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# DIGITAL COLLIMATED BORE SIGHTER

## BACKGROUND OF THE DISCLOSURE

### Field of the Disclosure

**[0001]** Disclosed herein is a Digital Collimated Bore Sighter with Integrated Sensors, AI, and Smartphone Integration. The disclosure encompasses is an advanced digital collimated bore sighter that in one example utilizes integrated sensors placed in the barrel chamber, at the muzzle end, and/or at the ocular piece (sight, scope) of a firearm. The disclosed apparatus and system may be incorporated with smartphone integration, to determine the line of sight, line of bore, and scope height. This system may also assess barrel integrity, correct scope cant, measure and analyze deviation from boresight to zero by separating these factors into contributory variables, and allow a user to adjust these variables to predict a new zero without firing. The device may operate with or without laser technology and will collect, structure, and may store data using AI and machine learning (ML) to ensure clean, pristine data without dark data. A pixel grid may also be used for precise digital collimation and detailed movement analysis. The system may be compatible with legacy optical sights and the digital scopes. It can stand alone as an upgrade to user technology or integrate into advanced fire control systems.

**[0003]** DETAILED DESCRIPTION OF THE DISCLOSURE

**[0004]**

**[0005]** The digital collimated bore sighter of one example integrates a secure mount on the rifle barrel. It may utilize sensors at critical points (barrel chamber, muzzle end, and ocular piece of the scope) along with smartphone integration to determine the precise center of the line of sight, line of bore, and scope height. This precision instills confidence in the system's accuracy. Additionally, it may assesses barrel integrity, corrects scope cant, and measures and analyzes deviation from boresight to final calibration location (zero) by breaking down the factors of deviation into contributory variables. Users can then adjust variables such as muzzle velocity, weather conditions, shooter ability, and manufacturing tolerances to predict a new zero without requiring live firing. The system employs AI and ML to collect and structure data, ensuring all data is valuable and accessible and avoiding dark data. Including a pixel grid ensures precise digital collimation and detailed analysis of all degrees of movement. The system is designed to work with all legacy optical sights and the latest digital scopes and can either stand alone or be integrated into advanced fire control systems.

**[0006]** The use of a digital collimator is a technology that may be used to link a scope and a rifle coordinate system together, creating a digital twin of the physical rifle and scope assembly. Classical analog collimators attached to the end of the rifle barrel are a physical grid with standard square spacing. Correlation between the grid density, scope reticle alignment, and range distances are known, and proper fine adjustments can be determined to predict some gross accuracy and precision. Each grid spacing is equal to some angular movement of the reticle which produces some larger deviation at the input range distance. The math for this angular movement is the same tangent function used and described elsewhere herein.

**[0007]** Integrated Sensor System Options:

- Barrel Chamber Sensor: Measures the precise position and orientation of the chamber.
- Muzzle End Sensor: Detects the exact center and alignment at the end of the muzzle.
- Ocular Piece Sensor: Captures the position and alignment data from the scope's ocular piece.

**[0008]** Barrel Mount Options:

- Secure Attachment: Mount securely attaches to the rifle barrel, providing stable and precise alignment.
- Adjustable Fit: Compatible with various barrel diameters and types through adjustable fittings.

**[0009]** Pixel Grid Options for Digital Collimation:

- High-Resolution Grid: A pixel grid displayed on the smartphone screen allows for precise alignment and collimation.
- Movement Analysis: Provides a system to analyze all degrees of movement once the data is captured and stored.
- Real-Time Feedback: Provides visual feedback through the pixel grid, ensuring accurate alignment adjustments.
- Digital Precision: Enhances the accuracy of the collimation process by using digital references.

**[0010]** Smartphone Integration:

- Sensor Utilization: Smartphones' gyroscopic, accelerometer, and camera sensors are utilized to detect minute movements and provide alignment data.

- Scope Data Integration: Uses the make and model of the scope along with optical measurements to determine the precise center of the line of sight.
- Barrel Measurements: Uses the diameter and length of the barrel to determine the precise center of the line of bore.
- Camera Alignment: The smartphone camera is used for visual alignment, and augmented reality (AR) is used for precise targeting.

**[0011]** Mobile Application Options:

- Real-Time Feedback: Provides real-time data and visual feedback for precise boresighting using AR.
- User Interface: Intuitive interface for easy operation and adjustments.
- Data Logging: Records alignment data for future reference and analysis.

**[0012]** Compatibility Options with Optical and Digital Scopes:

- Legacy Optical Sights: Designed to work seamlessly with all legacy optical sights.
- Digital Scopes: Fully compatible with the latest digital scopes, integrating with their sensor data and settings.

**[0013]** Standalone and Integrated Operation Options:

- Standalone Upgrade: This can be used independently to upgrade the technology of a user’s existing setup.
- Integration with Fire Control Systems: Can integrate into advanced fire control systems, such as the Next Generation Squad Weapons Fire Control Sighting System, enhancing their capabilities.

**[0014]** Laser and Non-Laser Operation:

- Laser Option: If desired, laser technology can be incorporated for visual alignment.
- Non-Laser Option: Can operate without laser technology, using integrated sensors and smartphone data for alignment.

**[0015]** Advanced Features:

- Barrel Integrity Assessment: Determines if the barrel is bent by comparing sensor data along the barrel.
- Scope Cant Correction: Uses sensor data to ensure the scope is correctly canted.
- Deviation Analysis: Measures deviation from the boresight location to the final calibration location (zero) and breaks it down into contributory variables to determine their impact on the overall trajectory.
- Variable Adjustment: Users can replace variables such as muzzle velocity, weather conditions, shooter ability, and manufacturing tolerances to predict a new deviation and zero without requiring live firing.
- Clean Data Collection: Collects data never before captured, carefully structured to ensure it is clean and pristine, avoiding unstructured dark data. Dark data, which is unstructured, accounts for about 80 percent of the data spectrum, and 90 percent is used only once. This system aims to minimize such data.

**[0016]** Artificial Intelligence (AI) and Machine Learning (ML) Integration:

- Predictive Modeling: Uses AI and ML to analyze collected data and predict the impact of various variables on the trajectory.

- Continuous Improvement: Improve accuracy by learning from new data and user feedback.
- Custom Recommendations: Provides personalized recommendations for adjustments based on the shooter's historical data and performance trends.

**[0017]** Data Utilization for Research:

- Military Research: Data can be used to further military research and enhance marksmanship training and firearm development.
- Commercial Market Research: Unclassified data can be utilized for commercial market research, providing insights into consumer preferences and improving commercial firearm products.

**[0018]** Durability:

- Rugged Design: Mount and sensors are built to withstand harsh field conditions.
- Weatherproof: Resistant to dust, water, and other environmental factors.

**[0019]** Mount: Adjustable and secure mount for various barrel sizes.

**[0020]** Integrated Sensors:

- Barrel Chamber Sensor
- Muzzle End Sensor
- Ocular Piece Sensor

**[0021]** Pixel Grid for Digital Collimation:

- High-Resolution Grid for precise alignment and collimation.

- Movement analysis capabilities to analyze all degrees of movement once data is captured and stored.
- Real-time visual feedback through the smartphone display.

**[0022]** Smartphone Compatibility: Compatible with iOS and Android devices.

**[0023]** App Features:

- Real-time alignment data using AR.
- Visual feedback using the smartphone camera.
- Scope height calculation.
- Data logging and performance analysis.
- Integration of scope data (make and model) for precise alignment.
- Use barrel diameter and length to determine the precise center of the bore line.
- Barrel integrity assessment, scope cant correction, deviation analysis, and variable adjustment.
- Clean, structured data collection to avoid dark data.
- AI and ML integration for predictive modeling and continuous improvement.
- Data utilization for military and commercial market research.

**[0024]** Laser Option: This feature is optional for users who prefer laser-based alignment.

**[0025]** Compatibility: Designed to work with all legacy optical sights and the latest digital scopes.

**[0026]** Standalone and Integrated Operation: Can be used independently or integrated into advanced fire control systems.

**[0027]** Power Source: Battery-powered sensors mounted with optional USB charging.

**[0028]** Weight: Lightweight design under 200 grams.

**[0029]** Dimensions: Compact size for easy portability and mounting.

**[0030]** Benefits

**[0031]** Precision: Ensures the highest level of accuracy in boresighting by leveraging advanced smartphone sensors, integrated sensor data, scope data, AR technology, AI, ML, and a pixel grid for digital collimation.

**[0032]** Efficiency: Reduces time and effort required for manual boresighting adjustments.

**[0033]** Versatility: Compatible with various firearms, scopes (legacy optical and the latest digital), and shooting devices.

**[0034]** Durability: Built to withstand harsh environmental conditions, ensuring long-term reliability.

**[0035]** Comprehensive Assessment: Provides additional features such as barrel integrity assessment, scope cant correction, and deviation analysis, offering a complete boresighting solution.

**[0036]** Predictive Adjustment: This feature allows users to adjust key variables to predict a new zero without the need for live firing, saving time and resources.

**[0037]** Clean Data Collection: Ensures that the data collected is structured and pristine, avoiding the accumulation of unstructured dark data and making all collected data useful and accessible.

**[0038]** Research Applications: Data can be used to further military research, enhance marksmanship training, and for unclassified commercial market research to improve firearm products and meet consumer needs.

**[0039]** Flexible Operation: Offers laser and non-laser alignment options, catering to user preferences and ensuring flexibility in various conditions.

**[0040]** AI and ML Integration: Enhances predictive modeling, continuously improves system accuracy, and provides personalized recommendations for optimal performance.

**[0041]** Digital Precision: The pixel grid ensures precise digital collimation, enhancing the system's overall accuracy and providing detailed movement analysis.

**[0042]** Standalone and Integrated Operation: Can be used as an independent upgrade or integrated into advanced fire control systems, such as the Next Generation Squad Weapons Fire Control Sighting System.

**[0043]** US Patent application serial number US13/928,153 incorporated herein by reference: Describes related technology and background on optical alignment and collimation, influencing the design of the bore sighter to ensure precision and ease of use.

**[0044]** US Patent Application serial number US15/798,329 also incorporated herein by reference: Provides insights into advanced sensor integration and data processing methods, helping to refine the data collection and structuring capabilities of the bore sighter system.

**[0045]** The digital collimated bore sighter with integrated sensors, AI, ML, and smartphone integration represents a significant advancement in boresighting technology. By leveraging sensors placed in the barrel chamber, at the muzzle end, and at the ocular piece of the scope, along with smartphone sensors to determine the line of sight, line of the bore (using barrel diameter and length), and scope height, and providing real-time feedback through a dedicated mobile app, this device will revolutionize the way shooters align their firearms, air rifles, and crossbows. Additionally, barrel integrity assessment, scope cant correction, deviation analysis, and adjustment offer a comprehensive and predictive boresighting solution. The device ensures clean data collection, avoids dark data, and employs AI and ML to enhance predictive modeling, improve system accuracy, and provide personalized recommendations. Including a pixel grid for digital collimation further enhances the system's accuracy and allows for detailed movement analysis. The system is compatible with all legacy optical sights and the latest digital scopes and can either stand alone or be integrated into advanced fire control systems. This innovation will provide valuable insights for military and commercial market research, ensuring a competitive advantage.

