PROPOSED SCOPE TESTS

Public Review

I'm publishing these proposed tests for public review, because I know the minute I publish the results of this field test I'll encounter heavy criticism regarding how the tests were conducted. While I understand that just comes with the territory, I'd like to actually solicit constructive criticism related to the testing methods **BEFORE I START TESTING** (tentatively set to be April 12, 2014). **If you know of a tweak to one of the tests that would make it more reliable or meaningful, please tell me. If you know of a different approach that is more repeatable or less error prone, please tell me.** The way I see it, I'm going to spend a ridiculous amount of time in the field testing all these anyway, so if anyone has a way to get more value out of that time … I'm all ears.

Guidelines for Feedback:

- **Can't involve buying more than $100 in equipment** (unless you're also sending me a check). I'm doing this all on my dollar, so I'm on a budget.
- **Can't require more than 5 people to conduct.**
- **Can't require a ridiculous amount of time to setup or conduct.**
- **Can't require an elaborate test environment.**

This is a rough draft of the tests I'm considering for my upcoming scope field test. The goal of this project is to analyze the performance of each scope using a very data-driven approach, and attempt to objectively quantify major design characteristics and features that are important to a long-range shooter. I'm attempting to do this in as objective and unbiased way as feasibly possible. Ultimately, I hope these might mature into a set of benchmarks that would help our industry more objectively compare optics.

Some of these tests are still unproven, and I may not end up publishing the results for all of the tests. I also hope to tweak these based on feedback over the next few weeks.

My tests are primarily focused on two areas:

1. **Optical Tests** (Resolution, Contrast, Field of View, etc.)
2. **Mechanical Tests** (Precision, Repeatability, Click Values, etc.)

While the series of mechanical tests I'm planning can be reasonably objective and repeatable, it is very difficult to do that for the optical tests without spending $20,000+ on lab equipment. That is one reason I'm framing this as a "field test" not a "lab test." **Objectively quantifying optical quality is *very* difficult, but I'm still planning to give it my best shot using the tools and techniques I can afford. While I don't claim these tests are perfect, I believe they can still provide value and insight.** I've read a ton of stuff on how other people have tried to test optics, a few specific to rifle scopes, and some testing other things like camera lenses. I've learned something from every one of them. A lot of smart people have already given me input on this, and I'm spending a significant amount of effort to try to account for all of the major aspects that could skew the tests (at least that are practically possible).

Varying Light

A very smart optics expert told me "the results of your resolution measurements are not really comparable between different days or even between morning and afternoon of the same day." That is because the fundamental dependence of optical performance on light. I have two ways I'm hoping to mitigate differences in lighting:

1. **Controlled Lighting Indoors** - The best plan may be to do all the testing indoors where you have complete control of lighting (likely use the continuous lighting kit that I use for photography). I'm trying to get access to an empty warehouse that would allow me to place charts 100 yards away and use my own flood lights to ensure the light that hits the target (and even the back of the target) is fully controlled and the same on every test. I'm still not certain if I'll be able to use that facility. What is more likely, is that I can place the optical resolution charts inside a dark building with controlled lights and use the scopes outside the building viewing inside. I can still light the charts with the continuous lighting kit. This is less ideal, but seems like I'd have more consistent lighting conditions than completely outdoors and this approach still seems more than adequate for a "field test."

2. **Light Meter** - I purchased a light meter (aka Digital Lux Meter) like those used by photographers, which essentially measures the intensity of light at a specific point. Regardless of whether I end up doing the tests indoors or outdoors, I plan to use the light meter to ensure the amount of light at the target doesn't vary by more than 5% among any of the tests. I will likely have to test at the same time of day and with the same exact cloud cover and visibility, but this is one of the most important aspects to fair optical tests. I plan to record this lux reading, along with the date, time, and temperature of each test as well.

Human Bias & Unique Vision

Anytime a person is part of a test, they could skew the results based on their own personal bias. Even the most logical among us is still biased. Because I know everyone is biased, I'll try to mitigate that as well. Only two of my tests involve something that isn't directly measureable. In those 2 tests, a person will be sitting behind the scope trying to determine how much detail they can make out. For those tests, I plan to involve multiple people (hopefully 5 or more) to increase the sample size.

