# Extended Range Truing

While the typical shooter or ballistician thinks of a bullet's behavior as a function of the range, it is more instructive to think of the behavior as a function of time. A bullet's range, velocity, and deceleration can be completely described by the curve of range [distance] versus time. The initial slope [first derivative] of the curve represents muzzle velocity and slope at any other point represents velocity at that time. The second derivative of the curve represents drag or deceleration as a function of time.

This range versus time curve is the "native language" of the System 88. Three skyscreens are used near the gun to measure the muzzle velocity [slope] of the curve at the origin. Sensors located at one or more downrange points measure times corresponding to these distances.

To construct a continuous curve meeting the conditions of zero origin, initial slope, and passing though the observed long-distance point at the observed time, we use the legacy drag function procedure. A drag function relates the deceleration to the velocity of a mythical standard bullet. The deceleration of the tested bullet is related to the standard bullet by a constant known as the "ballistic coefficient". Starting at the muzzle velocity and using the assumed ballistic coefficient, the bullet's implied deceleration is integrated with respect to time to obtain velocity versus time. The slowing velocity is integrated with respect to time to obtain range versus time. Now having both velocity and range versus time, the results are typically converted to velocities remaining at specified ranges and times-of-flight to these ranges. This is the language of the shooter.

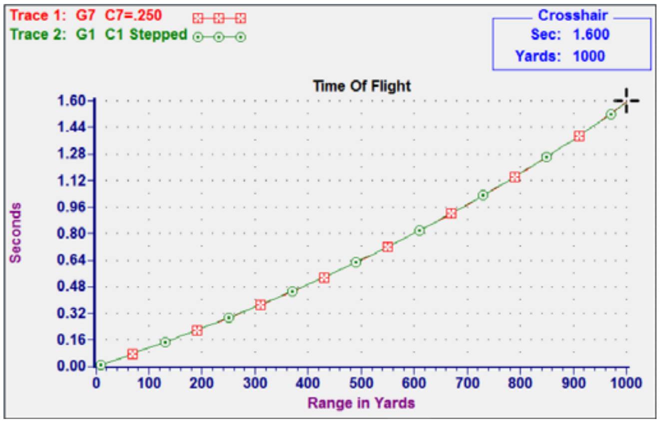
The ballistic coefficient is often discussed and quoted, but is little understood beyond "bigger is better". There are several techniques commonly used to measure the ballistic coefficient; all such measurements are difficult and subject to error.

Instead of attempting to measure the deceleration of the bullet, The System 88 minimizes the error by considering the effect of the ballistic coefficient over the entire flight to the target. The System 88 measures the muzzle velocity and actual time-of-flight to the distant target. It uses the chosen legacy drag function with the legacy procedures to predict a time-of-flight to the measured range. The ballistic coefficient is varied by successive approximation until the predicted time-of-flight matches the observed time of flight.

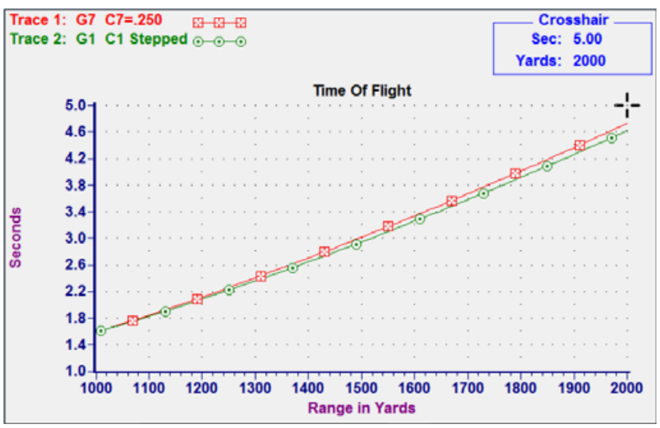
When the legacy time-of-flight versus range is plotted as range versus time curve, we have a complete curve meeting our requirement of matching the initial slope and passing through the measured time versus range point. The legacy procedures have been reduced to providing an interpolation between measured points instead of being an extrapolation from the muzzle to the distant target. While the fit of the curve to actual behavior may not be perfect at intermediate points, the curve has been forced to fit at the distant point.

You are accustomed to looking at curves plotted versus range or distance. Practically all ballistics programs show charts and graphs as a function of range. We will show our results plotted versus distance instead of time.