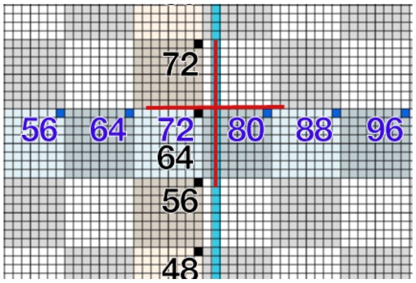
**[0046]**

**[0047]** The user may install the bore sighter much like a Bushnell mag bore sighter on the end of the barrel.

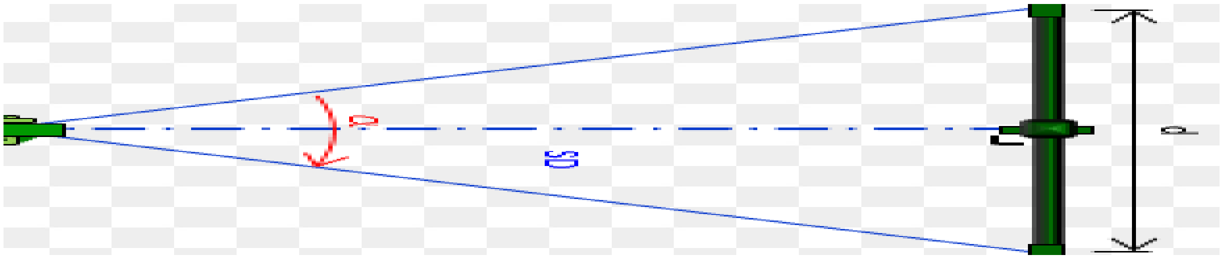
**[0048]**

**[0049]** Instead of a grid sheet, the bore sighter may have a pixelated sheet with gridlines and a reticle in the center.

**[0050]**



**[0051]** The user may be able to measure from one grid line to another with their rifle scope and feed that into the app. This will give the distance from the rifle crosshairs to the digital boresighter.



**[0052]** When placed on the end of the barrel, the bore sighter should have a system to reference the center of the barrel on the rifle. When moved up or down to provide a view of the pixelated sheet to the user, the bore sighter may be able to show a scale in inches.  This is the height of the scope above the rifle bore.  The measurement will be fed to the app.

**[0053]** The bore sighter should show a ring that if the user places the rifle scope diameter on the ring, it would confirm that the user has located the center of the scope diameter when the user looks at the reticle on the boresighter.

**[0054]** In long-range shooting, accuracy and consistency are paramount. Achieving this requires precise calibration of ballistic variables, detailed analysis of shooter characteristics, and accurate tracking of environmental conditions. Historically, these tasks have been managed using a combination of manual adjustments and empirical data, which can lead to inconsistencies and errors. Today, advanced off-the-shelf technologies offer new opportunities to enhance these processes through precise measurement, analysis, and real-time feedback.

**[0055]** This disclosure includes the integration of multiple technologies—into a comprehensive system designed to optimize ballistic calibration and shooter performance. The role of AI and ML, specifically in the subfields of Predictive Modeling, Data Validation and Verification, Collaborative AI Technologies, and Synthetic Data Generation, in further refining these processes is also discussed. Additionally, the insights of Bryan Litz on ballistic calibration and error propagation are integrated to provide a deeper understanding of the challenges and solutions in this field. Finally, we discuss how to build a structure that accumulates clean, ballistically-related data and avoids the generation of dark data, with an emphasis on the use of Bluetooth and Wi-Fi for seamless data collection.

**[0056]** The disclosed system and apparatus is an advanced digital collimated bore sighter system that provides precise measurement and calibration of ballistic variables. One core function of this may be to isolate and manage variables such as muzzle velocity, environmental conditions, and firearm-specific factors to ensure accurate boresighting. One of the key benefits of the disclosed zero process is its ability to isolate and minimize "baked-in" errors—errors that are inadvertently introduced during initial calibration and then propagate through subsequent ballistic calculations.

**[0057]** Integration with LabRadar and Garmin Xero CI Pro Chronograph: The disclosed system in one example integrates with both LabRadar and Garmin Xero CI Pro Chronograph to accurately measure muzzle velocity. LabRadar provides non-intrusive, Doppler radar-based velocity measurements, while the Garmin Xero CI Pro Chronograph offers a compact and easy-to-use solution with integrated sensor technology. The combination of these tools ensures that muzzle velocity data is accurate, comprehensive, and reliable, thereby reducing the risk of baked-in errors. Data from both devices is transmitted via Bluetooth or Wi-Fi to a central system for real-time analysis and integration.

**[0058]** Data Collection and Analysis: the disclosed zero process uses data from LabRadar and Garmin Xero CI Pro, combined with environmental data from Kestrel, to create a detailed profile of ballistic performance. This data is wirelessly transmitted to ensure seamless integration and is used to refine zero settings and improve shot accuracy across various shooting conditions. The ability to accurately isolate and measure each ballistically-related variable reduces the likelihood of errors becoming baked into the ballistic solution.

**[0059]** 2.2 Mantis X: Analyzing Shooter Characteristics

**[0060]** Mantis X is a device that monitors and analyzes shooter behavior, providing detailed feedback on shooting mechanics such as grip, trigger control, and follow-through. By isolating shooter-induced variables, Mantis X helps in ensuring that these factors do not contribute to baked-in errors during the calibration process.

**[0061]** Data Integration: Mantis X data, which is inherently ballistically-related, is transmitted via Bluetooth or Wi-Fi to integrate with the disclosed system, allowing for the identification of shooter-induced deviations from ideal ballistic performance. This integration helps shooters understand the impact of their technique on shot placement, leading to improved consistency and accuracy. By isolating the shooter's influence, Mantis X helps prevent these variables from introducing errors into the ballistic calculations.

**[0062]** Performance Feedback: The real-time feedback provided by Mantis X is crucial for identifying and correcting poor shooting habits, making it an essential tool in both training and live-fire scenarios. This feedback ensures that shooter-related errors are addressed before they can affect the calibration process.

**[0063]** 2.3 Kestrel: Monitoring Environmental Variables

**[0064]** Kestrel weather meters are essential for monitoring environmental conditions that affect ballistic performance, such as wind speed, temperature, humidity, and barometric pressure. Kestrel plays a vital role in isolating environmental factors that could otherwise introduce errors into the ballistic solution.

**[0065]** Environmental Monitoring: Kestrel provides accurate measurements of environmental variables, which are critical for making real-time adjustments to ballistic calculations. Data from Kestrel is transmitted via Bluetooth or Wi-Fi to the central system, where it is integrated with the disclosed system and other data sources to ensure that zero settings are optimized for the current shooting conditions, reducing the likelihood that environmental factors will contribute to baked-in errors.

**[0066]** Impact on Ballistics: By isolating environmental factors, Kestrel helps shooters understand how these variables influence bullet trajectory, allowing for more precise adjustments during long-range shooting. This isolation is critical for preventing environmental variables from corrupting the ballistic solution.

**[0067]** 2.4 LabRadar and Garmin Xero CI Pro Chronograph: Tracking Muzzle Velocity

**[0068]** Both LabRadar and Garmin Xero CI Pro Chronograph offer advanced capabilities for tracking muzzle velocity, a critical variable in ballistic calibration. These tools are essential for ensuring that muzzle velocity is measured accurately, thereby preventing velocity-related errors from becoming baked into the ballistic calculations.

**[0069]** LabRadar: LabRadar is a Doppler radar-based system that tracks the bullet's velocity from the muzzle to downrange, providing a detailed velocity profile. Its non-intrusive nature makes it ideal for a wide range of firearms and shooting scenarios. Data is transmitted wirelessly for immediate integration into the ballistic analysis.

**[0070]** Garmin Xero CI Pro Chronograph: The Garmin Xero CI Pro Chronograph is a compact and highly portable device that uses optical sensors to measure muzzle velocity. Its integration with Garmin's ecosystem allows for easy data synchronization and analysis. Data from Garmin Xero CI Pro is also transmitted via Bluetooth or Wi-Fi to ensure seamless data flow and integration with other systems.

**[0071]** Combined Use: Using both LabRadar and Garmin Xero CI Pro ensures that shooters have access to the most accurate and reliable velocity data. This redundancy allows for cross-validation of data, reducing the likelihood of errors and improving overall ballistic performance. The accurate measurement of muzzle velocity is crucial for preventing velocity-related errors from becoming baked into the ballistic solution.

**[0072]** 2.5 Kongsberg Electronic Target Systems (Kongsberg ETS): Providing Real-Time Feedback

**[0073]** Kongsberg ETS offers immediate feedback on shot placement, using acoustic sensors to detect the exact location of bullet impacts on the target. This system plays a critical role in verifying that the ballistic calculations and adjustments made during the calibration process are accurate.

**[0074]** Shot Placement Analysis: Kongsberg ETS provides precise data on where each shot lands, allowing shooters to confirm their zero settings and make necessary adjustments in real-time. This capability is particularly useful for verifying the effectiveness of adjustments made using the disclosed system and the other integrated systems. By providing immediate feedback, Kongsberg ETS helps ensure that any errors introduced during the calibration process are quickly identified and corrected before they can become baked into the ballistic solution. Data from Kongsberg ETS is transmitted via Bluetooth or Wi-Fi for real-time integration with other system data.

**[0075]** Integration with Other Systems: The feedback from Kongsberg ETS can be used in conjunction with data from LabRadar, Garmin Xero CI Pro, Mantis X, and Kestrel, creating a comprehensive feedback loop that informs all aspects of the shooter’s performance and equipment settings. This integration helps ensure that all potential sources of error are isolated and addressed.

**[0076]** 3. Application of AI and ML in Ballistic Calibration and Shooter Performance

**[0077]** 3.1 Predictive Modeling

**[0078]** Predictive Modeling, a subfield of AI, involves using historical data to predict future outcomes. In the context of ballistic calibration, predictive modeling can anticipate how changes in environmental conditions, shooter behavior, or equipment settings will affect shot placement. This capability is particularly useful for preventing errors from becoming baked into the ballistic solution.

**[0079]** Application in Ballistic Calibration: AI-driven predictive models can analyze ballistically-related data from this disclosed system Mantis X, Kestrel, LabRadar, and Garmin Xero CI Pro to forecast the trajectory of bullets under varying conditions. These models can then recommend adjustments to prevent potential errors, ensuring that the ballistic solution remains accurate. Data collected via Bluetooth and Wi-Fi ensures that the predictive models have access to the most current and comprehensive data sets.

**[0080]** Error Prevention: By predicting the impact of different variables on the shot outcome, predictive modeling can identify potential sources of error before they become problematic. This allows for proactive adjustments, preventing these errors from becoming baked into the ballistic solution.

**[0081]** 3.2 Data Validation and Verification

**[0082]** Data Validation and Verification is critical in environments where data integrity is paramount. This AI subfield involves developing techniques to ensure that data used in ML models is accurate, reliable, and free from tampering or errors. In ballistic calibration, this ensures that the ballistically-related data used to adjust the ballistic model is accurate and trustworthy.

**[0083]** Ensuring Data Integrity: AI can be employed to validate and verify data from devices like LabRadar, Garmin Xero CI Pro, and Kestrel, ensuring that the data used in ballistic calculations is accurate. Data transmitted via Bluetooth and Wi-Fi is automatically validated to prevent inconsistencies or errors. This is particularly important in contested environments where data manipulation could lead to incorrect ballistic solutions.

**[0084]** Preventing Baked-In Errors: By ensuring that all data inputs are accurate and reliable, AI-driven data validation and verification can prevent incorrect data from leading to baked-in errors. This is crucial for maintaining the integrity of the ballistic solution over time.

