**SmartShot™ User Manual**

© Projectile Science Inc 2020, Revision 200712

Preface

The SmartShot ballistic app is accurate from Mach 3 to Mach 0.6. It is complicated for two reasons: 1. It includes all significant bullet flight effects and 2) it supports both David Tubb’s unique Dynamic Targeting Reticle, for which it was designed, as well as traditional dial or grid reticle scopes. This manual is organized into three parts to simplify navigation: 1) A picture of the SmartShot screen which contains all input and output variables. 2) A Table of Contents in which every paragraph of the manual is page numbered and hyperlinked to the main body of the manual and 3) the main body of the manual which is paragraphed and numerated to four indenture levels.

Additionally a Quick Start manual is provided at www.projectilescience.com\manuals.

**Part One - The SmartShot™ Screen**

Yellow Cells are Output Variables.

All others are Input Variables

**Part Two - Table of Contents**

Hyperlinked to the referenced paragraphs

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | A | B | C | D | E | F | G | H |
| 1 | 200710 |  | | | iterations = "6" | |  |  |
| 2 | ColorCode | Settings | Rifle | System | Environment | | Primary | Input |
| 3 |  | Firing Solution | | Secondary Output | | |  |  |
| 4 | Zero Rng | SgtHt in. | Stab | Mass gn | Twist in. | Length | TPwdr F | dV/dT |
| 5 | 130 | 2.75 | 1.48 | 115 | 7.5 | 1.290 | 75 | 0.5 |
| 6 | Vmuz fps | VRSup | VRSub | BCg7 | BCg1 | Dia in. | TPwdr Tgl | CJ Ix |
| 7 | 2975 | 58.73 | 56.17 | 0.287 | 0.560 | 0.243 | 0 | 0 |
| 8 | Temp F | PLoc inhg | RH% | Vmuz Cal | VR Cal | P sl inhg | DWD Tgl | CJ ClDa |
| 9 | 75 | 27.52 | 50.0 | 2975 | 58.73 | 29.92 | 0 | 3.00 |
| 10 | M Tgl | WtrStaKda | Geo kft | Wind ° | Cor Lat ° | Obx yd | SpnDrfTgl | CJ CMa |
| 11 | 0 | 30.00 | 30.0 | 90 | 0 | 20 | 0 | 3.72 |
| 12 | **YARDS** | **Slope °** | NAV | Wind mph | Cor Hdg ° | ObxClr in. | SpnDrf moa | CJTgl |
| 13 | **2400** | **0** | 4.0 | 5 | 0 | 27.8 | 0.00 | 0 |
| 14 | **EHP yd** | **EHP Δ** | BE moa | BE mils | CJ Ix calc | ObxRqd yd | SpnDrf in. | CJ moa |
| 15 | **2400** | **0** | 146.5 | 42.6 | 0.00010 | 2 | 0.0 | 0.00 |
| 16 | Range yd | FAC | kDA kft | kDensity | 1st Dot | ObxBE | Stab | CJ inch |
| 17 | 2400 | 0.0 | 4.0 | 67.86 | 5.0 | 13.5 | 1.48 | 0.00 |
| 18 | Z mph | Z moa | Z inch | Z mils | ToF sec | ObxEHP | Rz Dot 1 | Rz Dot 2 |
| 19 | 5.0 | 10.1 | 254.3 | 2.9 | 4.933 | 720 | 100 | 200 |

[1. SmartShot Is Unique in Two Ways 7](#_Toc519171108)

[1.1. Designed for the Dynamic Targeting Reticles 7](#_Toc519171109)

[1.1.1. The DTReticles , a Family of Precision Reticles, 7](#_Toc519171110)

[1.1.2. Dynamic Targeting Reticles Are Much Faster 7](#_Toc519171111)

[1.1.2.1. No Computations Except for Extreme Range or Slope 7](#_Toc519171112)

[1.1.2.2. No Scope Dialing 7](#_Toc519171113)

[1.1.2.3. No Target Reacquisition 7](#_Toc519171114)

[1.1.2.4. No Conversion from mph to Angle 7](#_Toc519171115)

[1.1.3. SmartShot Enables The Use of DTReticles With Non-nominal Trajectories 8](#_Toc519171116)

[1.1.3.1. Most Real-world Shots Will Be Non-nominal 8](#_Toc519171117)

[1.1.3.2. Quick, Simple and Accurate EHP Compensations 8](#_Toc519171118)

[1.1.3.3. SmartShot Computes the EHP Instantly for Very Long Shots 8](#_Toc519171119)

[1.2. SmartShot Long Range Accuracy is Better 8](#_Toc519171120)

[1.2.1. Pejsa's Math Model Matches VLD Bullets 8](#_Toc519171121)

[1.2.2. Velocity Retention 8](#_Toc519171122)

[1.2.3. A Single VR Value Suffices For Each Regime . 8](#_Toc519171123)

[1.2.4. VRsup Can Be *Estimated* With BCg7 or BCg1 9](#_Toc519171124)

[1.2.5. Velocity Retention Works Better Than BC’s 9](#_Toc519171125)

[1.2.6. Experts Do Not Agree 9](#_Toc519171126)

[2. SmartShot Overview 9](#_Toc519171127)

[2.1. Input Variables Are In Four Groups; 9](#_Toc519171128)

[2.1.1. Range and Slope 9](#_Toc519171129)

[2.1.1.1. Range, Yards or Meters, A13 9](#_Toc519171130)

[2.1.1.2. Slope, °, B13 9](#_Toc519171131)

[2.1.2. Density, Wind and Coriolis 10](#_Toc519171132)

[2.1.2.1. PLoc – Station pressure, B9- 10](#_Toc519171133)

[2.1.2.2. Temp, A9 10](#_Toc519171134)

[2.1.2.3. Geo kft, C11 10](#_Toc519171135)

[2.1.2.4. Wtr Sta, B11 10](#_Toc519171136)

[2.1.2.5. RH%, C9 10](#_Toc519171137)

[2.1.2.6. Wind Speed, D13 10](#_Toc519171138)

[2.1.2.7. Wind Compass Heading, D11 10](#_Toc519171139)

[2.1.2.8. Coriolis Shot Heading, Hdg °, E13 10](#_Toc519171140)

[2.1.2.9. Coriolis Site Latitude, Lat °, E11 10](#_Toc519171141)

[2.1.2.10. NAV number, C13 10](#_Toc519171142)

[2.1.2.11. Obstruction Distance, Obx yd, F11 10](#_Toc519171143)

[2.1.3. Rifle System Variables 11](#_Toc519171144)

[2.1.3.1. Vmuz fps, A7- 11](#_Toc519171145)

[2.1.3.2. VRsup, B7 11](#_Toc519171146)

[2.1.3.3. VRsub, C7 11](#_Toc519171147)

[2.1.3.4. Zero Rng, A5 11](#_Toc519171148)

[2.1.3.5. Sight Height, B5 11](#_Toc519171149)

[2.1.3.6. BCg7, D7 11](#_Toc519171150)

[2.1.3.7. BCg1, E7 11](#_Toc519171151)

[2.1.3.8. Stab, C5 11](#_Toc519171152)

[2.1.3.9. Twist, E5 12](#_Toc519171153)

[2.1.3.10. Mass, D5 12](#_Toc519171154)

[2.1.3.11. Length, F5 12](#_Toc519171155)

[2.1.3.12. Diameter, F7 12](#_Toc519171156)

[2.1.4. Ballistic Management Variables 12](#_Toc519171157)

[2.1.4.1. Reference Sea Level Pressure, PSL inhg, F9 12](#_Toc519171158)

[2.1.4.2. Powder Temperature, TPwdr, G5 12](#_Toc519171159)

[2.1.4.3. dV/dT, H5 12](#_Toc519171160)

[2.1.4.4. Powder Temp Toggle, TPwdr Tgl, G7 12](#_Toc519171161)

[2.1.4.5. Spin Drift Toggle, SpnDrf Tgl, G11 12](#_Toc519171162)

[2.1.4.6. Differential Wind Drift, DWD Tgl, G9 12](#_Toc519171163)

[2.1.4.7. Crosswind Jump Toggle, CJTog, H13 13](#_Toc519171164)

[2.1.4.8. Moment of Inertia About the Longitudinal Axis, CJ Ix, H7 13](#_Toc519171165)

[2.1.4.9. Lift Force Coefficient, CDa, H9 13](#_Toc519171166)

[2.1.4.10. Overturning Moment Coefficient, CMa, H11 13](#_Toc519171167)

[2.1.4.11. Meters, A11 13](#_Toc519171168)

[2.2. Output Variables are in two groups 13](#_Toc519171169)

[2.2.1. Primary Output Variables 13](#_Toc519171170)

[2.2.1.1. EHP, A15 13](#_Toc519171171)

[2.2.1.2. EHP Δ, B15 13](#_Toc519171172)

[2.2.2. Secondary Output Variables 13](#_Toc519171173)

[2.2.2.1. Z mph (Wind), A19 14](#_Toc519171174)

[2.2.2.2. Z moa, B19 14](#_Toc519171175)

[2.2.2.3. Z inch, C19 14](#_Toc519171176)

[2.2.2.4. Z mils, D19 14](#_Toc519171177)

[2.2.2.5. FAC, B17 14](#_Toc519171178)

[2.2.2.6. Density Altitude, kDA, C17 14](#_Toc519171179)

[2.2.2.7. VR Cal, E9 14](#_Toc519171180)

[2.2.2.8. VMuz Cal, D9 14](#_Toc519171181)  
[2.2.2.9. kDensity, D15 14](file:///C:\Users\pd\Documents\MY%20DIRECTORIES\1Jarrett\1%20SMARTSHOT%20CONTRACT\SS%20Manual%20140526\Working%20Master\Block%2015%20LRZ%20Sub%20Zero%20etc\200705%20Revision\200706%20Manual%20Air%20Density%20test.docx)

[2.2.2.10. Stab, G17 14](#_Toc519171182)

[2.2.2.11. Barrel Elevation Angle, BE moa, C15 14](#_Toc519171183)

[2.2.2.12. Barrel Elevation Angle, BE mils, D15 14](#_Toc519171184)

[2.2.2.13. SpnDrf, inches, G15 14](#_Toc519171185)

[2.2.2.14. SpnDrf, moa, G13 14](#_Toc519171186)

[2.2.2.15. CJ, moa, H15 14](#_Toc519171187)

[2.2.2.16. CJ, in, H17 14](#_Toc519171188)

[2.2.2.17. ObxClr in, F13 14](#_Toc519171189)

[2.2.2.18. ObxReqd yd, F15 14](#_Toc519171190)

[2.2.2.19. Obx BE, F17 14](#_Toc519171191)

[2.2.2.20. Obx EHP, F19 14](#_Toc519171192)

[2.2.2.21. ToF sec, E19 14](#_Toc519171193)

[2.2.2.22. BE mils, D15 14](#_Toc519171194)

[2.2.2.23. CJ lx Calc, E15 14](#_Toc519171195)

[2.2.2.24. RZ Dot 1 and RZ Dot2, G19, H19 - 15](#_Toc519171196)

[2.2.2.25. Range, yds, A17 15](#_Toc519171197)

[2.2.2.26. 1st Wind Dot, E17 15](#_Toc519171198)

[3. Advanced Functions - 15](#_Toc519171199)

[3.1. BCs; "...the whole concept is badly flawed." Art Pejsa 15](#_Toc519171200)

[3.1.1. Velocity Retention 15](#_Toc519171201)

[3.1.2. A Single VR Value Suffices For Each Regime . 16](#_Toc519171202)

[3.1.3. VRsup Can Be Estimated With BCg7 or BCg1 17](#_Toc519171203)

[3.1.4. Velocity Retention Works Better Than BC’s 17](#_Toc519171204)

[3.1.5. Not All Agree 18](#_Toc519171205)

[3.2. EHP 19](#_Toc519171206)

[3.3. EHP Δ 19](#_Toc519171207)

[3.4. Density 20](#_Toc519171208)

[3.4.1. Temp, RH and Pres - 20](#_Toc519171209)

[3.4.2. Temp, RH and Geo Alt 20](#_Toc519171210)

[3.4.3. Weather Station 20](#_Toc519171211)

[3.4.4. 4 kDA Reference 20](#_Toc519171212)

[3.5. dV/dT – Velocity Sensitivity to Powder Temperature - 21](#_Toc519171213)

[3.6. Powder Temperature 21](#_Toc519171214)

[3.7. TPwdr Toggle 21](#_Toc519171215)

[3.8. Cross Range Effects 21](#_Toc519171216)

[3.8.1. CJ - Crosswind Jump 21](#_Toc519171217)

[3.8.2. SpnDrf Toggle 21](#_Toc519171218)

