Ballistic Coefficients, Velocities and Hit Probabilities of Long Range Bullets

To determine the maximum effective range of a cartridge is such an ambiguous statement it's not funny. Effective for what? Target Shooting, Hunting, Practical Competition, Sniping!! The crude maximum effective range of any cartridge is the supersonic distance of the projectile fired from it. This is crude though as only a few variables in the equation here have been met.

The hunting range of cartridges depends upon the terminal performance of the projectile, the accuracy of the projectile, accuracy of the rifle and shooter in wind, mirage and the immediate location, movement and temperament of the animal. Taking all these into account, the 700m supersonic distance of the average hunting .308Win Cartridge far exceeds the actual hunting ethical hunting distance of this cartridge on say…a Fallow Doe.

When it comes to target shooting and any competition shooting with the same cartridge, the distances obviously increase. The supersonic distance is often used as there is a dramatic loss of accuracy especially in changing winds when the target is outside the supersonic distance of the projectile. An example of this is the desire for competition shooters to increase barrel length and charge to have their .308Win 155gn Full-bore projectiles remain supersonic until the maximum target distance of 1000 yards (914m).

To avoid the misinterpretation and ambiguity of this issue, a more scientific approach to this area of hit probability is required. This approach will give a better answer to the question, "How accurate is your rifle at 1000m?"

Variables

Numerous variables can be present when determining hit ratios of rifle bullets at any range. Some of the variables here are;

1. How big is the target?
2. How strong is the wind?
3. Is the wind constant or changing?
4. Is there Mirage present?
5. How far can the projectile remain supersonic?
6. What dispersion can the rifle/projectile itself shoot (Group size)?
7. Can the shooter keep his/her dispersion equal to that of the rifle/projectile?

Attributes to some of these variables are;

1. Shape of the target (12" square ones are easier to hit than 12" round ones).
2. What error can the shooter estimate the wind within (+/- 1m/s, 2m/s 3m/s etc).
3. Mirage density.
4. Temperature and altitude at the time of shooting. Thinner air will increase hit probability.
5. Standard deviation of the ammunition velocity (+/- 10fps, 20 fps etc).
6. Dynamic Stability of the projectile (Cross winds can decrease stability).
7. Beam divergence and therefore accuracy of the Laser Range Finder.

The key word in all of this is "Hit Probability". This refers to the first round hit, not the second and definitely not the third. A true capability of the shooter and the rifle is the "First round, out of the box, no bull-shit round on target.

Hit Probability

Before we venture into the realm of increasing the hit probability of a rifle, we first must understand how it works. We need to first of all, develop some baselines or standards to work from. If we are to compare one cartridge to another to compare hit probabilities this is what we should do. We must make some assumptions or come to various agreements.

These are;

1. Standardise the target
2. Standardise or eliminate the standard deviation of the velocity.
3. Have a believable and likely average velocity of the projectile.
4. Have a likely efficiency rating (Ballistic Coefficient) of the projectile.
5. Use a projectile with the maximum or near maximum efficiency compared to all other in the same calibre for that cartridge.
6. Use the same error for a likely wind speed and change of speed.
7. Use the same dispersion error for every rifle.
8. Standardise the environmental conditions for every cartridge.
9. Standardise the Ballistics Software for the calculations.

Doing all this will not make every comparison fool proof and perfect, but it will eliminate some variables and reduce the errors enough between all of the cartridges to provide a reasonable comparison where some conclusions can be drawn with some degree of accuracy.

The hit probability of the cartridges in the following chart are expressed in percentages. This a commonly used measurement and obviously the easiest to understand. The following chart and resultant graph is a comparison of 25 Cartridges that I have used or observed students use over the past four years in long range shooting. The information standards are the following;

1. No Standard deviation for the ammunition.
2. Wind Error is +/- 1m/s from a full value 3m/s cross wind.
3. No mirage is present.
4. Rifle/Shooter dispersion does not exceed ½ MOA.
5. Target is a 12" Disc (Circular in shape)
6. Projectiles are specified for each cartridge with likely BC's.
7. Projectile velocities are specified and are likely for the cartridge.
8. Ballistic Software is of a certain type used for all calculations.