**[0085]** 3.3 Collaborative AI Technologies

**[0086]** Collaborative AI Technologies involve AI systems working together across different devices and platforms to achieve a common goal. In ballistic calibration, collaborative AI can facilitate communication between different technologies like the disclosed system, Mantis X, Kestrel, and Kongsberg ETS, ensuring that all systems work in harmony to optimize the ballistic solution.

**[0087]** System Integration: AI can enable seamless integration between different shooting technologies, allowing them to share ballistically-related data and insights in real-time via Bluetooth and Wi-Fi. For instance, the disclosed system can use data from

Kestrel to adjust its ballistic calculations, while Kongsberg ETS can provide immediate feedback on the effectiveness of these adjustments.

**[0088]** Real-Time Collaboration: By enabling real-time collaboration between different systems, AI ensures that all relevant data is considered when making adjustments to the ballistic model. This helps to isolate and address any errors before they become baked into the solution.

**[0089]** 3.4 Synthetic Data Generation

**[0090]** Synthetic Data Generation involves creating artificial data sets that replicate real-world conditions, allowing for the testing and refinement of AI models. In ballistic calibration, synthetic data can be used to simulate a wide range of shooting scenarios, helping to identify and mitigate potential sources of error.

**[0091]** Training AI Models: Synthetic data can be used to train AI models in conditions that may be difficult or costly to replicate in the real world. For example, synthetic data could simulate extreme weather conditions or unusual shooter behavior, allowing AI models to learn how to adjust the ballistic solution accordingly.

**[0092]** Enhancing Predictive Accuracy: By incorporating synthetic data into their training, AI models can become more robust and accurate in their predictions. This ensures that the ballistic solution remains reliable even in unexpected or extreme conditions, reducing the likelihood of baked-in errors.

**[0093]** 4. Building a Structure for Clean Data Accumulation and Avoiding Dark Data

**[0094]** 4.1 Importance of Clean Ballistically-Related Data

**[0095]** In the context of ballistic calibration and shooting performance, clean data refers to accurate, reliable, and properly labeled data that can be effectively used to calibrate models and make precise adjustments. Clean, ballistically-related data is essential for ensuring the accuracy of ballistic calculations and preventing the introduction of errors into the system. Conversely, dark data refers to data that is collected but not utilized or properly analyzed, leading to potential inaccuracies and inefficiencies.

**[0096]** 4.2 Strategies for Accumulating Clean Data

**[0097]** To accumulate clean data, it is crucial to establish a structured system that prioritizes data accuracy, validation, and integration across all platforms involved in the ballistic calibration process. The following strategies can be implemented:

**[0098]** Standardized Data Collection: Establish protocols for data collection that ensure consistency across all devices and platforms. For example, ballistically-related data from LabRadar, Garmin Xero CI Pro, and Kestrel should be collected in standardized formats via Bluetooth and Wi-Fi, allowing for seamless integration and analysis.

**[0099]** Automated Data Validation: Implement AI-driven data validation tools that automatically check for anomalies or inconsistencies in the ballistically-related data transmitted via Bluetooth and Wi-Fi. This ensures that only clean, reliable data is used in ballistic calculations, reducing the risk of errors.

**[0100]** Real-Time Data Synchronization: Use collaborative AI technologies to synchronize ballistically-related data from different devices in real-time via Bluetooth and Wi-Fi. This ensures that all relevant data is available when needed, and prevents the accumulation of dark data that is not effectively utilized.

**[0101]** Regular Data Audits: Conduct regular audits of the ballistically-related data to identify any potential issues or gaps. This can help prevent dark data from accumulating and ensure that all data is being properly utilized.

**[0102]** 4.3 Avoiding the Occurrence of Dark Data

**[0103]** Dark data occurs when data is collected but not properly analyzed or integrated into the decision-making process. To avoid the occurrence of dark data, it is essential to:

**[0104]** Ensure Data Accessibility: Make sure that all collected ballistically-related data is easily accessible to the systems and individuals that need it. This may involve integrating data management systems that allow for seamless access and retrieval of data collected via Bluetooth and Wi-Fi.

**[0105]** Utilize All Collected Data: Develop processes to ensure that all ballistically-related data collected is analyzed and used in the calibration process. This can include leveraging AI to identify and highlight data that may be overlooked or underutilized.

**[0106]** Integrate Data Across Platforms: Ensure that ballistically-related data collected from different platforms is integrated into a single, cohesive system via Bluetooth and Wi-Fi. This prevents data from being siloed or forgotten, ensuring that all information is used to its full potential.

**[0107]** 5. Insights from Bryan Litz on Ballistic Calibration

**[0108]** Bryan Litz is widely recognized as one of the foremost experts in external ballistics, with a reputation that extends globally. His extensive work in the field has provided invaluable insights into the science of bullet flight, including the intricacies of ballistic coefficients, drag models, and the impact of environmental variables on projectile trajectory. Litz's contributions have been instrumental in advancing both the theoretical understanding and practical application of ballistic science, making him a pivotal figure in the development of modern shooting techniques and technologies.

**[0109]** In his comments on July 23, Bryan Litz addressed the critical role of ballistic calibration, particularly the concept of "truing" to determine the average muzzle velocity (MV) when a precise chronograph is not available. Litz emphasized that accurate calibration is essential for ensuring that the muzzle velocity used in ballistic solvers reflects the actual performance of the projectile.

**[0110]** Calibration as a Necessity: Litz pointed out that "truing"—the process of adjusting the ballistic model to match observed impacts at a known distance—is often necessary to determine an accurate muzzle velocity when access to a high-quality chronograph is limited. This process involves shooting at a distant target, measuring the drop, and using these observations to calibrate the ballistic solver.

**[0111]** The Importance of Accurate BC and MV: Litz highlighted the significant impact that inaccuracies in the ballistic coefficient (BC) and muzzle velocity can have on long-range shooting performance. If either the BC or MV is incorrect, the solver will not accurately predict the projectile’s trajectory, leading to errors that compound over distance. This emphasizes the importance of using precise data for both BC and MV in ballistic calculations.

**[0112]** Error Propagation and Calibration Distance: Litz also discussed the propagation of errors when "truing" at different distances. He illustrated that the errors associated with incorrect BC and MV grow more significant as the distance increases. For example, truing at too close a range can result in calibration errors that become more pronounced at longer distances, potentially leading to significant deviations from the intended point of impact. He recommended truing at distances where the projectile is transitioning through critical points, such as when it slows to Mach 1.2, to minimize these errors.

**[0113]** The integration of Bryan Litz’s insights into ballistic calibration underscores the value of using advanced off-the-shelf technologies such as LabRadar, Garmin Xero

CI Pro Chronograph, and other systems discussed in this disclosure. By leveraging these tools, users/shooters can achieve the precise measurements needed for accurate ballistic calibration, minimizing the errors that Litz warns about.

**[0114]** Minimizing Errors: the disclosed system aligns with the importance of accurate initial calibration, as facilitated by known technologies. By ensuring that the correct BC and MV are used from the outset, these tools help prevent the propagation of errors that can lead to inaccurate shooting at longer distances.

**[0115]** Truing and Validation: The process of truing, can be enhanced by using other systems and data to provide immediate feedback on shot placement. This real-time feedback allows shooters to confirm the accuracy of their truing efforts and make necessary adjustments, further refining their ballistic solution.

**[0116]** Data Integration for Comprehensive Analysis: By integrating the precise data from other sources with the environmental measurements and the shooter performance insights, the combined system provides a robust framework for implementing error minimization. This comprehensive approach ensures that all variables are accurately accounted for, leading to more reliable and consistent long-range shooting results. Importantly, it allows for the isolation and correction of potential baked-in errors before they can affect the overall ballistic performance.

**[0117]** The integration into the disclosed system of advanced off-the-shelf technologies into such as ZeroVerify, Mantis X, Kestrel, LabRadar, Garmin Xero CI Pro Chronograph, and Kongsberg ETS represents a significant leap forward in ballistic calibration and shooter performance optimization. These technologies provide a comprehensive system for managing the ballistically-related variables that affect shooting accuracy, leading to more consistent and reliable results. The ability to isolate and correct potential baked-in errors is a critical advantage of this integrated approach.

**[0118]** The addition of analytics (AI and ML) further enhances these capabilities, offering new opportunities for predictive modeling, real-time adjustments, and personalized training programs. Bryan Litz’s insights into the importance of accurate ballistic calibration and error management are central to maximizing the effectiveness of these technologies. As these systems continue to evolve, they will play an increasingly important role in both civilian and military shooting applications, setting new standards for accuracy and performance.

**[0119]** Military service members qualify/demonstrate proficiency with small arms once or twice a year. This calibration contains constant and variable data. The individual uses the calibration (zero), and the data produced has no lone value.

**[0120]** The data when collected, contains a snapshot of all variables and constants that affect the projectile's (bullet) flight. The constants deal with the user's expertise and the tolerances of the equipment manufactured. The data will also include the variables present during the recording of zero. The variables are weather, temperature, location, and weapon performance.

**[0121]** The data can be collected in the cloud, much like water being held by a dam, with the amount increasing as the data accumulates. The information important to marksmanship, marketing, and research can be scooped out, analyzed for trends, patterns, or similarities, and processed using predictive analysis.

**[0122]** This data may be proprietary and, along with information pulled from other sources such as public domains or confidential business and military databases, may be processed and used as business intelligence.

**[0123]** The system includes amalgamation of the data collected by the sensors and the app.

**[0124]** The disclosed apparatus may include multiple (three or more) sensors. It may collect data and send it to a storage location such as the cloud, server hard drive, etc. The apparatus and system may determine the constant associated with the user and the equipment if needed. Isolation of the constant will allow the input of a new constant and variables with the possibility of new calibration.

**[0125]** One example of the disclosed system may use one sensor and the same app and operate much like the magnetic bore-sighters attached to a rifle barrel's end. It can conduct boresight, record zero, and recall zero. The user will have to enter scope height and barrel length

**[0126]** The apparatus and system may include a structure to accumulate clean, ballistically-related data while avoiding the creation of dark data for the success of these systems. By implementing standardized data collection, automated validation, real-time synchronization, and regular audits, shooters and researchers can ensure that all collected data is accurate, reliable, and fully utilized. This approach not only ensures the highest levels of precision in shooting but also provides a robust framework for ongoing research and development in ballistic science. By addressing and correcting baked-in errors early in the calibration process, these systems help shooters achieve the most accurate and reliable results possible, regardless of the shooting conditions.

**[0127]** Key Definitions

**[0128]** Bore Sight - The process of intersecting the scope’s line of sight to the rifle’s line of bore at any range distance

**[0129]** Digital Bore Sight - The process of sighting a digital (virtual) rifle bore and connecting it to the physical bore sight process

**[0130]** Digital Collimator- A device that attaches to the end of the rifle and the user interacts with to convert physical inputs into digital data in a smart phone application.

**[0131]** Digital Twin - The link within a smart phone app that matches the virtual rifle, scope, coordinate system, environment and range to the physical rifle, scope and environment.

**[0132]** Line of Bore - A theoretical perfect line projected from the center of the rifle bore to a specified target at a specified range distance.

**[0133]** Line of Sight - A theoretical perfect line projected from the scope reticle (cross hairs) to a specified target at a specified range distance.