[3.8.3. Differential Wind Drift 22](#_Toc519171219)

[3.8.4. Crosswind Boundary Layer Correction 22](#_Toc519171220)

[3.8.5. DTReticle Shooters Can Handle Cross Wind Two Ways 22](#_Toc519171221)

[3.9. Obx, Shooting Over an Obstacle 23](#_Toc519171222)

[3.9.1. Obx yd, F11 23](#_Toc519171223)

[3.9.2. Obx BE, F17 - 23](#_Toc519171224)

[3.9.3. Obx Clr in, F13 23](#_Toc519171225)

[3.9.4. Obx Reqd yd, F15 23](#_Toc519171226)

[3.9.5. Obx EHP, F19 23](#_Toc519171227)

[3.10. Coriolis 24](#_Toc519171228)

[3.10.1. Lat°, E11 24](#_Toc519171229)

[3.10.2. Hdg°, E13 24](#_Toc519171230)

[3.11. NAV, FAC, ADC 24](#_Toc519171231)

[3.12. 1st Dot, E17 24](#_Toc519171232)

[3.13. Long Range Zero 25](#_Toc519171233)

[4. Estimates for Non-Nominal Solutions 25](#_Toc519171234)

[4.1. kDA, C17 26](#_Toc519171235)

[4.2. NAV, C13 26](#_Toc519171236)

[4.3. FAC, B17 27](#_Toc519171237)

[4.4. ADC 27](#_Toc519171238)

[4.5. Slope 27](#_Toc519171239)

[5. Transition and Subsonic Regime 28](#_Toc519171240)

[6. Range Table 29](#_Toc519171241)

[6.1. Input Variables 29](#_Toc519171242)

[6.2. Output Variables 29](#_Toc519171243)

[7. Rifle System Calibration 29](#_Toc519171244)

[7.1. Why Calibrate 29](#_Toc519171245)

[7.2. Two Range Data Points, Or Maybe Just One 29](#_Toc519171246)

[7.3. Calibrate Your Rifle System 30](#_Toc519171247)

[7.3.1. Dopper Radar - 30](#_Toc519171248)

[7.3.2. Time of Flight - 30](#_Toc519171249)

[7.3.3. Direct Path Measurement 30](#_Toc519171250)

[7.4. Compute The Velocity Retention 31](#_Toc519171251)

[8. Putting It All Together 31](#_Toc519171252)

[8.1. Verify The 11 Ballistic Mgmt Input Variables - 31](#_Toc519171253)

[8.2. Enter Ten Rifle System Input Variables - 31](#_Toc519171254)

[8.3. Determine The VR Values - 31](#_Toc519171255)

[8.4. Enter The Density, Wind and Coriolis - 31](#_Toc519171256)

[8.4.1. Determine The Air Density - 31](#_Toc519171257)

[8.4.2. Enter The Wind - 31](#_Toc519171258)

[8.4.3. Enter The Coriolis Input - 32](#_Toc519171259)

[8.5. Compute the NAV - 32](#_Toc519171260)

[8.6. Enter The Range - 32](#_Toc519171261)

[8.7. Enter The Slope - 32](#_Toc519171262)

[8.8. Hold The EHP And The Wind; Release The Shot - 32](#_Toc519171263)

[9. Examples 32](#_Toc519171264)

[9.1. Example One 32](#_Toc519171265)

[9.2. Example Two 33](#_Toc519171266)

[9.3. Example Three 34](#_Toc519171267)

[10. Appendices 35](#_Toc519171268)

[10.1. Crosswind Effects - 35](#_Toc519171269)

[10.2. Summary of Input Notes 35](#_Toc519171270)

**Part Three - SmartShot™ Manual**

**Important Notes:**

1. SmartShot is 73% simpler than it appears at first glance. SmartShot accepts 36 input variables and returns 28 output variables. However we use only 15 input variables and two output variables during our long range testing on live targets in Africa. The 73% of rarely used functions are included to support dialed and grid reticles and special capabilities such as shooting from behind cover such as a window sill, parapet or dirt berm.
2. Output variable values are "holds" against bullet deflections, not the deflections themselves.
3. Sign convention: Downrange is + X; Up is + Y; Right is + Z.
4. SmartShot Is Unique in Two Ways – 1) It was designed specifically for Dynamic Targeting Reticles and 2) It employs a ballistic system which appears to be accurate for all low drag bullets through the supersonic regime, transition and deep into the subsonic regime. Ballistic Coefficients are replaced with an improved drag metric, Velocity Retention following Art Pejsa's method.
   1. Designed for the Dynamic Targeting Reticles. David Tubb contributed design philosophy, operational guidance and field testing at long range and steep slopes in the US and Africa.
      1. The DTReticles , a Family of Precision Reticles, match the trajectories of three nominal bullets under a set of nominal conditions: 1) 223 77gn Sierra Match King for close range, 2) 308 175gn Sierra Match King for intermediate range and 3) 6xc 115gr DTAC for long range as well as several other special purpose reticles for short barrel and subsonic rifles. There is a SmartShot version for each of the DTReticles.
      2. Dynamic Targeting Reticles Are Much Faster than traditional dialed or grid reticles for long range shots because the reticle reads directly in range (yards or meters) rather than in angles (moa or mils). Once zeroed, the scope knobs are never again touched for that rifle/ammo system. Thus the DTReticle in inherently much faster because: 1) most shots do not require any computer or a ballistic card and 2) the operator never comes out of the scope to access a computer or card or to dial scope settings.
         1. No Computations Except for Extreme Range or Slope - For all but the longest and steepest shots the shooter sets the range mark in the reticle directly on the target without the need for either a computer or ballistics card to convert the range and slope to barrel elevation angle. For very long and or very steep shots, the slant range and slope can be entered into SmartShot for an instantaneous firing solution.
         2. No Scope Dialing - The firing solution in range is used directly as measured with a range finder. There is never any need to transfer angle barrel angle data from a computer or card into the scope. In addition to speed, eliminating scope dialing eliminates Return-to-Zero errors.
         3. No Target Reacquisition – The requirement for reacquisition of targets is eliminated because the operator never comes out of the scope.
         4. No Conversion from mph to Angle - Wind holds are in wind speed (mph) not angles (moa or mils). So a ten mph wind at any range is a ten mph wind at all other ranges. Traditional wind holds in moa and mils are provided for dialed or grid reticles.
      3. SmartShot Enables The Use of DTReticles With Non-nominal Trajectories by computing the Effective Hold Point© (EHP©) for any firing solution, i.e., any combination of bullet, velocity, air density, range, slope, rifle configuration, etc.
         1. Most Real-world Shots Will Be Non-nominal due to normal variations of drag, velocity, air density, slope, rifle barrel, etc.
         2. Quick, Simple and Accurate EHP Compensations can be made instantly with neither a computer nor data card for most shots.
         3. SmartShot Computes the EHP Instantly for Very Long Shots which are non-nominal. For example, if the actual muzzle velocity is higher than nominal a 1,000yd shot might need to be held at the 950y dot. If the velocity is lower, the correct hold point might be at 1050y. SmartShot computes the combined effects of all important variables that effect a trajectory; a total of 32 input variables from the most obvious such as range and crosswind to the most obscure such as crosswind jump, differential wind drift and crosswind boundary layer effects to compute the hold point that will put the bullet on target, i.e., the Effective Hold Point (EHP).
   2. SmartShot Long Range Accuracy is Better than all other ballistic programs we have checked because Velocity Retention is a better drag metric than ballistic coefficients and SmartShot employs separate but coupled supersonic and subsonic firing solutions.
      1. Pejsa's Math Model Matches VLD Bullets better than any BC based system we have seen. Remarkably, once the Pejsa calibration coefficients are determined, field data out to two miles has shown the coefficients are constant over a very wide range of bullets from the 6mm, 115gn, DTAC to the 375 caliber, 364 gn, Warner Flatline. Even more remarkably, the Pejsa math enables the supersonic regime analysis to be followed seamlessly with a separate analysis of the subsonic regime.

Systems based on doppler measurement of velocity retention which is then processed mathematically to compute actual trajectories, such as the fine Hornady 4DOF, might be expected to be more accurate than Pejsa's method but there seem to be two problems: 1) apparently each bullet has to be individually doppler tested and 2) our first look at such systems has not produced the expected accuracy through transition and into the subsonic regime. There is recent evidence that McCoy’s McDrag understated the drag by 12%. Additionally, we have not seen proof that advanced systems such as PRODAS are accurate at extreme ranges.

* + 1. Velocity Retention. The input variable which SmartShot uses to describe bullet is Velocity Retention or VR; the distance in feet over which the bullet will lose 1% of velocity, or said another way that is easier to think about, the distance over which it will retain 99% of velocity.
    2. A Single VR Value Suffices For Each Regime . The beauty of Pejsa's ballistic math model is that it can be shaped to match the actual bullet behavior with remarkable accuracy. A single VR value enables accurate bullet performance prediction over the entire supersonic regime. A second VR value enables performance prediction in the subsonic regime. Thus SmartShot uses two VR values for each bullet: VRsup and VRsub. Further, once calibrated for one VDL bullet, Pejsa's model fits every VLD bullet we have tested from the 115gn 6mm DTAC to a .375 cal, 364 grain Warner Flatline, for both the supersonic and subsonic regimes as long as the bullet remains stable. To clarify, the VR values change from one bullet type to another change but, surprisingly, the trajectory equation *shaping coefficients are unchanged* for all VLD bullets we have tested.
    3. VRsup Can Be *Estimated* With BCg7 or BCg1. To support the use of BC's VRsup defaults to BCg7 and BCg7 defaults to BCg1. Caution: The estimated BC can only be approximate because BCs and VRs are completely different parameters.
    4. Velocity Retention Works Better Than BC’s. BCg1 is such a bad match to modern low drag bullets that three different BC’s are frequently required for different velocity ranges in the supersonic regime alone. BCs simply do not apply in the subsonic regime.

Pejsa understood the fundamental limitations of ballistic systems based on ballistic coefficients decades ago as demonstrated in his many articles for Precision Shooting and his book, *New Exact Small Arms Ballistics*. He summarized this contentious and complex topic with the following sentence on page 65: "The fact that 'the BC' of your bullet at slower speeds may be half of its BC at its 'muzzle velocity' Vo (so that you really need several BCs for each bullet) should tell you that the whole concept is badly flawed."

For these reasons, SmartShot, being based on Velocity Retention, uses only one value for the entire supersonic regime and a one other for the subsonic regime. Neither bullet weight, diameter nor any other bullet parameter is required for bullet drop computation because VR's are computed based on actual range observations.

* + 1. Experts Do Not Agree. Ballistic experts generally seem to not like Pejsa's Velocity Retention concept. In fact we have never read a complimentary review. Despite the experts, Mother Nature seems completely satisfied with Dr. Pejsa’s work.