What all of this means is that we are assuming that all cartridges are fired with the same accuracy, in the same winds, same environmental conditions, with no mirage and that the information on the ballistic coefficients and velocities are not inflated to unrealistic numbers. Then and only then can we start to make a comparison between the hit probabilities of these cartridges.

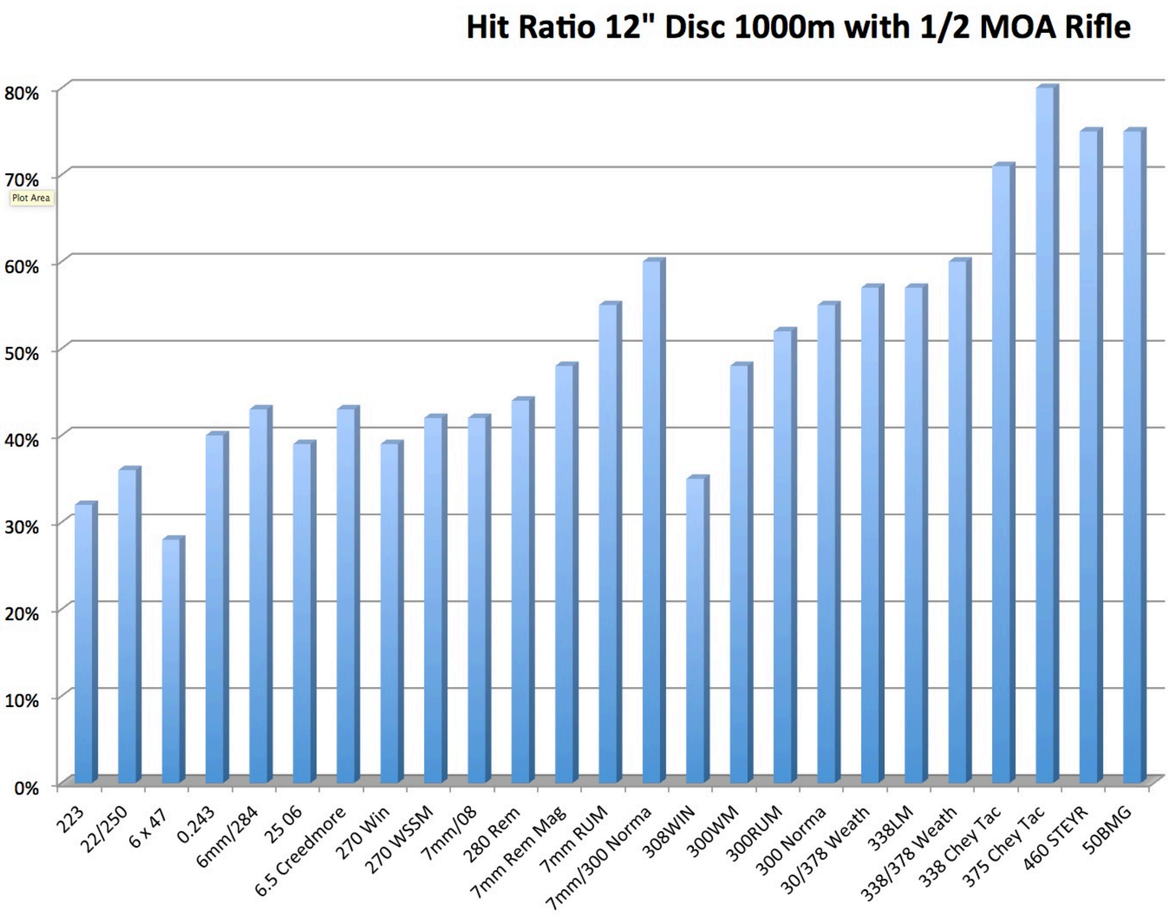

Figure 1. Percentage Hit Probability Graph of 25 rifle cartridges

Cart	Projectile	BC	Velocity (fps)	Wind Drift in " 3m/s	Wind Drift in " 2m/s	Wind Drift error 3m/s +/- 1ms	1/2 MOA Error = 6"	Hit Ratio 12" Disc 1000m with 1/2 MOA Rifle
223	80gn Berg VLD	0.445	2600	97	65	32	38	32%
22/250	80gn Berg VLD	0.445	3000	81	54	27	33	36%
6 x 47	87gn Berg VLD	0.412	2550	109	73	36	42	28%
0.243	95gn Berg VLD	0.486	3000	71	47	24	30	40%
6mm/284	95gn Berg VLD	0.486	3150	66	44	22	28	43%
25 06	115gn Berg VLD	0.466	2950	77	52	25	31	39%
6.5 Creedmore	140gn Berg VLD	0.612	2500	66	44	22	28	43%
270 Win	150gn Berg VLD	0.514	2750	75	30	25	31	39%
270 WSSM	150gn Berg VLD	0.514	2950	68	45	23	29	42%
7mm/08	168gn Berg VLD	0.617	2480	68	45	23	29	42%
280 Rem	168gn Berg VLD	0.617	2600	63	42	21	27	44%
7mm Rem Mag	168gn Berg VLD	0.617	2750	58	29	19	25	48%
7mm RUM	180gn Berg VLD	0.659	3000	47	31	16	22	55%