**[0134]** Range - The distance in feet, meters, or yards the target is from the end of the scope.

**[0135]** Zero - Synonymous with zeroed, zeroing and zero point. A theoretical state were the bore sight and the scope sight meet at a point on a specified target and specified range distance.

**[0136]** The disclosed system includes a mathematical method and model for automatically sighting-in a rifle that has completed “Phase 1” of feasibility testing for demonstrating its technical merit. Testing in Phase 1 has included initial physical prototypes, testing procedures, data collection and analysis. The testing involved replicating real-world target practice conditions with a simulated smart phone application. A physical smart phone was used as a stand-in for different types of sensors and digital devices, where live real-world data would be collected instantly and automatically as inputs into the application. In the final product, the smart phone will perform the necessary mathematical functions and produce the outputs that the user needs to sight the rifle at the desired range distance. In testing, the smart phone provided the sensors needed to bore sight the rifle and calculations were performed on a separate laptop computer. It is the intent of the final product to perform all the details listed in this document quickly, automatically and only requiring a few inputs from the user.

**[0137]** The mathematical model detailed in this document provides a base technology platform for sighting-in any arms technology or platform. This platform is first demonstrated on a simple rifle-scope assembly for automatic sighting. After the sighting-in (zeroing) process is complete, this model allows the user to verify the zero point without firing another round via the smart phone application. This is most useful when scopes are bumped, or traveling to difference range locations with changing elevations, temperatures, and climates.

**[0138]** Therefore, the following details the mathematical model that will be validated and verified in

**[0139]** “Phase 2”

**[0140]** Before the disclosed zero process can be initiated, the user may perform the Bore Sight process. This is the initial process that creates the desired intersection of the scope’s line of sight and the rifle’s line of bore at the desired range distance. The key difference between the Bore Sight process and the disclosed zero process is in how the physical information of the Bore sight process is converted into digital data. The disclosed zero process may include a digital check that compares the physical scope/rifle assembly to its digital twin within the smart phone application. In short, the Bore Sight process is the initial digital setup, while the disclosed zero process is a comparison check between the real-world record fire results and the digital twin. Both processes together, create digital means to record, monitor and measure target practice data in real time and determine if any adjustments are needed.

**[0141]** The model is based on basic trigonometric functions built from coordinate points using the direction of gravity as the primary y-axis and assuming two theoretical horizontal perpendicular axes as secondary and tertiary. The x-axis is a horizontal line from left to right as the user looks through the scope and the z-axis is a horizontal line along the axis of the “line of sight”.

**[0142]** The user’s eye point is the initial point (0,0,0) in the coordinate system. The second point (0, 0, z) is the scope reticle (cross hairs). Connecting these points creates a vector that can be projected along the z-axis to any range distance set by the user. The x or y deviation as seen through the scope and this projection along the z-axis can be calculated with the tangent function.

**[0143]** The technical details that make this possible may be contained in the scope design, particularly its optical configuration. It is important for the internal optical configuration to be well understood so that the user’s eye point (0,0,0) and the scope’s reticle (0,0, z) are established. There are multiple styles and optical designs that could produce different eye point and reticle locations relative to one another, however the basic premise is based on optical refraction, focal length and the focal convergence point. Basic scope manufacturer information can be used to calculate the exact eye point and reticle relative locations. The output of this method is the calculated distance between the user’s eye point and the reticle projection on the focal plane. This distance value is set as the scope’s axis or “line of sight” and is used to calculate the angle between it and the barrel axis or line of bore.

**[0144]** Testing and verification of this method is important to show that the line of sight and line of bore can be predicted to intersect at any range distance. This can be accomplished through a detailed testing procedure of several scope models. A mixture of existing laser-sighting and optical technologies can be leveraged to calibrate this method to standard quantities. In this case, the standards quantities are: 1) range distance, 2) bullet drop, and 3) scope angle adjustments specific to the manufacturer.

Because scope adjustments are the most complex of the three quantities, it will be the focuses of this method for developing the technology.

**[0145]** There are two top-level variables to be tested: Var1 = Calculated distance between user's eye point and reticle focal plane based on user's input. Var2 = Physical scope reticle focal plane location relative to user's physical eye point. Therefore, the hypothesis is: Across several scope models, there is correlation between the calculated distance between the focal plane and eye point and the physical focal plane distance to the physical eye point. That is, if calculations can be performed to estimate the intersection point of the line of sight and line of bore at the desired range, the required focal plane distance from the user's eye point can be calculated, compared to and shown to match the manufacturer's actual focal plane distance. The degree to how closely they match is the total error of the process and method. Gross error indicates a misunderstanding of the method, its application or the mathematics. Therefore, the null hypothesis is: Across several scope models, there is no correlation between the calculated distance between the focal plane and eye point and the physical focal plane distance to the physical eye point. That is, if the calculations for predicting the distance between the focal plane and the eye point never match the physical scope's optical configuration, the method is not valid for predicting the intersection of line of sight and line of bore at any given range.

**[0146]** Figure A shows a diagram of a common scope model and the user's eye point. The diagram shows the relative distance between the eye point and the potential reticle locations inside the scope assembly. As reticle adjustments are made in the y-direction (elevation), the distance value between the eye point and the reticle is used in the calculation for determining the angle that the line of sight was changed by. For adjustments made in the x-direction (windage), the calculations are the same. (In this case, windage is in and out of the page.)

**[0147]** Figure B shows the simple trig. relationships that are required. In this case, the line a-b, is the distance between the eye point and the reticle. The line b-c is any adjustment value of the reticle. The Tangent function is used to calculate the angle the line of sight is adjusted to. This angle is projected along the Z-axis to predict its intersection with the line of bore.

**[0148]**

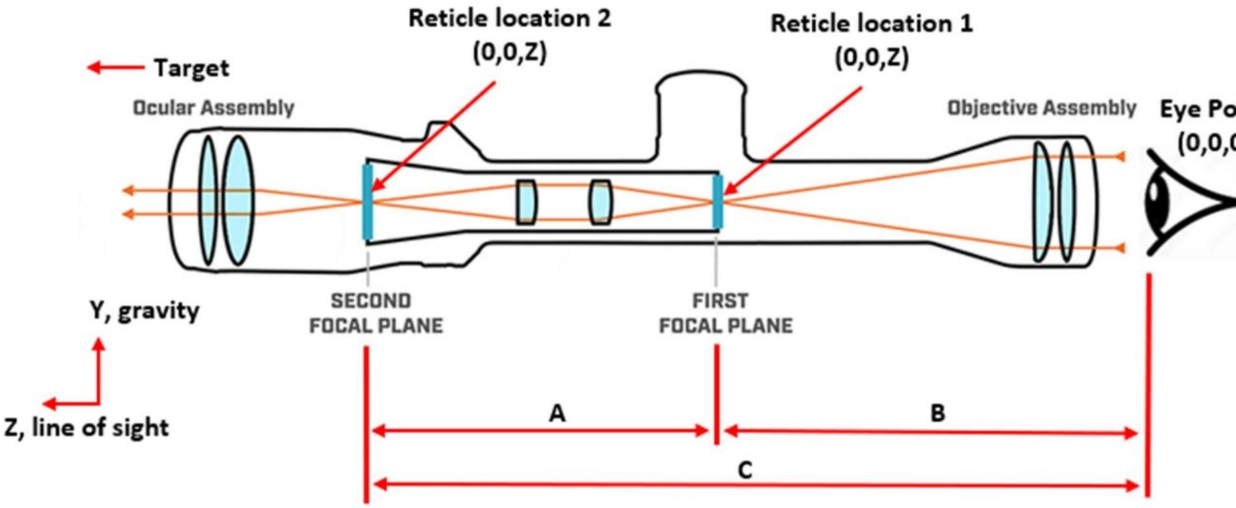
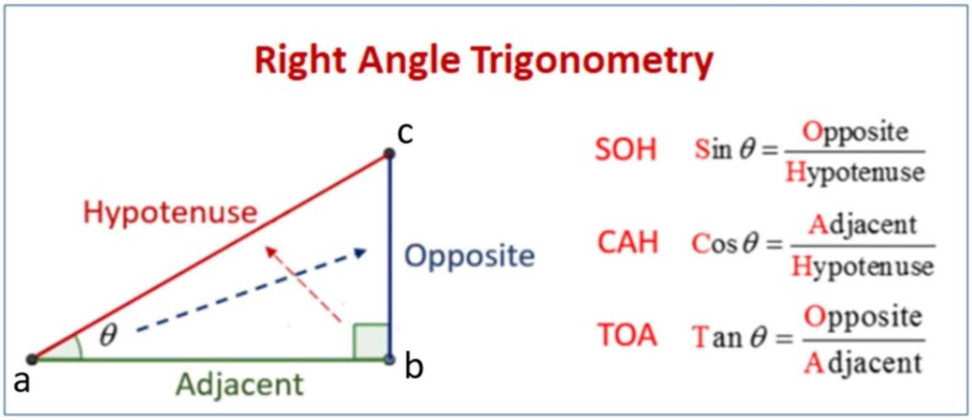


Fig. A: Basic Scope Diagram

**[0149]**

**[0150]**



**[0151]**

**[0152]** Fig. B: Right Angle Trig.

**[0153]** Line of Bore

**[0154]** The center of the bullet where it rests inside the rifle chamber is a point (0, y, z) relative to the scope coordinate system. This point assumes a vector originating from it that is coincident with the axis of the bore and projected out at the range distance. The other axes directions are copied from the scope's coordinate system. This means that a scope and rifle assembly are two coordinate systems whose axes are parallel to each other but offset in the y-direction.

**[0155]** Figure C shows the same scope diagram now mounted with a rifle cross section. The y-direction offset is indicated between the two parallel axes (the scope line of sight and the barrel line of bore). The center point of the bullet rests at some position on the line of bore with coordinates (0, y, z.) This indicates that the x-direction is intended to be aligned with the x-direction line of sight by default (windage direction left to right). The y-direction is accounted for with the y offset. The z-direction from the scope origin (eye point) is unknown and is not used in this method. However, this value can be used in alternative techniques that use proximity sensing and triangulation.