1. SmartShot Overview – SmartShot uses six groups of variables: four groups of input variables and two groups of output variables. Each individual variable is briefly described in the following paragraphs.
   1. Input Variables Are In Four Groups; 1) range and slope, 2) density, wind and Coriolis, 3) rifle system and 4) ballistic management.
      1. Range and Slope **–** Range and slope are the primary input variables which will likely change with every shot, or at least every string of shots, even if the shooting site does not change. They are located at the center-left of the SmartShot screen in bold letters on a dark green background.
         1. [Range, Yards or Meters, A13](file:///C:\Users\pd\Documents\My%20Directories\1Jarrett\1%20SMARTSHOT%20CONTRACT\SS%20Manual%20140526\Working%20Master\Block%203%20Beta\180703%20Revision\180707%20Manual.docx) - Slant range to the target as measured with a range finder.
         2. [Slope, °, B13](file:///C:\Users\pd\Documents\My%20Directories\1Jarrett\1%20SMARTSHOT%20CONTRACT\SS%20Manual%20140526\Working%20Master\Block%203%20Beta\180703%20Revision\180707%20Manual.docx) - The slope of the line of sight to the target in degrees.
      2. Density, Wind and Coriolis **–** Eleven input variables are used to define air density, wind and Coriolis. These variables are adjacent to Range and Slope, have a medium green background and are in medium font. They will generally not change from shot to shot but are likely to change hourly or if different shooting sites are used. SmartShot will accept density input in either of three forms: 1) Temperature, relative humidity and station pressure, 2) Temperature, relative humidity and geometric altitude (as read on a topo map or GPS) and 3) station density altitude as indicated by a portable weather station such as a Brunton ADC Pro or similar device. See Advanced Functions below.
         1. PLoc – Station pressure, B9- Ambient pressure in inhg at the shooting site as recorded with a portable weather station or a smart phone.
         2. Temp, A9 – Ambient air temperature in °F. Accurate air temperature measurement with any instrument mounted on a weapon is difficult in bright sunlight. Resulting firing solutions may be unusable. See the Sensitivity Analysis, <https://projectilescience.com/tech-notes/>
         3. Geo kft, C11 – True geometric altitude at the shooting site as read from a topographical map or a GPS unit, in thousands of feet. Enter 5200 feet as 5.2 kft. Enter any number => 30 to disable this input.
         4. Wtr Sta, B11 – Density altitude in thousands of feet as indicated by a portable weather station. Set the relative humidity (C9) to zero if the weather station reading includes the relative humidity. Assure the air temperature is nor affected by solar or weapon heating.
         5. RH%, C9 - Relative humidity is a weak variable and can usually can be left at 50%. If more precision is needed, enter 80% in very humid weather and 20% in extremely dry weather. RH% should be set to zero when using a portable weather station that compensates for relative humidity. See Advanced Functions below.
         6. Wind Speed, D13- in mph. Be aware the wind speed will increase with distance from the ground. So longer shots will fly in stronger winds. Compensation for this effect over flat ground is built into the DTReticle. Wind over valleys might be higher.
         7. Wind Compass Heading, D11 - SmartShot will include the range and cross wind effects in the EHP. A wind from the right is 90 degrees, etc. Crosswind jump can also be included if desired, cell H13.
         8. Coriolis Shot Heading, Hdg °, E13 - Enter the compass heading of the shot to enable calculation of Coriolis effects. Enter a “0” to ignore Coriolis effects.
         9. Coriolis Site Latitude, Lat °, E11 - Enter the latitude of the shot site to enable calculation of Coriolis effects. Northern latitudes are positive and conversely. Enter a zero to ignore Coriolis effects.
         10. NAV number, C13 – The Nominal Assignment Value is the density altitude at which a non-nominal rifle system will have a nominal trajectory. Understanding this variable is necessary for shooting non-nominal trajectories. This value is not automatically computed. See Advanced Functions paragraph 3.
         11. Obstruction Distance, Obx yd, F11 – Enter the distance to a close obstacle such as a window ledge, a parapet or a dirt berm inside the first crossing of the bullet on the line-of-sight to determine the closest target which can be addressed without hitting the obstacle. See Advanced Functions paragraph 3.
      3. Rifle System Variables – There are 12 rifle system input variables which are not likely to change during a day or even a mission. They have a light red background.
         1. Vmuz fps, A7- Velocity at the muzzle at the nominal temperature, 75 F. If the powder temperature is different than nominal the firing solution can be corrected three ways: 1) Manually enter the correct muzzle velocity in A7, 2) Manually enter the correct powder temperature in cell G5 or 3) force the powder temperature to be the same as the air temperature by setting the Powder Temp toggle to the value "1" in cell G7. See Powder Temperature, Paragraph 3.
         2. VRsup, B7 – Bullet Velocity Retention in the supersonic regime quantifies the bullet’s ability to retain velocity, which depends on the bullet mass, drag and stability. Velocity Retention replaces ballistic coefficient, bullet weigh and diameter. SS operates best with VR but will accept BCg7 or BCg1. See Advanced Functions in paragraph 3.1., "BC's...The whole (BC) concept is badly flawed".
         3. VRsub, C7 - Velocity Retention subsonic describes the bullet ability to retain velocity in the subsonic regime.
         4. Zero Rng, A5 – DTReticles handle the zero range differently than dial and grid reticles. Zero ranges can be any value from 100 yd to many hundreds of yards but the dot selected for the hold point must match the actual range, i.e., use the 100 yd dot to zero at 100 yds; use the 200 yd dot to zero at 200 yds, etc. So changing the zero range does not change the barrel angle as long as the zero hold point dot matches the zero range set into cell A5. To emphasize this important point: The 200 yd dot can be used to zero the rifle at 200 yds but the zero range in cell A5 is still 100 yds because the barrel elevation angle is the same as for the 100 yd dot used with a 100 yd target. A special very-long-range zero (VLZ) capability is explained in paragraph 3.13.
         5. Sight Height, B5 - SmartShot uses a nominal of 2.75 but any scope height can be accommodated by simply entering it in cell B5 and holding the indicated EHP. The scope height will change the zeroed range. See paragraph 2.2.2.16.
         6. BCg7, D7 - If the Velocity Retention value of the bullet is not known, it can be estimated by entering the ballistic coefficient, either BCg7 or BCg1, from other sources such as the manufacturer's data, *Applied Ballistics for Long Range Shooting* by Brian Litz, Hornady, Sierra or JBM. See Advanced Functions in Paragraph 3.
         7. BCg1, E7 - If BCg7 isn’t known use BCg1. See Advanced Functions in paragraph 3.
         8. Stab, C5 – Enter the Stability Factor directly into cell C5. If it is not known enter a zero in cell C5 and SmartShot will estimate the value using the bullet length, weight and caliber and the twist rate of the rifle.
         9. Twist, E5 - Barrel twist rate in inches.
         10. Mass, D5 - Bullet mass in grains
         11. Length, F5 - Bullet length in inches
         12. Diameter, F7 - Bullet diameter in inches
      4. Ballistic Management Variables - There are 11 ballistic management variables which once set will rarely change during a multi-day mission. These variables have a light blue background and are located as far away as possible from the primary variables yet they are still on the screen so their status can be instantly verified.
         1. Reference Sea Level Pressure, PSL inhg, F9 - Barometric pressure corrected to sea level only effects the density calculation when using geometric altitude and temperature. Leave as 29.92 except under extreme conditions such as in a tornado or hurricane. Under these conditions pay attention to the wind effects. See Advanced Functions in paragraph 3.
         2. Powder Temperature, TPwdr, G5 - If the powder temperature is known to be substantially different than the powder calibration temperature, enter the temperature in cell G5. Powder Temperature will usually be close to the ambient air temperature unless the ammo is in the direct sunlight or carried inside a coat on a cold day. The powder temperaure can be automatically track the ambient by setting the powder temperature toggle, G5, to “1”. (see below)
         3. dV/dT, H5 - Muzzle velocity sensitivity to temperature, fps/F, is used to compensate the muzzle velocity for powder temperature. Stable powder is about 0.5 fps per degree F. Sensitive powder can be 2 fps/F or more.
         4. Powder Temp Toggle, TPwdr Tgl, G7 – Enter a "1” in the cell G7 to set the powder temperature equal to the air temperature. Air temperature changes will automatically included in the EHP calculation. If the ammo temperature is different than the air temperature such as in sunlight or extremely hot or cold weather turn off the toggle by entering a zero and enter the correct ammo temperature in cell G5. This toggle should be set to “1” for normal conditions. See Advanced Functions paragraph 3.
         5. Spin Drift Toggle, SpnDrf Tgl, G11 - Spin drift is built into the DTReticles so enter a zero to avoid double counting. For dial and grid reticles, enter a “1” to include spin drift in the wind hold. See Advanced Functions paragraph 3.
         6. Differential Wind Drift, DWD Tgl, G9 - DWD is a little known, strongly disputed, but absolutely real mechanism that causes a right hand spinning bullet to react more strongly to a right crosswind than a left crosswind. DTReticle users must enter a zero in cell H13 because DWD correction is built in. Dial and grid reticles users must enter a “1” to include DWD in wind hold. See Advanced Functions in paragraph 3. Proof of the mechanism is shown in David Tubb's excellent test report: <http://www.zediker.com/DTR_PDF_links/DTR_DWD_article_testing_2015.pdf.>
         7. Crosswind Jump Toggle, CJTog, H13 - Crosswind jump, aka aerodynamic jump, causes a right spinning bullet to deflect up in a right crosswind and down in a left crosswind. DTReticle users must enter a zero in cell H13 because crosswind jump correction is built in. Dial and grid reticles users must enter a “1” to include crosswind jump the barrel angle calculation.
         8. [Moment of Inertia About the Longitudinal Axis, CJ Ix, H7](file:///C:\Users\pd\Documents\My%20Directories\1Jarrett\1%20SMARTSHOT%20CONTRACT\SS%20Manual%20140526\Working%20Master\Block%203%20Beta\180703%20Revision\180705%20Manual.docx) - Moment of Inertia for the crosswind jump calculation can be entered two ways depending on whether the value is know. If the value is known enter it in cell H7. If the value is not known, enter a zero in H7 and SmartShot will estimate the moment of inertia and disolay it in cell E15 and use it in the CJ calculations in moa (cell H15) and inches (cell H17).
         9. [Lift Force Coefficient, CDa, H9](file:///C:\Users\pd\Documents\My%20Directories\1Jarrett\1%20SMARTSHOT%20CONTRACT\SS%20Manual%20140526\Working%20Master\Block%203%20Beta\180703%20Revision\180705%20Manual.docx) - The change of lift force with changes of pitch/yaw angle.
         10. [Overturning Moment Coefficient, CMa, H11](file:///C:\Users\pd\Documents\My%20Directories\1Jarrett\1%20SMARTSHOT%20CONTRACT\SS%20Manual%20140526\Working%20Master\Block%203%20Beta\180703%20Revision\180705%20Manual.docx) - The change of overturning moment with changes or pitch/yaw angle.
         11. Meters, A11 - This toggle serves two purposes, one obvious and one obscure. To use yards as the units of range, enter the number zero in cell A11. To use meters enter the number "1". The obvious purpose is simply to use meters. The obscure reason is to change the units of the DTReticle trajectory by 9% to match the trajectory of a flatter shooting bullet. For a full explanation, see the Example 3 in paragraph 9.
   2. Output Variables are in two groups, Primary and Secondary**.**
      1. Primary Output Variables - SmartShot provides two primary output variables in bold font with a bright yellow background located adjacent to the two primary input variables which change with most shots, Range and Slope. See Advanced Functions, paragraph 3.
         1. EHP, A15 – By far the most important output variable is Equivalent Hold Point, the hold point that will produce a hit on the target for a non-nominal trajectory. If the trajectory is nominal, the EHP will be the same value as the range, i.e., an 800 yd EHP will produce an 800 yd hit. If however, as is usually the case, the shot is non-nominal the actual trajectory will not match the reticle, i.e., the hold point will be different than the true range; thus, the Equivalent Hold Point, EHP.
         2. EHP Δ, B15 – The EHP Δ, the difference between the EHP and the true range, is useful for rapidly addressing multiple individual targets in a cluster but at ranges that are sufficiently different to require a different EHP. See Advanced Functions, paragraph 3.
      2. Secondary Output Variables - SmartShot provides 26 secondary output variables that are not needed for the firing solution but are of varying degrees of interest. Output variables are controlled by the input variables and the equations and cannot be changed by direct entry. All have a pale yellow background
         1. Z mph, A19 – The computed crosswind component in mph which is the wind hold for the DTReticle. A very strong advantage of the DTReticle is that the wind *hold* does not change with range even though the wind *drift* angle does change with range. Coriolis effects can be included in the cross wind computation.
         2. Z moa, B19 - Wind hold angle in moa for dial and grid reticles
         3. Z inch, C19 - Wind hold in inches for dial and grid reticles
         4. Z mils, D19 - Wind hold angle in mils for dial and grid reticles
         5. FAC, B17 - The FACtor number is the difference between the NAV number (the density altitude at which the trajectory is nominal) and the actual density altitude, in thousands of feet. The FAC is used to compute the EHP correction for non-nominal trajectories.
         6. Density Altitude, kDA, C17 – The computed density altitude in thousands of feet; i.e., 5,400ft is 5.4 kDA.
         7. kDensity , D17- Air density in lb per 1,000 cubic feet.
         8. [VR Cal, E9](file:///C:\Users\pd\Documents\My%20Directories\1Jarrett\1%20SMARTSHOT%20CONTRACT\SS%20Manual%20140526\Working%20Master\Block%203%20Beta\180703%20Revision\180707a%20Manual.docx) – The calibrated VRsup is corrected for non-nominal air conditions.. The purpose is to allow instant visual confirmation of the VRsup that is being used in the firing solution.
         9. [VMuz Cal, D9](file:///C:\Users\pd\Documents\My%20Directories\1Jarrett\1%20SMARTSHOT%20CONTRACT\SS%20Manual%20140526\Working%20Master\Block%203%20Beta\180703%20Revision\180707a%20Manual.docx) – The calibrated Vmuz sup is corrected for non-nominal conditions including powder temperature. The purpose is to allow confirmation of the V muz sup that is being used in the firing solution.
         10. Not Used
         11. Stab, G17 – The stability factor used in the firing solution that is the result of input of Stab into cell C7 or the computation of Stab using bullet variables.
         12. Barrel Elevation Angle, BE moa, C15 – The barrel elevation angle, or “come-up”, required to hit the target, in moa. Used only for for dial or grid reticles.
         13. [Barrel Elevation Angle, BE mils, D15](file:///C:\Users\pd\Documents\My%20Directories\1Jarrett\1%20SMARTSHOT%20CONTRACT\SS%20Manual%20140526\Working%20Master\Block%203%20Beta\180703%20Revision\180707a%20Manual.docx) – The barrel elevation angle, or “come-up”, required to hit the target, in mils. Used to compute the EHP for DTReticles. Used directly for dial and grid reticles
         14. SpnDrf, inches, G15 – The value of the spin drift in inches; built-into the DTReticles. Use the toggle, cell G11, to turn the Spin Drift calculation on for dial or grid reticles.
         15. SpnDrf, moa, G13 - The value of the spin drift in MoA; built-into the DTReticles. Use the toggle, cell G11, to turn the Spin Drift calculation on for dial or grid reticles.
         16. [CJ, moa, H15](file:///C:\Users\pd\Documents\My%20Directories\1Jarrett\1%20SMARTSHOT%20CONTRACT\SS%20Manual%20140526\Working%20Master\Block%203%20Beta\180703%20Revision\180707a%20Manual.docx) - Crosswind Jump in moa
         17. [CJ, in, H17](file:///C:\Users\pd\Documents\My%20Directories\1Jarrett\1%20SMARTSHOT%20CONTRACT\SS%20Manual%20140526\Working%20Master\Block%203%20Beta\180703%20Revision\180707a%20Manual.docx) - Crosswind Jump in inches
         18. ObxClr in, F13 – The clearance between a bullet and a horizontal obstacle closer than the first crossing.
         19. ObxReqd yd, F15 – The range to the obstacle required for bullet clearance for the selected firing solution.
         20. Obx BE, F17 – The barrel angle required to clear an obstacle at the input obstacle range.
         21. Obx EHP, F19 – The EHP of the closest target which can be addressed with the input obstacle range.
         22. ToF sec, E19 – Time of flight to the target.
         23. BE mils, D15 – Barrel elevation angle in mils for dial or grid reticles.
         24. [CJ lx Calc, E15](file:///C:\Users\pd\Documents\My%20Directories\1Jarrett\1%20SMARTSHOT%20CONTRACT\SS%20Manual%20140526\Working%20Master\Block%203%20Beta\180703%20Revision\180707a%20Manual.docx) - Longitudinal moment of inertia, pound inches^2, used in the crosswind jump calculation.
         25. RZ Dot 1 and RZ Dot2, G19, H19 - Used for non-nominal scope heights, i.e., a scope height different than 2.75 inches. SS displays the correct zero range for the first dot, nominally 100y and the second dot, nominally 200y.
         26. [Range, yds, A17](file:///C:\Users\pd\Documents\My%20Directories\1Jarrett\1%20SMARTSHOT%20CONTRACT\SS%20Manual%20140526\Working%20Master\Block%203%20Beta\180703%20Revision\180707a%20Manual.docx) – Displays range in yards when the input is in either yards or meters.
         27. [1st Wind Dot, E17](file:///C:\Users\pd\Documents\My%20Directories\1Jarrett\1%20SMARTSHOT%20CONTRACT\SS%20Manual%20140526\Working%20Master\Block%203%20Beta\180703%20Revision\180707a%20Manual.docx) – Displays the value of the 1st wind dot for non-nominal bullets. Heavy bullets with low drag will need more wind, say 8 mph, to get the same wind deflection as the nominal bullet in 5 mph.
2. Advanced Functions - The user must understand how to use SmartShot in order to avoid getting incorrect firing solutions. SmartShot is complex for three reasons:   
   1) The physics of long range ballistics is complex. A number of exceedingly weak effects that can normally be ignored must be considered such as relative humidity and Coriolis.   
   2) Several of the ballistic effects can be computed in different ways depending on the user’s resources and preferences. Density, for example, can be calculated three different ways depending on the available air data.   
   3) The third kind of complexity is a consequence of including the functionality required to support dial and grid reticles as well as the DTReticle. For example DTR users do not compute spin drift, crosswind jump, boundary layer or differential wind drift effects because these are etched into the reticle. However, dial and grid reticles require these effects be included in long range firing solutions. To enable dual functionality, toggles are provided to allow user controls of these mechanisms. The two methods of handling spin drift illustrate the dual functionality. A careful examination of the DTReticle shows the zero wind lines are not vertical because they include spin drift. If the wind is zero, a DTR shooter can simply hold zero wind and spin drift will be automatically included in the firing solution. However, dial and grid reticles do not include spin drift so it must be manually inserted into the firing solution.. Each of the following mechanisms requires careful attention to avoid firing solution errors.
   1. BCs; "...the whole concept is badly flawed." Art Pejsa
      1. Velocity Retention. The input variable which SmartShot uses to describe bullet drag is Velocity Retention or VR. It is the distance in feet over which the bullet will lose 1% of velocity, or said another way, the distance over which it will retain 99% of velocity. SmartShot (SS) is based on the ballistic concepts Art Pejsa described in *New Exact Small Arms Ballistics*. He replaced the widely used but now inadequate concept of ballistic coefficients with a more fundamental mathematical description which quantifies with great accuracy the decay of velocity during a bullet's flight. The dramatic advantage of Pejsa's ballistic solution is that the trajectory can be shaped to match the actual trajectory using two shaping factors. Thus traditional shaping techniques utilizing G1, G7 and others are no longer needed. While it's not intuitive, experience has shown that the Pejsa ballistic solution matches real trajectories of real bullets with great precision. Further, separate trajectory definitions can be used for supersonic and subsonic regimes, again with great precision. The last advantage is that, once the trajectory shaping variables are defined for one VLD bullet, experience has shown that, to our great surprise, the same shaping variables apply to every VLD bullet we have tested. The shaping variables we developed for the DTAC 115gn bullet (very similar to a Sierra Match King) work perfectly for every bullet we have tested out to the 364gn 375 Warner Flatline. The trajectories for all these bullets are certainly different but Pejsa's basic closed-form equation has worked perfectly for all we have tested at ranges as far as two miles.

