Precision Guided Firearm (PGF)
White Paper
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Precision Guided Firearms

Based on fighter jet technology, Precision Guided Firearms (PGFs) deliver a quantum leap in shooting accuracy. PGFs amplify innate human ability by exploiting target tracking, heads-up-displays, and advanced fire control technology. With PGFs, First Shot Success Probability (FSSP) is significantly increased out to extreme ranges of 1200 yards or more. Precision Guided Firearms are fully integrated systems comprised of a rifle, networked digital tracking optic, guided trigger, and precision loaded ammunition. PGFs are based on standard rifles and have military and commercial applicability. Wireless connectivity allows Precision Guided Firearms to integrate seamlessly with local and wide area networks providing voice, video, and data connectivity to remotely connected devices and systems.

Historical Overview

The club and spear, early weapons of the Pre-Historic Age, were very simple machines. During the Copper Age these simple weapons ultimately gave way to more complex machines like the bow and arrow. The first major leap in weapon systems was enabled by the invention of gun powder by the Chinese around 850 AD.

First generation rifle systems emerged in the late 1700s and early 1800s and incorporated iron sights. Rifles evolved from muskets and the primary advantage of rifles over muskets comes from the actual rifling or “lands” in the gun barrel. These lands impart spin on the projectile thus giving the bullet gyroscopic stability as it penetrates the air resulting in much greater accuracy in comparison with spherical non-stabilized musket rounds.

Second generation rifle systems emerged in the 1800’s principally driven by the advent of the telescopic sight in 1835 and the proliferation of elongated bullets resulting in the extension of effective ranges between 100 and 200 yards.

The Problem – Rifles Shoot Better Than People Can

Third generation rifle systems evolved throughout the 20th century as rifles and ammunition were continually refined greatly extending the potential effective range of shooting systems. However, these advances in rifle and ammunition outstripped human shooting ability. For instance, a high quality 338 Lapua Magnum (LM) rifle with precision loaded ammunition has the potential to be accurate and lethal to 1200 yards but very few people have the ability to engage targets at that range. Incredibly, on 1000 yard e-silhouette targets operational snipers have First Shot Success Probability of only 3%1. Limited by the human nervous system, shooters find it very difficult to hold a steady point of aim at extended target distances. Furthermore, making a long distance shot beyond point blank range requires that a tremendous amount of environmental variables must be comprehended, processed (with a ballistics calculator or other processing device), and “dialed” into a telescopic sight before a shot can be taken. This process takes minutes and perhaps tens of minutes by which time the intended target is likely gone.

In essence there has been an ‘innovation gap.” Rifles and ammunition advanced over time in the face of a paucity of innovation in the areas of optics and fire control. There have been past

1 Raymond Von Wahlde, Dennis Metz, “Sniper Weapon Fire Control Error Budget Analysis” Army Research Laboratory, ARL-TR-2065, August 1999. 300WM.
attempts to close this innovation gap such as digital scopes and telescopic sights with built in range finders but neither solution proved capable of extending the ability of the average shooter.

The Advent Of The Precision Guided Firearm
Precision Guided Firearms (PGF) are fourth generation rifle systems and have application in shooting sports and national defense. PGFs enable shooters of all skill levels to rapidly engage stationary or moving targets out to the maximum effective range of the rifle (e.g. 1200 yards for a 338LM). There are three fundamental elements of a PGF - a networked digital tracking scope, a guided trigger, and a precision standard caliber rifle. The networked digital tracking scope is electronically hard wired to the guided trigger. PGFs have only recently become economically and technically feasible. The arrival and proliferation of smart phones accelerated innovation in sensors and displays while driving down the costs of such components through sheer volume.

Amplifying Innate Human Ability
PGFs incorporate computer vision and object tracking technologies to help the shooter launch a precise shot. A shooter “tags” a target which designates the shooters intended shot impact point (Figure 1 Tag, Track, Fire Sequence). The networked digital tracking scope then tracks the target and maintains a visual indicator of the intended impact point. The scope instantly computes a firing solution based on range, wind, ballistic curves, temperature, humidity, incline, cant, Coriolis effect, barrel wear, zeroing shift, and other variables related to shot accuracy. The reticle of the PGF instantly adjusts to represent the precise firing solution. The shooter realigns the reticle with the designated impact point and pulls the trigger. If the barrel is not perfectly aligned to make the shot at time of trigger pull trigger pressure increases to defer launch until the barrel is in the proper position to launch. Once the barrel is properly aligned by the shooter the trigger deflates to normal trigger pressure and shooter pull force launches the round. The only way around can be launched is through human pull force. The networked digital tracking scope is incapable of launching a round. The shooter is always in the loop – tagging, aiming, and pulling the trigger.