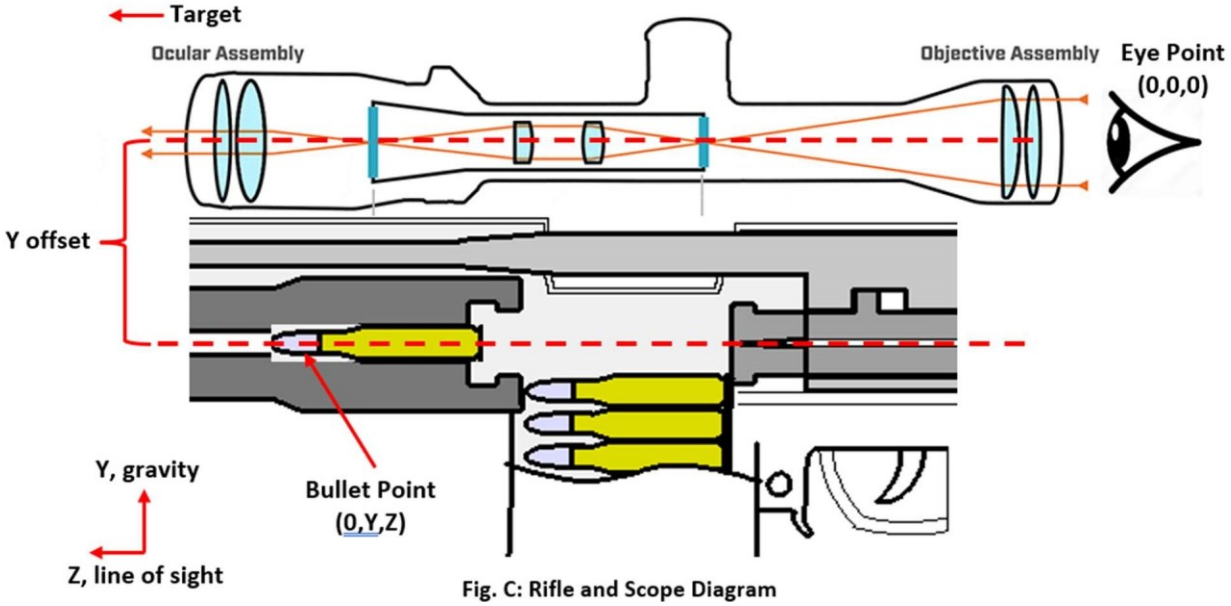
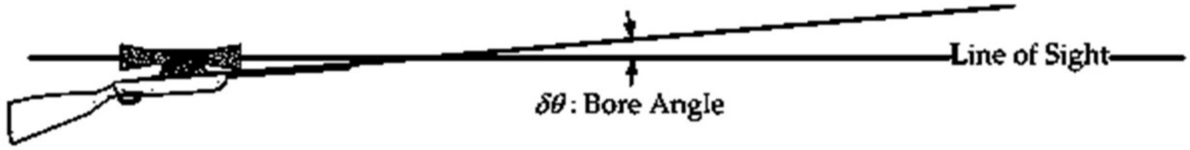


Fig. C: Rifle and Scope Diagram

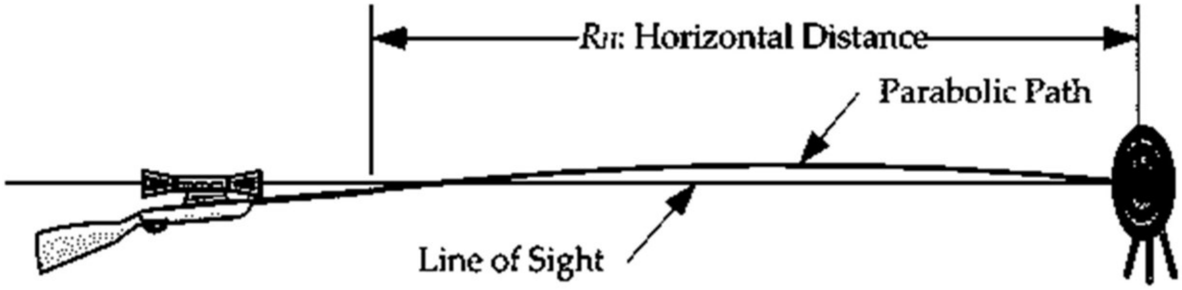
**[0156]** Once the scope coordinate system and optical configuration is defined and the y offset to the line of bore is established, angle projections can be performed at any range distance to predict line of sight and line of bore intersection.

**[0157]** Figure D shows a simple diagram of how a scope’s line of sight and rifle’s line of bore may not be initially parallel. But once parallelism between them can be established and verified, angle deviations can be calculated, and predictions can be made on their intersection projected at any range distance.

**[0158]** Figure E shows the same diagram adjusted for a range distance. Here, it is assumed that parallelism between the line of sight and the line of bore were first established, all the necessary inputs were entered, and all the necessary calculations were performed. The output of the calculations are the necessary scope adjustments for intersection at the input range distance (the prediction of “Will Hit” location). It is important to note that bullet drop adjustments can be easily entered as an input to allow for the parabolic drop due to gravity at any range distance. It is also important to note that windage adjustments can be input as a function of wind velocity and air density with relative humidity. It is assumed that the scope’s line of sight and rifle’s line of bore are always aligned in the windage direction. Therefore, the same calculations are made that predict intersection in the windage direction as for in the elevation direction.



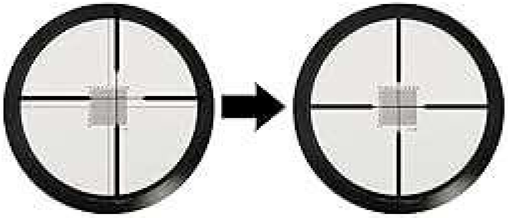
**[0159]** Fig. D: Line of Sight relative to Line of Bore



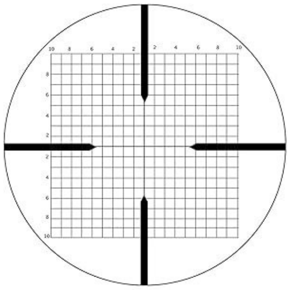
**[0160]** Fig. E: Prediction of Line of Sight and Line of Bore Intersection

**[0161]** Any deviation from the predicted “Will Hit” location is called the “Did Hit” location. The physically measured deviation from the Will Hit location is the combined system error stack. This error can be entered into the calculations as recursive feedback. With repeat record fire sampling, plotting of total system error will show correlation of the inputs and adjustments to the measured error.

**[0162]** The use of a digital collimator is one technology that links the scope and rifle coordinate systems together, creating a digital twin of the physical rifle and scope assembly. A Classical analog collimator attached to the end of the rifle barrel are a physical grid with standard square spacing. Correlation between the grid density, scope reticle alignment and range distances are known, and proper fine adjustments can be determined to predict some gross accuracy and precision. Each grid spacing is equal to some angular movement of the reticle which produces some larger deviation at the input range distance. The math for this angular movement is the same tangent function used and described previously. The primary difficulty to this method is that the user must perform a series of trigonometric calculations based on the reticle alignment to the physical grid and several other key inputs such as range distance and scope mounted height from the rifle barrel. Typically, a manual is provided with a complex table of values for the user to reference. Figures F and G show a typical analog collimator setup. A grid of some known spacing, contained inside a housing, is affixed to the end of the rifle barrel and the physical grid is viewable through the scope (Fig. G).



**[0163]** Fig. F: Typical Analog Collimator Setup



**[0164]** Fig. G: Analog Collimator - Scope View of Grid

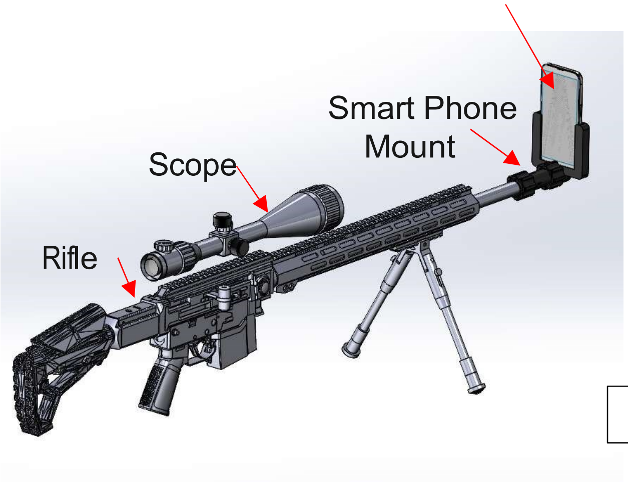
**[0165]** Smart Phone Application

**[0166]** The principle underlying function of this math model is twofold: 1) To define both the scope and bore coordinate systems. 2) To link and relate both coordinate systems together. This is achieved in three steps: 1) a: use of digital collimator, b: use of sensors 2) User input. 3) Calculations within the smart phone app.

**[0167]** Digital Collimator

**[0168]** The use of collimators to sight-in a rifle is nothing new. However, converting the information that surrounds its use into digital information that links the scope’s and rifle bore’s coordinate systems is the novel idea and is the principal focus. The digitization of a collimator is accomplished using a smart phone mounted on the end of the barrel and viewable through the scope lens. This standardized mount sets the smart phone at a known distance from the rifle bore centerline. This links the coordinate system of the smart phone screen to the rifle’s. The visible smart phone screen through the scope allows for the user to store the reticle location information digitally. When the Bore Sight process is complete, the reticle alignment is linked by pixel number and stored as the Bore Sight prediction. The smart phone must be removed to proceed to the record fire sampling. Between each record fire sample, the smart phone can be re-installed in the barrel mount and the disclosed zero process will show any deviations from the digital prediction. The disclosed zero process can also be initiated before any shots are made. This is made possible through the digital twin link. A user will be able to enter their range distance into the smart phone application and verify if the physical scope reticles are aligned to the predicted Bore-Sight stored value. Scope bumps, vibration from transportation, or movement of any kind will show up in this comparison. Figures H and I show the proposed digital boresight setup. The similarities between this and the classic analog collimator setup are in physical appearance only. The primary difference between the digital collimator process and the analog collimator process is that the disclosed system simplifies and consolidates the user manual, the trigonometric calculations, user inputs and reference tables within the smart phone application itself. The app. Guides the user through each required input and provides checks for data quality along the way. In this way, the user no longer needs to remember instructions or information on their setup. The app. simply stores and organizes the entire collection process for efficient calculations of the outputs.

**[0169]** Smart Phone and App.



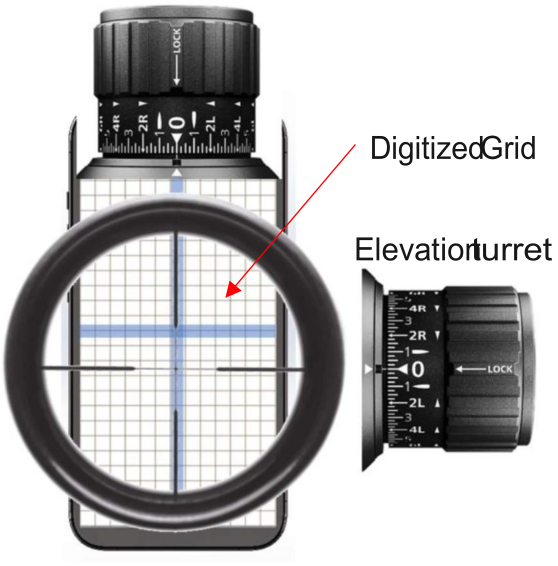
Will be available after boresight setup is complete

Smart Phone App. View

**[0170]** Full setup

**[0171]** Fig. H: Smart Phone mounted as “Digital Collimator”

**[0172]** Windage turret



**[0173]** Fig. I: App. Grid Scope View

**[0174]** The technical details behind the digital collimator are within modern smart phone technology. There are multiple sensors that make this possible all contained within and sold as a standard smart phone platform.

**[0175]** The following is a list of important smart phone sensors the disclosed system may utilize:

- Multidirectional Gravity Accelerometer – for leveling/plumbing and establishing the y-direction
- Led pixel grid (the collimator grid)– for aligning reticles and linking line of sight and line of bore
- Proximity Sensing – sensors for determining Euclidian distances to other objects
- Several types of Cameras – for determining focal length and object gross distances

**[0176]** Adjunct Sensors

**[0177]** In the case when higher fidelity is needed, other types of sensors in conjunction with a smart phone can be used to collect more coordinate system information. There are at least three potential sensors that can be used to define the scope and barrel coordinate systems:

- Scope sensor: Is a wireless transmitter, has an accelerometer sensor for defining the gravity direction vector, has independent high sensitivity x, y, and z proximity sensors, has an integrated high-definition camera
- Bore sensor: Is a wireless transmitter, has independent high sensitivity x, y, and z proximity sensors.
- Muzzle Sensor: Is a wireless transmitter, has an accelerometer sensor for defining the gravity direction vector, has independent high sensitivity x, y, and z proximity sensors.