Pejsa used the term "Retard Coefficient" but, although conceptually identical, we have replaced "Retard Coefficient" with "Velocity Retention". We like to think about a bullet having better *retention* of velocity than a bullet having better *retardation* of velocity; but it's only semantics actually. One other minor difference is the SmartShot "Velocity Retention" is distance over which the velocity will decay one percent whereas Pejsa's "Retard Coefficient" is the 1% velocity decay distance times 100. For example, the SmartShot "Velocity Retention" value for the 175gn 308 Sierra Match King is 45.1feet whereas Pejsa's "Retard Coefficient" is 4510. The trajectory equation can be calibrated to match a specific bullet with amazing precision. But even more amazing is the fact that once the equation is calibrated, it matches the trajectories of all VLD bullets we have tested through transition and well into the subsonic regime.

* + 1. A Single VR Value Suffices For Each Regime . One of the advantages of Pejsa's ballistic model is that it can be *easily* calibrated to match the actual bullet behavior. A single VR value accurately describes the performance of a specific bullet over the entire supersonic regime. A second VR value describes the performance in the subsonic regime. Thus SmartShot uses two VR values for each bullet: VR supersonic and VR subsonic. Further, once the shape of the trajectory is calibrated for one VDL bullet, Pejsa's model fits every VLD bullet we have tested from the 115gn 6mm DTAC to a 375 caliber 364 grain Warner Flatline, as long as the bullet remains stable. The only change from one bullet type to another is the two Velocity Retention values. Thus, the three Dynamic Targeting Reticles, 6xc, 308 175gn Sierra Match King and 223 77gn Sierra Match King match any VLD bullet we have tested. There are several additional DTReticles for special short barrel and subsonic rifles.

**Nominal Bullets:**  VRsup VRsub

6mm, DTAC 115gn 6xc, original version 58.3 53.2

308, Sierra 175gn Match King (M118LR) 45.1 36.8

223, Sierra 70gn Match King 36.5 28.3

**Non-nominal Bullets:** SmartShot provides VRsup and VRsub for approximately 50 bullets such as the following; see projectilescience.com\manuals. Six examples are shown below. For a more complete list see: http://projectilescience.com/manuals.

VRsup VRsub

22RF, 45gn, 23.0 20

6mm, DTAC 115 gn 6xc, Jan 2017 version 64.0 135

300, Berger 200 gn 59.7 160

338, Barnes Triple Shock 250 gn 44.5 135

338, Berger VLD 300 gn 82.0 160

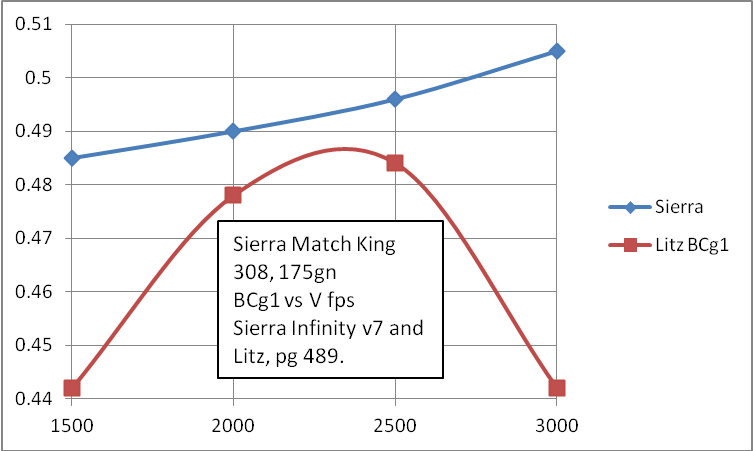
375, Warner Flatline, 364 gn 105 160

* + 1. VRsup Can Be Estimated With BCg7 or BCg1. If VRsup isn’t known, SmartShot can estimate a value. Enter a zero in the VRsup cell and the known BCg7  value in that cell. SS will estimate the VRsup based on BCg7. The value in BCg1 is ignored. If the BCg7 is unknown but BCg1 is known, enter a zero in the BCg7 cell and the known value of BCg1 in the BCg1 cell. SS will estimate the VRsup value using BCg1. Caution: Values of VRsup computed with BC's are only approximations because VR's and BC's are not direct equivalents.
    2. Velocity Retention Works Better Than BC’s. BCg1 is such a bad match to modern low drag bullets that three different BC’s are frequently required for different velocity ranges in the supersonic regime alone. BCs simply do not apply in the subsonic regime.

For example Sierra uses three BCg1 values for their 308 175gn Match King depending on the velocity as follows:

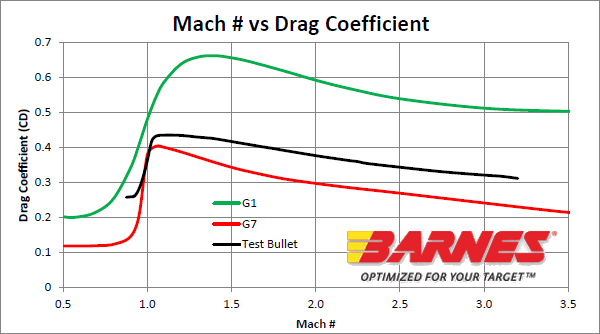
∞ to 2800fps, BGg1=0.505: 2800 to 1800, BCg1=0.496; below 1800 BCg1 is 0.485. (Sierra Infinity v7).

Another sources, Litz, *Applied Ballistics for Long Range Shooting, 2nd Edition*, page 489, shows BCg1 values of 0.442, 0.484, 0.478 and 0.442 at 3000fps, 2500, 2000 and 1500 respectively.



Thus, two of the most respected ballistics data sources provide dramatically different BCg1 values. Worse, the effect of velocity on the BCg1 values is also dramatically different. The Sierra line is almost straight while the Litz line is parabolic.

In another demonstration of the inadequacy BC as a drag metric, Barnes has been studying bullet trajectories with a Doppler radar and reducing the data with PROTAS, a six degree of freedom ballistic program. See: https://www.barnesbullets.com/files/2015/01/Use-of-Doppler-Radar-to-Generate-Trajectory-Solutions-Rev-1-6-15-V2.pdf. They demonstrate the dramatic differences between BCg1, BCg7 and a real bullet.



Hornady's doppler testing showed similar discrepancies between BCg7 and actual drag curves on page 3 of their fine 4DDegree of Freedom (4DoF) Ballistic Trajectory Program. See: https://press.hornady.com/assets/site/hornady/files/ballistic/hornady-4dof-technical-paper-v2.pdf.

Pejsa understood the fundamental limitations of ballistic systems based on ballistic coefficients decades ago as demonstrated in his many articles for *Precision Shooting* and finally when he summarized this contentious and complex topic with the following sentence from page 65 of his book: "The fact that 'the BC' of your bullet at slower speeds may be half of its BC at its 'muzzle velocity' Vo (so that you really need several BCs for each bullet) should tell you that the whole concept is badly flawed."

