ISSF Pistol Sighting Simulator

Mathematical Foundation, Physics Reference, and User Guide

Documentation for `simulator.js` / `index.html`

June 2026

Contents

1 Introduction

The ISSF Pistol Sighting Simulator is a browser-based pedagogical tool that models the optics and physics of *open-sight* (notch-and-post) pistol marksmanship, shot one-handed and unsupported (free arm). Unlike the rifle, whose closed aperture (diopter) sight is treated in the companion ISSF Rifle Sighting Simulator, the pistol sight picture is a three-element alignment: the shooter's eye, the rear-sight notch, and the front post, held against the target [1, 2].

The simulator lets students and athletes isolate, vary, and observe the effects that are difficult to separate on the range:

1. **Sight-alignment (angular) error**—how a small displacement of the front post within the rear notch is amplified into a large miss downrange (section 3).
2. **Arm sway (wobble)**—why a *parallel* movement of the whole pistol hurts far less than a constant alignment error (section 4).
3. **Visual accommodation**—why the eye can focus on only one plane and must focus on the front sight (section 5).
4. **Hold**—the six-o'clock (sub-six) hold versus the centre hold (section 6).
5. **Mechanical sight adjustment**—how rear-sight clicks translate into impact shifts (section 7).
6. **Exterior effects**—gravity, cant, and wind (section 8).

Each phenomenon is developed in its own section with the competitive-shooting context, a physical explanation, a mathematical derivation, a reference to the implementing JavaScript code, and suggested exercises with the simulator.

2 User Manual

2.1 Running the Simulator

Open `index.html` in any modern web browser. No build step or dependency is required; all logic lives in `simulator.js` and runs client-side on an HTML5 canvas. On tireur.org the simulator is embedded through a PHP wrapper that supplies the same control panel and loads `simulator.js`.

2.2 Interface Layout

The canvas is split into two viewports:

- **Left — sight picture.** The shooter's view of the rear notch, the front post, and the target. A CSS blur is applied per plane to simulate visual accommodation (section 5).
- **Right — target face.** The scoring rings, the aiming mark, and the predicted/served shots.

Below the canvas, control panels expose the target and aiming zone, the wobble and wind, the sight alignment, and the mechanical adjustments, together with a shot table and session statistics (average, last shot, dispersion).

2.3 Controls Reference

The on-screen panels drive the simulator. When the canvas has focus (mouse over it), the following keyboard shortcuts are also available:

Input	Action
A / **D**	Horizontal alignment error $\mp/\pm\,0.02$ mm (0.05 with **Shift**)
W / **S**	Vertical alignment error $\mp/\pm\,0.02$ mm
Z / **X**	Firearm cant $\mp/\pm\,0.5°$
Space	Fire a shot
R	Reset the sights

2.4 Quick-Start Walkthrough

1. Open the simulator; the default view is a 10 m air-pistol sight picture with the sights perfectly aligned.
2. Set the focus to *Target sharp, sights blurred* and note how alignment becomes impossible to judge—the classic beginner error.
3. Introduce a small alignment error (**A**/**D**) and fire (**Space**); observe how the error is amplified on the card.
4. Compare with wobble alone (preset *Confirmed*, sights aligned): the impact stays much closer to centre.
5. Switch to the 25 m target and raise the wind to see the drift grow.

3 Sight-Alignment (Angular) Error

3.1 The Issue for Competitive Shooters

On an open-sight pistol the shooter aligns the front post inside the rear notch (equal light on either side, tops level) and holds that assembly on the target. A small lateral or vertical displacement of the post within the notch is a tiny angular error of the wrist—but, projected to the target, it becomes a large miss.

3.2 Why It Matters

Sight alignment dominates pistol accuracy because the *sight radius* b (the distance between the rear notch and the front post) is short compared with the range D. The lever arm D/b multiplies every alignment error. This is the single most important reason a pistol is harder to shoot than a rifle of equal intrinsic precision [2].

