A new framework for quantifying free throw success: consistency at launch drives command

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With the NBA's adoption of in-game limb tracking in 2023, the updated Hawk-Eye system captures high-resolution, 3D pose estimations of players and the ball 60 times per second. Linking this spatiotemporal data to key events—like shots, passes, rebounds, and fouls—enables analyses previously impossible and signals a new era for NBA analytics. Here, we leverage Hawk-Eye to introduce a novel ensemble of metrics for evaluating free throw shooting, and through a case study, we demonstrate how our approach better characterizes free throw skills than traditional methods.

First, utilizing precise ball location data, we introduce *command* inspired by the concept of a pitcher's command in baseball. A commanding shooter consistently hits the basket's bullseye (2 inches behind rim center): this new metric distinguishes players who consistently swish from those who merely 'get-lucky' sometimes. We define a shooter's command as

$$C = \frac{1}{1 + \sqrt{\mu^2 + \sigma^2}}$$

where μ is the ball's average distance from the bullseye and σ is the ball's shot-to-shot variation in landing location. Players who are both accurate (on the bullseye, low μ) and precise (with little variation, low σ) demonstrate true command of their shot—players like Klay Thompson and Kyrie Irving routinely connect with the basket's sweet spot, while players like Andre Drummond and Nic Claxton rarely do the same. Command correlates with shooting percentage but captures underlying shot quality, thus providing additional information and, especially in small samples, predicts future performance more reliably than shooting percentage alone.

Next, we develop metrics that capture consistency in the ball's launch dynamics and examine their relationship with command. An analysis of 286 NBA players with at least 100 free throws in the 2023–25 seasons shows that struggling shooters often display inconsistency in the physics of the ball's launch. Meanwhile, shooters who reliably reproduce launch angle and speed demonstrate the strongest command over their shot. Release position plays a smaller role as variations in angle and velocity can offset positional shifts. Table 1 summarizes this for 12 notable shooters—six strong and six weak—illustrating how consistency in launch dynamics explains performance differences. These methods can guide targeted interventions to address the specific launch issues behind poor free throw shooting.

	Launch			Response	
	Angle Consistency	Velocity Consistency	Overall Consistency	In-Ring Command	Free Throw Percentage
Walker Kessler	52	39	35	0	57
DeAndre Jordan	39	0	0	9	47
Nic Claxton	42	27	20	19	53
Dereck Lively	0	38	1	29	57
Andre Drummond	72	22	36	29	61
Jusuf Nurkić	48	31	27	31	65
⋮	⋮	⋮	⋮	⋮	⋮
James Harden	56	87	69	95	88
Steph Curry	94	65	79	95	93
Lauri Markkanen	74	65	66	96	89
Kyrie Irving	84	53	65	97	91
Bogdan Bogdanović	80	63	68	99	91
Klay Thompson	70	42	48	100	93

Table 1: Launch consistency shapes shot outcomes. Overall consistency is decomposed into angle and velocity (percentiles). The table highlights six players with the highest and lowest command (percentiles), illustrating that command is driven by consistent launch dynamics.

Finally, we construct a physics-based model to show that shot outcomes are determined at the launch. For a given release location, the model identifies all combinations of launch angle and velocity that reliably produce makes, thereby defining the optimal launch conditions for a successful shot.

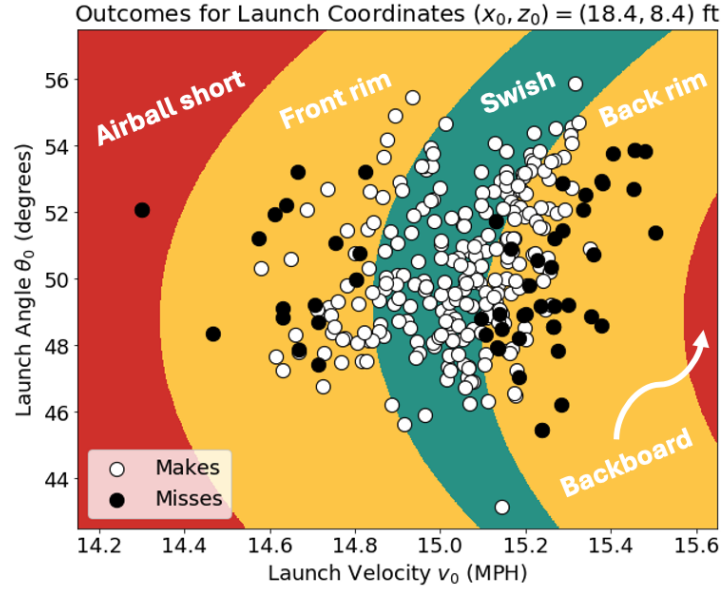Outcomes for Launch Coordinates $(x_0, z_0) = (18.4, 8.4)$ ft

Figure 1: Physics-based model: red indicates miss, yellow indicates rim-hit, green indicates swish. Hawk-Eye foul shots are superimposed (white indicates make, black indicates miss) for a collection of players.

Grounded in the Hawk-Eye data, our results introduce a new level of quantitative rigor to NBA analysis. We formalize the concept of command and show that it arises from repeatable launch dynamics and, thus, the ability to reliably control the ball's trajectory. Using a physics-based model, we characterize the launch conditions that maximize shot success. This framework provides both predictive tools for evaluating shooter quality and actionable insights for players seeking to refine their mechanics.