For these reasons, SmartShot being based on Velocity Retention uses only one value for the entire supersonic regime and a one other for the subsonic regime. Bullet weight, diameter and other bullet parameters affecting bullet drop computation are included in the VR value.

* + 1. Not All Agree. Ballistic experts generally seem not to like Pejsa's Velocity Retention concept. Damon Cali at Bison Ballistics has this to say about Pejsa's method at http://bisonballistics.com/articles/the-details-of-a-ballistics-calculator-solver.

"Several smart people have come up with alternate ways of solving the ballistics equations, often attempting to model drag with equations (as opposed to the empirical standard drag curves or Doppler based curves). That is interesting to me in an academic sort of way, and they do work pretty well (within their constraints). But they're just not necessary these days. I would include the work of Arthur Pejsa and the lesser known George Klimi (who strangely uses Snell's Law in his calculations) in this category. Interesting, but largely academic stuff."

Others say less polite things, but the bullet holes continue to appear on the targets as called by Pejsa's ballistic math.

* 1. EHP – SmartShot's firing solution variable is the Equivalent Hold Point, i.e., the hold point that will produce a hit on the target for a non-nominal trajectory. If the trajectory is nominal, the DTReticle dots will be the same value as the range, i.e., an 800 yd dot will produce an 800 yd hit. If however, as is usually the case, the trajectory is not nominal, the range dot will not match the actual range, i.e., the hold point range will be different than the true range. The hold point that matches the non-nominal trajectory is named the Equivalent Hold Point or simply EHP.

To illustrate, open the SmartShot 6xc version, see projectilescience.com\products\6xc. Enter the range of 1,000y. Note that the EHP is 1,000y because the trajectory is nominal. So the EHP is exactly the true range. Note the barrel elevation, BE, is 23.5moa.

Now assume the kinds of changes a shooter might encounter. Set the muzzle velocity is 3100fps and the temperature is 85F. The higher velocity and lower density cause the trajectory to be a bit flatter so the BE is reduced fr 23.5moa to 21.2 moa. SS computes that the 941 yd range dot (etched in the reticle) will have a BE of 21.2moa and displays this value in the EHP cell. So the user places the target at 941y and releases the shot.

If the line of sight is 18° up the side of a hill, enter 18 in the Slope input and read the new EHP of 908y. Hold 908y and release the shot. If a second target appears at 920y, enter 920 in the Range and hold the new EHP of 834y.

* 1. EHP Δ – Equivalent Hold Point Delta (Cell B15) is a powerful output variable for rapidly addressing a group of targets that are in close proximity but far enough apart that different EHPs are required. Rather than computing a new EHP for each target, the user can simply read the slant range to an adjacent target and add the value of the EHP Δ from the prior shot. Using the prior example, 1000 yd and 18 degrees, notice the EHP Δ is -92. This value is the difference between the slant range and the EHP was 908-1000 = -92y. Continuing, the EHP Δ for the second target at 920 yd and 18 degrees was 834-920 = -86y. The two targets were 80 yards apart but the EHP Δ’s were only six yards different. So the EHP of the second target can be estimated with and error of six yards by simply subtracting the EHP Δ of the first target from the slant range of the second target; 920 – 92 = 828y. Thus, the time needed to compute the second and subsequent EHP's is eliminated.
  2. Density – Traditional shooters operating inside 350y on large targets can usually ignore air density. However the difference between a hot day and a cold day can change a 1,000 yd PoI 20 to 40 inches depending on the bullet. SmartShot will accept density input in either of three formats: 1) temperature, relative humidity (RH) and station pressure, 2) temperature, RH and geometric altitude (as read on a topo map or GPS) or 3) station density altitude as indicated by a portable weather station such as a Brunton ADC Pro. To illustrate these three methods, set the SmartShot screen to the nominal 6xc firing solution. Press the Reset button at the top right then enter 1000 yd in the Range cell. The Barrel Elevation (BE) should be 23.5moa and EHP should be 1000y.
     1. Temp, RH and Pres - Note the pressure is 27.52inhg, temperature is 75F, RH is 50% and kDA is 4.0kft. This is the nominal air density reference used throughout SmartShot. Now set the pressure to, say, 26.04 inhg, the temperature to 95F and RH to 20%. Read the density as 7.0 kDA, or 7,000 feet density altitude. The EHP is reduced to 973y due to the reduced density.
     2. Temp, RH and Geo Alt - Press the Reset button. Set the Range to 1000 yd and the geometric altitude (Geo kft) to the local altitude, say 2.24kft (read from your topo map or your GPS), the temperature to 45F and the RH to 50%. Read the density altitude as 1.9 kDA and the EHP as 1021 yd, up 21y due to the increased density. Additional accuracy can be obtained by entering the barometric pressure corrected to sea level (cell F9) as widely reported on weather sites. This is a very weak variable and rarely of significance except in extreme storms which are usually accompanied by very high winds – not conducive to long range shooting.
     3. Weather Station. Press the Reset button and change the Range to 1000 yd. Assume your weather station indicates the density altitude is 7244ft. Enter 7.24kft in the WrtSta cell. But one additional step is required for precision: the weather station density computation includes the relative humidity so to avoid computing the relative humidity effect twice, enter “0” in the RH cell. Read the density altitude as 7.2 kDA. SmartShot ignores other entries in Geometric altitude, pressure and temperature if there is a valid value entered for weather station density altitude. A valid value is any number less than 30. Read the new EHP of 971 yd. Now, return all settings to nominal: 27.52inhg, 75F, 30kda, 30kda and 50% RH by pressing Reset. Change the Range to 1000 yd. Confirm that the BE is 23.5 and the EHP is 1,000.
     4. 4 kDA Reference. SmartShot uses the reference density altitude of 4.0 kDA or 4,000 ft. It's no coincidence; 4.0 kDA is the density at David Tubb’s ranch in Texas on a 75F day. But more importantly, it is a good estimate of the density at many popular ranges throughout the US during the summer. So rather than referencing SmartShot to standard day air density at sea level, SmartShot is referenced to 4,000ft ICOA altitude which is a much closer to the density at most ranges. SmartShot's numbers can be confirmed by entering standard day conditions of 59F, 29.92inhg and 0% RH and read the computed density is 76.47 pounds per thousand cubic feet, or 0.07647 pounds per cubic feet.

The following were used during the development of SmartShot: <https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/pilot_handbook/media/PHAK%20-%20Chapter%2003.pdf>.

McCoy, *Modern Exterior Ballistics*, pg 167, equation 8.18 and

http://wahiduddin.net/calc/density\_altitude.htm

* 1. dV/dT – Velocity Sensitivity to Powder Temperature - The fundamental laws of thermodynamics require that all powders produce higher velocities at higher temperatures and conversely. The most stable powders such as the stabilized Hodgdon family produce on the order of 0.5 fps of additional velocity for every additional degree F. Most powders are much more temperature sensitive and thus produce more velocity change for the same temperature change. Considering that the temperature of the powder in the cartridge when shot might be as much as 40F higher or lower than when the load was calibrated, the sensitivity of the powder is an important variable.
  2. Powder Temperature – If SmartShot knows the powder temperature and the powder velocity sensitivity to temperature, dV/dT above, the corrected muzzle velocity can be automatically used to compute the firing solution. A load using sensitive powder and calibrated at 75 F but shot at 35 F might drop 1.4 MoA at 1000y.
  3. TPwdr Toggle– If the ammo is expected to be close to the ambient air temperature, set the toggle to “1” so that the powder temperature is automatically set to the ambient temperature and, thus, corrects the muzzle velocity which is then used to compute the trajectory. If the ammo temperature is significantly different from the ambient air, turn off the toggle by entering a zero in cell G7 and enter the correct ammo temperature in cell G5.
  4. Cross Range Effects – There are four cross range effects, one of which affects only the vertical PoI while the other three affect only the horizontal PoI. The four effects are: crosswind jump, also known as aerodynamic jump, (vertical PoI only), spin drift, differential wind drift and crosswind boundary layer drift.
     1. CJ - Crosswind Jump, also known as aerodynamic jump, is the gyroscopic and aerodynamic response to the yawing effect of the cross wind immediately out of the muzzle. A right cross wind yaws the bullet to the right which produces a pitch-up response which causes the PoI to deflect upward; conversely for a left crosswind. The gyroscopic response is similar to spin drift but different in two important ways: 1) the forcing mechanism for spin drift is gravity so the deflection response is in the horizontal plane while jump is driven by the crosswind which is in the horizontal plane so the deflection response is in the vertical plane, and 2) gravity acts on the bullet all the way to the target so spin drift deflection angle increases with range while the crosswind yaw acts on the bullet only immediately out of the barrel so the jump deflection angle does not increase with range.

Crosswind jump is built into the DTReticles so the CJ toggle (H13) should be set to zero which will delete the effect from the wind hold calculation. Users of dial and grid reticles should set the toggle to “1” which will add the effect to the Barrel Elevation angle. Remember that the cells display the HOLD against the deflection, not the deflection itself. If the deflection is up (positive), the hold will be down (negatve).

* + 1. SpnDrf Toggle – Spin drift is the right deflection of a right spinning bullet caused by gyroscopic and aerodynamic effects of stabilization. All spin stabilized bullets are statically unstable because the center of gravity is behind the center of pressure – think of an arrow with the head in the back and the fins in the front. Immediately upon leaving the barrel, the gravity pulls the back of the bullet down and the nose pitches up. Without spin stabilization the bullet would immediately tumble. However, the gyroscopic stability pulls the nose down but in doing so, the nose processes to the right (right spinning bullets) thus producing an aerodynamic force to the right which in turn produces a drift to the right. Gravity acts on the bullet all the way to the target so the gyroscopic response is cumulative thus the deflection angle increases with range.

Spin drift is built into the DTReticles so users should set the spin drift toggle (cell G11) to zero to exclude the effect from the wind hold solution. Users with dial and grid reticles should enter a “1” to include in the wind hold.

The spin drift calculation requires the stability factor which can be either entered directly from a reference source or approximated by entering the bullet weight, length, diameter and the twist rate of the barrel. See the Stability Factor discussion.

* + 1. Differential Wind Drift – David Tubb has shown with carefully controlled tests that a right spinning bullet will respond to a right crosswind more strongly than to a left crosswind. See David Tubb, "Dissimilar Wind Drift Testing", Jan 2013. Consequently, the DTReticle includes this effect. DTReticle users should set the DWD toggle ( cell G9) to zero. Users of dial and grid reticles should set the toggle to “1” to include the effect in the wind hold calculation. Experts seem not believe that the DWD mechanism is real despite the outstanding experimental work reported above. See also: http://www.zediker.com/DTR\_PDF\_links/DTR\_DWD\_article\_testing\_2015.pdf.
    2. Crosswind Boundary Layer Correction – Another trajectory effect which David Tubb developed is included in only, so far as we know, in his DTReticle and SmartShot. It is compensation for the *fact* that wind increases with height. A 10 mph crosswind at six feet from the ground might be 12 mph at 20 feet. David Tubb noticed that as target range increased, the wind drift increased. Boundary layer theory (Herman Schlicting, *Boundary Layer Theory, Sixth Edition,* pg 597, Fig 21.1 and Rudolph Geiger, *Climate Near the Ground, Sixth Edition,* pg 94, Fig 16.4) show the reason. As range increases, the apogee increases and the bullets fly further from the ground and thus in a stronger wind which requires more wind hold. David quantified the effect which is built into the DTReticle and SmartShot. For users of dial and grid reticles, the boundary layer effect is built into the equation for the wind hold. No toggle is required because the DTR users do not use the wind hold calculation.
    3. DTReticle Shooters Can Handle Cross Wind Two Ways: 1) Hold the estimated cross wind component in mph directly on the reticle or 2) Enter the estimated speed and compass heading in SS and read the cross wind velocity in cell A19. Then hold that velocity in the reticle. Most experienced shooters use the first method because wind is rarely steady enough to justify the time required to enter it. SS supports dial and grid reticles by displaying the cross wind component in minutes of angle in cell B19 and inches and mils in adjacent cells.
  1. Obx, Shooting Over an Obstacle – This useful and, so far as we know, unique tool displays the closest target which can be engaged beyond an obstacle such as a window ledge, parapet, dirt berm or other horizontal obstacle which is closer than the first bullet crossing of the sight line. SmartShot assumes the line of sight (LoS), the top of the obstacle and the target are in the same plane which need not be horizontal. SS uses the firing solution and the distance to the obstacle to determine whether the bullet will impact the obstacle.

