Ballistic Calibration, a misunderstood process:
By Doc Beech

Ballistic Calibration is not as simple as we would all like to believe. While the process itself seems simple, it is actually deceptively easy. Making for simple mistakes that can cost you in the long run. The purpose of this short article is to help you gain an understanding of where you should focus a good portion of learning. This article has also been written to help point you to the right resources to learn how to do a ballistic calibration, and is a small culmination of information from multiple sources. All of them being Applied Ballistics Resources. Please keep in mind, this article does not address the weapon itself. Such as making sure your sights are level, making sure your LRF is accurate, making sure your target is level, and chronograph performance.

Where we need to start is an understanding of our limitations. Specifically, how industry standards do not always match up. As a shooter we have all seen G1 and G7 Ballistic Coefficients. It is important to know that Ballistic Coefficients are velocity dependent. A Bullets BC changes, as its velocity changes. But what a lot do not know, is that those coefficients are not all created equal. Some manufacturers calculate their BC using the ASM (Army Standard Metro) and others use the ICAO (International Civil Aviation Organization). Where this comes in, is that different ballistic calculators are also designed around one of these two standards, which gives you about a 3% error off the top. When it comes to a BC there are also other Standards besides G1 and G7. These just happen to fit in to what most shooters experience. A G1 Standard is a Flat Base Bullet. Think 22LR or .224 Berger 35 Grain Varmint Bullet. A G7 Standard is what most long range shooters are used to. Think .308 185 Juggernaut, or .264 140 Grain Hybrid. Why is this deceptive? Well, a G7 Bullet can be "trued" using a G1 BC with good results. Leaving the shooter thinking they have a solid ballistic trajectory, until you hit the transonic to subsonic range. Then all of a sudden the shooter starts having to adjust multiple inputs to get the supersonic and subsonic trajectories to line up. This is why you have a heavy need for segmented BCs when using a G1 BC for a G7 bullet, and why when you use a G7 BC you almost always only need 1 number that ends up being good for all velocities. To get the best results, you need to make sure you use the correct standard, but you also need to make sure you use a ballistic calculator that is designed to use the same atmospheric standard. I cannot stress enough how important it is to use the correct drag model (G1 vs G7), especially when you do a ballistic calibration. To learn more about this, you need to read Applied Ballistics for Long Range Shooting. Aside from that you can also read this article:
http://www.bergerbullets.com/form-factors-a-useful-analysis-tool/

Short Range BCs. Some companies produce their BC numbers with short range calculations. Which actually leads to far greater error in their calculation. BC numbers need to be tested over long range. While the prediction error of 3% from using a G1 instead of the proper G7 is about the same as having a 15 FPS MV Error with a good long range BC, it quickly inflates with a poor BC. Here at Applied Ballistics we test over long range, so you can be sure the BC we provide is accurate.

The little things matter, a lot. You can just go out and shoot a group at 500 yards, take it as gold, and input it in as a ballistic calibration. However there is a good rule to use when doing a ballistic calibration. Keep in mind, that this is contingent on you using the correct BC and drag model. **If your trajectory is off in the supersonic range, then you need to true your muzzle velocity. If your trajectory is off in the transonic - subsonic range, then you need to true your BC.** Also the question comes up, should I alter my BC or should I alter my MV (Muzzle Velocity). If you use our published data, then you should more often than not be altering the MV. If you are pointing your own bullets, and trying to fine tune your BC for this. You need to make sure you do everything possible to eliminate error. To see exactly how this can be harmful you should read page 129 of Accuracy and Precision for Long Range Shooting by Bryan Litz. It covers this in great detail. Ballistic Calibration should be used for ELR (Extended Long Range). ELR is essentially where you are shooting through the transonic in to subsonic range. There is no set standard distance for where this occurs. It is weapon specific. A 22LR is typically transonic at the muzzle, while a .260 Remington might go transonic at 1200 yards for some shooters. This will be determined by your particular setup. Drag Scale Factor truing (Or DSF on the Kestrel) should be done at Mach 1.2 and Mach .9. Remember if your trajectory is off in the supersonic range, you need to true your MV, if it's off at ELR then you need to continue with a DSF calibration. This kind of calibration is not as simple as going out, shooting at 900 yards, getting your true drop and inputting it. There are some things that can cause errors here. The first thing being direction of fire. More specifically the vertical component of Coriolis Effect. If you shoot to the east at 1000 yards in North Texas (30 Cal 155 Grain HBC at 3000 fps), and don't take in to account your nearly + 3" of vertical and 2.3" Right of horizontal Coriolis Effect, then you turn around and fire to the West you now have 6 inches of vertical error built in to your ballistic calibration. Horizontal Coriolis and spin drift are both lateral effects which won't affect your drop and are not a direct part of a ballistic calibration.