As an example, let's match the behavior of a G7 drag function using the old G1 drag function. We will assume a C7 of 0.250 and a muzzle velocity of 2800 fps with standard atmosphere. We see from the tables that the bullet goes subsonic at roughly 1100 yards. We step back away from the troublesome sonic transition and note that the G7 time-of-flight is 1.367 seconds at 900 yards. Using the G1 procedure shows that a C1 of 0.495 provides the same time-of-flight to 900 yards.

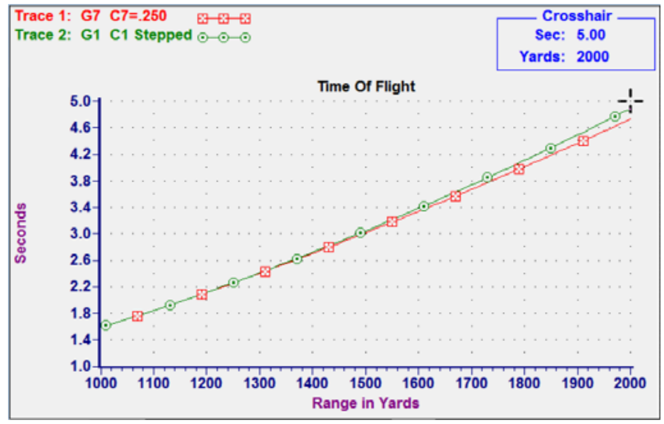



Here is the time-of-flight versus distance for G1 and G7. Note that out to approximately 1000 yards, the curves are practically identical. We can say that we have matched G7 behavior using the old G1 drag function out to a range of approximately 1000 yards. If you expect to predict behavior only to 1000 yards, then you can stop here.



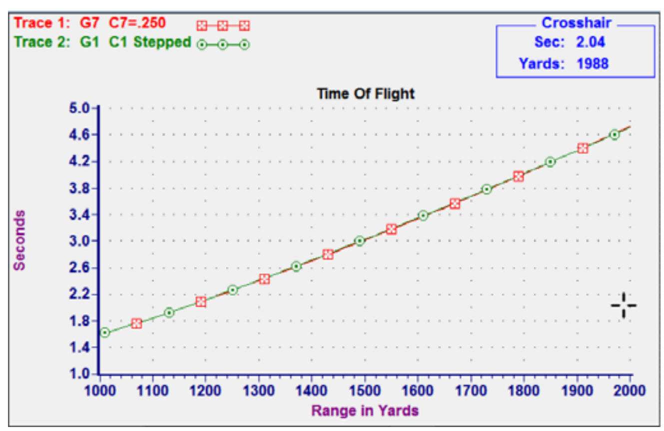

If we look at the curves extending beyond the 1000 yard range, we see significant differences at the longer ranges. It is time to apply a step correction to C1.

By 1350 yards, the predicted velocities decay to approximately 1000 fps. At this range, the C7 time-of-flight is 2.554 seconds. We leave C1 at 0.495 down to 1410 fps and step C1 down to 0.364 to match the C7 time-of-flight at 1350 yards.



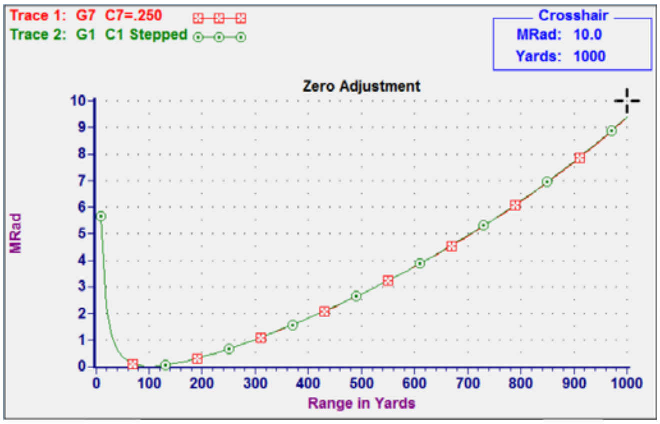

We again look at the time-of-flight curves for the farther ranges. We see that the curves coincide out to approximately 1400 yards, but still diverge at the longer ranges. With only one step in our G1 ballistic coefficient, we have extended our effective range from 1000 yards to almost 1400 yards.