The problem can be demonstrated assuming a nominal 308 rifle with a target at 200y and the obstacle is at 30 yards. For most rifles, say a nominal 308, the bullet will be below the LoS at 30 yd for a 200 yd target. Enter Range of 200 yd (cell A13) and Obx yd (cell F11) of 30 yd. Read the bullet clearance of the obstacle, ObxClr in, (cell F13) of *minus* 2.5 inches; the bullet will hit the obstacle 2.5 inches below the top. However, if the target is much further out, say 600y (cell A13), the barrel elevation required to address the 600y target will cause the bullet to cross the LoS 1.8 inches clear of the obstacle (cell F13). If the target range is increased, the barrel angle will be increased and the bullet cross the line of sight closer.

The EHP required to just clear the obstacle, Obx EHP, displayed in cell F19, is 456 yds. Set the Range to 456 (cell A13) and read OBX Clr (cell F13) of Eventually there will be a target range, read 456 yd in Obx EHP (cell F19), where the bullet will have zero clearance to the obstacle. This then is the closest target which can be addressed with this rifle system and obstacle distance. Verify by entering 456 in Range (A13) and read zero clearance in Obx Clr (F13) of zero. If the trajectory is not nominal the EHP will not exactly match the Range. If a close target range requires more obstacle clearance than is available such as when shooting through a window in a small room, the negative obstacle clearance is the approximate distance the rifle has to be raised for the bullet to clear the obstacle.

* + 1. Obx yd, F11 – The range to the obstacle is the only additional input variable needed for the obstacle calculation; all other input variables are already in the firing solution. The obstacle range could be as close as 2y or as far as 100y. Obstacle impact ceases to be a matter of concern for target ranges beyond the range at which the bullet path first intercepts the LoS which is close to 100y for the nominal trajectories. SmartShot will output an Out of Range (OoR) notice if the obstacle is further than the zero range.
    2. Obx BE, F17 - is the barrel angle to the obstacle which is a function of only the distance to the obstacle and the height of the scope over the bore.
    3. Obx Clr in, F13 – SmartShot displays the clearance between the bullet and the berm assuming a 50 cal bullet. If the bullet will hit the obstacle the clearance is negative.
    4. Obx Reqd yd, F15 – This is the required minimum distance to the obstacle for the specific trajectory. If the obstacle is closer the bullet will hit and conversely.
    5. Obx EHP, F19 – This is the closest target that can be addressed for this obstacle range and bullet trajectory. If the target is at this range or further the bullet will clear the obstacle. If the target is closer the BE is not sufficient for the bullet to clear the obstacle. The user must raise the rifle, not the BE but the whole rifle, by the amount of negative clearance shown in ObsClr. Confirm by entering the Obx EHP value (cell F19) into the Range (cell A13) and read zero clearance in ObxClr (cell F13).
  1. Coriolis – Coriolis effects are deterministic, i.e., they can be computed precisely, but they are negligible for most firing solutions. However, if the wind is really zero and the range is long enough and the target small enough the Coriolis effect may not be negligible. See McCoy*, Modern Exterior Ballistics*, p179 or Litz, *Applied Ballistics for Long Range Shooting*, p97 for detailed explanations but in plain language Coriolis works like this:

Azimuth deflection (horizontal deflection) or deflection about the rifle's yaw axis is caused by the angular velocity of the earth’s rotation. The yaw axis of the rifle is a vertical line through the rifle perpendicular to the surface of the earth at the shooting site, i.e., aligned with the gravity vector. When the yaw axis is aligned with the spin axis of the earth, the Coriolis Az deflection is greatest – at the poles. When the yaw axis of the rifle is perpendicular to the earth’s spin axis, the Coriolis AZ deflection is zero – at the equator. At other latitudes, say 45°, the Az deflection is the Sine of the latitude, 0.71 or at 30° it’s 0.50. In the northern hemisphere the Az deflection of the bullet is always to the right so the hold is always to the left. The Az deflection is not affected by the heading of the shot. If this seems illogical, visualize a shooter at the north pole. He, his rifle, his ammo, his sled, the snow he is standing on, everything is rotating about the axis of the earth. So any bullet carries the same rotation about the axis of the earth - regardless of whether the shot is toward Russia or Canada or any other direction.

Vertical deflection or elevation deflection about the pitch axis is the result of the tangential velocity of the surface of the earth. The earth's rotational velocity adds to the muzzle velocity and is greatest at the equator for shots pointing east. The earth's tangential velocity is subtracted from the bullet velocity relative to the rifle. So actual bullet velocity is minimum at the equator for shots pointing west. That's the reason that most rocket launching sites are near the equator and launch to the east. The effect of the earth's tangential velocity is zero for shots to the north and south. The earth’s tangential velocity is zero at the poles so the vertical Coriolis effect is zero. The vertical Coriolis effect at different latitudes and shot headings are described by the Cosine and Sine respectively.

The additional bullet velocity of an easterly shot causes the centrifugal force, directed outward, to partially offset the force of gravity, effectively reducing the force of gravity, with the result that the bullet will strike higher on the target. Conversely, it will strike lower if shot to the west. There is no effect for shots north or south. The Coriolis calculations are turned off by entering zeros in both the Lat° and Hdg° cells, E11 and E13 respectively.

* + 1. Lat°, E11 - Enter the latitude of the shooting site: positive for the northern hemisphere, negative for the southern. For DTR users the hold for the horizontal effect is included in the azimuth hold in mph (Az mph, cell A19). For dial and grid reticle uses the hold is build into the azimuth in moa (Az moa, cell B19). Enter zero in Lat° to turn off the Coriolis effect.
    2. Hdg°, E13 - Enter the heading of the shot; north is 0, east is 90, south is 180 and west is 270. For DTR users the effect is included in EHP. For dial and grid reticle users the effect is included in the barrel angle in moa (BE moa, D15).
  1. NAV, FAC, ADC – See “Approximations for Non-Nominal Trajectories”, paragraph 4.0, below.
  2. 1st Dot, E17 - The DTReticles provide wind dots at five mph intervals to 25 mph for nominal trajectories with 2.5 mph dots at long ranges. If a nominal bullet, say a Sierra 175gn 308 Match King, is shot at a non-nominal velocity, the EHP will be change and the wind dots scale will change accordingly to adjust for the different velocity. However, a bullet with significantly different drag will drift more or less than the wind dots indicate. A 220gn 308 Sierra Match King with a VR of 52.6 will require 6.4mph to have the same drift as the nominal 175gn SMK bullet at 5.0 mph. Thus, the 1st Dot value will be 6.4 mph. The wind hold can then be adjusted to compensate for the cross wind characteristics of the non-nominal bullet.
  3. Long Range Zero - For decades the standard method of adding barrel angle, sometimes called "come-up", for ranges exceeding the capability of the scope has been to tilt the scope rail down 20 to 40 moa. This is not required for scopes with DTReticles because all such scopes have several hundreds of moa built into the reticle so very long shots can be routinely made. However, on the rare occasions when additional barrel angle is desired, the DTReticle can accomplish this without changing the rail. If the barrel angle requirement for a selected range exceeds the elevation capability of the reticle, a firing solution can be developed by setting the zero range to some large value and then using the resulting smaller Barrel Elevation angle for the firing solution, thus moving the point of aim up toward the center of the reticle.

For example, the maximum range on the DTR V2D reticle (6xc) is 2200 yards but that dot is hard to use because the scope power must be reduced. A 2400 yard shot is off the reticle but SmartShot will compute the Barrel Elevation of 146.5moa but it's not usable because it's off the reticle.

But there is a simple solution which at least three shooters have validated in the field under the time pressure of a live target. For this example, we will use nominal 6xc input but any set of input variables can be used. So, enter all nominal 6xc input variables. Then pick an long range that could be dialed with the vertical turret, say 1800y. Set 1800 yards as the Range to Target (cell A13) and note the Barrel Elevation (cell C15) is 72.3 moa. Set the scope vertical turret to 72.3moa. This is the only time the turret is changed when using a DTReticle. Now set the Zero Range (cell A5) to 1800y. Now the scope and SmartShot are ready for a Long Range Zero firing solution.

Then enter the long range to target value, in this example, 2400y, into cell A13. Read the new EHP of 1820 in cell A15. Hold 1820 in the reticle, clear the target and release the shot.  
 As a check, the Barrel Angle corresponding to EHP 1820 is 74.2moa (cell C15). Recalling that the Barrel Elevation associated with the Zero Range of 1800y was 72.3 moa. Thus, the zero range Barrel is 72.3 and the EHP of 1820 is 74.2, return a total Barrel Elevation of 146.5moa, exactly the Barrel Elevation computed for the 2400y shot at nominal Zero Range. The EHP of 1820 is well inside the reticle limits and the scope power can be increased considerably.

1. Estimates for Non-Nominal Solutions – kDA, NAV, FAC, ADC and Slope; The DTReticle has the unique capability of providing an immediate Equivalent Hold Point (EHP) in yards, not moa or mils, for any rifle system, any target at any range and slope, any density altitude and any bullet shape or velocity. If the combination of variables results in a trajectory that matches the trajectory etched in the reticle, the user holds the actual range without adjustments. However, if the actual trajectory is not nominal, as is the usual case, the EHP will be slightly different than the actual range to the target. For example, if the rifle system and the air density are nominal, the hold point for a 1,000 yard target would be the 1,000y dot on the reticle. But if the actual trajectory is not nominal due to, for example, more dense air, say 2.0 kDA instead of 4.0 kDA, the PoI for a nominal 6xc shot would be eight inches lower at 1,000y. The EHP would be 1020 yards. Thus the user would visually interpolate between the 1000yd dot and the 1025yd dot to hold an EHP of 1020 yards.

There are two ways to calculate the non-nominal EHP. If time permits the most accurate method is to enter the input variables into SmartShot or David Tubb's DTR App and read the output EHP. If however, as is normally the case for dynamic targets, time is crucial approximations are provided which are simple, fast and accurate out to about 1400yd for small targets depending on the circumstances. Moreover, the approximations can be used without coming out of the scope. These approximations have proven accurate in many hundreds of shots for small dynamic targets at slopes of 30 degrees and ranges out to about 1400 yards. Skilled shooters use this approximate method far past 1400 yards.

While testing in Africa during the past ten years we never use a computer or ballistics card except on the longest, steepest shots. Mastering these approximations is fundamental to operation against dynamic targets for which the DTReticle and SmartShot were designed. The variables involved in the approximations are defined in the following paragraphs. These approximations are discussed in more detail in David Tubb’s DTReticle manuals; see: <https://www.davidtubb.com/index.php?route=account/download/free&download_id=30>.

These calculations can be done in several seconds while the shooter is still in the scope because: 1) all calculations can be rounded to the nearest 10 yards and 2) the user need not keep track of the minus signs; simply remember that more dense air needs more barrel angle and thus more range and conversely. The only numbers the user needs to memorize are the ADC values; less than ten single and two digit numbers for a specific reticle.

The process for computing an approximation for a non-nominal trajectory is as follows:

1) Estimate and enter the Nominal Assignment Value (NAV), e.g., the air density at which the rifle system would shoot a nominal trajectory, in cell C13.

2) Compute the local air density.

3) The Factor (FAC) which is the NAV minus the local air density will be displayed in cell B17.

4) Compute the correction to the range by multiplying the FAC times the Air Density Correction (ADC) and finally,

5) Compute the Equivalent Hold Point (EHP) by adding or subtracting the range correction to the EHP. If the slope is greater than five to ten degrees depending on the range, reduce the EHP as shown below.

6) Shoot the computed EHP.

This process sounds complicated when expanded to it's fine grain details but it is easily done mentally in a couple of seconds while maintaining visual on the target through the scope.