7mm/300 Norma	180gn Berg VLD	0.659	3200	42	28	14	20	60%
308WIN	175gn SMK	0.496	2600	85	57	28	34	35%
300WM	210gn Berg VLD	0.631	2700	58	39	19	25	48%
300RUM	210gn Berg VLD	0.631	2900	52	35	17	23	52%
300 Norma	210gn Berg VLD	0.631	3000	49	33	16	22	55%
30/378 Weath	210gn Berg VLD	0.631	3150	46	34	15	21	57%
338LM	300gn Berg Hyb	0.816	2600	44	29	15	21	57%
338/378 Weath	300gn Berg Hyb	0.816	2700	42	28	14	20	60%
338 Chey Tac	300gn Berg Hyb	0.816	3100	34	23	11	17	71%
375 Chey Tac	375gn RM	0.926	3070	29	20	9	15	80%
460 STEYR	500GN WC	0.89	3200	29	19	10	16	75%
50BMG	750GN AMAX	1.02	2800	30	20	10	16	75%

Figure 2. Table containing most of the data that created the graph in Figure 1.

Now the "Wotifs" come. What if there was no wind? Then the hit probabilities of all cartridges would sky rocket. The .308Win would be above 60%. All the others would be a lot higher like the 100% mark. What if there was a dense changing mirage? The hit probability would be even less for all cartridges. What if the 460 Steyr used a higher BC projectile than 0.89? The hit probability would at least equal the 375 Cheytac, maybe even exceed it. The list is endless.

Here are some examples in Figures 3 to 6 illustrating the hit probability change in the 338LM at 1000m with changing rifle accuracy and the absence of wind.

