Nocturnality

Understanding Handguard Flex and Point of Impact Shift for Laser Aiming Devices

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Introduction to Laser Based Aiming Devices for Night Vision Use

Night vision technology, though widely used today across a myriad of applications, was primarily and originally developed for military uses. The ability for missions to be carried out both during the day and at night -especially when an opposing force may not be similarly equipped to see in the dark -creates significant advantages and benefits for military forces. Over time, additional technologies were developed and integrated to further evolve the concept of night time operations. Perhaps the most notable of these complementary technologies are visible and infrared aiming laser and illumination devices. Several terms have been coined to describe these devices which are used interchangeably in today's modern military literature. The term 'multi-function aiming laser,' or MFAL, is one such term that suitably describes the devices utilized today.

The integration of the MFAL into the standard loadout of the night vision equipped infantryman or operator is key to effective tactics and engagements in the dark. These devices have been developed primarily as a weapon mounted device, with two key functions in the modern context. These functions are:

- Projecting a 'point' laser beam in order to effectively aim at targets downrange and fire the weapon while using night vision
- Projecting spot or flood infrared light in order to provide supplementary illumination to the user of a night vision device, such that the additional illumination is only visible by a user of modern night vision technology

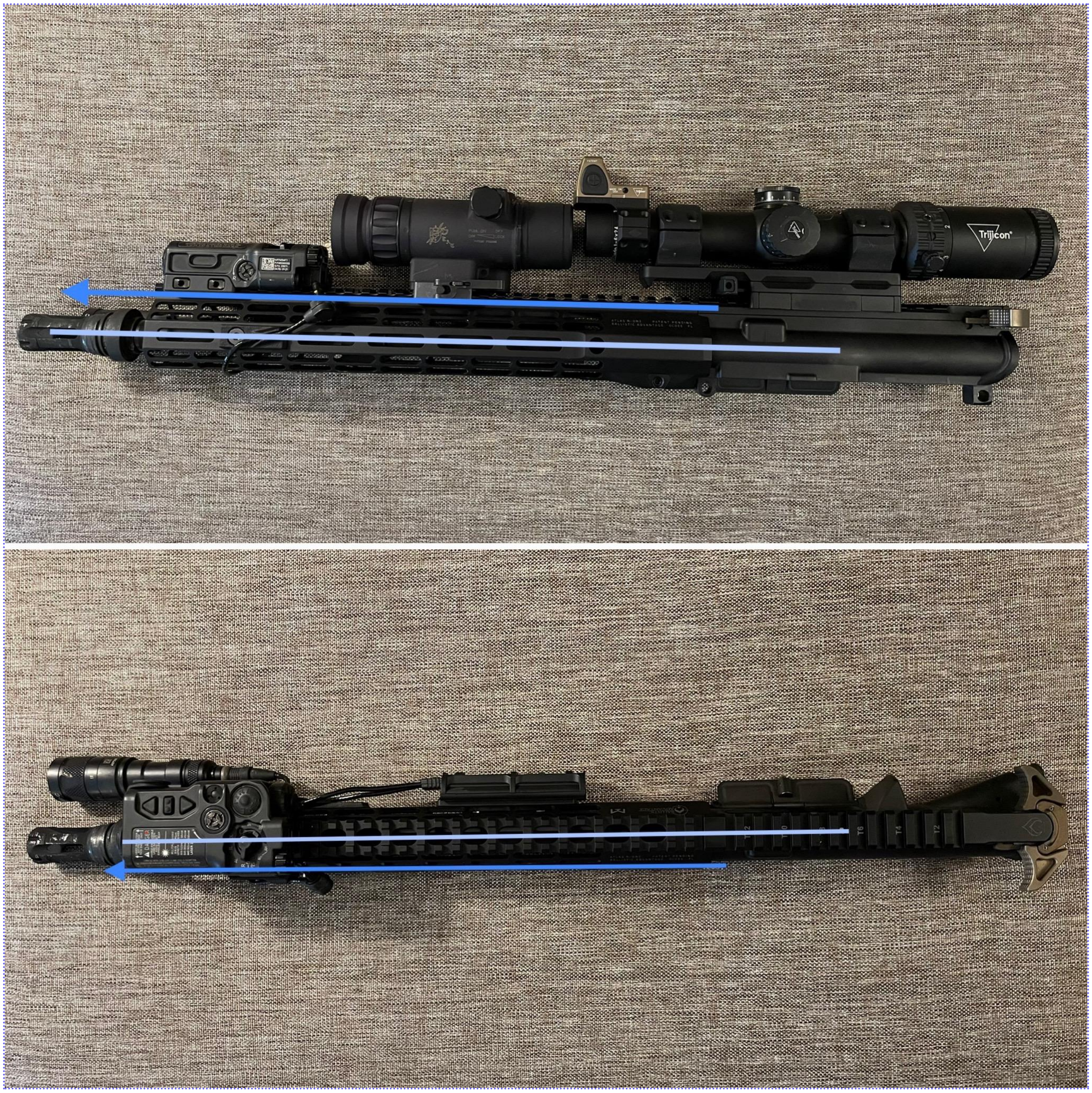
With regard to the first point above, aiming a weapon such as a rifle or a sidearm with a laser device mounted on it was not exclusively developed for the purpose of complimenting night vision technology. The first laser-based aiming devices developed utilized visible lasers which could be seen by the average infantryman during both day and night but without the use of a specialized night vision device. However, use of lasers has evolved and adapted to be synchronous with use of night vision technology today.

