Understanding Long Range Bullets
Part 2: Practical Considerations and Decision Making

By Bryan Litz

Abstract

Last month, we identified some basic trends that occur when you scale bullets up and down in caliber. Most of our findings were fundamental and academic. This month, I want to take a close look at some of the practical consequences of scale. Whereas last months article focused on establishing facts, this part will give some conclusions, judgments and some of my opinions based on the facts.

Who Cares?

Caliber and bullet choice are two very important considerations that a shooter has to make regarding his equipment. Too often, important choices like these are made for the wrong reasons and shooters end up disappointed in the performance of their equipment. Choosing components based on how well they work for others can be a bad idea. Every shooter has unique objectives, preferences, abilities and budget. In this article, I'll attempt to present some information that new shooters can use to make informed decisions about what equipment is best for them based on the consequences of scale.

Defining 'Superior Ballistic Performance'

When it comes to ballistic performance and long range target shooting, there are things that are important, and things that are not. For example, some people may compare trajectories, and conclude that a 'flatter' trajectory is better for long range target shooting. Well, it's not. The reason that drop is not important to target shooting is because all of the targets we shoot at are at known distances! A flat trajectory is important if you're unsure how far the target is, and you want to minimize your vertical miss distance due to errors in range judgment.

So what *is* an important 'measure of merit'? *When it comes to long range target shooting, wind deflection is the most important factor of external ballistic performance.* The caliber/bullet/velocity combination that is least affected by wind deflection will stand the highest chance of consistently shooting the smallest group and the highest score, period. There are many other factors like consistent muzzle velocity, seating depth, leade angle, optics, quality of components, etc. All these things are important factors, but they're not external ballistics. More importantly, all of these things are 'deterministic', meaning that once you figure them out, you're good to go. A load that's good this year will be just as good next year, provided nothing else changes. The wind, however, is *not deterministic*. The wind blows different every day, and for every shot. *Having good external ballistics can help you to better cope with the indeterminate wind that plagues long range shooting.*

I know that wind is not the *only* consideration; we'll get to others later on. Right now, I want to show you something about wind deflection.

Table 1 illustrates some trends regarding the .224 thru .30 caliber bullets that we analyzed last month. Remember, the 6.5 mm 142 grain SMK at 2950 fps is the 'benchmark' to which the other bullets are compared. I chose this caliber, bullet and velocity because of its popularity with long-range shooters. A velocity of 2950 fps is typical for the popular 6.5-284 cartridge which is often used with the 142 gr bullets.

What you should notice right away about Table 1 is the fact that the larger calibers require a lower muzzle velocity in order to match the ballistic performance (wind deflection) of the benchmark, and the smaller calibers require more velocity. That shouldn't be a surprise. So what's Table 1 telling us that we don't already know? Well, first thing is that it's nice to know the actual velocities

Caliber: mm inches	5.56 .224	6.0 .243	6.5 .264	7.0 .284	7.62 .308
Bullet weight (gr)	90	115	**142**	175	220
Advertised BC[1]	.502	.585	**.565**	.596	.627
Velocity (fps)	3270	3065	**2950**	2800	2650
Wind deflection[2]	70"	70"	**70"**	70"	70"
Recoil energy (ft-lb)	6.67	7.63	**9.07**	10.70	13.15
Barrel life	Much shorter	Shorter	**800-1200**	Longer	Much longer

Table 1. Shows what velocity other bullets need to match the wind deflection of the 6.5mm 142 gr benchmark at 2950 fps.

that are required to match the benchmark for other calibers and bullets. From those velocities, it's possible to compare the recoil of other calibers to the benchmark, and get an idea of barrel wear. We'll talk in more detail about recoil and barrel life in the next section. Right now, let's continue the discussion of wind deflection.

Understanding Wind Deflection

One way to think about wind deflection is in terms of 'lag time'. Lag time is the difference between the vacuum time of flight[3], and the actual time of flight. For example, say you shoot at a target 1000 yards away with a bullet of initial speed 3000 fps. The vacuum time of flight is 1.00 second (3000 feet at 3000 feet per second). Due to atmospheric drag slowing the bullet down, the actual time of flight may be closer to 1.6 seconds. In this case, the lag time is 0.6 seconds. From here, calculating the wind deflection is easy. Just multiply the lag time by the cross-wind speed, being careful of units. Lets say there was a 10 mph (14.66 fps) crosswind for the 1000 yards of bullet flight. 14.66 fps X 0.6 seconds = 8.8 ft, or 105 inches. The hard part in all of this is figuring out the actual lag time. It depends on actual time of flight, which depends on BC.

