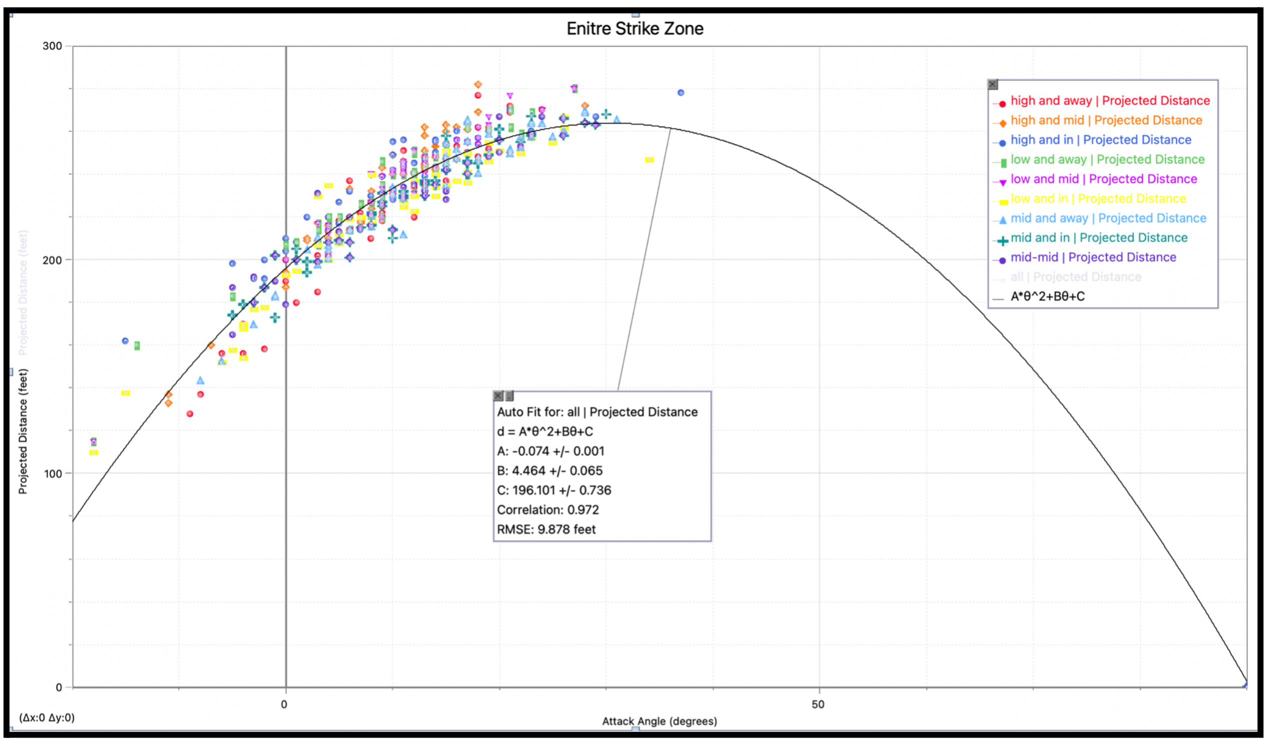

Figure 14

Subzone	Max Attack Angle (degrees)	Max Projected Distance (feet)
High, Away	32.53	273
High, Middle	28.41	263
High, Inside	31.57	276
Middle, Away	31.81	266
Middle, Middle	30.10	258
Middle, Inside	30.91	261
Low, Away	29.53	265
Low, Middle	29.96	266
Low, Inside	29.69	256
All Data Combined	30.16	263

Table 2