Aiming lasers are critical to the current doctrine of military night vision shooting, and the same concepts are widely used today in other areas of night vision adoption, including law enforcement, recreational hunting, and competitive night shooting.

Battling the Challenge of Mount Surface Shift When Utilizing Laser-Based Aiming Devices

With regard to effectiveness of the ability to point, aim, and ultimately engage a target accurately at distance, unlike a traditional daytime optical scope which is mounted to the firearm’s receiver, aiming lasers are commonly mounted to the forward rail or handguard of a rifle. Therefore, the achievable accuracy in terms of consistency and reliability is inherently dependent on the ability of the mounting surface (i.e. the handguard) to remain rigid and equally parallel to the bore of the weapon. Figure 1 below attempts to visualize the ideal laser mounting interface between a handguard of a weapon and the barrel/bore.

Figure 1: Visualization of Ideal Rail to Bore Alignment



In the field, input force is regularly applied to the rail system or handguard of a weapon. Two common sources of input force directly onto the rail system are either directly from the user of the weapon gripping with a support hand in a normal firing stance near the muzzle (close to where a laser is often mounted), or input force from a supporting surface on which the rail system is resting to provide improved stability of the weapon (such as from a bipod, or a barrier on which the weapon is rested where the rail contacts the surface of the barrier).

Traditional shooting doctrine will encourage both of the two above scenarios often in the field. Free float rail designs, which are commonplace on today's modern rifles used in military and civilian applications, purposely do not make contact with the barrel of the weapon, so that any input force is not directly transferred to the barrel itself causing point of impact shift and reduced accuracy. In addition, modern rifle kinetics emphasizes gripping a rifle as far forward onto the handguard or rail system as is comfortable to the user, to control the weapon during recoil. And finally, laser systems have been traditionally encouraged to be mounted as far forward onto the handguard as possible to reduce the tendency of the weapon itself to block part of the illumination cone of an MFAL when used as an illumination tool (also often called "shadowing.")

These and other commonly accepted shooting practices all result in input force onto the rail system throughout use in the field. For the purposes of laser based aiming which has become synonymous with night vision use, **this means that to maintain the proper alignment of the device relative to the bore of the weapon, the rail system on which the aiming laser is mounted must be of sufficient stiffness to not flex or bend as a result of those common input forces.**

The results of the testing conducted and described in this document demonstrate the phenomenon of point of impact shift downrange when a handguard system shifts under input force while it is also the primary mounting surface of a laser based aiming device.

Motivation For Testing, Disclosures, and Information About the Research

Night vision employment requires the understanding of a suite of technologies and gear for the most effective use, regardless of the application. For those applications where firearms are involved, Nocturnality believes it is necessary to add an understanding of how point of impact (POI) can shift as a result of input force onto a handguard or rail system on which an aiming laser or clip-on night vision scope is mounted. The focus of this research relates to laser based devices, because these have become the defacto aiming method for users of night vision, especially with regards to military and law enforcement use and leading civilian applications. However, the findings herein are also applicable to use of aiming lasers in visible or daytime scenarios, and may be relevant also for other sighting systems that are commonly mounted on the forward rail of a rifle, such as a clip on night vision optic.