Bullets with higher BC's will always have less lag time when fired at the same velocity. The question is, how much velocity can you give up with a higher

[1] Average advertised BC for 2000 fps thru 2850 fps from last months article.
[2] Wind deflection is for a 10 mph crosswind at 1000 yards.
[3] Vacuum time of flight is the time it would take the bullet to get to the target if it maintained its original muzzle velocity all the way.

BC bullet, and still have less lag time? We can get a rough idea about this from looking at Table 1. As a general rule, you can go about 496 fps slower for every +0.100 counts of BC, and match wind deflection. For example, our benchmark 142 gr bullet going 2950 fps (BC = .565) has 70 inches of wind deflection in a 10 mph crosswind at 1000 yards. What speed does a heavier bullet having a BC of 0.596[4] need to match the wind drift of the benchmark? Well, there's 0.031 difference between the BC's, so .31 x 496 fps = 154 fps. So a bullet with a BC of 0.596 only needs to have a muzzle velocity of 2950 fps – 154 fps = 2796 fps in order to match the wind deflection of the lighter faster benchmark. This compares well with the 2800 fps in Table 1.

To echo last month: Most of the calculations in these articles are not intended to show hair splitting precision, but rather to illuminate some basic trends, and approximate magnitudes. Having an educated intuition and some useful rules of thumb can be helpful when you're trying to make decisions involving so many complex variables. In other words, don't hold me to it; it's just an estimate.

BC Advantage of the Larger Calibers

In Table 1, I've shown the velocities required for each bullet to match the wind deflection of the benchmark. What may not be clear is that it is easier to achieve those velocities with the larger calibers than the small ones. For example, the little 90 gr .224 bullet has to get to 3270 fps. That's not easy. Excessive pressure, accelerated barrel wear, and possible bullet failure happen at this kind of speed. The 2950 fps of the benchmark is a 'stout' velocity for the 6.5-284. 2800 fps in the 7mm can be done with the same case and powder as the 6.5-284. I don't want to get into a discussion about case volume and powder efficiency here because I'm frankly not that knowledgeable about it. Besides, this is about external ballistics, not internal. What I can say is that it's easier to achieve 2650 fps with a number of .30 caliber chamberings and 220 grain bullets than it is to achieve 3270 fps with .224 chamberings. That means that *there is more potential to beat the benchmark 70" of wind drift by going to a larger caliber, rather than smaller.*

Of course, driving the heavy bullets at higher speeds results in less wind deflection, but you may run into the same problems that the smaller calibers have like high pressure and short barrel life. Not to mention the crippling recoil! Fast heavy bullets are best suited for heavy benchrest rifles that can absorb the recoil. I know only a few people who can successfully manage the recoil of a 30-338 prone rifle. Those who handle the recoil definitely have an edge in the wind. Be honest with yourself about your recoil comfort level before you decide to go with such a monster. More on recoil considerations later.

BC Isn't Everything… or is it?

I've made a big deal out of BC so far. I've claimed that it's the most important measure of merit for long range ballistic performance, and that it's easier to achieve overall better ballistic performance with the larger calibers.

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[4] Average BC of the 7mm 175 gr bullet from 2000 fps to 2850 fps.

However, before we leave the subject, I'd like to make an important point. BC's by themselves don't win matches! You can't show up at a match with what you believe to be a superior ballistic combination of caliber and bullet, and expect your equipment to win for you. The difference in ballistic performance among long range rifles at any given match is relatively small. Only a couple percent separates the best from the worst ballistic performer. Your ability to effectively read the wind and properly adapt to the subtle changes are far more important than a few points of BC. However, high BC is still important.

Consider the following situation. Two competitors shoot a match against each other in the same conditions. Shooter A has a small (5%) ballistic advantage over shooter B. If both shooters are equally skilled at reading the wind, shooter A stands a *slightly* better chance of winning that match. If these two shot 20 matches against each other, Shooter A is almost certain to out 'agg' shooter B (have a smaller average group size). The more the wind blows, the more advantage shooter A has.