Many people claim that because everyone's eyes are different, there is no way to objectively test optical clarity so you just have to look through each one for yourself. Even if that's the case, couldn't you test several people and then average the results? That would at least give you some indication of whether a particular scope will be more or less likely to be clear and sharp for someone's special unique eyes. So this larger sample size will also average out those effects.

I also plan to do blind tests by covering each scope during the optical resolution tests. I also plan to run each tester through independently, so they aren't influenced by other's comments.

True 18x Magnification

The max zoom of the scopes range from 18x to 30x. So I'm hoping to be able to run through many of the optical tests at the max zoom for each scope, but then also at 18x in order to have results that are directly comparable among all the scopes. This is more tricky than it might sound, because you can't trust the "18" mark on the scope to be exactly 18x. As FinnAccuracy has said, "marked numbers cannot be trusted." So I hope to find a way to precisely locate where a true magnification of 18x is on the scope and index it, so that zoom level can be used as a baseline for a few tests.

In an Outdoor Life article, it actually says "It turns out to be tricky to measure apparent magnification of an optic, for reasons too mathematical and abstract to mention here."

Here are a few methods I've considered to find this "true 18x magnification" that works for both FFP & SFP scopes. I've read a spectrometer would be the most exact what to calculate this, but I don't have thousands of dollars to spend on this.

a) **Calculate based on field of view:** First, I'll measure the exact field of view at the max zoom for each scope (see how I'm testing the field of view for more on how I'll do this). Then I could calculate what the field of view would be proportionally at 18x, and rotate the zoom until the measured field of view matches what the calculated value should be for 18x. I'd mark the place on the scope with a wet erase marker, and reference that exact point instead of the marked numbers for all of the tests.

b) **Direct Visual Comparison:** Set a target that is basically a ruler with marks a unit distance apart. From some distance away (e.g. 50 yards), focus the scope on the ruler. Now look through the scope while keeping both eyes open; you should see a double image of the ruler, where one image is magnified and the other is not. Compare the two images; how many of the unmagnified units fit within one magnified unit? The answer is a direct measurement of the scope's magnification.

c) **Transparent Scale & Micrometer:** The magnification may be determined by finding the ratio of the diameters of entrance and exit pupil, or, what amounts to the same thing, by measuring the size of an object placed at some distance before the scope and the size of the image of this object formed by the scope. A transparent scale may be placed just in front of the scope objective, the scope, of course, being focused for parallel light, and then the image of this scale formed near the exit pupil may be measured with a micrometer microscope. *(This method was presented in a document published by the US National Bureau of Standards in 1918 named "The Properties and Testing of Optical Instruments." Although that is old, optics fundamentals haven't changed much and it seems like a valid approach. I'm not sure what products I'd need to buy to be able to do this. I talked to a rep at Edmund Optics, and they said they didn't carry what I'd need. They suggested that I essentially try what I had already thought of in option a.)*

If anyone knows a better way to find the "true 18x magnification, please let me know.

Scope Mounts

I've built two different test setups to hold the scopes as I run through these tests.

- **Fixed Mount**: The fixed mount is designed to mostly be to hold a mounted scope in a very solid way (without having to try to steady a rifle), and this will be mostly used for several of the mechanical tests. I have Spuhr mounts for every scope, which are extremely solid scope mounts. The idea for the fixed mount came from TimK on Sniper's Hide.
- **Multi-Scope V Block:** I've also built a tripod-mount V block that can hold multiple scopes, similar to the one shown below. This will be used on a Manfrotto 055XPROB tripod, which is very solid. This will be used for many of the optical tests where the scopes don't need to be mounted. The idea for the multi-scope test bench came from FinnAccuracy.