Nocturnality began researching rail system designs and products which would aid in the reduction of point of impact shift through its night time product testing activities. Companies in the firearms manufacturing industry such as Ripcord Industries, Midwest Industries, and others have developed rail systems for standard AR15 style rifles which are specifically optimized for stiffness and to reduce the negative influence of input forces on the handguard with regards to accuracy in laser-based shooting.

This document is intended to summarize some of the test results for some popular rail and handguard systems on the market today with regards specifically to POI shift in the elevation (or shift in the vertical plane), which can result from input force onto a handguard from resting a weapon on a surface or bipod for added stability, as is especially common in shooting at longer distances. Although we recognize that aiming lasers are not often associated with long distance shooting, in the context of military and certain civilian applications (such as predator hunting), the use of a laser to engage targets out to 200 and 300 meters can be not only feasible, but relatively common.

This document is intended to be a living document which will be continually updated over time as new handguard products can be tested and their summary results added, with the intent that end users can take into consideration the potential for point of impact shift using a particular setup for laser-based aiming. **The intent of this document is not to present products as ‘superior’ or ‘inferior’ to one another.** Point of impact shift can happen across many setups and handguard types based on their design, but this factor should not be considered in a vacuum -rail design often directly influences potential for shift, but it also can directly provide other overall system benefits such as reduced weight, ease of installation, etc. The authors of this research stress that what is important is not necessarily the presence or degree of tested shift of any product in this document, rather it is the knowledge and understanding of point of impact shift by the end user on their specific platform of choice. There are many variables which can introduce point of impact shift in the spectrum of performance shooting, and understanding these variables is key so that adjustments can be made in the field to aid in performance.

Disclosures

One rail system was provided directly by a manufacturer during testing *at the request of Nocturnality*. The Ripcord Industries LDR1 was specifically identified due to its design as a possible test candidate for eliminating point of impact shift. The manufacturer of this product did not approach Nocturnality requesting paid test and evaluation (T&E) services. All other tested products were purchased by Nocturnality or provided on a temporary basis by third parties not associated with the manufacturer, for the sole purpose of testing.

Testing Methodology for Vertical Point of Impact Shift Using Laser Aiming Devices

Point of impact (POI) shift can result in both the windage and elevation directions based on the input force onto a handguard. Practically speaking, in field operations the most common cause of POI shift is from a force applied to the handguard from below the rail, such as from a supporting surface or object used to stabilize the weapon. Because this is the most common real-world cause of potential shift, and because it is repeatable and therefore quantifiable, a vertical shift test was performed using multiple test host weapons, with one optical and laser based aiming setup transferred to the various hosts for consistency.

Vertical POI Shift Testing Approach

A vertical shift test is a basic procedure which involves patterning the host weapon at a given distance using a suitable number of shots to produce a valid statistical grouping, using the laser aiming device without any input force onto the rail (the control group). This group is then measured against additional groups fired utilizing the exact same point of aim under applied force to the handguard which serves as the mounting surface for the laser (a 'shift' group).

All handguard hosts utilized in the initial testing were AR-15 style upper receivers. The laser aiming and optical equipment utilized to perform and aid in the testing included the following:

- Wilcox RAIDX MFAL utilizing visible green VCSEL laser
- Trijicon Accupower 1-8x low power variable optic (to ensure consistent repeated point of aim to a very fine degree)

The utilization of a high output visible green laser was necessary to achieve a consistent point of aim at the chosen testing distance of 100 yards during daylight conditions. The utilization of a low power variable optic with at least 8x magnification was chosen as a way to ensure consistent point of aim for all groupings to significantly reduce the possibility of human error.

To remove as many potential unrelated variables as possible from the data, a testing protocol was developed and utilized as described below:

- All test groups fired from the prone position – control groups fired with support hand gripping the magwell/receiver of the weapon only for stability with no supporting surface contacting any part of the handguard, barrel nut or other mounting surface
- The 'shift' groups fired from the prone position utilizing a solid supporting surface which is placed directly underneath the mounting point of the laser device on the rail
- The laser device on each host was mounted at a distance of 11 inches (11") from the upper receiver of each host weapon for a consistent angle of potential flex occurring on the handguard. In the case of one rail tested with a shorter overall length than 11" (9.3) the laser mounted as close as possible to the standard 11" distance
- A test target using a 2"x1" visual reference point placed down range at a distance of 100 yards from the firing position. The specific point of aim for all shots for all groups was the upper left corner of the rectangular visual aiming reference point
- The visible laser was coaligned with the day optic reticle at 8x magnification while aimed at the 100y reference target so that the visible laser signature impacting the downrange target was perfectly aligned the reticle's primary aiming point
- The actual point of aim utilized for each shot taken was the position of the visible laser projection onto the precise chosen location of the visual aiming reference point on the target, not the magnified optic reticle aiming point
- A five shot grouping was performed for each host after proper coalignment, and subsequent 'shift' groups fired using the same hosts were also five shots each