If you are trying to have the correct elevation at ranges of a mile or more, you must add an additional step in the ballistic coefficient. The G7 time-of-flight at 2000 yards is 4.730 seconds. We leave C1 at 0.364 down to 970 fps, and find that a C1 of 0.693 is required at the lower velocities to match the C7 time-of-flight at 2000 yards.

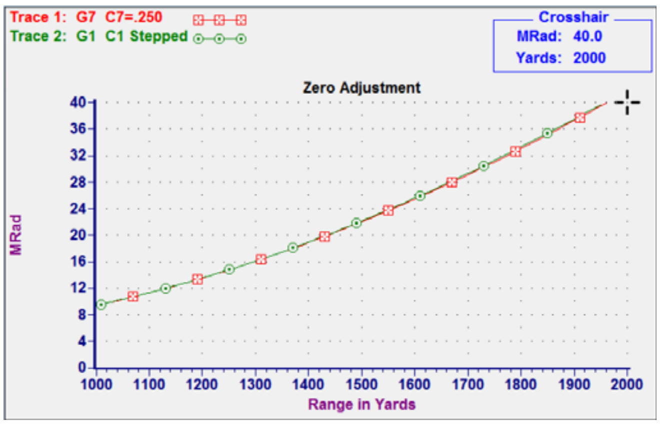



Times-of-flight now agree out to 2000 yards and a velocity of 840 fps. Below 840 fps, the ballistic coefficient reverts back to its initial value.

Theoretical folks may relish looking at time-of-flight graphs, but practical shooters are much more interested in zero adjustment for elevation.




Out to 1000 yards, the maximum difference in zero adjustment if 0.03 mils




The difference in zero adjustment remains under 0.1 mil out to 1500 yards and under 0.25 mil out to 2000 yards.

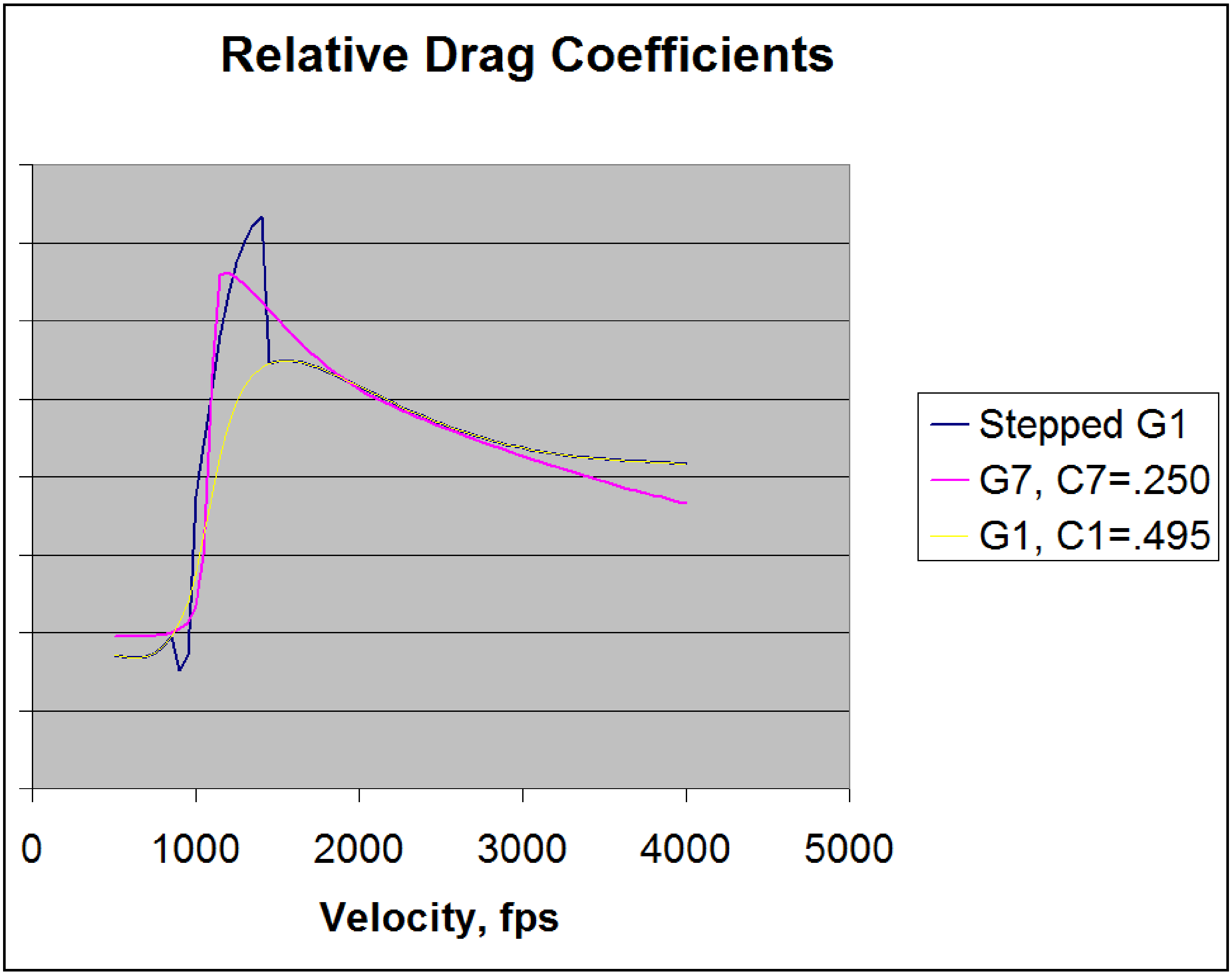
This demonstration demonstrates that you can use a stepped G1 ballistic coefficient to model a G7 bullet.

