The Tank Accuracy Error Budget and Screening Policy

by Sergeant First Class David Cooley

SSG Highspeed is a tank company master gunner fresh out of school. We join him at the NTC, where he is preparing to screen his company's tanks at the Coyote Canyon range. It is a beautiful day, with a fresh 25 mph wind out of the north. The first tank hits almost dead center with SABOT. They load HEAT — and the round strikes to the left, outside the octagon. He checks the CCF — it's good. The boresight must be good, or they wouldn't have hit with SABOT. He thinks, maybe the gunner jerked, or it was a bad round. He has them load another HEAT and fire — the second round misses to the left as well. The stress level is rising. What does he do?

A disturbing trend has been evolving over the last few years concerning the Live Fire Accuracy Screening Test (LFAST). In a nutshell, units are circumventing the screening doctrine and putting their own policies in effect. These policy changes are often driven by a desire to save ammunition and, though they may seem to make sense, are actually counterproductive.

First, a quick review of the doctrine. We do not individually zero our tanks. Instead, a common, or fleet, zero has been established for each type of main gun ammunition. Each tank must go through the LFAST process prior to live-fire gunnery training. The purpose of the LFAST is to ensure that the tank can fire accurately using the fleet zero method of calibration. In order to pass the LFAST, the tank must hit, with one of the first two rounds fired of each type, fully within a 175 cm octagon, (soon to be changed to a circle), and placed at 1500 meters +/- 20m. A tank that successfully does so is said to be "screened." Tanks that do not hit within the octagon are checked for mechanical faults and crew errors, and if none are found, are given their own individual zero data. This is known as a discrete CCF (Computer Correction Factor). The process for determining a discrete CCF is to fire a three-round shot group, determine the Mean Point of Impact (MPI), and adjust the reticle to the MPI. A single confirmation round is then fired to ensure the tank will hit.

Every master gunner knows all of this already. Nevertheless, some are not carrying it out, either on their own initiative or in compliance with orders from their commanders. Often, this is done in order to save ammunition. The most common alteration is to give discrete CCFs after the *first* round fired fails to hit within the octagon. The rationale is that *DA PAM 350-38* only authorizes two rounds of each type for screening purposes. To do a discrete CCF by the book requires four.

To simply say that we must follow doctrine because it *is* doctrine is not good enough, especially in this case. We have to understand *why*. The process does have flaws, certainly, and we will discuss those flaws as well, but some of the changes are much worse.

Complete understanding of the screening process requires a basic familiarity with the error budget. The error budget is the influence of hardware design and manufacture, environmental conditions, and human factors on main gun accuracy and consistency. Put another way, it is all of the things which could cause a main gun round to miss its desired point of impact. We break the error budget down into three major categories: fixed biases, variable biases, and random errors. Fixed biases are errors induced by ammunition, weapon, and fire control system (FCS) design and manufacture. They are essentially constant, and they are present all of the time. Therefore, they are easily corrected in modern fire control systems. Examples are drift and gun-sight parallax. Variable biases are errors that remain fairly constant during a single engagement, or firing occasion, but may change considerably from one occasion to the next. In other words, when you fire two HEAT rounds at an enemy APC, that is one occasion. As soon as you shift fires to another target, or change ammunition, or the range to the target changes considerably, it's a new occasion, and the effects of the variable biases may change as well. While variable biases cannot be corrected automatically by the FCS, they can often be

Figure 1. Stationary Firer versus Stationary Target Error Sources

FIXED BIASES:

Projectile drift
Gun-sight parallax
Uncompensated Mean Jump

VARIABLE BIASES:

Horizontal Variable Biases:
Cant
Crosswind
Jump
Fire Control
Parallax, Drift Compensation (PDC)
Rotation of the Earth
Boresight Retention
Calibration/Zeroing

Vertical Variable Biases:
Muzzle Velocity Variation
Angle of Site
Range Estimation + PDC
Jump
Fire Control
Range Wind
Air Temperature
Air Density
Boresight Retention
Windage Jump
Optical Path Bending
Vertical Cant
Calibration/Zeroing

RANDOM ERRORS:

Round-to-round Dispersion
Gunner Lay Error
Visual Resolution

minimized by the FCS or through crew training. Examples of variable biases are boresight retention error and range estimation error. Random errors are errors whose magnitude and direction change from round to round. They are much more difficult to correct because they are so unpredictable. Examples of random errors are round-to-round dispersion and gunner lay error. (See Fig. 1 for the entire list of error sources.)

Now we must further focus on three individual error sources: mean jump, variable jump, and round-to-round dispersion. (Note: The section in Chapter 7 of *FM 17-12-1-1* does not reflect the following definitions; the new *17-12-1-1* will.)