3.3 Physical Explanation and Illustration

Figure 1 shows the geometry. An offset e of the front post relative to the line through the eye and the rear notch subtends an angle $\theta \approx e/b$. The same angle, carried to the target at range D, produces a displacement

$$\Delta \;=\; D\,\tan\theta \;\approx\; \frac{D}{b}\,e.$$

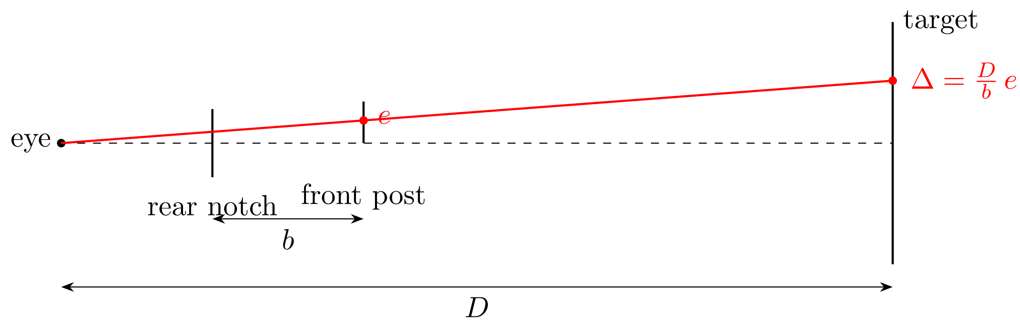

Figure 1: Sight-alignment error. A front-post offset e over the short sight radius b is amplified to $\Delta \approx (D/b)\,e$ at the target.

3.4 Mathematical Model

With sight radius b and range D, a small-angle approximation gives the target displacement from an alignment error $\mathbf{e} = (e_x, e_y)$:

$$\Delta_x = \frac{D}{b}\,e_x, \qquad \Delta_y = \frac{D}{b}\,e_y. \tag{1}$$

For the defaults $b = 220$ mm and $D = 10\,000$ mm, the gain is $D/b \approx 45.5$: an alignment error of only 0.1 mm becomes ≈ 4.5 mm on the card. At $D = 25\,000$ mm the same 0.1 mm becomes ≈ 11.4 mm.

3.5 Implementation

```
const distScale = activeTarget.distance_mm / L_SIIGHT_RADIUS_MM; // D / b
const alignmentShiftX = alignErrX * distScale;
const alignmentShiftY = alignErrY * distScale;
```

The alignment vector is then rotated by the cant angle (section 8) before being added to the impact point.

3.6 Simulator Exercises

1. Set the alignment error to 0.1 mm horizontally and read the target shift; verify it matches $D/b \times 0.1$ mm.
2. Switch from 10 m to 25 m and confirm the same alignment error now costs more than twice as many millimetres.

4 Arm Sway (Wobble): Angular vs. Parallel Error

4.1 The Issue for Competitive Shooters

Held at arm's length with one hand, the pistol never stops moving. This *wobble area* is a *parallel* displacement of the whole sight system relative to the target: the sights stay aligned, but the aligned assembly drifts over the aiming mark.

4.2 Why It Matters

A parallel error maps *one-to-one* onto the target (gain 1), whereas an alignment error is amplified by D/b (eq. (1)). Hence the classic coaching rule: it is better to release a shot with a small wobble and perfect sight alignment than with the gun frozen on centre but the sights misaligned [2].

4.3 Physical Explanation and Illustration

Figure 2 contrasts the two errors. An alignment error is taken over the short sight radius and amplified by D/b, while a parallel wobble of the correctly aligned assembly is carried to the target unchanged.

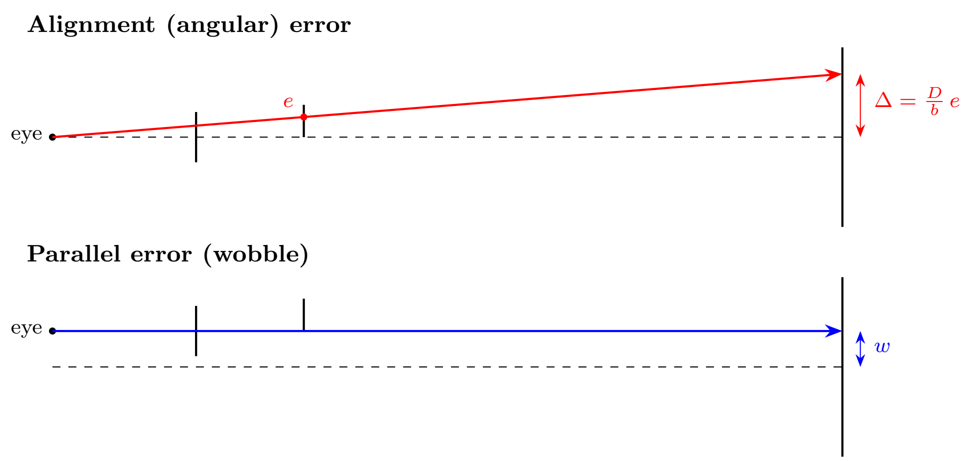

Figure 2: Angular vs. parallel error (schematic, not to scale). A front-post offset e is amplified to $\Delta = (D/b)\, e$ (top); a parallel wobble w of the aligned assembly maps one-to-one to the target (bottom).