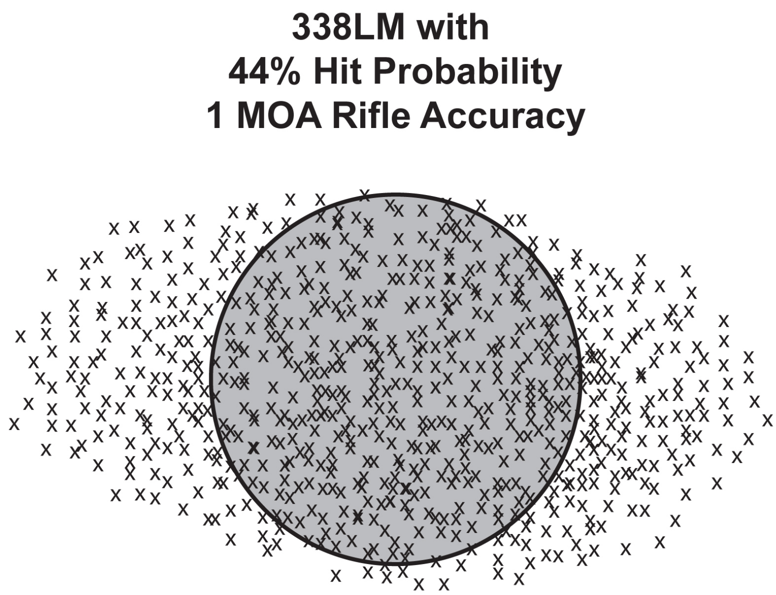

Figure 3.

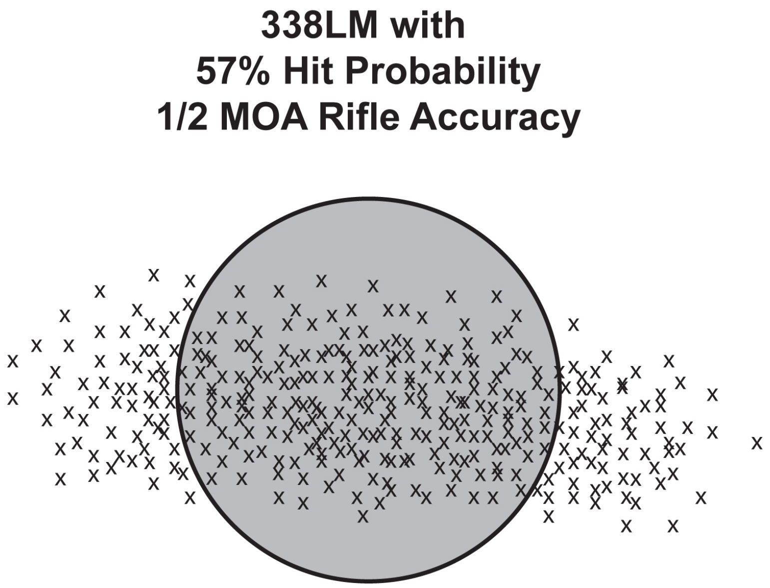

Figure 4.

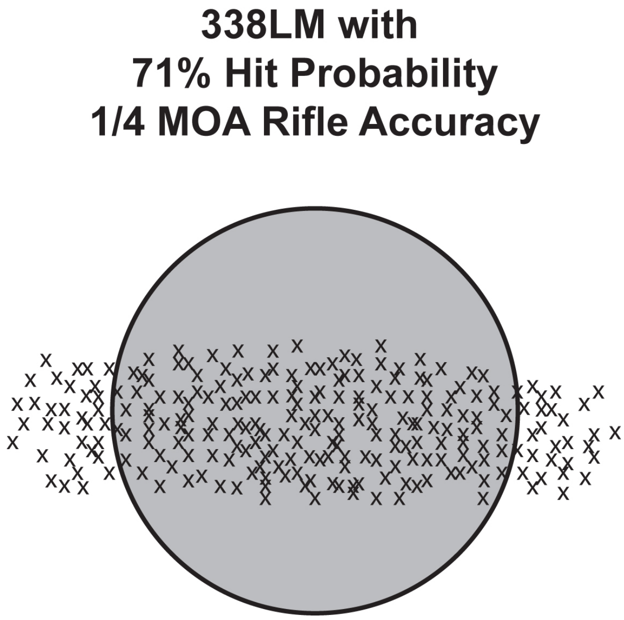

Figure 5.