![Figure 1 Tag, Track, Fire Sequence](image)

Precision Guided Firearm Components
To ensure accuracy at range a PGF is a fully integrated matched component shooting system – scope, rifle, and ammunition (Figure 2). The scope is a networked digital tracking scope (Figure 3) and PGF rifles are low dispersion high accuracy heavy barreled guns with state-of-the-art guided triggers. The ammunition is precision loaded and matched to a particular PGF type.
Figure 2

Figure 3
Precision Guided Firearms Primary Capabilities

Heads-Up Display (HUD)
Similar to a fighter jet HUD, the PGF provides the shooter with visuals to aid shot set up and enhance the shooting experience (Figure 4). Similar to a fighter jet HUD, the PGF HUD is overlaid into the shooters field of view in a non-obscuring manner. Typical HUD elements include range to target, wind speed (manually set by the shooter), shot angle, rifle cant, compass direction, battery life, and zoom setting.

Modes of Operation
PGFs have two modes of operation, Traditional and Advanced. In Traditional Mode the PGF operates just as a standard rifle operates today. Target tagging and tracking are disabled and the guided trigger acts as a traditional trigger with no “pushback” on the shooter. The reticle is a standard duplex reticle zeroed at 100 yards. Automatic ballistics is disabled.

In Advanced Mode all of the extended range capabilities are operational – tagging, tracking, guided trigger, and automatic ballistics.

High Powered Optics
Precision Guided Firearms have stronger optics than a typical rifle scope. More magnification is necessary because of the range at which targets are now engaged (up to 1200 yards) compared to target engagements of traditional rifle. A typical PGF will have native optical zoom of 30x to 35x.
Long Distance Range Finder
PGF range finders tend to have more power that standard Commercial-Of-The-Shelf range finders. A PGF range finder will predictably range semi-reflective targets out to 1500 yards.

Wind Rocker
Current PGFs allow the shooter to rapidly enter in cross-winds from a simple rocker button on the top of the scope. Wind is entered in MPH up to 40mph. The wind setting is used by the automatic ballistics solver.

Stabilized Target Tagging
When a shooter presses the tag button the target image and the reticle are auto-stabilized by the scope. This stabilization allows the shooter to quickly and accurately tag a target.

Automatic Ballistic Solution
The networked digital tracking scope instantly calculates a precise firing solution for a given shot. The Automatic Ballistic Solution accelerates target engagement times and eliminates shooter error due to mis-estimation of conditions. The Automatic Ballistic Solution is continuously adapting to all environmental and positional conditions relative to an acquired target including range, wind, target velocity, temperature, pressure, incline/decline, cant, Coriolis effect, and barrel temperature (cold barrel vs, warm barrel) such that the shooter has no need to perform calculations, adjust turrets (there are no turrets on a Precision Guide Firearm), estimate holdovers for wind, or hold for lead on moving targets. The PGF has a lifecycle ballistic capability that adjusts ballistic solutions based on the age of the barrel predicated on how many shots have been fired. Internal ballistics change predictably as more rounds are fired. This prediction curve is an input to the automatic ballistic solution. All environmental and positional conditions serve as inputs to the Precision Guided Firearms embedded ballistics computers. The calculated firing solution is then used to instantly adjust the view area and reticle to reflect the calculated firing solution. This entire process from tag to solution is less than 1 second.

Target Tracking
Upon designation by the shooter, a Precision Guided Firearm utilizes computer vision based digital image processing techniques to track targets. Images from the optical sensors are analyzed and targets are identified and tracked using techniques such as edge detection, blob detection, fast fourier transforms and correlation. Moving target velocity is determined using image registration techniques and an internal Inertial Measurement Unit (IMU) to track the scene background relative to the target. Moving target velocity is used by the automatic ballistic reticle to set moving target lead. By tracking the target and the barrel position relative to the target the networked digital tracking scope can determine a precise launch time for a given round.