Solid Fixed Mount

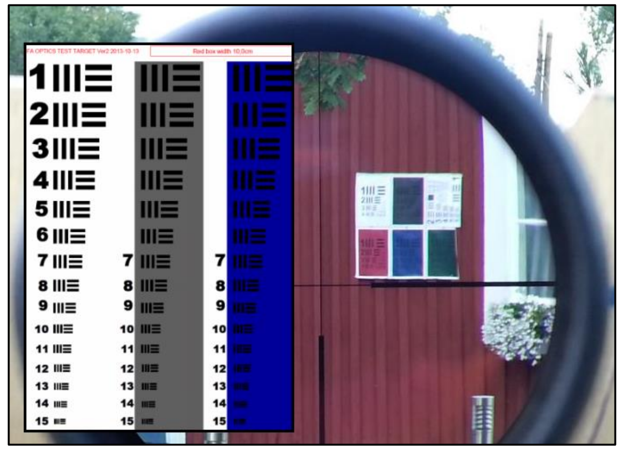
Multi-Scope V Block

Measured Distances

All distances for testing (i.e. 100 yards, 25 yards, etc.) would be *exactly* measured using a Leica DISTO E7400x laser distancemeter (aka digital tape measure). This device is accurate to ±1 mm.

Optical Tests

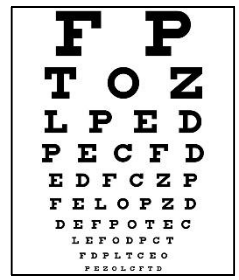
Resolution Test #1: FinnAccuracy Resolution Test



This test will be similar to the resolution test devised by FinnAccuracy, which seems well thought out. Line charts similar to the 1951 USAF resolution test chart will be placed at 100 yards. I will record the smallest number where each tester can still differentiate between individual lines for each of the 6 charts. The charts with the colored backgrounds help indirectly quantify the contrast of the scope as well. Each tester will be instructed to look through the center of the field of view for each chart.

Testers would run through this test twice for each scope, once at the max zoom and then again at a measured “true magnification” of 18x, to allow for more direct comparison of optical resolution (see “True 18x Magnification” section for more info). I plan to involve multiple people on this test to diminish human bias (see “Human Bias” section for more info).

Resolution Test #2: Snellen Eye Chart Test



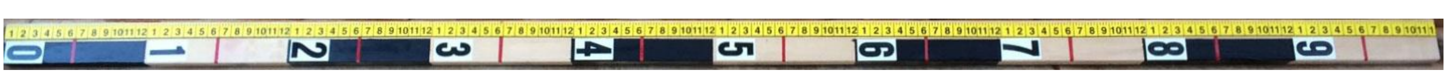
This test would use Snellen eye exam charts placed at 100 yards. It will be similar to what I came up with for the optical tests in my rangefinder binocular field test, except targets would only be placed at 100 yards (to avoid mirage). I plan to create custom charts (using official Snellen letters and font) for this test where each row has different sized letters around 5 MOA (some larger, some smaller) when 18-30x magnification is taken into consideration. I’d have at least 10 custom charts with each one having different nonrepeating letter patterns so the testers couldn’t memorize patterns. Each tester would be asked to read the smallest letters they could make out, and their accuracy would be scored. This kind of testing is similar to the FinnAccuracy test, but keeps the testers more honest because they actually have to accurately read the letters instead of just calling out the number of the line they can differentiate. Ultimately, the results of the two tests should correlate.

Testers would run through this test twice for each scope, once at the max zoom and then again at a measured “true magnification” of 18x, to allow for more direct comparison of optical resolution (see “True 18x Magnification” section for more info). I plan to involve multiple people on this test to diminish human bias (see “Human Bias” section for more info).

Measure Field of View

I want to measure the exact field of view for the scope. I’ll do this for the max zoom at 100 yards (the expected values will be 3-7 feet for this set of test scopes). I’ll also do this for the min zoom, but at 25 yards and then calculate the proportional field of view at 100 yards. That’s because these values would be almost 40’ wide at 100 yards for scopes like the S&B 3-27x56. That would be very hard to measure accurately, especially when the scope is only at 3x zoom. So I’ll measure the field of view at the minimum magnification at 25 yards, which will equate to 25% of that value (around 10’ wide).

For this test, I need a precise way to measure that can be viewed 100 yards away. I looked for different products, but there didn’t seem to be many out there. I thought about painting marks on a 2x4, but that wouldn’t be as precise as I’d like. In my research, I stumbled upon a 30’ role of continuous ruler tape with X-Large numbers. This is actually used to document crime scenes, and seems to be perfect (“Excellent for use on larger scale photographic needs such as blood spatter evidence”). I adhered this tape to a painted 2x4, which should make this simple and precise.