Figure 6.

By creating baselines for this comparison, we can see there is a relationship happening here. The higher the BC and the higher the velocity, the higher hit probability there is. We can draw a crude formula from this and therefore a numerical factor.

$$BC\ x\ \frac{Velocity}{1000} = x$$

X = BC /Velocity factor that indicates a flight time/wind drift combination. The higher the number, the shorter the flight time and smaller the wind drift. Generally with small arms ammunition, these numbers are between 1 and 3, with 1 being a 223 Rem and 3 being up near the 50 Browning Machine Gun (BMG).

An example of this for the .308 Win is;

$$0.496\ x\ \frac{2600}{1000} = 1.2896$$

An example of the 300WM is;

$$0.631\ x\ \frac{2700}{1000} = 1.7037$$

Cart	Projectile	BC	Velocity (fps)	BC x Vel/1000
223	80gn Berg VLD	0.445	2600	1.157
22/250	80gn Berg VLD	0.445	3000	1.335
6 x 47	87gn Berg VLD	0.412	2550	1.0506
0.243	95gn Berg VLD	0.486	3000	1.458
6mm/284	95gn Berg VLD	0.486	3150	1.5309
25 06	115gn Berg VLD	0.466	2950	1.3747
6.5 Creedmore	140gn Berg VLD	0.612	2500	1.53
270 Win	150gn Berg VLD	0.514	2750	1.4135
270 WSSM	150gn Berg VLD	0.514	2950	1.5163
7mm/08	168gn Berg VLD	0.617	2480	1.53016
280 Rem	168gn Berg VLD	0.617	2600	1.6042
7mm Rem Mag	168gn Berg VLD	0.617	2750	1.69675
7mm RUM	180gn Berg VLD	0.659	3000	1.977
7mm/300 Norma	180gn Berg VLD	0.659	3200	2.1088
308WIN	175gn SMK	0.496	2600	1.2896
300WM	210gn Berg VLD	0.631	2700	1.7037
300RUM	210gn Berg VLD	0.631	2900	1.8299
300 Norma	210gn Berg VLD	0.631	3000	1.893
30/378 Weath	210gn Berg VLD	0.631	3150	1.98765
338LM	300gn Berg Hyb	0.816	2600	2.1216
338/378 Weath	300gn Berg Hyb	0.816	2700	2.2032
338 Chey Tac	300gn Berg Hyb	0.816	3100	2.5296
375 Chey Tac	375gn RM	0.926	3070	2.84282
460 STEYR	500GN WC	0.89	3200	2.848
50BMG	750GN AMAX	1.02	2800	2.856

Figure 7. Table containing the last column of the BC/Velocity Factor

The Factor for the .308Win is 1.2896 and the factor for the 300WM is 1.7037. When these among the other 23 cartridges are plotted on a line graph the relationship becomes very clear. This is a linear relationship.