**[0178]** Accumulation of Error

**[0179]** It is important to note that because the disclosed system may include digital technology that identifies, tracks and stores all the potential accumulation of error at each process step, it can help the user improve performance more quickly compared to the analog collimator process. For example, with the classic analog collimator process, one of the first potential error sources is in how the user affixes the grid and it’s housing to the rifle barrel. In practice, the user manual provides rules-of-thumb, best practices and guidelines for adjusting-out this built-in error. In reality, there is much more unaccounted-for error in this highly manual setup. This means there are error portions in the process that the user will never know about using an analog collimator.

**[0180]** The disclosed system in one example performs a series of calculations that determines the maximum accumulated error based on physical variations of the mount, the smart phone, the screen pixels, the scope reticles and adjustments, levelness of the phone and range distance. Each physical object has a maximum calculated variation that effects the total calculated outputs. This total accumulated error shows up in the form of a probability value for being able to hit the intended target. This probability value is shown to the user through the app. based on their input at each step in the process. Thie variation of each physical object is copied over into the digital twin of the full setup. These two sets of values are constantly compared and adjusted based on the user's input and final record fire data. As the user performs the record fire process, the app. adjusts the probability value based on the user's performance. This can help the user understand what adjustments matter and provides a direct path to quickly understand what improves their performance the most.

**[0181]** The disclosed system includes both a product and a service. The product offering is a physical patent pending device that mounts a smart phone to standard rifle barrels, and a software application that walks the user through the entire Bore Sight process. The service offering is a set of analytical (AI and machine learning) tools, libraries and data management subscriptions that give the user a wide range of analytical tools at their fingertips. Additionally, a broader service offering for Metadata management will be available for research, innovation and defense industries. Additionally, licensing will be available.

**[0182]** This disclosed system may include a smart phone application and barrel mount only. Users will be able to select the barrel mount that fits their rifle and download the corresponding application. There may be limited data management and no AI or machine learning tools available at this level.

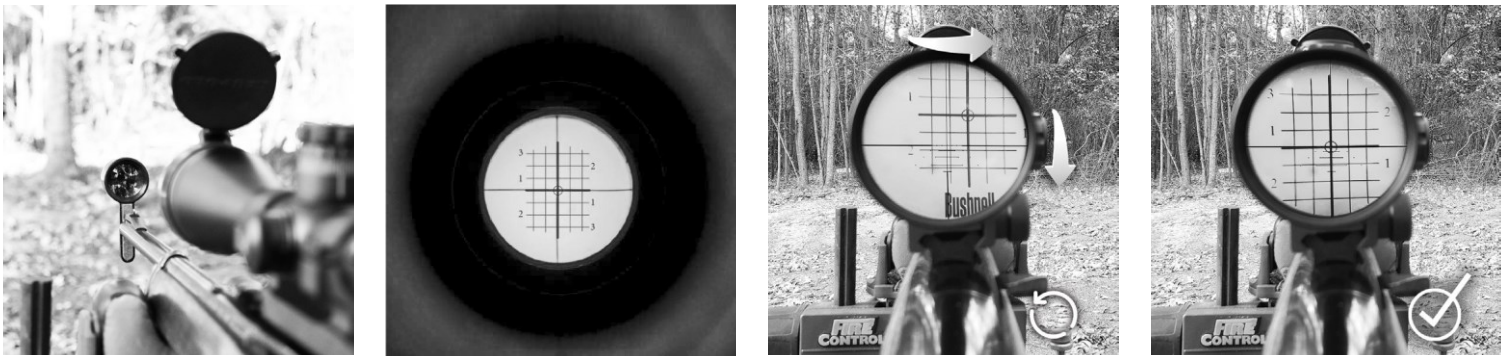
**[0183]** The disclosed system may combine the above system with analytics (AI, machine learning and full data management). Users may be able to track their record fire accuracy/precision progress. AI and Machine learning tools will analyze the data based on several key factors such as, weather, location information, manufacturer’s information, user’s tendencies and other statistics.

**[0184]** Licensing models of the disclosed system will help other research companies, schools and agencies to integrate the mathematical model and method into their product or services. This can be packaged into a library of plug-and-play software tools that will require certain inputs for desired outputs.

**[0185]** The disclosed system has completed “Phase 1” prototyping and testing. “Phase 2” will validate and verify the described mathematical model to real-world use and conditions. Furthermore, Phase 2 will start the initial integration with cloud computing and data management, AI and machine learning analysis.

**[0186]** The user may install the boresighter much like a Bushnell magnetic collimated boresighter on the end of the barrel.

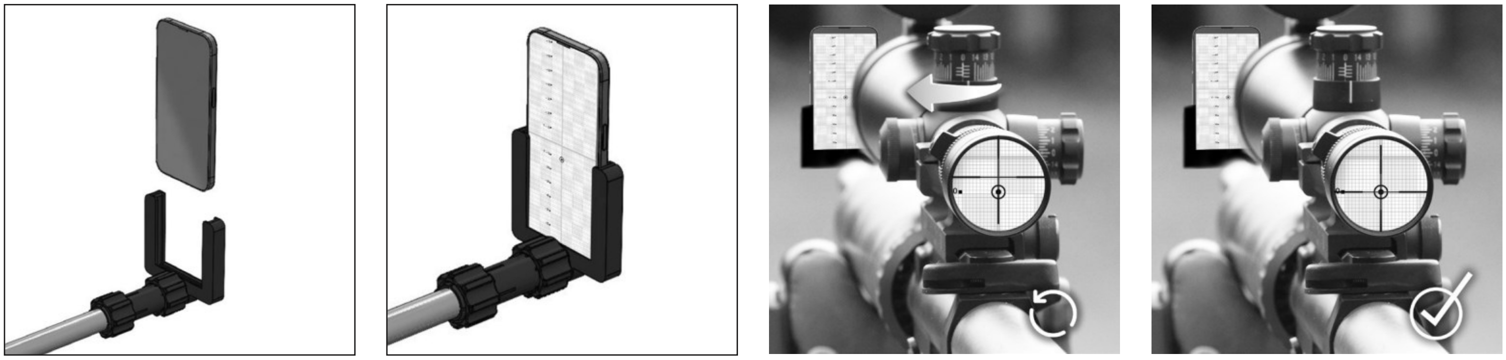
**[0187]** PHOTOGRAPHS OF A MAGNETIC BUSHNELL BORESIGHTER



**[0188]** (L) Collimator placed on muzzle (LC) View through collimator of grid (LC) View through eyepiece of the scope showing collimator grid and scope crosshair overlay. (LR) Windage and elevation turrets are adjusted up and to the right aligning reticle.

**[0189]** Instead of a collimator grid, the disclosed boresighter may have a pixel grid with gridlines and a dot indicator for alignment of sights.

EXAMPLE OF TESTING GRID AND



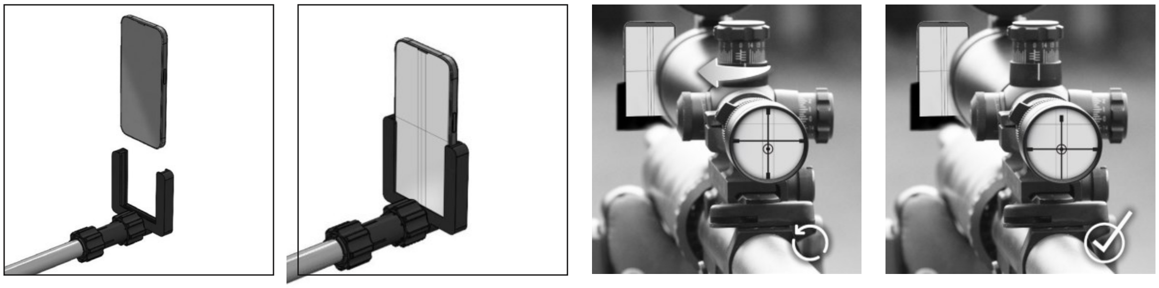
Smartphone inserted into

View of boresighter testing

View through eyepiece of the scope showing testing grid

Elevation turret

**[0190]** EXAMPLE OF POSSIBLE BORE SIGHTER SETUP WITH LCD PIXEL GRID IN BACKGROUND



Smartphone inserted

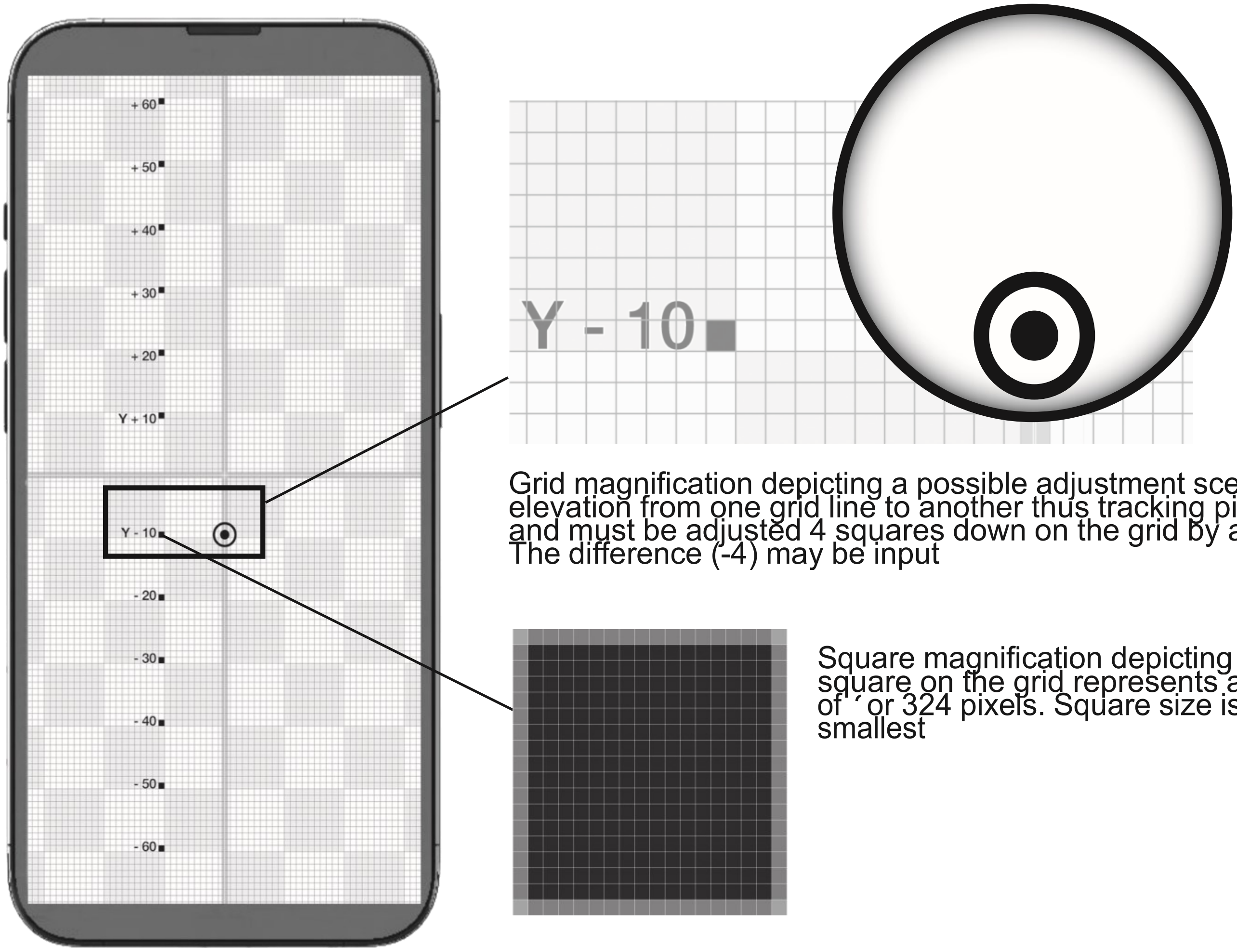
View of

View through eyepiece of the scope showing

**[0191]** While looking through the scope, the user may be able to measure from one grid line to another and input the value into the app. This will give the distance from the rifle crosshairs to the digital boresighter.