We can take it a step farther. If we can use the stepped G1 to model G7, we can model any other bullet. If our computer can handle a stepped G7 function, and our bullet is better described by G7, then we can make the smaller step corrections to G7 for even better results. If our drag function is a close fit to the bullet without steps, then the stepped values will be almost constant. If we use measured muzzle velocity and times-of-flight, we obtain a functional description of the tested bullet.

What if you don't have the muzzle velocities and corresponding times-of-flight at appropriate ranges? That's why Oehler built the System 88. It provides you with these numbers, measured with your gun and on your range.

The software in the System 88 automatically provides you with the proper ballistic coefficient to make the first time-of-flight match. If your downrange sensor is located at the range corresponding to remaining velocities of Mach 1.2 down to Mach 1.1, then you will have a ballistic coefficient and muzzle velocity allowing accurate elevation estimates down to approximately Mach 1.0. Your values for stepped ballistic coefficients provide reliable predictions out as far as your longest measured time-of-flight. If you want elevation estimates valid down through the sonic range, then you must test at a range that has allowed the bullet to pass through that nasty region.

The Extended Range Truing program available for the System 88 automates the process for up to four different ranges. Install the program using **SetupTruing.exe.** This installs the program and leaves an icon on the desktop. At the present (July 2016), the program does its intended job of computing and displaying the stepped ballistic coefficients to accurately describe the bullet behavior over long ranges. All program inputs must be manually entered via keyboard and output is only shown on the screen display. There are no printed output reports and there are no detailed instructions. The program expects that you will make an initial test with the range corresponding to Mach 1.2. To extend the range through the sonic region, you must make additional tests at ranges approximating Mach 0.9 and even longer ranges. The program accounts for differing atmospheres, muzzle velocities and ranges encountered in the separate tests. (Multiple targets on one test would be nice. With the example we used, the mid-range trajectory is approximately 100 feet. That takes a long pole elevate the sensors.)




The idea of stepped ballistic coefficients has been around for many years. It has been thought of as a gentle and innocuous procedure. In reality, the change at each step is abrupt. The size of the jump depends on the fit of the assumed drag function to the behavior of the tested bullet. In our previous example, there are significant differences between G1 and G7, especially over the transonic region.

The sharp sonic peak of G7 and the rounded G1 are familiar when viewed in the common "drag coefficient versus velocity" format. Recognizing that a step in ballistic coefficient can be interpreted as an equivalent step in the drag coefficient curve, observe the plots of G7, regular G1, and the stepped G1 yielding the same results as G7.

Stepped G1 and regular G1 are identical down to the first velocity step. At this point there is a significant decrease in ballistic coefficient or increase in drag. The peak of the step acts similar to the peak of G7 to force the results of the curves to match after the sonic transition. The curves look different, and they are different, but fortunately they provide essentially the same prediction results. The muzzle velocity and times-of-flight from the System 88, used as a truing method, allow for accurate predictions at extended range.