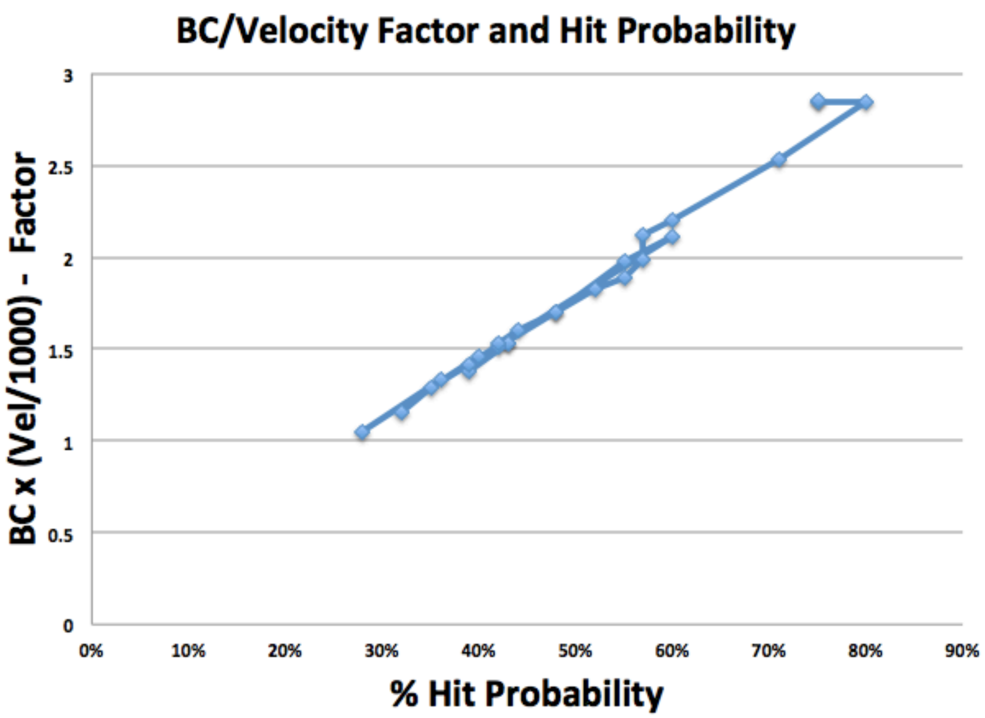

Figure 8. Line Graph illustrating the BC/Vel Factor and Hit Probability.

The line, apart from a few minor anomalies from small errors in assumed velocity and BC, illustrates the proportional relationship between these areas. To put things very simply here, the higher BC the projectile is and the higher muzzle velocity, the higher the hit ratio on the target. When a projectile with a low BC is launched at low muzzle velocities in comparison, the hit ratio just has to be lower.

Now with all this in mind, can two completely different rifle cartridges in shape, calibre, BC and velocities have a very similar Factor and therefore hit probability percentage? Yes of course.

Figure 9. Visual comparison of four different rifle cartridge cases, all within 2% of each other in terms of hit probability. Image courtesy of www.ammoguide.com.

Just look at the 7mm/08 and the 270WSM. Due to the 270WSM having a narrow selection of 0.277" projectiles and the 7mm/08 having a wide selection of higher BC 0.284" projectiles, the 7mm/08 can produce the same hit ratio on the 12" disc. There is a vast visual difference between the 6mm/284 and the magnificent 280 Remington, however they are only 1% apart from each other when it comes to hit probability under these parameters.

So if large terminal energy is not a requirement (Large Game), at longer ranges, one may not require a super-magnum sized cartridge to increase the hit ratio to an acceptable level. A 7mm RUM with a 180gn VLD projectile has a hit ratio very near a 338LM 300gn match projectile. The 300gn projectile will in most cases be more effective on large game at range than the 180gn VLD, but with less recoil, chance of ricochet and terminal effects on smaller game, the fast 7mm's have a number of positive attributes.

Looking at the 7mm/08, the 280 Rem, 7mm Rem Mag, 7mm RUM and the 7mm Long Range Magnum and Dakota (Not mentioned previously), these are stand-outs for their overall size and powder capacity when compared to the Chey-Tac line of cartridges.

So when at the range or on private property and you are shooting your favourite cartridge for one reason or another, please don't be disappointed why your cartridge may not do as well as others that are higher in *BC* and *Velocity*, as that is just the way the cookie crumbles with bigger and faster guns.

References

1. JBM Ballistics: JBM Ballistics, LLC; 2013 [Trajectory Calculations. Available from: http://www.jbmballistics.com/cgi-bin/jbmtraj-5.1.cgi.

2. Haas M. Ammo Guide Interactive: Mike Haas; 2015 [Cartridge Reloading and Comparison Tool]. Available from: https://www.ammoguide.com/cgi-bin/aicompare.cgi?sn=BOmNrZIPOU.

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