Mean jump is the average difference between the actual impact of a group of rounds fired over many occasions and the intended strike of those rounds, given that all inputs to the FCS are correct or within tolerance. When we first test a new main gun round, we perform fixed gun-mount firings to determine the ballistic properties of the projectile — the data that you can find in the firing tables. This data is "hard-wired" into the computer, and is accessed by entering the ammunition subdes. The next step is to fire the round from a tank — many, many rounds. The fact that we are firing from a tank, and not a fixed gun, will in itself cause some error. This error is part of mean jump, and there are many other factors as well. As we perform these tank firings, a pattern will begin to develop, and the MPI of those rounds will be determined. For example, the MPI for training HEAT, M831, was right .15 mils and down .35 mils from the aimpoint, hence the CCF published in *FM 17-12-1-1*, which compensates for mean jump. Occasionally a tank will not hit with this CCF — the mean jump for that particular tank is different to a degree that the fleet CCF will not correct for it. A discrete CCF is given, which compensates for mean jump for that particular tank. The key is, CCFs compensate for mean jump *only*. Any CCF given to compensate for any other variable or random error source *will not work*. And, mean jump can never be identified on the basis of one round; even *three* isn't really enough.

Next, let's discuss variable jump. Variable jump is the average difference between actual impacts for a **particular occasion** and the intended strike of those rounds, given that all inputs to the FCS are correct or within tolerance. This means that, after all preparation is complete (CCFs properly entered), and all the variable biases are eliminated or otherwise compensated for (good boresight, correct range determined, cant sensor working, etc.), there are still variable error sources not otherwise accounted for, or not perfectly corrected. All these sources together make up variable jump. An example is if there is a headwind or tailwind. The crosswind sensor on the M1-series tanks only reads crosswind. Therefore, a headwind or tailwind will cause the round to strike lower, or higher, respectively, because the system does not correct for these influences. That error is part of variable jump. To give a discrete CCF to compensate for variable jump, or any other of the variable biases, will be ineffective. This is because once the error source changes, or is eliminated, the correction you made is now *inducing* error. And the variable biases, by definition, will *always* change.

Lastly, let's look at round-to-round dispersion. This is the plain fact that, all conditions being perfect, every round will not hit the same point on a target. Instead, there will be a spread of hits around a central point, and the area into which the rounds fall is known as the dispersion zone. As range to the target increases, so does the dispersion zone. In the tank accuracy error budget, round-to-round dispersion is the second largest error. (Jump error is the largest by far, while boresight retention and gunner lay error are both slightly smaller than round-to-round dispersion.) Consequently, it is quite a gamble to estimate a tank's true MPI based on one round fired. In fact, this gamble applies to the confirmation round as well! (More on that later.)

All of this explains why a discrete CCF should never be given on the basis of one round. The CCF, as a correction that is always present, can only correct for errors that are always present. If given under conditions that are going to change, it becomes an error source itself. Let's look at a specific example. On the following page are plots of a 10-round sample fired from a lot with a dispersion of 0.25 mils x 0.25 mils. Figure 2 shows the 10-round sample impacts on an ST4 at 1500 meters. This 10-round sample came out quite well. The center of the group is good in azimuth, but is a little low (MPI=0 mils x -0.1 mils). The dispersion of the 10-round sample is 0.23 mils x 0.25 mils, which is pretty close to the dispersion of the lot itself. (Note: it's very possible that a 10-round sample group from a 0.25 x 0.25 mil lot could be as tight as 0.20 x 0.20 or as loose as 0.30 x 0.30).

Figure 3 shows what might happen if a crew decides to do a one-round zero using the first round fired. Since round 1 was right and slightly high, rounds fired after the referral will likely be left and a little low. In this particular case, without a one-round zero, rounds 6, 3, 2, 10, and 9 are clearly hits. After a one-round zero, those round are close

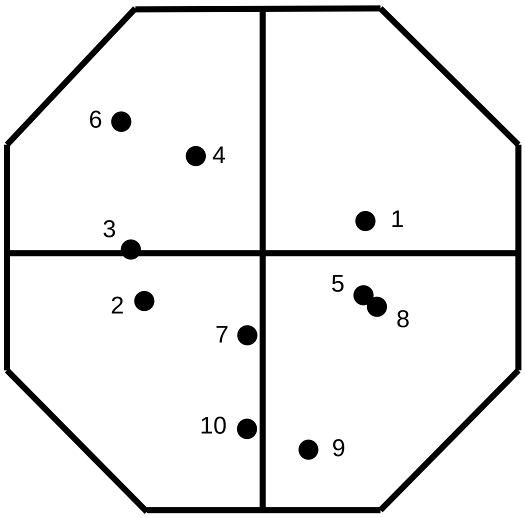

Figure 2. 10-Round Group Simulated Impacts on ST4, 1500 meters.