Guided Trigger
PGF Triggers are wired directly to the Networked Digital Tracking Scope. The scope can control the trigger weight in order to guide the shooter; when the shooter is off target trigger weight is temporarily inflated which defers launch. When the shooter precisely intersects the target trigger weight is decreased allowing normal trigger pull force to launch the round. The
Guided Trigger is based on the Jewel trigger and includes sensors and control electronics to ensure reliable and accurate firing.

**Barrel Reference System**

All PGFs are factory zeroed electronically eliminating human zeroing error. Each PGF incorporates a Barrel Reference System (BRS) in order to maintain the factory zero. The BRS is an eye-safe laser based system mounted to the barrel. The BRS laser is injected into the networked digital tracking scope to continuously monitor any alignment shift between the barrel and the scope. Microscopic shifts between the barrel and scope are measured by the BRS and provided to the automatic ballistics solver. In effect, the scope and barrel are always zeroed so less lead goes into the environment and off target shots are less likely.

**Smart Phone Centricity**

PGFs are configured and managed via a smartphone or tablet device running either Apple iOS or Android operating systems. Videos and photos can be downloaded from the scope to a smart device.

**Social Media**

PGFs record videos and photos each time a target is tagged and a shot is fired. The shooter is able to voice annotate his video as he is shooting. The built-in PGF microphone is highly sensitive allowing the shooter to whisper if necessary. All photos and videos can be uploaded to a smartphone gallery and shared on Facebook, Twitter and other social media sites.

**Streaming Video**

PGFs include Wi-Fi video servers. Any Wi-Fi enabled device such as a smartphone, tablet or PC can be used to see what the shooter sees in real time (Figure 5). In the future, if the shooter is in a 4G enabled zone then the shooter view can be streamed to any smart device around the world.

![Figure 5](image-url)
Software Extensibility
Much like a smartphone Precision Guided Firearms are functionally extensible through software applications and upgrades. New PGF capabilities are purchased on iTunes or the Android app store. In essence, Precision Guided Firearms are “evergreen” systems meaning that new capabilities can be added for the life of the firearm through software applications and enhancements. For instance, if a breakthrough in ammunition or ballistics occurs, a fielded Precision Guided Firearm can be software upgraded with these new capabilities. These applications might be developed by Precision Guided Firearm manufacturers or by third party software developers. Applications available today include streaming video viewers that allows a remote user to connect to a scope in the field and view live streaming video of what the shooter is seeing. Some Precision Guided Firearms include a microphone allowing the user to voice annotate video and talk live with remote users. Capabilities such as prey scoring, prey identification, reticle packages, post-hunt mapping, night vision, and proximity warning systems (other hunters in vicinity), are all feasible on an open platform Precision Guided Firearm.

Primary Uses
Extended Range Fair Chase Hunting
The PGF enables extended range fair chase hunting. Today, the fair chase spectrum starts with bows at 10 to 20 yards and ends with point-blank rifle hunting at 80 to 200 yards (Figure 6). In some states point-blank hunting is aided by prey baiting. With the PGF hunters can move beyond point-blank baited hunting in a blind to true active-tracking (on foot) fair chase pursuit of game.

<table>
<thead>
<tr>
<th>Bow Hunting</th>
<th>Point Blank Rifle Hunting</th>
<th>PGF Hunting</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 20</td>
<td>80</td>
<td>200</td>
</tr>
<tr>
<td>1200 Yards</td>
<td></td>
<td></td>
</tr>
</tbody>
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Figure 6

PGF Role in Mentoring
The streaming video capabilities enable mentors to be actively involved in a new hunter’s shot. For instance a father, via his smartphone view his son’s intended target and tag point prior to shot launch. He can quickly advise his son as to the acceptability of harvesting the intended prey (does it meet state requirements as far as size, age, antler geometry, etc.), determine if the intended impact point is ethical and humane, and generally guide his son through the shot.

