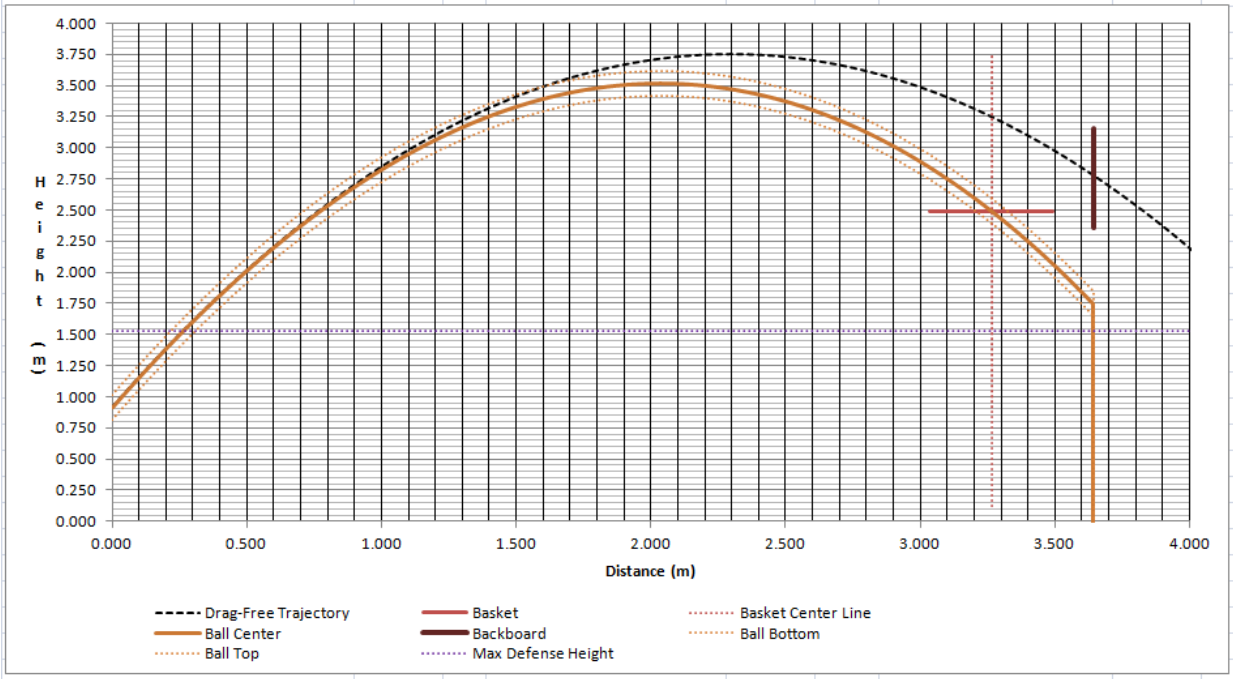
Shot Trajectory and Scoring Simulator
Accounts for Drag and Potential Rebounds

Launch:								
Launch Height (Inches)	36.0	in	Initial Velocity	8.056	m/s	Initial Velocity x	3.018	m
Target Basket (Top=1,Middle=2,Bottom=3)	1	Top	Angle	68.0	deg	Initial Position x	-	m
Shoot ("S" or Lay-Up "L")	S					Initial Velocity y	7.469	m
If "L", Extension from Frame Perimeter	14.0	in	Air Density (F5 for Calc)	1.218	kg/m^3	Initial Position y	0.914	m
If "S", Launch Distance from Base of Key	-	in						
Distance to Basket Center	10.71	ft	To Avoid Block Shots	12.19	in	"Bulls-Eye Speed No Drag"	7.567	m/s
Distance to Basket Center	3.264	m	Launch Distance from Base>	0.310	m	"Bulls-Eye Speed No Drag"	16.95	mph
Target:								
Shoots Through Net:								
Bottom of Ball 1st Passing Front of Rim	2.789	m	Clear +	0.30	Hit	Basket Height	2.489	m
Top of Ball 1st Passing Back of Rim	2.116	m	Clear -	(0.37)	1	Relative Height	1.575	m
Potential Rebounds:						Top of Backboard	3.159	m
Angle of Backboard Impact	0.0	deg				Bottom of Backboard	2.359	m
Speed of Rebound	0.000	m/s				Speed at Basket CenterLine	5.107	m/s
Bottom of Ball 2nd Passing Back of Rim	(0.394)	m	Clear +	(2.88)	Net	Height at Basket Center	0.000	m
Top of Ball 2nd Passing Front of Rim	(0.293)	m	Clear -	(2.78)	-	Time to Target (No Drag)	1.082	s
Glancing Shots Tolerance (% of Ball Radius)	50%	(50% - Forgiving - to 100% - Relaxed)				Time to Target (Drag)	1.177	s
Shot Outcome	Scores							



Input & Output Section–

Input Variables:

Target Basket (Top, Middle, or Low), Launch Height/Angle/Velocity, Air Density (w. link to online calculator), Variable Tolerance for Rim Clearances, Simulates Shooting or Lay-Up with Extension (robot geometry may require tweaking of Lay-Up function). You can also change (elsewhere) other variables from drag coefficients to ball bounciness.