Measure Reticle Calibration

In this test, I would check that the reticle marks perfectly align with the expected measurements at max zoom. This could be done with a test chart at 100 yards with dark boxes that are exactly 1 mil x 1 mil, and 1 MOA x 1 MOA. I would also make some boxes in smaller increments. If a reticle didn't exactly match the expected value, the difference would be measured and recorded.

Eye Box Tests

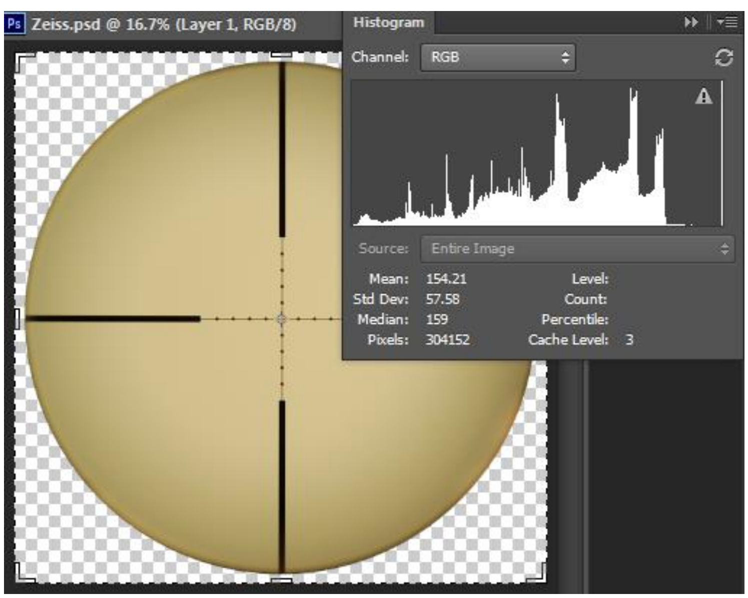
In this test, I'd measure the max/min eye relief possible for a full field of view. I'll likely use a camera for this test instead of a person, so that I could get a more precise measurement. I'd set the scope in the fixed mount, then position the camera precisely behind it and record the min and max distance from the ocular lens to get a full field of view. I'll account for where the sensor is on the camera body, to ensure I report this value in the expected way (i.e. the distance from the ocular lens to the eye).

I would repeat this measurement for both max and min zoom on each scope, so that any change in eye relief that may occur when changing magnification can be easily seen. I may also measure the max height of this max as well, but I'm not sure if that would be feasible.

Brightness Test

I would like to quantify how bright each scope is using a camera approach. I would perform this test indoors with controlled lighting (verified by a light meter). I will focus each scope on a fixed point (likely a target on a large flat, white target), and then perfectly center the high-pixel camera behind each scope within the center of the eye relief, and carefully focus on a camera lens on the fixed point as well. I plan to ensure the exposure of the photo is the same for each scope by manually setting these parameters: aperture, shutter speed, ISO, white balance, and focal length (35mm seems ideal). I'll also use a wireless remote for the shutter so I don't disturb the camera. Photos would be taken at the min, max, and true 18x zoom levels.

Then on a computer, I plan to take crop the photo through the scope so it only includes the circular field of view through the scope. I can then use the Histrogram's luminosity statistics in PhotoShop to quantify an average brightness score of the view through the scope. I would record the mean, median, standard deviation, and number of pixels for each photo.



I will also try to use the light meter to measure the light through the scope in that same controlled lighting situation. I could use a hood to ensure that only the light being transmitted through the scope was being read by the light meter. That would give another average brightness through the scope that should agree with the photo analysis.

NOTE: At least one expert has commented that these approaches may not accurately represent what the brightness as a shooter would know perceive it. Please let me know if anyone has a better approach than this.