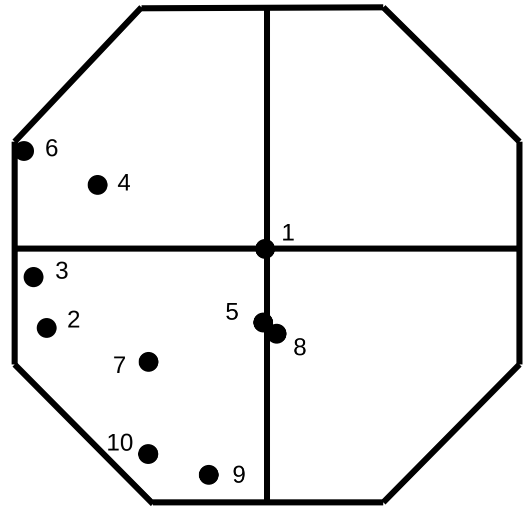

Figure 3. 10-Round Group Simulated Impacts on ST4. Group referred based on Round #1.

to edge of the panel. With luck, one-round zeroes can work — sometimes, but much of the time a one-round zero will hurt accuracy.

Having said that, the policies currently in effect are not perfect by any means. Even three rounds, fired over a short period of time, are not always enough to eliminate all the variable and random error sources. Ideally, you would want to fire a number of rounds over a longer period of time, to see if you observed the same results. Or, you could fire at different targets, at different ranges, thereby getting data for more than one firing occasion (sound familiar?) Also, more than one confirmation round is needed. Honestly, saying that a tank is *good* based on one round violates our stated rule of not making one-round judgments as well. (Look in the tank operator's manual and you'll see suggested zeroing procedures that include a 5-round initial group, sight referral, then a 3-round confirmation group.)

The natural question for a tank crew to ask is, "Why don't we just zero all the tanks and be done with it?" The first response to that is, we intend to do all we can to make sure tanks hit in combat, and our assumption is that the first round fired may actually be at an enemy vehicle. We cannot assume that tanks will have the luxury of time or the political support to fire DU rounds prior to actual combat. Using a fleet zero for combat rounds is the only feasible means of handling this situation, and if we use fleet zero for combat rounds, we should use fleet zero for training rounds. The other answer to that is, the rules that apply to a discrete CCF apply to any zeroing procedure. For that matter, determining a discrete CCF *is* zeroing. No matter what is wrong with a tank, or its crew, we can zero it and get it to hit — for a while. As soon as the conditions under which you zeroed change, the zero starts to add error. If we zeroed to overcome a bad boresight, as soon as the crew boresights properly, the tank will start to miss. But screening would be more effective if we allotted more ammunition to it — say, firing four rounds and hitting the octagon with three. This would also increase crew confidence in their tank. Additionally, using a larger shot group to determine a discrete CCF would be more accurate, and two confirmation rounds would be better than one.

Of course, our challenge is to make our current policy work. The key to this, as in many things, is preparation. Specifically, Phase I of Crew Skills Training must be conducted to standard, as outlined in *FM 17-12-1-2*. This consists of classroom training on the FCS, switchology training, prep-to-fire checks, boresighting weekly, and AACs monthly. A unit that does this training to standard, and has a good turret maintenance program in effect, will screen the vast majority of their tanks with one round of each type, thus saving rounds for the very few that need a discrete CCF. The main cause for the M1A1 to miss targets is crew error, pure and simple. Eliminate that, and your results will show it.

Getting back to the opening situation, the master gunner has to identify why his tanks are failing to hit the octagon. He has to look at the whole situation, use his knowledge of the error budget, the tank, ammunition, his crews, and *find the problem.* What he should *not* do is start handing out discrete CCFs, except as the very last resort. The missing piece of information is that, at the Coyote Canyon range, the firing tanks sit in a hole, with a large berm to the left and right. The berm to the north of each tank is preventing the wind sensor from accurately determining the wind's effect on the rounds fired, causing HEAT rounds to strike left. Luckily, after several tanks experience the same problem, SSG Highspeed has a flash of inspiration. He brings one of the tanks which failed to screen out of its hole and fires a HEAT round, which splits the bull. The tank company goes up to the live-fire and is rewarded by seeing the third MRB come down the *other* side of the valley. Where do you think they would have attacked if he had given discrete CCFs for all of his tanks?

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