Numerical Outputs:

Useful dimensional and trajectory calculated outputs, including Set-Back from Base of Key to avoid Block Shots at maximum encroachment.

Graphical Output:

Ball Trajectory with and without Drag Effects (Center, Top and Bottom Envelopes of the ball), Layout of Basket and Backboard

Solver Functions: Excel Solver can be used to solve for value of key variables resulting in a bulls-eye shot (sets yellow cell to zero).

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											Launch Speed (mph and m/s)										
		11.20	11.76	12.32	12.88	13.44	14.00	14.56	15.12	15.68	16.24	16.80	17.36	17.92	18.48	19.04	19.60	20.16	20.72	21.28	21.84	22.40
	X	5.000	5.250	5.500	5.750	6.000	6.250	6.500	6.750	7.000	7.250	7.500	7.750	8.000	8.250	8.500	8.750	9.000	9.250	9.500	9.750	10.000
	80.00																					
	78.00																					X
	76.00																			X	X	
	74.00																	X	X			
	72.00															X	X					
	70.00														X	X						
	68.00													X	X							
	66.00												X	X								
	64.00												X									
Launch	62.00											X	X			X						
Angle	60.00											X										
	58.00											X			X	X						
	56.00											X			X	X						
	54.00											X			X	X						
	52.00														X	X	X					
	50.00												X			X	X	X				
	48.00															X	X	X				
	46.00																X	X	X			
	44.00																X	X	X			
	42.00																	X	X	X		
	40.00																			X		

	40.0	deg	Minimum Angle		Launch Height	36	in		
	2.0	deg	Angle Increment		Shoot or Roll	S		If Roll, Extension Length	14 in
					Distance	10.71	ft		
	10.000	m/s	Maximum Speed		Shooting at	Top	Basket		
	22.40	mph	Maximum Speed		Glancing Shots	50%			
	0.250	m/s	Speed Increment		Air Density	1.22			
	0.56	mph	Speed Increment						

											Launch Speed (mph and m/s)										
		11.20	11.76	12.32	12.88	13.44	14.00	14.56	15.12	15.68	16.24	16.80	17.36	17.92	18.48	19.04	19.60	20.16	20.72	21.28	21.84	22.40
	X	5.000	5.250	5.500	5.750	6.000	6.250	6.500	6.750	7.000	7.250	7.500	7.750	8.000	8.250	8.500	8.750	9.000	9.250	9.500	9.750	10.000
	0.00											X										
	0.80												X	X								
Air	0.90												X	X								
Density	1.00													X								
kg/m^3	1.10													X								
	1.22													X	X							
	1.30													X	X							

	68.0	Deg	Launch Angle		Launch Height	36	in		
					Shoot or Roll	S		If Roll, Extension Length	14 0
					Distance	10.71	ft		
	10.000	m/s	Maximum Speed		Shooting at	Top	Basket		
	22.40	mph	Maximum Speed		Glancing Shots	50%			
	0.250	m/s	Speed Increment		Air Density	1.22			
	0.56	mph	Speed Increment						

Sensitivity Tables –

Two preset sensitivity tables:

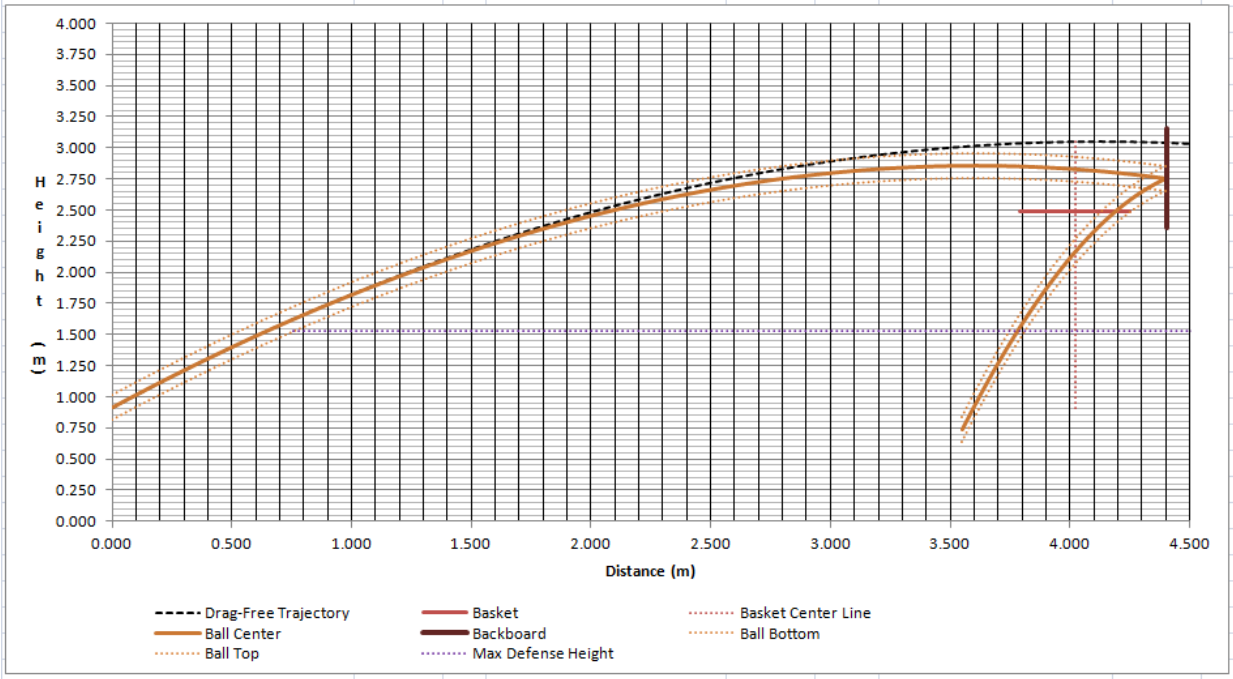
One displays shot Hits "X" and Misses as a function of Launch Velocity and Angle.

The second displays shot Hits "X" and Misses as a function of Launch Velocity and Air Density for a given Launch Angle.

A somewhat experienced user could set up additional tables to suit. (Tables should be "deactivated" (set to values) if solver is to be used, as solving routine appears to want to re-calc everything iteratively!)

Shot Trajectory and Scoring Simulator
Accounts for Drag and Potential Rebounds

Launch:								
Launch Height (Inches)	36.0	in	Initial Velocity	9.000	m/s	Initial Velocity x	6.252	m
Target Basket (Top=1,Middle=2,Bottom=3)	1	Top	Angle	46.0	deg	Initial Position x	-	m
Shoot ("S" or Lay-Up "L")	S					Initial Velocity y	6.474	m
If "L", Extension from Frame Perimeter	14.0	in	Air Density (F5 for Calc)	1.218	kg/m^3	Initial Position y	0.914	m
If "S", Launch Distance from Base of Key	29.9	in						
Distance to Basket Center	13.20	ft	To Avoid Block Shots	29.94	in	"Bulls-Eye Speed No Drag"	7.968	m/s
Distance to Basket Center	4.023	m	Launch Distance from Base>	0.760	m	"Bulls-Eye Speed No Drag"	17.85	mph
Target:								
Shoots Through Net:								
Bottom of Ball 1st Passing Front of Rim	2.800	m	Clear +	0.31	Long	Basket Height	2.489	m
Top of Ball 1st Passing Back of Rim	2.839	m	Clear -	0.35	-	Relative Height	1.575	m
Potential Rebounds:						Top of Backboard	3.159	m
Angle of Backboard Impact	-14.6	deg				Bottom of Backboard	2.359	m
Speed of Rebound	2.145	m/s				Speed at Basket CenterLine	5.510	m/s
Bottom of Ball 2nd Passing Back of Rim	2.527	m	Clear +	0.04	Hit	Height at Basket Center	0.339	m
Top of Ball 2nd Passing Front of Rim	1.612	m	Clear -	(0.88)	1	Time to Target (No Drag)	0.643	s
Glancing Shots Tolerance (% of Ball Radius)	50%	(50% - Forgiving - to 100% - Relaxed)				Time to Target (Drag)	0.692	s
Shot Outcome	Scores							



Accounting for Backboard Rebounds–

Ball trajectory programmed to respond to a first bounce off the backboard towards the rim, capturing an ability to score over a wider range of launch velocities (for some launch angles). User can tweak parameters such as ball bounciness (coefficient of restitution) and rim-bounce clearances to suit. Second order bounces and bounces off the rim attachment plate may also produce a few additional scoring trajectories!

(In the example above, the Launch point has been moved back almost 30 inches (from the Base of the Key) to ensure the shot is not blocked even if the defensive robot is at maximum encroachment – next to the Base of the Key.)

Some useful resources and references:

Simulating Projectile Motion in the Air with Spreadsheets, Jan Benacka , Spreadsheets in Education (eJSiE), 10-9-2009

Modeling Basketball Free Throws, Gablonsky and Lang, SIAM Review 2005

Physics for Game Programmers, Chapter 7

The Physics of Sports, The Physics of Basketball, p.86