PGF Enables Mindful Hunting
PGFs create a “moment of introspection” that is normally not available when taking a shot. First, the PGF target tagging process sharply focuses the hunter on choosing an impact point that is humane and ethical. When tagging the shooter is less likely to be overcome by adrenaline and his or hers mind is not cluttered with thoughts of when the gun will go off or if
they are steady enough – their entire attention is the proper tag point. Second, the hunter is given a moment of reflection post tag before pulling the trigger. During this moment the hunter has a second chance to decide if the shot is an ethical and humane shot and if the prey meets local regulations.

**Potential to Grow Hunting and Shooting Markets**
The youth of today are immersed in technology. They are adept users of smartphones, video games, personal computers, and the internet. They have an expectation that products are technologically sophisticated. The technologically advanced state-of-the-art PGF is likely to appeal to emerging hunters and shooters and bring people into the market that don’t find point-blank hunting appealing. The PGF social media and sharing capabilities will likely create a viral awareness of hunting and bring a level of cache’ to the sport.

**Safari Hunting**
Safari hunting is an expensive proposition. To make such an investment and fail to get an intended trophy is disappointing. The PGF significantly raises the probability of success well beyond point-blank range. Additionally, Professional Hunters (PH) can utilize PGF streaming video to more closely guide his client. Calling out targets, redirecting the shooters aim, and confirming tag points.

**Western Hunting**
Trophy Elk, Moose, Bear and other North American big game are often observed well beyond point blank range. While the average hunter often attempts these long shots success rates are low. The PGF makes these shots probable. Often these hunts are guided and the guide can utilize the PGF streaming video to more closely guide his client. Calling out targets, redirecting the shooters aim, and confirming tag points.

**Texas Hunting**
White tail and mule deer are the primary game animals in Texas. Most deer are taken in baited situations from a blind at point-blank-range. The PGF enables active –tracking fair chase pursuit of native deer and exotics such as Axis deer and Blackbuck antelope.

**Wildlife Management**
In order to protect habitat and keep species healthy many states have licensed managed land permits. These permits allow harvesting game in numbers beyond a typical hunting license. Often times the number of animals to be harvested can be daunting. The PGF increases success rates efficiently improving habitat and species health.

**Predator Control**
Predators such as coyotes, feral hogs, raccoons, and prairie dogs cause tens of millions in damage to habitat, ranch land, crops, and livestock. Controlling the predator population is an ongoing challenge and the PGF brings a high degree of efficiency to the process.
Target Shooting and Competitive Shooting
The average shooter at a range is effective out to 250 yards. They look wistfully at the 1000 yard targets and marvel at how a sniper could make such a shot. With a PGF the average shooter can now experience the thrill of hearing the impact-echo on a metal e-silhouette out to 1200 yards static or moving. The PGF may drive the development of more long range shooting facilities and bring more people into the sport of recreational target shooting.

The PGF may drive the creation of more challenging long range shooting competitions which include 1200 yard movers and much smaller targets and time trial type events. The PGF will likely be banned from traditional long range competitions.

Law Enforcement
The PGF enables local and regional law enforcement organizations to more safely handle long range encounters. Hostage situations and criminal stand offs can be handled with less risk to the public while ensuring mission success. Training times and training costs are greatly reduced and shooting competency is highly persistent.

National Defense
The PGF is likely to be a game changer in the current theatres of war. In effect, any soldier becomes an extraordinary marksman when armed with a PGF. Within hours of starting basic training a soldier can consistently overcome targets at extreme ranges. The PGF will be a tremendously effective weapon system in many types of war including nation state conflicts, unconventional warfare, and extremist engagements.

The PGF reduces training time, enables mastery persistence (follow-up training is minimal), collapses target engagement times from minutes to seconds, and increases success rates dramatically. The PGF creates substantial squad overmatch capability and delivers asymmetric battle stand-off ranges. The advent of the PGF is likely to change doctrine and tactics and has the potential to act as a deterrent to war.

The Future of Precision Guided Firearms
Current PGFs are bolt action long range platforms – 338LM (1200 yards) 300WM (1000) yards. PGF systems are likely to arrive on .223 and .308 semi-automatic gun platforms and mid-range hunting platforms such as 30-.06, 7mm, and .243 calibers. As in any new technology price points will decline in accordance with the manufacturing learning curve.