4.4 Mathematical Model

The wobble is modelled as a quasi-periodic sum of sinusoids with amplitude set by the stability preset. Writing A for the preset scale, the displacement is

$$w_x(t) = 2A\big[0.60\sin(1.1\,t) + 0.35\sin(0.35\,t) + 0.05\cos(2.1\,t)\big], \tag{2}$$

$$w_y(t) = 2A\big[0.50\cos(0.9\,t) + 0.40\sin(0.45\,t) + 0.10\sin(1.8\,t)\big], \tag{3}$$

which the aiming point inherits directly, $a_{x,y} = m_{x,y} + w_{x,y}$, with no D/b amplification. The presets are $A = 0$ (bench), 2 (expert), 5 (confirmed), and 10 (beginner), in millimetre scale.

4.5 Implementation

```
const baseAmp = wobbleAmp * 2.0;
wobbleX = baseAmp * (Math.sin(wobbleTime*1.1)*0.6 + Math.sin(wobbleTime*0.35)*0.35
     + Math.cos(wobbleTime*2.1)*0.05);
wobbleY = baseAmp * (Math.cos(wobbleTime*0.9)*0.5 + Math.sin(wobbleTime*0.45)*0.4
    + Math.sin(wobbleTime*1.8)*0.1);
```

4.6 Simulator Exercises

1. With the *Beginner* preset and perfect alignment, fire ten shots and note the group size; it reflects the wobble amplitude almost directly.
2. Repeat with a fixed 0.1 mm alignment error and the *bench* preset: the group is tight but badly off-centre—the amplified angular error.

5 Visual Accommodation (Front-Sight Focus)

5.1 The Issue for Competitive Shooters

The eye can sharply focus on only one plane at a time. Three planes compete for focus: the rear notch (≈ 0.5 m), the front post (≈ 0.7 m), and the target (10–25 m). Beginners instinctively focus on the target; experts focus on the *front sight*.

5.2 Why It Matters

Sight-alignment error (section 3) can only be judged if the front post and notch are sharp. Focusing on the target blurs the sights and makes alignment guesswork, reintroducing the most heavily amplified error of all. A sharp front sight is therefore the prerequisite for everything else.

5.3 Physical Explanation

Depth of field around the focused plane is finite; planes outside it form a blur circle whose diameter grows with the dioptric distance from focus. The simulator renders this with a per-plane Gaussian blur (in pixels), choosing the front-focus profile as the "correct" one (fig. 3):

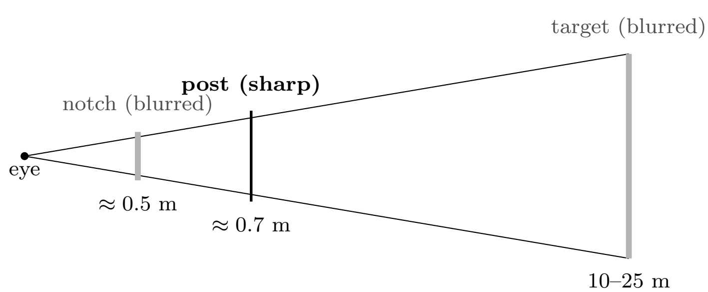

Figure 3: Visual accommodation (schematic, not to scale). The eye focuses on a single plane; the front post is kept sharp while the rear notch and the target are left blurred.

Focus	Front post	Rear notch	Target
Front (correct)	0	1.5	8
Target (error)	6	9	0
Rear	2.5	0	9

5.4 Implementation

```
function getBlurFilters() {
  if (focusType === "front")  return { front: 0,   rear: 1.5, target: 8 };
  if (focusType === "target") return { front: 6,   rear: 9,   target: 0 };
```

```
  return { front: 2.5, rear: 0, target: 9 }; // rear focus
}
```

5.5 Simulator Exercises

Cycle through the three focus modes while holding a small alignment error. Only in front-focus is the misalignment clearly visible—demonstrating why the front sight must stay sharp.

6 Hold: Six-O'Clock vs. Centre

6.1 The Issue for Competitive Shooters

Two holds are common in precision pistol. In the *six-o'clock* (or sub-six) hold the shooter places the front post just under the black bull, leaving a thin band of white; the sights are zeroed so the bullet still strikes the centre. In the *centre* hold the point of aim equals the point of impact.