**[0192]** PRE-PROTOTYPE TESTING GRID

**[0193]** Example of a testing sheet where pixel tracking is simulated using a fine but visable square grid system.

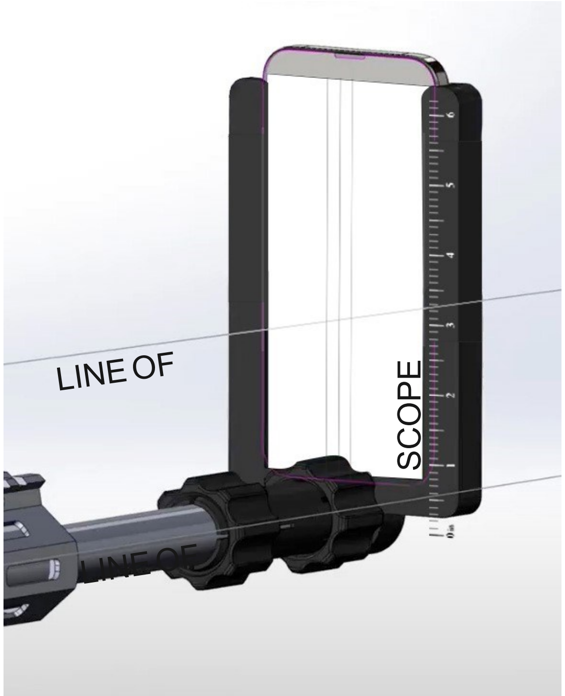


Grid magnification depicting a possible adjustment scenario where
elevation from one grid line to another thus tracking pixels.
and must be adjusted 4 squares down on the grid by adjusting the
The difference (-4) may be input

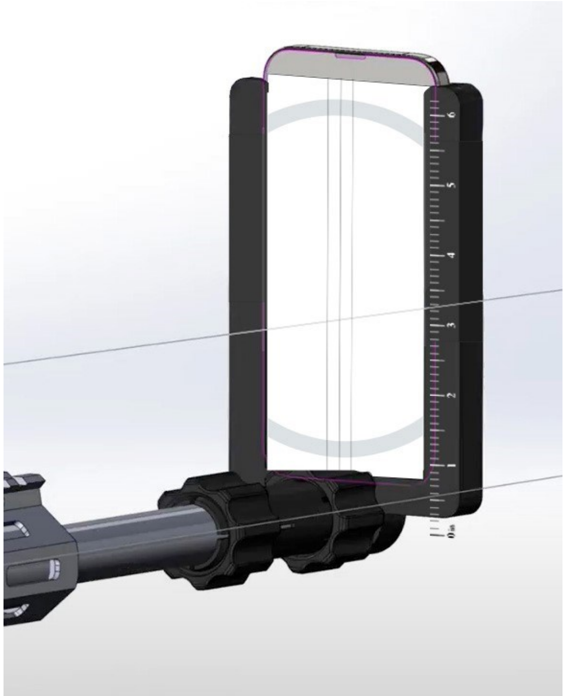
Square magnification depicting a
square on the grid represents a
of ´or 324 pixels. Square size is
smallest

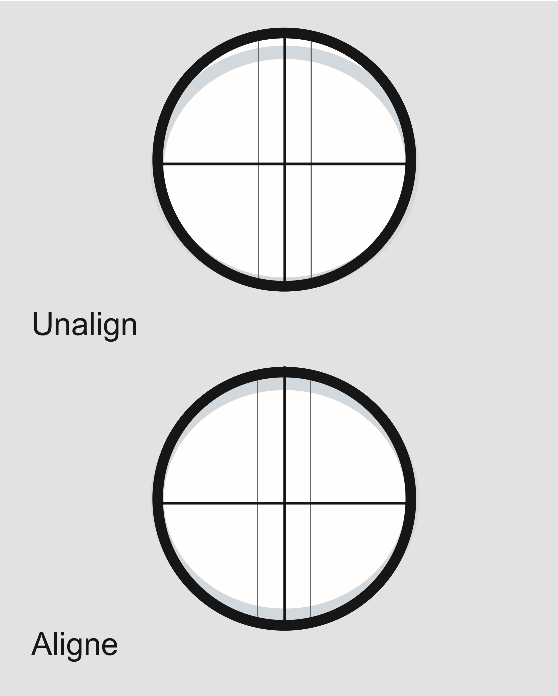
Pre-prototype testing grid with dot indicator for
Illustration based on a 1179 X 2556 resolution I-phone where
represent

**[0194]** The bore sighter should have a system to reference the center of the barrel on the rifle and also may be able to show a scale in inches along side the mounting system bracket at end of the barrel. When moved up or down the scale provides a view of the pixel grid. This is the height of the scope above the rifle bore. The measurement will be fed to the app.

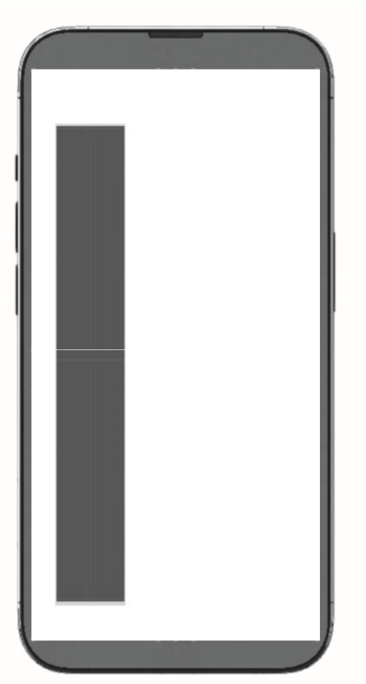


**[0195]** The bore sighter should show a ring that if the user places the rifle scope diameter on the ring, it would confirm that the user has located the center of the scope diameter when the user looks at the reticle on the boresighter.





**[0196]** Example of what the setup may look like depicting the line-of-sight and line-of-bore, and the smartphone mounted in a double-collet smartphone bracket.

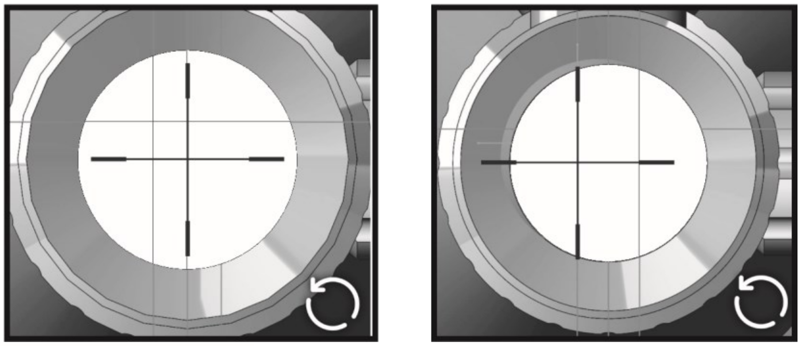


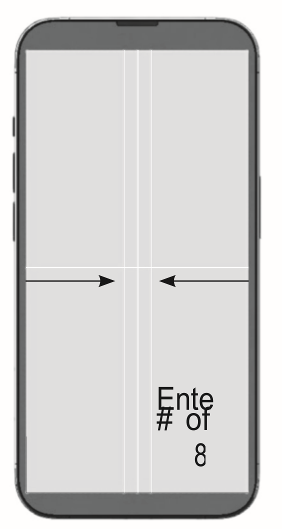
**[0197]** Example of zeroing the scope vertical. Three parallel vertical lines may show windage indication on the X-axis.

**[0198]** The center vertical line depicts the center of the phone and also vertical center of the bore. The vertical line left and right of center are known values the app knows.

**[0199]** The user adjusts the scope crosshairs to one of these lines counting the number of clicks it takes to get there. The number clicks is entered into the app so that the app can calculate how many clicks total angle it took to get to that vertical line. This gives the app a good understanding of how the scope and bore are related to one another before boresighting. Optional variable inputs such as wind and drift may be added to the app affecting horizonal alignment on the X-axis.

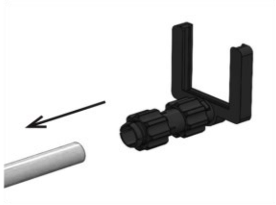
**[0200]** Example of possible crosshair adjustments in the windage direction on the X axis after inputting windage and drift into the app.





**[0201]**

## **[0203]** EXAMPLE OF APP AND SMARTPHONE MOUNTING SYSTEM



Possible smartphone barrel mount

Tightening nuts around barrel

Inserting smartphone into mount and launching app

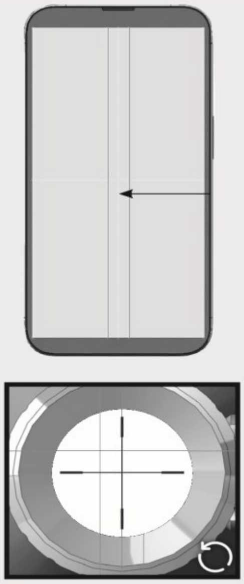
Scope's distance to reticle focal plane (see manufacturers specs) 12 in.

Scope Type (see manufacturers specs) ¼ MOA

Range distance 25 yds.

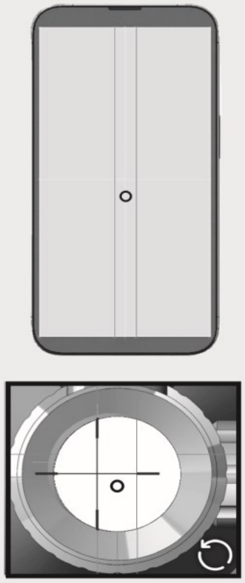
Boresight setup and entering inputs

Leveling barrel mount before boresighting

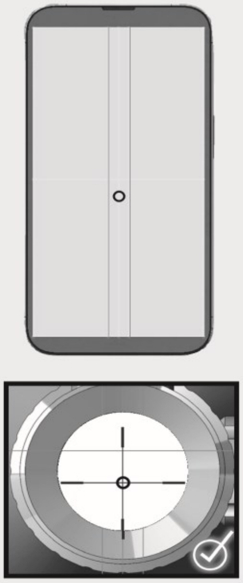


Zero the scope vertical by adjusting vertical crosshair to the center line on smartphone.