Depth of Field Test

I would like to somehow quantify the depth of field for each scope. This can vary largely by scope, and if the depth of field is not adequately large then you'll find yourself constantly adjusting the side focus. I could set out large 1951 USAF resolution test charts at distances of 50, 100, 150, 200, and 250 yards (beyond if necessary), and focus the parallax on the scope for the middle target. I would then look at each target and determine what the minimum number was where I could still differentiate between the lines. This should give a rough numeric representation of the depth of field for each scope.

Mechanical Tests

Bryan Litz has a great quote from his Applied Ballistics book that really illustrates the fundamental philosophy of these tests:

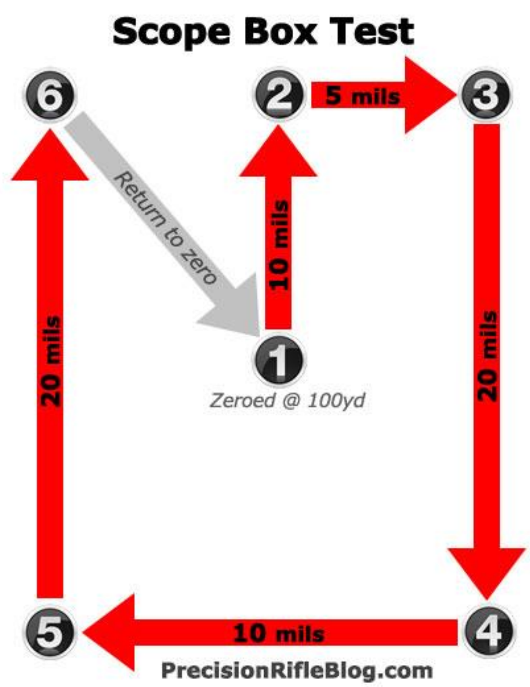
> *The overall philosophy of dealing with sights is: DON'T TAKE ANYTHING FOR GRANTED! Don't take it for granted that the crosshairs move exactly as advertised. Don't take it for granted that the crosshairs are actually level, and track exactly vertical. Don't take it for granted that the range you're shooting the calibration test at is exactly 100 yards without measuring it. The bottom line is to deal in absolute fundamentals, measure them, and remove all the assumptions. If you don't measure everything directly with calipers, tape measures, rangefinders, levels and plumb lines, you can 't be sure that your sights are properly calibrated.* ***Don't ever assume that something is what it says without measuring it.*** *This is the key to insuring that the bridge between your predicted bullet path and your intended impact point is solid and reliable. Failing to be meticulous about sights is a huge reason for missing targets at long range.* ***Don't take sights for granted!***

Box Test

I'll perform this box test two different ways:

1. From the fixed mount without firing
2. Mounted to a magnum rifle and firing 3 shot groups at each position

This primarily focuses on precise mechanical adjustments and an exact return to zero. All tests will be done at 100 yards, and I plan to record any difference between the expected and actual adjustments for each numbered spot in the diagram, with a heavy emphasis on the exact return to zero.



Fixed Mount, No Fire Box test

This will be on a large, 10' x 10' surface 100 yards away that I can tape printed rulers on (with mil & MOA units). The 10'x10' surface should allow plenty of area to get near the max the elevation and windage adjustments of each scope. The target could also have each spot marked where the scope is expected to be after the standard adjustments I plan to run on each scope. It would be critical for the target to be plumb and level. I'll start by ensuring the fixed mount is level and even with the target, then I'll mount the scope and zero it on a target in the very center of the 10'x10' surface. I also plan to mark that spot with a Viridian laser that is directly attached to each Spuhr scope mount. That should ensure that there is no movement of the platform, although that is very unlikely.

I may be able to gather more precise data with this no-fire test, because there are less moving parts than a live fire test. Although the magnum rifle I plan to use on the live fire test is capable of accuracy under ½ MOA, this test won't be dependent on the accuracy of the shooter or the rifle.

During the no fire test, I plan to run through the loop 5 times before returning to zero. This should make any mechanical flaws very evident in the return to zero.

Magnum Recoil, Live Fire Box Test

I plan to perform a box test using my custom 7mm Rem Mag rifle to ensure the scope can remain zeroed through significant recoil. The rifle is capable of average groups under ½ MOA. I'll fire a 3 shot group at each number in the diagram. For the live fire test, I may only be able to test it on my 6x6 target frame (I don't have a 10x10 frame), so I'll be able to get about 18 mils of total elevation adjustment within the target frame.