Practical Consequences of Stability

Last month, we noted that the larger bullets require slower twists to be stable, and explained why. Now for the important question: Is there any practical consequence to a faster or slower twist? I can think of a couple things here.

The first one has to do with the structural integrity of the bullets. It's believed by many shooters that high twist rates combined with high muzzle velocities are responsible for bullets breaking apart in flight. Many other factors play into the bullet failure problem like roughness and length of the bore, sharpness of the riflings, etc. It seems that people with the most bullet failure problems are shooting small bullets at high speeds, thru fast twist barrels.

The second consequence of high twist rate has to do with accuracy 'potential'. Some major factors affecting dispersion are related to the spin rate of the bullet. Jacket eccentricity and in-bore yaw are two examples. These types of dispersion are directly related to the RPM of the bullets, which increases with twist rate and velocity. Twist and velocity are two things you need a lot of to be competitive with smaller calibers, and can exacerbate certain types of dispersion.

Keep in mind these are only 'potential' consequences of excessive twist. Many shooters do very good shooting long, small caliber bullets at high velocity without having bullet failure problems, and with amazing accuracy. However, it's something to consider.

To be fair, there are similar 'potential' accuracy robbing effects with larger calibers like excessive recoil on not just you, but on your rifle. There's a video online that shows someone shooting a .50 cal rifle in slow motion. During recoil, you can see the scope wiggling like a noodle! I know most of us don't shoot .50 calibers, but that video drove home the point that you better bolt things down hard if you're dealing with a lot of recoil. Excessive recoil is more likely to mess with your optics and bedding. Also, barrel whip and muzzle blast are potential accuracy robbing side effects of the larger calibers.

One last point regarding stability: Starting as soon as the bullet leaves the barrel, gyroscopic stability begins to increase. The reason is simply because the

forward motion of the bullet is decreasing much faster than the rotational speed of the bullet. In other words, de-stabilizing effects are going away quicker than stabilizing effects. The result is that Sg grows as the bullet goes downrange. Now wait a minute, why is it that some bullets are known to tumble at long range? Well, everything changes when you enter the transonic speed regime. Aerodynamic coefficients spike, unsteady shocks and transient effects are acting to erode the *dynamic stability* (Sd) of the bullet, which is different from the gyroscopic stability (Sg) that we've been talking about. I'll save transonic stability for another article.

For now, just remember that a safe rule of thumb is to insure that your projectiles are fired at a high enough muzzle velocity that they will remain comfortably supersonic (greater than 1120 fps) all the way to the intended target. This way, you will always insure stability.

Up until this point, we've been talking mostly about the external ballistic effects of scaling bullets to different weights and calibers. Of course, there are other things to consider when you decide what caliber and bullet will be best for you.

Comparing Recoil

Recoil is an important consideration that many shooters probably wish they had made more carefully. Sometimes the superior ballistics of the big magnums and high BC bullets are so compelling that folks don't think about the beating that they're in for! Make sure you know how much recoil you are comfortable with before you decide on a caliber and bullet. The flinching caused by heavy recoil may do more damage to your group or score than the little bit you gain from better ballistics.

Table 1 shows the recoil energy, in foot-pounds, for a 16-pound rifle. The recoil was calculated using the method given in Ref 1, where the recoil energy of the powder is accounted for as well as the bullet itself. Table 1 is meant to show the recoil generated by the different caliber/bullet/velocity combinations required to match the wind deflection of the 6.5mm benchmark.

Once again, it's important to understand the trend here, more than the actual numbers. If I told you my rifle had "X" foot-pounds of recoil, that wouldn't mean much to most people. But Table 1 *compares* the numbers, which allows you to see *how much* the recoil is different for the various calibers and bullets. For example, you can say that the 7mm, 175 gr bullet has 18% more recoil than the 6.5mm benchmark[5]. When recoil is compared to a known value, it actually means something.

Of course, you may choose to offset recoil energy by shooting a heavier rifle. If you wanted to shoot the .308 220 gr bullets at the speed required to match the wind deflection of the benchmark, you would need a 23.2-pound rifle to also match the felt recoil of the benchmark. Matching recoil with the 7mm 175 gr bullet requires an 18.9 pound rifle. The 6mm could weigh as little as 13.5 pounds and match the recoil of the 16.0 pound benchmark, and the .224 caliber rifle would weigh 10.3 pounds.