- Ammunition utilized for each host was kept the same between control and shift groups, and varied between 75gr Frontier BTHP Match, 69gr Frontier BTHP match, and 55gr Wolf Gold (M193)

Using the methodology above, the authors believe that most potential variables for error were greatly reduced or eliminated entirely. The handguards tested included various lengths, which is why the laser aiming device was mounted at the same distance from the receiver. Likewise, the supporting surface used during shift groups was carefully positioned directly underneath the laser aiming device on the rail for consistency.

In a vertical shift test, the actual position of the grouping relative to the aiming point is irrelevant, and changed slightly between hosts. The optical setup transferred between each host was roughly zeroed so that all groups landed onto the visible target backing material, but was not precision-zeroed so that every group achieved the same relative position on the target backer. What is measured in a vertical shift test is only the relative elevation distance change in group-average POI between the control group and shift groups for each given host, making sure the exact same point of aim was used for all shots *based on the position of the visible laser only*.

In some cases the horizontal average position (windage) of each group shifted slightly between control group and shift group on certain hosts. This is not a relevant indication of the tested criteria since force onto the handguard is only applied onto the bottom surface of the handguard which can only result in vertical shifting of the POI – any minor horizontal shifting was believed to be the result of conditions during testing for wind or in certain instances the aiming laser windage adjustment slipping under recoil from numerous adjustments platform-to-platform, which was occasionally observed in the field of view mid-group relative to the reticle of the day optic.

Other Relevant Qualitative Tests Performed

In addition to vertical shifting of the POI induced by force being applied from a supporting surface or object, it is also possible to induce POI shift in the horizontal direction (or windage direction) by shooting with a grip closer to the end of the handguard from the supporting hand.

Although the results were not quantifiable, each rail or handguard system tested was also visually evaluated for horizontal flex with force applied with an ‘aggressive’ support firing grip. Using the described optical setup with the use of visible aiming lasers, it is possible to visualize the degree of shift in left/right directions of a handguard system by using the reticle of the magnified day optic when the laser is perfectly coaligned. By aiming the weapon at the 100 yard reference target with the laser projecting, applying pushing or pulling force with the support hand near the muzzle of the weapon would often result in a visible shifting of the laser relative to its resting position when measured against the reticle of the 8x day optic.

Combined with the quantified vertical shift testing, the concept of a ‘return to zero’ for the handguard system is able to be verified by the user of a weapon system that utilizes a laser based aiming device. The phrase “return to zero” in this context refers to the rail mounting systems ability to flex when pressure is applied, but then return to the original orientation when pressure on the rail is removed.

Observations on the qualitative tests are presented in the section *“Discussion and Takeaways for Rail Stability in Laser Based Aiming Systems”* at the end of this document