I do own a Hyskore Precision Rifle Rest with a remote hydraulic trigger release that I may use for the live fire tests. I will use it if I'm able to produce more precise groups using the rifle vise than a standard benchrest setup. Regardless of which method I use, I'll definitely repeat the same method with every scope.

Litz Tall Target Test

This test ensures 10 mils of adjustment is exactly 36" of adjustment at exactly 100 yards, elevation adjustments are consistent through the entire range, and the erector and reticle are properly aligned. I don't plan to make this a live fire test, but instead would have the scope in a fixed mount. I'd use the same ruler tape in this test that I mentioned in the Field of View test, and I'd ensure the line was perfectly plumb by using a 6' level. By taking exact measurements from a fixed mount instead of firing rounds, I'm hoping to get results that are more precise and less dependent on the precision of the rifle/shooter. The basic idea would follow Bryan Litz's test, which he outlined in book Applied Ballistics for Long-Range Shooting (p124):

Litz Tall Target Test

> *If you need to adjust the scope by a precise amount in order to account for gravity drop on a long range shot, it's imperative that you know exactly how much your crosshairs actually move when you turn the knobs. Simply assuming that each click is what it's advertised to be is a bad policy, and will cause misses at long range.*
>
> *…The good news is that the problem of uncertain sight adjustments can be fixed with one trip to the range. Here's how to do it.*
>
> 1. *At a measured distance of 100 yards, set up a 4 foot tall target with the aim point near the bottom of the target.*
> 2. *Using a plumb bob or level, draw a vertical line extending from the aim point up to the top of the target.*
> 3. *Fire a 5 shot group at the aim point with your 100 yard zero.*
> 4. *Adjust the scope up 10 MOA and fire another 5 shot group.*
> 5. *Adjust the scope up 10 more MOA and fire another 5 shot group.*
> 6. *Adjust the scope up 10 more MOA and fire another 5 shot group. At this point, you should be hitting 30 MOA above your aim point.*
> 7. *Measure the distance between the centers of the groups and see if they're truly 10 MOA apart (10.47" at 100 yards). If not, you need to establish a correction factor for your sight adjustments.*

Measure Total Internal Adjustment

This test should determine the total amount of elevation and windage adjustment a scope provides, and show how centered those adjustments are within the range. I'd install each scope in the fixed scope mount, after ensuring the rail of that mount is completely level and aligned with a target set at 100 yards. I'd ensure the scope was precisely pointed at the center of that target, then measure the amount of elevation adjustment you have up from that zeroed point, and then down from that same point. Then I'd measure the amount of windage adjustment you have to the left and right of that zeroed point. I need to ensure that the erector cell actually moves with each click at the extreme adjustments, because some scopes are known to not actually move the reticle on the last few clicks.

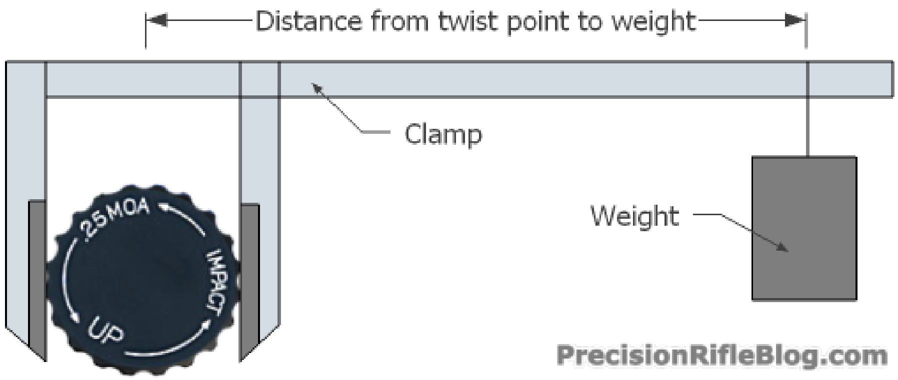
Measure Force To Adjust Scope

This test will quantify how much force it takes to turn the elevation, windage, and parallax knobs, as well as how much force it takes to adjust the magnification ring. This can vary significantly by scope, and some people prefer heavier or lighter adjustments.