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[5] When loaded to match the wind deflection of the benchmark.

Comparing Barrel Life

Barrel life is one of those things that can't be nailed down because it's different in every case. Also, there are many factors involved that can help or hurt the useful barrel life you get out of a given rifle. For this reason, I chose words instead of numbers to describe the barrel life in Table 1, just to show the trend.

The caliber, bullet, powder charge and resulting velocity are the most important factors that determine barrel life. However, there are things you can do to promote longer barrel life like proper cleaning and using moly-coated bullets. Excessive or improper cleaning can decrease barrel life.

You should think about the following things when considering how important barrel life is to you.

1. How often do you shoot, and what types of matches? If you're a casual benchrest shooter who makes it out to 5 or 6 matches a year to fire 30-40 rounds per match plus a few practices, it may take several years to wear out even a short life barrel. However, if you're a long range prone 'junkie' who attends 3 or 4 matches a month, sometimes firing over 150 rounds in a single weekend, you will wear your barrel out much faster, possibly in less that 1 season.
2. How deep are your pockets? A new barrel chambered and installed runs about $500.
3. How much do you want to bother with the inconvenience of packaging up your rifle and sending it away to be re-barreled? The tragedy of having a barrel go out in the middle of the season can lead to desperate times. Trying to find a gunsmith who has a barrel and time to chamber and install it for you in a rush isn't easy. Even if you have a back-up barrel ready to go, you need to send your rifle away to have it installed, unless you have the tools and know-how to do it yourself.
4. How high are your standards for accuracy? This is important because some barrels wear out slowly, and you may get several hundred rounds of 'acceptable' accuracy after the peak accuracy of the barrel is gone. Serious shooters often change out their barrel as soon as they suspect that accuracy is starting to go downhill, whereas casual shooters may finish out the season with a barrel that's past it's prime. Of course, some barrels stop shooting all at once, within less than 20 rounds.

In my opinion, the uncertainty involved in barrel wear is a big problem. Barrels that wear out quickly make it hard to plan. Even if you keep an exact record of how many rounds you've fired, the barrel may wear out sooner than expected.

Another thing that's annoying about barrels that wear out quickly is that the lands wear so fast that you're constantly seating the bullets out longer. Each match is like an experiment and you may never settle on a consistent seating depth for the whole life of the barrel. Of course, soft seating the bullets into the lands helps with this problem.

Having said all that, there is some recent activity involving small caliber (6mm) cartridges that have case capacities and shoulder angles carefully designed to be gentle on barrels, and wear them out slower. I haven't kept up with the onslaught of new 6mm case designs, but it sounds like they're making some progress regarding barrel life and combustion efficiency.

Remember, it is possible to achieve very long barrel life with a smaller caliber *at reduced velocity*. If you want to keep up with the ballistic performance of the 6.5mm benchmark, you're .224 or 6mm barrel is gonna cook!

Miscellaneous

What about bullets that are not the heaviest for the caliber? Sierra just came out with a 6.5 mm 123 gr Matchking (Ref 3). Can this bullet be better for long range shooting? How about midrange? Speaking only in terms of wind deflection, the short answer is no.

A lighter bullet goes faster for the same powder charge, but it also slows down faster. I'll spare you the math on this one, the bottom line is that the elevated muzzle velocity you get from a lighter bullet going faster will not beat the heavier bullet going slower *at any range.* I'd better explain. When I say faster, I mean using the same powder charge as for the heavier bullet. Of course if you dump enough powder in behind the lighter bullet, you might eventually beat the heavier bullet, but that's not a fair comparison.

When talking about midrange shooting, I say there's no advantage for the lighter bullets in terms of wind deflection, which is true. However, the disadvantage is less profound at mid-range (300-600 yards) than at long range. You may only be talking an inch or two difference in a 10 mph crosswind at 600 yards.

Of course, there are other practical considerations when choosing a bullet weight like: overall length required to feed, and recoil. What if you sprung for that 30-338 prone rifle and planned to shoot the 220's and it beat you up too much. You might drop down to a 175 or a 190 grain option.