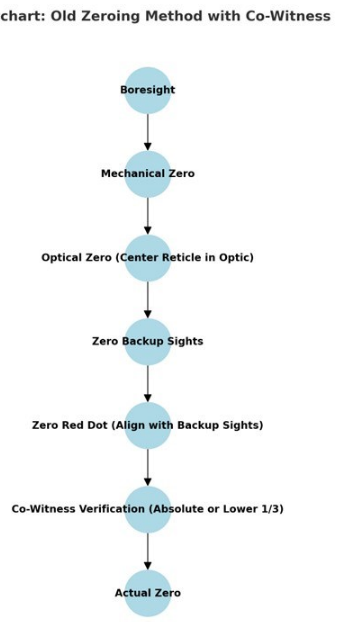
Windage adjustment by aligning vertical crosshair to one of the windage lines and inputing number of turret clicks into the app.

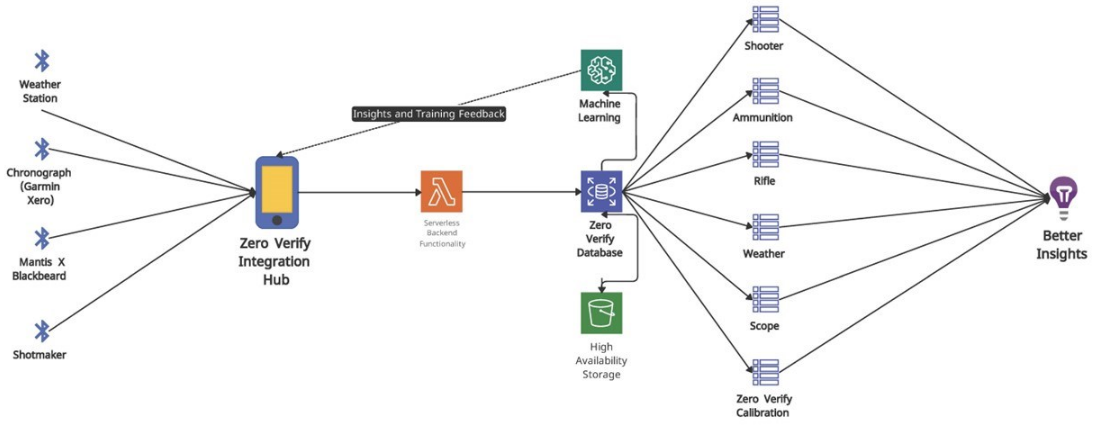


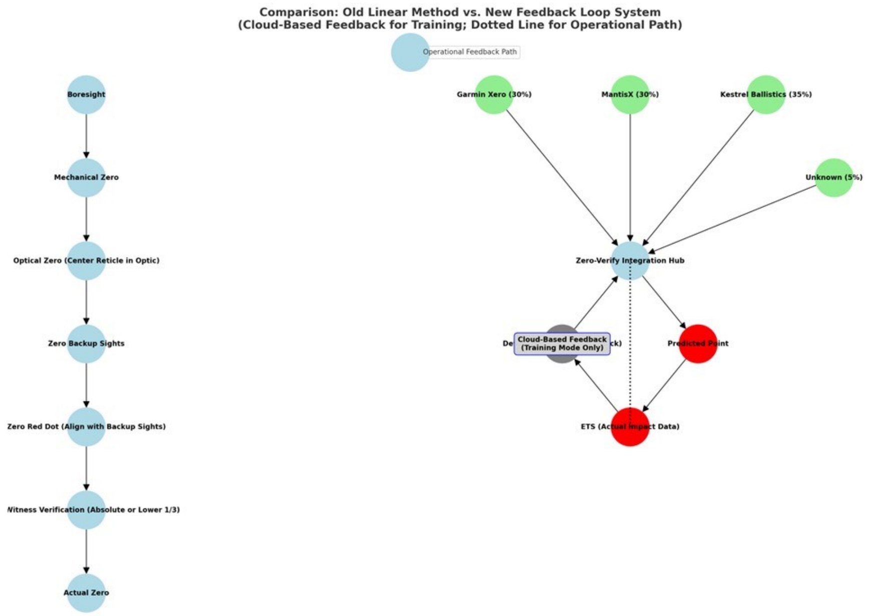
Point appears on smartphone centerline for adjustment indication

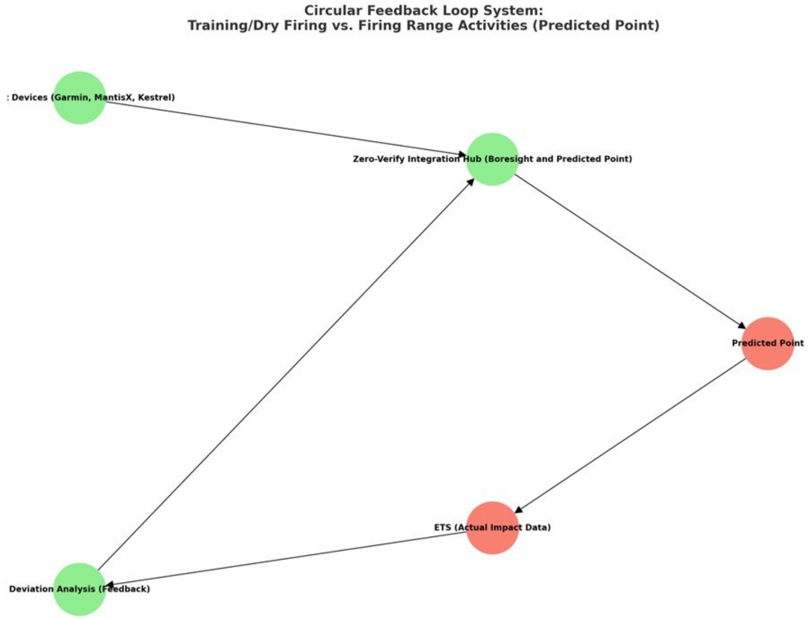


Aligning crosshairs to point


Flowchart: Old Zeroing Method with Co-Witness
Boresight
Mechanical Zero
Optical Zero (Center Reticle in Optic)
Zero Backup Sights
Zero Red Dot (Align with Backup Sights)
Co-Witness Verification (Absolute or Lower 1/3)
Actual Zero


Weather Station
Chronograph (Garmin Xero)
Mantis X Blackbeard
Shotmaker
Zero Verify Integration Hub
Insights and Training Feedback
Serverless Backend Functionality
Machine Learning
Zero Verify Database
High Availability Storage
Shooter
Ammunition
Rifle
Weather
Scope
Zero Verify Calibration
Better Insights





**[0070]** While the present invention is illustrated by description of several embodiments and while the illustrative embodiments are described in detail, it is not the intention of the applicants to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications within the scope of the appended claims will readily appear to those sufficed in the art.

The invention in its broader aspects is therefore not limited to the specific details, representative apparatus and methods, and illustrative examples shown and described. Accordingly, departures may be made from such details without departing from the spirit or scope of applicants' general concept. The invention illustratively disclosed herein suitably may be practiced in the absence of any element which is not specifically disclosed herein.

**[0204]** CLAIMS

**[0205]**

**[0206]** Claims

**[0207]** Therefore I claim:

1. Integrated Sensor System:
    - A system comprising sensors placed in the barrel chamber, at the muzzle end, and at the ocular piece of the scope to measure precise positions and alignments.
    - Includes the ability to assess barrel integrity, correct scope cant, and measure and analyze deviation from boresight to final calibration location by breaking it into contributory variables.
2. Barrel Mount System:
    - A secure and adjustable mount that attaches to the rifle barrel, providing stable support for the bore sighter.
    - Compatibility with various barrel diameters and types through adjustable fittings.
3. Pixel Grid for Digital Collimation:
    - A high-resolution pixel grid displayed on the smartphone screen for precise alignment and collimation.
    - Capability to analyze all degrees of movement once data is captured and stored.
    - Real-time visual feedback through the pixel grid to ensure accurate adjustments.
4. Smartphone Sensor Integration:
    - Utilization of gyroscopic, accelerometer, and camera sensors available in smartphones to detect and measure minute movements for precise alignment.

- Determination of the line of sight, line of bore, and scope height using smartphone sensors.

5. Scope Data Integration:
   - Incorporation of scope data (make and model) and optical measurements to determine the center of the line of sight.
   - Use of scope specifications to enhance the accuracy of the boresighting process.
6. Barrel Measurements:
   - Utilization of barrel diameter and length to determine the precise center of the line of bore.
   - Calculate alignment based on barrel measurements to ensure precision.
7. Mobile Application for Real-Time Feedback:
   - A dedicated mobile application that provides real-time data and visual feedback for boresighting using AR technology.
   - An intuitive user interface for easy operation, adjustments, and data logging capabilities for future reference.
8. Advanced Deviation Analysis and Variable Adjustment:
   - Measure and analyze deviation from boresight to final calibration location, broken down into contributory variables to determine their impacts on the trajectory.
   - Allows users to replace variables such as muzzle velocity, weather conditions, shooter ability, and manufacturing tolerances to predict a new deviation and zero without the need for live firing.
9. Clean Data Collection and Storage:
   - System and method for collecting, structuring, and storing data using the latest technology to ensure clean, pristine data without accumulating dark data.

10. AI and ML Integration:
    - Uses AI and ML to analyze collected data, predict the impact of various variables on trajectory, and continuously improve accuracy.
    - Provides custom recommendations for optimal performance based on the shooter's historical data and trends.
11. Laser and Non-Laser Operation:
    - Capability to use laser technology for visual alignment or operate without laser technology, leveraging integrated sensors and smartphone data for alignment.
12. Research Applications:
    - The system can provide data for military research to enhance marksmanship training and firearm development.
    - Utilization of unclassified data for commercial market research, providing insights into consumer preferences and improving commercial firearm products.
13. Durability and Weatherproofing:
    - A rugged design for the mount and sensors, resistant to dust, water, and other environmental factors, ensuring durability in harsh field conditions.
14. Enhanced Precision and Efficiency:
    - System and method for providing precise boresighting by leveraging advanced smartphone sensors, integrated sensor data, scope data, barrel measurements, AR technology, AI, ML, and a pixel grid for digital collimation, significantly reducing the time and effort required for manual adjustments.
15. Data Logging and Analysis:
    - The mobile application can log and store alignment data, allowing for performance analysis and historical tracking of boresighting accuracy.

16. User-Friendly Interface:
    - A mobile application interface designed for ease of use, enabling quick adjustments and real-time feedback to enhance the user experience.
17. Standalone and Integrated Operation:
    - System and method for standalone use as an upgrade to user technology or integration into advanced fire control systems, such as the Next Generation Squad Weapons Fire Control Sighting System.

# ABSTRACT OF THE DISCLOSURE

**[0208]** The digital collimated bore sighter with integrated sensors, AI, ML, and smartphone integration represents a significant advancement in boresighting technology. By leveraging sensors placed in the barrel chamber, at the muzzle end, and at the ocular piece of the scope, along with smartphone sensors to determine the line of sight, line of the bore (using barrel diameter and length), and scope height, and providing real-time feedback through a dedicated mobile app, this device will revolutionize the way shooters align their firearms, air rifles, and crossbows. Additionally, barrel integrity assessment, scope cant correction, deviation analysis, and adjustment offer a comprehensive and predictive boresighting solution. The device ensures clean data collection, avoids dark data, and employs AI and ML to enhance predictive modeling, improve system accuracy, and provide personalized recommendations. Including a pixel grid for digital collimation further enhances the system's accuracy and allows for detailed movement analysis.