So why do we true at long distance, or why do we measure BC at long distances? This is best shown through a table. The amount of error we will be using is ½ MOA. Plenty of good shooters can shoot 1 MOA groups, or even ½ MOA groups. Looking at Table 11.2 which is from *Accuracy and Precision for Long Range Shooting*. You can see that ½ MOA of error at 200 yards is equal to 180FPS Error in MV. Yet at 900 yards that same amount of error is equal to 15 FPS. A 180 FPS shift at 1000 yards is roughly 8 MOA of difference or 80 inches (6 2/3rd Feet). You can see from this simple table that <u>we always want to shoot long range when doing a ballistic calibration</u>.

1/2 MOA error in drop measurement				
Range Yards	Velocity fps	Trajec Inches	Error Inches	MV error fps
200	2241	-3.2	1.0	180
300	2073	-13.4	1.6	100
400	1913	-31.6	2.1	62
500	1758	-59.4	2.6	44
600	1609	-98.4	3.1	32
700	1466	-150.9	3.7	25
800	1330	-219.7	4.2	20
900	1201	-308.2	4.7	15

Table 11.2. Small errors in drop measurement can imply dramatically inaccurate velocity especially at shorter ranges.

Turret tracking errors should also be accounted for. However, these errors can easily be accounted for when truing your MV. You do not necessarily need to input these errors in to the program to get a correct firing solution. You can calibrate them in. A good shooter however still needs to know how much error his turret and reticle have in them, and know how to account for them.

Atmospheric inputs are important when doing a Ballistic Calibration. Specifically because of Density Altitude, and the Speed of Sound. Both of which change with changes in weather. Make sure your software can account for this when doing a calibration otherwise you have added error in to the firing solution. The interesting thing is a 3% error in Atmospherics has the same effects as a 3% error in BC to the ballistic trajectory. But what does 3% error look like? 15 deg F (8C) or .87" HG, or 682' Altitude, or 1035' Density Altitude are 3% error. This is how much error is required in a single variable to be 3% error. Think about how quickly those can compound. You might notice that Humidity is not included. Well Humidity from 0-100% only effects air density by 0.7%.

It is important to know how and when to alter which variable during a Ballistic Calibration. This is covered in full detail in the book Accuracy and Precision for Long Range Shooting by Bryan Litz. It is highly recommended that you read, study, and understand how to do this. A lot of times shooters blame the algorithm when in reality they have unknowingly introduced error. Imagine if you compounded multiple (3-5%) error variables in to your Ballistic Calibration.

1. The use of the correct drag model is important.
2. It is important to calibrate for the variable we are the least uncertain of.
3. It is highly important when calibrating to have accurate tools for data collection. This includes Atmospheric Measure Devices (Kestrel 4500 Applied Ballistics) Laser Range finders, Measuring tapes, and angle and cant indicators. But also that the equipment on your rifle is reliable, and repeatable such as scope tracking.
4. If you trajectory is off in the supersonic range, and you are using the correct drag model and an accurate BC, then you need to true your muzzle velocity.
5. If your trajectory is off in the transonic-subsonic range then you need to true the drag model
6. You need to use BCs from a reliable source.
7. When doing a ballistic calibration, you need to take great care choosing the ranges in order to be more accurate. Short ranges inherently introduce a lot of error. Specifically the most ideal point is Mach 1.2 and Mach .9.
8. Atmospheric Data that is not accurately accounted for can quickly compound in to errors.
9. When shooting, fire enough shots to accurately resolve the group's center. You can get a basic idea in 1-3 shots, but you can refine this with a 5 or 10 shot group. Turret errors can easily be accounted for, with fairly good accuracy, in the MV Calibration. It is recommended that you still measure the turret error, and have a good understanding of your equipment's performance.
10. When doing a ballistic calibration, great care should be taken to minimize uncertainties in all variables (atmospherics, range, sight height, wind, aerodynamic jump, and rifle zero) but to especially not to forget to account for the vertical component of Coriolis effect.
11. When calibrating at ELR every variable increases in importance. For accurate drag calibration at extended range, a great deal of certainty is required when measuring all variables.
12. Most importantly, shooters tend to blame the software, when it is more than likely the inputs that the software was given. Bad inputs will always result in bad firing solutions. It is in the shooters best interest to fully understand all aspects of their software, each variable, and how to account for each variable as well as what that variable effects.

Most importantly all of this is covered in great detail through the books *Applied Ballistics for Long Range Shooting*, and *Accuracy and Precision for Long Range Shooting*. The latter specifically having multiple chapters dedicated to Ballistic Calibration and how to account for certain errors, as well as how to avoid others. It is also recommended that you read the Practical Ballistics article. http://www.appliedballisticsllc.com/Articles/ABDOC118_PracticalBallistics.pdf.