Lighter bullets also have merit with hunters, or anyone shooting at uncertain ranges. Unlike known distance target shooting, having a lighter bullet with a flatter trajectory can mean the difference between a hit or a miss when you get one shot at a target of unknown range.

Bottom line here is, *there are reasons to go with lighter bullets but it's not because they are better ballistic performers*, at least not for known distance target shooters.

Some Examples

Let's look at a couple case studies to try and illustrate some of the points we've been talking about. I'll warn you, this section is largely my opinions. You may weigh the pros and cons differently, and that's ok.

Take Scott for example. Scott is a 20 year old college student who loves 1000 yard benchrest shooting, but has very little money to invest in his shooting equipment. I would probably recommend the .30 caliber with the 220 gr bullets for someone like Scott for the following reasons:

1. It's easy to find a relatively inexpensive factory rifle chambered for something large enough to push the 220's at 'benchmark' speeds. Also, Reloading equipment and components may be cheaper and easier to come by for a standard chambering.
2. As a benchrest shooter, Scott can add weight to the rifle to make the recoil more manageable.
3. The bigger bullet going slower will not wear the barrel as fast, which is important to Scott, who can't afford to re-barrel.
4. Scott will get more chicks with a bigger gun. (size matters)

Now lets take a guy named James. James has a developing interest in prone shooting. He's got a decent amount of money to invest in his shooting. For James, I might recommend either the 6.5 or 7mm caliber for the following reasons.

1. For long range prone shooting, the shooter has to support the rifle, so the weight is limited by what the shooter is comfortable holding. Unless James has a high tolerance for recoil, I advise against the 30 caliber for prone shooting. Recoil for the 6.5mm is 'pleasant', and the 7mm is in between 6.5mm and .30 cal.
2. For mostly long range work, the 6.5 and 7mm options have the *potential* of giving James a slight ballistic edge over those shooting smaller calibers.
3. Having enough money to work with makes the 6.5 a more viable option. Depending on how active James is in shooting, he could use up barrels in less than a season (cha-ching…$500).

Now let's consider a mid-range and long range F-class shooter named Roger. Roger is a very observant shooter who is better than most at reading wind. Roger also has discovered that in the absence of abusive recoil, he is able to concentrate better and break his shots exactly where he wants them. For Roger, the choice is clear: .224 or 6mm. Furthermore, I would advise a smaller capacity case that gives up a little ballistic performance and doesn't blow primers and kill barrels.

1. Roger can make up for the slight ballistic deficit with his superior wind reading skills.
2. At midrange, what you give up in ballistics is very small.
3. Most importantly, *if you discover that you can concentrate and execute better shots with mild recoil, that is more important that a couple inches of wind drift.*

So we've looked at 3 individual shooters, with 3 individual sets of circumstances, and arrived at 3 different combinations of caliber/bullet that are, in my opinion, best suited for what we know about each shooter.

Notice what works best for Roger had nothing to do with what worked for James, Scott, or any other shooter in the world. Too often folks invest in expensive equipment for no other reason than because it's what the winners are using. The winners are winning because they're using the equipment that works best for them. You should give yourself that same chance.

One area this isn't necessarily true is with equipment quality. If all the winners are shooting custom barrels, but you just really like your 'ol factory deal,

that's a different story. Of course, when it comes to judging the quality of equipment, studying the choices of those at the top of their game isn't a bad idea. Just make sure you know the difference between good *universal* choices and good *personal* choices.

Conclusion

I've tried to highlight practical considerations throughout the article, and not to make it sound like external ballistics should completely govern your decision of caliber/bullet. Also, I've tried not to be bias in any direction because there is no combination that's hands down best for everyone! Every caliber/bullet combination has it's pro's and con's. It's possible to match the benchmark with any caliber from .224 thru .308. Your choice should be a personal one, according to your specific circumstances.

Shooters all have individual preferences, priorities, and budgets that should be considered on a case-by-case basis when deciding on a caliber/bullet to shoot at long range. Going with what works best for others may not be what works best for you. I hope I've presented some material here that will help shooters, new and seasoned, make better informed decisions about his equipment. Concerning my writing, my highest goal is to help shooters enjoy shooting as much as possible thru greater understanding.

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