Test and Evaluation Results – Vertical POI Shift Testing

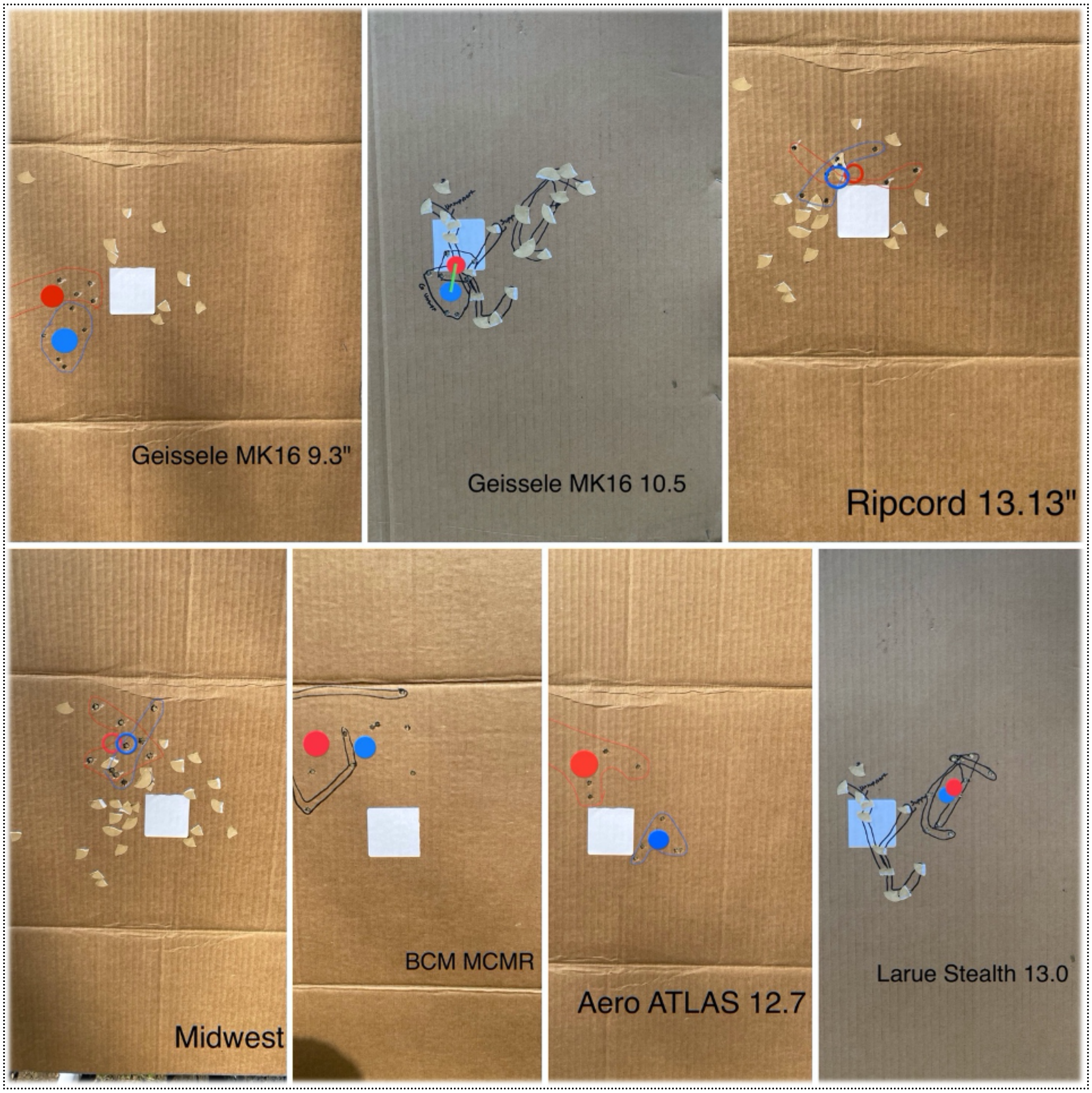
The table below, Figure 2, summarizes the results of the described vertical POI shift testing for the products tested.

Figure 2. Averaged MOA Vertical Shift Values

	Length	Average Shift (MOA)
Aero Precision ATLAS R1	12.7	2.660
Geissele SMR MK16	9.3 and 10.5	1.475
Larue Stealth Keymod	13.0	0.240
BCM MCMR	13.0	0.180
Ripcord LDR1	13.13	0.155
Midwest Industries OEM Keymod	13.5	0.132

Representative group images for the tested handguards from Figure 2 are shown below. Each host had at least 3 confirming shift groups shot, the images below represent some of the extremes in terms of highest or lowest amount of shift for a given host. The white center visual aiming point (of which the top right corner was the true point of aim for each shot) is 2”x1”.

Figure 3: Representative Groups



Seen above, the blue circle indicates the center of a given ‘shift’ group while the red circle indicates the center of the control group for the hosts. Blue circles positioned **beneath the red circles** indicate the existence of some degree of rail shift from applied force of a supporting surface. Because the force from a supporting surface on the underside of a rail causes rails to flex and push the laser aiming device higher above the bore of the weapon, the resulting correction from the shooter when returning to the same point of aim results in POI shift down on the target.

Discussion and Takeaways for Rail Stability in Laser Based Aiming Systems

A wide range of vertical POI shift was observed across the initial test handguards used in this research. Some handguards exhibited negligible shift of less than ¼ MOA, while others observed between 1 and 3 MOA shift.

In addition to the quantified vertical shift, the author observed consistent horizontal flex of handguards which also exhibited higher than average vertical shift when under pressure from a support firing hand or other force applied to the sides of rails for those systems. In cases of other platforms which were tested significantly enough to include in the data, such as the Sig MCX platform with a factory installed OEM rail system, both horizontal and vertical shift of levels exceeding the highest quantified data shown in Figure 2 were observed, but test groupings were not fired to quantify.