* 1. kDA, C17 – As a reminder, SmartShot computes the density altitude in thousands of feet (kDA) in either of three ways as described in paragraph 3.4.: 1) Temperature, RH and station pressure, 2) Temperature, RH and geometric altitude or 3) with a handheld weather station. All SmartShot calculations are based on a nominal density altitude of 4.0 kDA rather than sea level/standard day because, as explained above, air density at most shooting sites are much closer to 4 kDA than a standard day at sea level and 59F, 0 kDA. The air density in pounds per 1,000 cubic feet is shown in the adjacent cell, D15.
  2. NAV, C13 – The Nominal Assignment Value (NAV) is the density altitude at which any given rifle system, i.e., rifle and ammunition will shoot the nominal trajectory, i.e., the trajectory that is etched into the reticle glass. The NAV is computed prior to the mission, entered into the NAV cell, C13, and used in subsequent calculations. The concept is based on the fact that there is a density altitude at which the trajectory will be nominal even though an input, say the bullet velocity, is non-nominal. For example, if the actual muzzle velocity is 3040 fps instead of the nominal 2975fps, the barrel angle (BE) required for a 1,000y shot is 22.4moa instead of the nominal 23.5moa at the nominal density, 4kda. Using successive approximations, the user can quickly determine that if the density altitude is 1.0 kdDA, the BE required for the 1,000y shot is the nominal BE of 23.5moa. Thus the trajectory of the higher velocity ammunition will be nominal at a density altitude of 1.0 kDA. So we say that the rifle system has a NAV of 1.0. The user then enters 1.0 in the NAV cell. Again, the NAV calculation is done in preparation for the mission because it does not normally change for a given rifle and ammunition although if a mission comprised 500 precision shots the muzzle velocity decrease a bit. So it pays to continue to monitor the condition of the rifle system for precision results.
  3. FAC, B17 – The Factor (FAC) is automatically displayed in the FAC cell (B17) by subtracting the local air density in kDA from the NAV of the specific rifle system. If the local density altitude is lower (higher density) than the NAV, the FAC is positive and conversely. If the local KDA is 1 (more dense air) and the NAV is 4, the FAC is 4 minus 1 = 3. If the local KDA is 7 (less dense air), the FAC is 4 minus 7 = -3. The significance of the plus or minus sign is explained below. Again, the FAC is automatically computed by SmartShot and displayed in cell B17.
  4. ADC – The Air Density Correction (ADC) is the number of yards of range correction required for each 1kDA of FAC. The ADC for the Tubb 115gn DTAC bullet (6mm) at 1,000y is nine yards; i.e., nine yards per one kDA FAC. In the previous paragraph the NAV was 4 and the local air density was 1 kDA for a FAC of 3. So multiplying the FAC times the ADC shows EHP must be adjusted by adding 27 yards. So if the range is 1,000 yd, the EHP is 1000y + 27y or 1027y. Similarly, if the local density is 7kda, the FAC is -3, so the EHP is 1000 - 27 = 973y. This calculation is done mentally while watching the target in the scope. Rounding to the closest 10 yards is usually permissible.

Verify this approximation by setting the Weather Station kDA, cell B10 to 1.0 and RH to 0 (assuming the Weather Station density includes relative humidity). Range to 1000 yards and read the EHP as 1030 yards. Change the Weather Station to 7 kDA and read the EHP as 973 yards.

* 1. Slope – Slope shots always have a closer EHP so they are also handled with a simple rule: subtract yards from the EHP according to the slope in degrees as follows:

Slope ° EHP Reduction yd

10 10

15 20

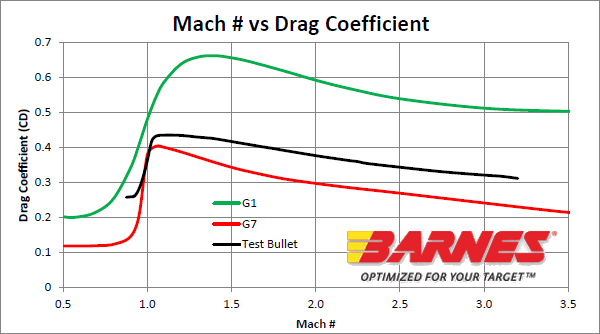
20 40

25 60

28 80

These approximations are good for the 6xc reticle from about 500y to about 1200y. Below 500y use less correction; above 1200y use more. David Tubb sells a simple but powerful Distance Reduction Indicator (DRI) which attached to the rifle and reads directly in Hold Closer yards. See: http://www.davidtubb.com/dtr-scopes/distance%20reduction%20indicator,%20dri,%20angle%20cosine%20firing%20solution. The Tubb DRI is adequate for all slope shots except for the most extreme ranges and slopes for which a calculation rather than an approximation might be required.  
The DRI has Hold Closer values for targets at 600y and 1200y. Interpolation between these two sets of values supports targets at 900y.

1. Transition and Subsonic Regimes **–**  SmartShot computes trajectories through the transition and into the subsonic regime with the same equations as for the supersonic regime but of course with different shaping coefficients because of the fundamental drag coefficient differences as shown in the Barnes graph.



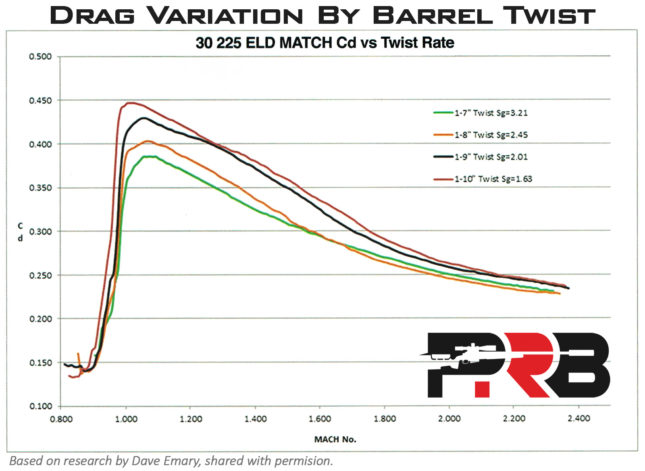
The velocity, position, heading and other properties of the bullet at the end of the supersonic regime are used as the starting conditions for the subsonic regime. The only subsonic input variable the users supplies is the Velocity Retention in the subsonic regime, VRsub, cell C7.

We have determined experimentally the VRsub values for a wide range of bullets as shown in the Non-Nominal Bullet table in the Manuals section of the ProjectileScience.com web site. Most VLD bullets seem to be in the 100 to 135 range. The 6mm DTAC 115gn bullet, similar to a Sierra Match King has a VRsub of about 135. The 375 Warner Flatline 364gn bullet has a VRsupersonic of about 96 and a VRsubsonic of 101, among the highest we've tested.

Bullet stability is a major factor through transition and beyond. Reliable doppler data show the 308, 175gn, Sierra Match King needs an eight twist barrel to reliably remain stable through transition and beyond. We have replicated these data with hundreds of eight twist shots out to 1800 yards in air density of approximately three kDA. Twelve twist barrels do not stabilize these bullets sufficiently as evidenced by the significant number which diverge. A ten twist is better but some bullets still diverge. Large vertical scatter near transition or beyond is probably indicating a stability issue with a rifle system.

1. Range Table– The SmartShot range table uses all the input variables defined on the screen but computes firing solutions at the specified range intervals rather than at only the specified input range. The table computes EHP and four other output variables.
   1. Input Variables– The Range Table Input Variables in yards are: Start, End and Range Interval.
   2. Output Variables– The Range Table Output Variables are: EHP, BE moa, Z mph, Path inches, BE mils.
2. Rifle System Calibration **.** 
   1. Why Calibrate – Identical ammunition will likely perform differently in different rifles, i.e., different serial numbers, not just different models, because the subtle characteristics of the rifle such as chamber length, jump, twist, bore quality, bore wear, straightness, etc., affect the behavior of the bullet as it leaves the muzzle. Thus the same bullet will behave differently once out of the muzzle. Most obviously, the velocity and pitch/yaw motion will likely be different. The transition from internal ballistics to external ballistics will be different because the pattern and amount of gas leakage at the muzzle will be different. The first hundred yards will be different and the bullet is very busy as it sorts out the coupled gyroscopic and aerodynamic effects. So while we may get a VRsup of 64.0 in all of our 6xc rifles that have 7.5 inch twist, another 6xc rifle platform with a different twist might produce slightly different performance. The differences might not be significant at 600 yards but they may become significant at 1400 yards. These are differences that are absolutely insignificant at normal hunting ranges of 400 yards. So the traditional practice of assuming a constant drag metric is obsolete for precision long range shooting.

Recent data published by Dave Emary makes this point clearly. The following drag curves were for the same bullet at different twists from 7.5 to 10 inches. The dramatic difference is almost certainly due to different gyroscopic behavior of the bullets. Bullets with high twist (7.5 inch) bullets have better stability than low twist (10 inch).

See: [https://precisionrifleblog.com/2019/06/30/personalized-drag-models-the-final-frontier-in-ballistics/.](https://precisionrifleblog.com/2019/06/30/personalized-drag-models-the-final-frontier-in-ballistics/.%20) Thanks to PRB for this important graph.

* 1. Two Range Data Points, Or Maybe Just One – When we started testing SmartShot in 2009 we collected data at approximately four supersonic ranges and three subsonic ranges. The purpose of course was to measure the entire trajectory to assure that SmartShot correctly defined the middle points not just the end points of both regimes. In time we learned that we needed only four data points: mid-range supersonic, transition range, mid-subsonic and end subsonic. The reason we did not need so many points is the bullet trajectory is a "well-behaved" curve. i.e, it has no irregular slope changes, etc., assuming it doesn't change shape such as when a plastic nose falls off. So a trajectory that contained the initial point, the muzzle for the supersonic regime and the transition for the subsonic regime, a mid-point and the end point will contain all other points. Thus instead of seven points we needed only four. This realization greatly simplified our testing.

The next simplification came when we realized to our surprise that the trajectories of all VLD bullets we tested had the same general shape. They had different drag of course, i.e., different Velocity Retention values, but the *shape* of the trajectory was the same. So in time we came to the cautious conclusion that we needed only two points: the muzzle of course plus the transition and the longest subsonic point we expected to shoot. So every bullet we have tested has the same trajectory shaping coefficients so only two range data points are required: one at transition and one at the longest expected range.

* 1. Calibrate Your Rifle System – There are at least three ways to calibrate a trajectory: 1) Doppler radar, 2) Time of flight and 3) Direct path measurement, i.e. holes in paper.
     1. Dopper Radar - Probably the most accurate method is to measure the bullet velocity continuously as it flies down range. The US Government has a number of such ranges, one at Dalghren, VA and another at Hawthorne, NV and presumably many others These ranges measure the bullet velocity at every millisecond out to very long ranges. Thus the rate at which the bullet surrenders velocity (Velocity Retention) is directly measured and with that the instantaneous drag can be computed. The point at which a bullet becomes unstable is easy to determine.

The only problem is the prohibitive expense. LabRadar makes an affordable system but the maximum range is on the order of a hundred yards which is insufficient to measure trajectories. Hornady is apparently measuring trajectories with an in-house capability which is supported by their new 4DOF ballistic system. Ballistic coefficients are not used for this work except as a way to reference back to legacy performance data. Point of aim errors do not affect the doppler measurements.

* + 1. Time of Flight - Bullet trajectories can be measured using acoustical gates which record with great precision the time the bullet passed through or near the gate. Brian Litz apparently used acoustical gates to develop the unique set of bullet drag data published in his fine book, *Applied Ballistics for Long Range Shooting, 2nd Edition*. Oehler makes a powerful system, the Oehler 88, which used acoustical timing data to measure bullet properties. By measuring the muzzle velocity and the time of arrival at the target, the Oehler 88 can compute a BC value which may or may not be consistent with other BC data points. This is a criticism of the BC concept not the Oehler 88 system. Like the Doppler systems, point of aim errors do not affect the time of flight data.
    2. Direct Path Measurement - The traditional method of direct path measurement is based on looking at the bullet holes or the point of impact. There are three huge problems that get worse with increasing range: 1) Point of Aim errors directly affect the trajectory measurement, 2) At long range, just hitting the target is sometime an overwhelming problem and 3) Getting the point of impact data from the target, once it is actually hit, back to the shooter is technically challenging or time consuming, or both. Once problems two and three are overcome, the fundamental problem of Point of Aim errors can only be handled with statistically, which means lots of shots. I typically shoot 100 rounds to measure the drag and PoI dispersion for a new load or bullet. The Oehler 88 can do it in five or ten shots.
  1. Compute The Velocity Retention - Once the bullet path near transonic and at maximum range are measured, by whatever method, SmartShot can compute the Velocity Retention of the bullet in both regimes. Simply enter the salient input variables, i.e., temperature, pressure, RH, wind, muzzle velocity, scope height, etc., and by successive approximation compute the VR that produces the observed point of impact. Getting the bullet path data is hard. Using SmartShot to compute the VRsup and VRsub is easy. If the bullet path data and all of the input variables are correctly measured, the VR data will be correct and the correct EHP or Barrel Angle for any shot under any conditions can be accurately computed in a couple seconds.