I was originally researching specialized meters to measure this, but torque is relatively easy to measure directly (if it is torque arising from a perpendicular force, which is what I'm looking for). I plan to use clamps and weights to determine the amount torque (in inch-pounds) it takes to turn each item on the scope.

The equation for the magnitude of a torque, arising from a perpendicular force:

Torque (inch-pounds) = distance from twist point to weight (inches) × weight (pounds)



For example, if a person places a force of 0.5 pounds at the terminal end of a wrench which is 10" long (or more precisely a force of 0.5 pounds exactly 10" from the twist point of a wrench of any length), the torque will be 5 inch-pounds – assuming that the person moves the wrench by applying force in the plane of movement of and perpendicular to the wrench.

Zoom POA Change Test

With the scope mounted in the fixed mount, center it perfectly on a target at min zoom. I also plan to mark that spot with a Viridian laser that is directly attached to each Spuhr scope mount. That should ensure that there is no movement of the platform, although that is very unlikely. Then zoom the scope all the way to the max magnification, and measure any POA change.

Parallax POA Change Test

With the scope mounted in the fixed mount, center it perfectly on a target at max zoom. I also plan to mark that spot with a Viridian laser that is directly attached to each Spuhr scope mount. That should ensure that there is no movement of the platform, although that is very unlikely. Adjust the parallax knob to both extremes, and measure the max POA change (if any).

It would normally be difficult to see if any POA shift, because the scope would be out of focus at one extreme or the other. But it was suggested that I could essentially drill a hole in a lens cap and place that over the objective lens, which should effectively shrink the aperture of the optics system and increase the depth of field dramatically. I haven't tried this, but it seems like it could work. Ultimately, this might not be that important of a test. I don't think I've ever heard of a scope's parallax changing the POI, but I also don't know if I've ever heard any actually testing that. It seems theoretically possible that it could move it (at least to an amateur like me).

Shock POA Change Test

I want to test how well each scope will hold its zero under mild field conditions. Someone suggested mounting each scope and tapping it with a rubber mallet, but it would be hard to ensure you applied exactly the same amount of force in exactly the same way on every scope. A more controlled and repeatable test would be to mount each scope in the fixed mount, and center it on a target 100 yards away. You could then drop a rubber-coated weight (e.g. 5 pounds) onto the objective bell from a specified distance (e.g.

12"), and repeat that 10 times in a row. One critical aspect to ensure the force is applied consistently for each scope, which means the weight must impact the same way each time. To help with this I could to use a mechanical release.

After watching the NightForce torture test video, I'm not sure I'll be even close to the amount of force it would take to change the POA on these high-end scopes. While this amount of force may show something valuable on low and mid-range scopes, I may end up striking this test all together for these scopes. I know I could up the force, but I don't want to risk permanent damage to any of the scopes.

Subjective Take-Aways

I originally planned to only publish data that was directly measurable, because I try to be sensitive about inserting my opinion in any of my posts. I prefer to simply present data as much as I can, and allow the user to formulate their own opinion. But at this point I've asked a few people to read through this and one of them had this suggestion: *"For as much as we work to have objective, repeatable measurements, there is always room for and interest in subjective reviews. Ratings for factors like tunneling, edge-to-edge clarity, and even general appeal are hard to measure, but can still be a large factor in one's evaluation of a scope. Don't be afraid to note your general impressions of a scope."*

So I likely will include a few notes of things like that which I notice as I'm running through the tests. ILya Koshkin, author of OpticsThoughts.com, has written several GREAT articles on these high-end tactical scopes. In my view, ILya is an optics expert among experts (I don't claim to be an expert in any of this). I've read stacks and stacks of articles he's written, and I'll likely try to take a similar approach for those factors (plus things like flare and any unique features that are notable among the scopes). I really appreciate ILya's approach to discussing these aspects that are difficult to quantify. He seems to be as objective as possible, and his findings are very helpful. I also plan to link to his articles in my results, because he does offer so much good information. I'm just hoping my findings somehow compliment what he has already published, by comparing these scopes from a little different direction.