The applicability of this data will vary user to user, but Nocturnality believes it is important for night vision users to verify the degree of potential vertical and horizontal POI shift resulting at least at a visual level from rail flexing of their chosen systems using the methodologies described in this document. For some uses, even a 2.0 MOA POI shift with a laser aiming system will be of negligible significance, while for others it may be of greater relevance, all depending on the application or operational profile. Again, the author would like to stress that the presence of some rail POI shift is not necessarily in itself a reason to not consider the use of a certain handguard or system – what is important is being to visualize, and potentially quantify any shift, and then apply suitable mitigating principles if needed.

However, the presence of POI shift in laser based aiming due to flex in a handguard should also not be downplayed, because of the interrelationship that is often seen between a day optic, a laser, and the zeroing procedures of these tools when used in tandem. If the zeroing of a laser system is completed using a supported position for stability of the laser, it is critical to understand if the reference point of aim is being affected by flexing of the rail. Users may adjust zero when shooting unsupported, and then at a later time experience rail related POI shift shooting supported, then make further zero adjustments on an incorrect basis.

Discussion and Observations of Test Subject Performance and Data

The OEM Midwest Industries handguard exhibited almost no noticeable shift, despite being of similar attachment design to other rails which have exhibited shift in other tests. The authors believe that this result was likely achievable because the rail was installed onto a larger caliber platform which would use a larger, potentially much stiffer, barrel nut onto which the rail clamps. Additional testing on this design of rail utilizing a similar .223/5.56 platform may have resulted in greater vertical shift.

Other handguards which utilize a more custom attachment system, such as the Larue Stealth, can provide better ability to reduce POI shift. In the case of the Stealth system, it is directly fixed to a custom billet upper receiver to create a pseudo-monolithic upper receiver group.

The procedures followed during this research began to identify another directly related, and arguably more important, potential issue for laser based aiming systems mounted on handguards. This is the characteristic of a given handguard to return the precise original orientation of which the laser module itself was zeroed, after force has been applied and removed from the handguard. This concept might be thought of as the 'return to zero' ability of a handguard. During testing, some handguards which exhibited excessive POI shift also appeared to have inconsistent visual 'return to zero' properties when utilizing the aiming laser and magnified optic. Though this phenomenon was not tested, it is one area of further research which may be explored in the future.

Mitigating POI Shift Resulting from Rail Flex on Laser Based Aiming Systems

For night vision users (or others who may rely on a visible aiming laser), mitigating the POI shift that can result from rail flex can be important to maintain trust in their chosen sighting systems and weapon configurations. Throughout the testing described, some mitigation efforts were identified, though not formally quantified or tested. We anticipate further testing of these efforts to quantify their capability in reducing or eliminating POI shift for handguard or weapon systems which presented shift of greater than 2.0 MOA.

Moving the laser rearward onto the rail system close to the receiver, where the rail connects to a barrel nut or other part of the receiver directly, tended to produce less visual flex. How much mitigation this can provide will vary handguard to handguard, or system to system, and has not been quantifiably tested, only qualitatively confirmed.

The use of monolithic style weapon systems, where the forward handguard and rail system is a continuation of the upper receiver to form one monolithic piece, also in theory should eliminate the possibility of POI shift from applied force onto the forward portion of the weapon.

For night operations, adapting an alternative firing grip may also be of use and require re-training for certain scenarios. Using a grip on the magazine well of the weapon and without the use of a forward stabilizing surface or bipod is also a field adaptation that can eliminate POI shift and applied when necessary or feasible.

Finally, utilizing a ‘partial passive’ or ‘fully passive’ aiming technique where the operator utilizes a day optic mounted on the receiver of the weapon to aim for longer distance shots instead of relying on the laser aiming system (while also utilizing the onboard illumination function only of the MFAL for target identification at distance) is another possible technique that can be adopted.

Conclusion and Acknowledgements

POI shift using many modern rail-attached weapon platform designs can be inevitable. It is critical to test and evaluate the induced shift when preparing for night operations especially if there is higher possibility of aimed firing at a distance of 200 or more yards. Experimentation with equipment setup, and field techniques, can mitigate some rail-induced POI shift when aiming with a multifuncion aiming laser.

Nocturnality will continue to test more handguard and weapon systems to quantify mounting surface stiffness and any resulting vertical rail shift.

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