1. Putting It All Together– This manual has to this point explained all of the functions required to compute firing solutions for almost any set of requirements, but because of the complexity of the physics and the user environment, the path from the beginning through to a firing solution in the field may need clarification. Perhaps the following sequence of steps will help. Each of the steps is discussed in detail elsewhere in the manual.
   1. Verify The Ten Ballistic Mgmt Input Variables - SmartShot highlights the ten ballistic computation management input variables with a light blue background. SmarShot defaults to settings for the DTReticle but the toggles can be set for a dial or grid reticle. Once set for either system, these variables rarely change.
   2. Enter 10 Rifle System Input Variables - These variables, muzzle velocity, Sight Height, Zero Range, etc., shown with a pink backgroune, will rarely change for a specific mission.
   3. Determine The Two VR Values - The next step is determining the Velocity Retention values for the selected bullet. Select VRsupersonic if the bullet is supersonic at the muzzle. Select VRsubsonic if the bullet is expected to carry past transition. The VR Non-Nominal.htm file on the web site, projectilescience.com\manuals, contains VRsupersonic and VRsubsonic values for over 50 of the most popular VLD bullets. If the bullet is not in this list, SmartShot can convert the BCg7 or BCg1 from another source to an approximate VRsupersonic. Use the VRsubsonic of a similar bullet in the VR Non-Nominal file as explained in detail elsewhere in the manual. If the mission requires extreme accuracy over a very long range, calibrate the rifle system as described.
   4. Enter The Density, Wind and Coriolis -
      1. Determine The Air Density - Remember the density altitude can be computed from three different sources of data. Select the one that fits the available data and enter the input data.
      2. Enter The Wind - If the wind call will be computed, enter the wind speed and incoming direction in degrees; wind from the right is 90 degrees, etc. Experience has shown that wind strength, heading and air temperature from nearby weather stations, at the same altitude, in flat country is often sufficiently accurate to be useful. However, for shots on dynamic targets, almost all of our wind calls have been made at the moment of the shot because our shooting sites are in mountain country so headings and the local wind changed too rapidly to be efficiently entered and computed.
      3. Enter The Coriolis Input - If Coriolis is expected to be relevant enter the latitude and shot heading. We almost never use the Coriolis output on dynamic targets.
   5. Compute the NAV - All salient input variables have now been entered so the NAV can be computed. Recall the NAV is the density altitude at which the rifle system will have a nominal trajectory. We normally only change the NAV when the temperature or altitude changes.
   6. Enter The Range - Enter the slant range in yards as measured with a laser range finder. If the rifle system shoots more than 5% flatter than the selected reticle, select the Meters toggle and enter the range in meters. If the firing solution is being developed without a computer, simply shoot the range dot if the trajectory is nominal or as adjusted for a non-nominal trajectory. The NAV is the starting point for compensating a non-nominal trajectory using the FAC and the ADC.
   7. Enter The Slope - If the slope is greater than 10 degrees for short range or greater than 5 degrees for long range, enter the slope in degrees as measured with a laser range finder. Alternatively the slope can be read directly with David Tubb's DRi which is completely mechanical. Unlike most slope meters the output is not degrees but number of yards to subtract from the range (hold closer) to correct for the slope effect.
   8. Hold The EHP And The Wind; Release The Shot - The EHP of a specific shot can be computed in the field using a smart phone or estimated using the approximations which correct for rifle system variations which result in a non-nominal trajectory. We have used the approximations for thousands of shots over nine years in Africa. However we have used computed firing solutions for the longest and steepest shots.
2. Examples
   1. Example One is the same as used in the Dynamic Targeting Reticle Manual on page 22, a target is at 770 yards, 20 degrees slope at 4,600 feet geometric altitude, 95 F and 50% RH. The cartridge is a 175 grain, 308 Sierra Match King at 2575 fps. The scope height is 2.5 inches above the bore.

Open projectilescience.com and select the Products page. Select the 308 Win.htm file. The default firing solution range is 1800 yards. Plug in the input variables for this problem: Range 770 in cell A13, Sight height 2.5 inches in cell B5, Temp 95 in A9, RH 50 in C9, Slope 20 in B13 and Geometric altitude in thousands of feet 4.6 (4,600 ft) in C11. Read EHP of 715 yards in A15. Same as the DTR manual, page 24. For dial and grid reticles, read the Barrel Elevation Angle (come up) of 20.8 moa in cell C15.

* + 1. Now assume the ammo is the same temperature as the local air, 95 F. SmartShot's default powder temperature is 75 F. Set it to 95 F in cell G5. Read the new muzzle velocity 2585 (Vmuz Cal) in cell D9. This is an output variable and therefore cannot be changed directly. Now read the new EHP of 711 yards in cell A15. The new Barrel Elevation angle is 20.6 moa, a change of only 0.2 moa but if the range were longer or the temperature difference greater, the effect would be significant.
    2. Smart Shot users have the option of linking the powder temperature automatically to the air temperature. Go back and reset the powder temperature, G5, to 75 F. The EHP will return to 715 yards and Barrel Elevation to 20.8 as in example 9.1.1 above. Now change the Powder Temperature toggle, G7, from zero to one to couple it to the air temperature. Read the new EHP of 711 yards and Barrel Elevation of 20.6 moa, same as above in example 9.1.2.

DTReticles have built-in corrections for spin drift, cross wind jump (aka aerodynamic jump) and Differential Wind Drift but dial and grid reticles do not. So SmartShot provided toggles for these effect which can be controlled by the users.

* 1. Example Two is a target at 1846 meters, slope is 17 degrees, weather station density altitude is 1,345 ft, temperature is 42 F. Cartridge is nominal 6xc except the muzzle velocity is down due to the cold ambient air and the bullet has a VRsupersonic of 64 and a VRsubsonic of 120. Sight height is 2.0 inches.

Open projectilescience.com. From the Products page select the 6xc file. Plug in the input variables: The range is in meters so replace the 0 with a 1 in cell A11. Enter the range 1846 meters in cell A13. Notice that the range in yards appears in A15. Enter the remaining input variables: Air temperature 42 in A9; Density altitude entered as 1.345 kft in B11; Slope 17 in B13; VRsup 64 in B7; VRsub 120 in C7; Sight height 2.0 in B5. The muzzle velocity is nominal at 2975 fps at 75 F but the ammo is at 42 F. The muzzle velocity can be compensated for temperature manually by entering the ammo temperature in cell G5 or automatically by linking the muzzle velocity to the air temperature by setting a 1 in cell G7. Either way notice the muzzle velocity used in the firing solution is 2959 fps in cell D9. Remember that yellow cells are output variables and cannot be changed directly.

RH must be set to 0 because the weather station setting of 1,345 ft includes the effect of RH. If the RH setting remains at 50% the RH effect will be double counted. The effect of double counting is negligible for all except the longest shots.

Now read the EHP of 1965 yd or barrel elevation angle of 88.7 moa for dial and grid reticles.

* + 1. To see this firing solution with range measured in yards instead of meters, change the 1 to a 0 in cell A11. Read the revised EHP as 1807 yards and the barrel elevation angle as 73.0 moa.
    2. Now change the air temperature from 42 F to 105 F, enter 105 in A9. Notice the muzzle velocity has increased from 2959 to 2990 fps. The EHP is reduced from 1802 yd to 1786 yd and the barrel elevation angle is reduced from 73.0 moa to 71.1 moa.
    3. Multiple Targets in Close Proximity: The primary target at 1846 yards and 17 degrees disappeared but another target, perhaps the same one, appeared a bit down the slope at 1820 yards and 16 degrees. Leave the temperature at 105F. A new firing solution can be developed by quickly changing the range and slope to the revised values and read the EHP has changed from 1786 to 1767 yards; barrel elevation angle from 70.7 to 69.4 moa.

But SmartShot offers an quicker way to compensate for small changes in range and slope which result from engaging a group of dynamic targets operating in close proximity. Return to the Range to 1846 yd and Slope to 17 degree target and notice that the output variable EHP Δ, cell B13, has a value of -59 yards. This is the difference between the range and the EHP; i.e., EHP minus the range, 1787 - 1846 = -59 yards. The EHP Δ will not change significantly for near-by targets. So compute the EHP of a secondary target faster by simply adding the EHP Δ, -60 yards, to the range to the new target. Thus the EHP to the secondary target is at 1820 yards, 1820 - 59 = 1761 yards. The error of this quick approximation is 1767 - 1761 = 6 yards which is insignificant. Notice that this EHP adjustment can be made instantly without coming out of the scope. The only data needed from the spotter is the range.

So, in summary, if the rifle system is nominal, i.e., a target at 1000 yd has an EHP of 1000 yd; simply hold the range. But if, as is normally the case, the rifle system is not nominal and there is a significant difference between the range and the EHP, the EHP Δ can be used to quickly engage multiple targets in close proximity. This is a powerful tool for multiple target engagements.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | EHP Delta Example | |  |  |  |
|  |  |  |  |  |  |  |
|  |  | Range | Temp | Slope | EHP | EHP Δ |
| First Target, 9.2.2. | | 1846 | 105 | 17 | 1787 | -59 |
| New Target Near By | | 1820 | 105 | 16 | **1767** |  |
|  |  |  |  |  |  |  |
| Using EHP Δ | |  |  |  |  |  |
|  | New Target | 1820 |  |  |  | -60 |
|  | EHP Δ | -59 |  |  |  |  |
|  | Est EHP | **1761** |  |  |  |  |
|  | Error of est | 1767-1761=-6 yds | |  |  |  |

* 1. Example Three - A DTReticle being used for a rifle system that shoots substantially flatter than the nominal trajectory. For example, the 6xc reticle was designed to have a barrel angle of 43.0 moa at 1400 yards under nominal conditions. Assume the VRsupersonic of the bullet for this example is increased from the nominal value of 58.7 to 64.0 and the velocity is increased from nominal 2975 to 3125 fps. The barrel elevation at 1400 yd decreases from 43.0 moa to 36.3 moa so the EHP decreases from 1400 yards to 1279 yards, an EHP Δ of -121 . This is a large change and difficult to estimate at very long ranges without a computer of some kind. But notice that the actual trajectory closely matches the nominal trajectory if the range is measured in *meters*; 1400 yards is 1283 meters.

SmartShot can handle this compensation automatically. Find the range in meters by changing the range finder from yards to meters. Enter a "1" in cell A11 to convert to meters; enter 1283 meters in the range, cell A13, and read the EHP value of 1283 yards and the EHP Δ value of zero. So by reading range in meters and EHP in yards, the trajectory of the reticle has been flattened by the difference between yards and meters, 9.14%, thus allowing the EHP of 1281 yards to match the range input of 1283 meters. This is a very powerful tool which we now routinely use as the trajectory of the 115 gn DTAC bullet has become flatter due to decreased the drag and increased velocity over a decade of development.

1. Appendices **.**
   1. Crosswind Effects - Wind, spindrift and boundary layer effects are either indeterminate or difficult to compute. Worse, erect targets are smaller horizontally than vertically. So cross range deflections are simultaneously the most sensitive and the most difficult to compute. Consequently, all cross range calculations are moderately imprecise thus wind calling skills are probably more rare and valuable than trigger skills.
   2. Summary of Input Notes - As a consequence of requiring SmartShot to support both the DTReticles and traditional and grid reticles, ballistic effects which are built-in to DTReticles but not others requires toggles to turn corrections off for DTReticles and on for the others. Further, Excel-like applications adapted for smart phones often have different syntax than the native Microsoft Excel. Thus syntax used in logic commands sometimes requires contortions. For example, the command for Geometric Altitude, cell C11, would more logically be a one or a zero for on and off. Or perhaps "on" for on and "off" for off. But some applications require a number greater than one for the logic command. Thus, to use the Geometric Altitude command, enter the number of thousands of feet at the shooting site; 4,600 feet is entered as 4.6. So far so good. But then to turn that command off, instead of word like "Off", a number is required. SmartShot uses the number "30", selected because precision rifle fire from higher than higher than 30,000 feet is highly unlikely. The following table describes most of these odd characteristics.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Input | Description…………………………. | DTR | Dial | Comments………………………………. |
|  | Temp, RH and Station Pressure |  |  | Computes density |
|  | Temp, RH and Geometric kFT |  |  | Set actual kDA to select or 30 for off |
|  | Weather Station kDA and 0 RH |  |  | Set actual kDA to select or 30 for off. Set RH to zero for greatest accuracy |
|  | NAV - Nominal kDA |  | - | Set nominal kDA for rifle system |
|  | Zero range | See note |  | DTR; For X zero range, use X range dot. Closest dot is 100y. |
|  |  |  |  |  |
|  | Velocity Retention, sup and sub |  |  | Set 0 if not known. Enter BCg7 |
|  | BCg7 |  |  | Set 0 if not known. Enter BCg1 |
|  | Stability Factor |  |  | Set actual stab or 0 for off. Enter bullet parameters to compute stability factor |
|  | Barometric pressure at sea level |  |  | Set actual or use Geo kFt,T,RH or kDA |
|  | Powder temperature in F |  |  | Set actual powder temp if different from calibration temperature |
|  | Powder temp toggle |  |  | Set 1 to match air temp, 0 to ignore |
|  | Spin drift toggle | 0 | 1 | Built into DTR |
|  | Differential Wind Drift toggle | 0 | 1 | Built into DTR |
|  | Crosswind Jump toggle | 0 | 1 | Built into DTR |
|  | Obstacle range |  |  | Must be inside 100y |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

END