6.2 Why It Matters

A black front post against a black bull is hard to align precisely. The six-o'clock hold detaches the post from the bull against a white background, sharpening the alignment and elevation judgment. The trade-off is sensitivity to changes in light and bull size.

6.3 Mathematical Model

The six-o'clock hold offsets the aiming mark below centre by the bull radius plus a small white margin, $h_{\text{hold}} = r_{\text{black}} + 6$ mm, and the sight zero adds the same amount back, so a correctly aligned shot lands at the centre:

$$m_y^{(0)} = -h_{\text{hold}}, \qquad \text{zero offset} = +h_{\text{hold}}. \tag{4}$$

6.4 Implementation

```
const holdOffset_zero = (holdType === "6oclock")
                        ? (activeTarget.black_r + 6.0) : 0.0;
// aim point default: mouseAimY = -(black_r + 6.0) for the six-o'clock hold
```

7 Mechanical Sight Adjustment (Clicks)

7.1 The Issue for Competitive Shooters

The rear sight is adjustable in windage and elevation by detented clicks. A target-pistol click is typically 0.1 mrad, moving the zero by a fixed, range-dependent amount.

7.2 Mathematical Model

For an angular click value $\delta = 0.1$ mrad and range D, one click moves the impact by $D\,\delta$:

$$\Delta_{\text{click}} = D\,\delta \approx \begin{cases} 1.0 \text{ mm} & D = 10 \text{ m}, \\ 2.5 \text{ mm} & D = 25 \text{ m}. \end{cases} \tag{5}$$

A positive windage click moves the impact right; a positive elevation click moves it up.

7.3 Implementation

```
const clickX_mm = clicksX * activeTarget.click_value_mm;
const clickY_mm = clicksY * activeTarget.click_value_mm;
```

8 Exterior Effects: Gravity, Cant, and Wind

8.1 Gravity

The projectile falls under gravity during its time of flight $t = D/v$. The drop is [3]

$$y_{\text{drop}} = \tfrac{1}{2}\, g\, t^2 = \tfrac{1}{2}\, g \left(\frac{D}{v}\right)^2. \tag{6}$$

The sights are zeroed for this drop, so it matters only through the cant interaction below. With $v = 175$ m/s at 10 m the drop is a fraction of a millimetre; with $v = 330$ m/s at 25 m it is a few millimetres.

8.2 Cant

Tilting the pistol by an angle ϕ about the bore rotates the sight correction (sight height h plus zeroed drop) out of the vertical, producing *both* a lateral shift and a vertical loss—the canting paradox [4]:

$$\Delta x_{\text{cant}} = (h + y_{\text{drop}}) \sin\phi, \tag{7}$$

$$\Delta y_{\text{cant}} = (h + y_{\text{drop}})(1 - \cos\phi). \tag{8}$$

The alignment error vector (1) is likewise rotated by ϕ. Figure 4 shows how the upright sight-height correction, once canted, splits into a lateral shift and a vertical loss.

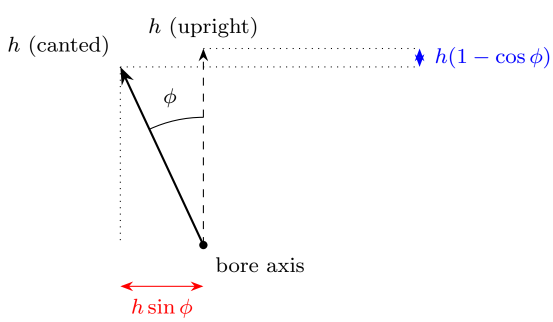

Figure 4: The canting paradox. Tilting the pistol by ϕ rotates the upright sight-height correction h, producing both a lateral shift $h\sin\phi$ and a vertical loss $h(1 - \cos\phi)$.

8.3 Wind

Only the crosswind (lateral) component deflects the bullet appreciably at pistol ranges. With wind speed w from clock direction φ ($\varphi = 90°$ from the right) and a range-dependent factor k,

$$\Delta x_{\text{wind}} = -\, w\, k\, \sin\varphi, \qquad \Delta y_{\text{wind}} = 0, \tag{9}$$

with $k = 0.5$ mm/(m/s) at 10 m and 1.5 mm/(m/s) at 25 m.

8.4 Total Impact

Collecting all terms, the impact point (mm from centre) is

$$X = a_x + \Delta_x^{\text{align}} + \Delta x_{\text{cant}} + \Delta x_{\text{wind}} + \Delta_x^{\text{click}}, \tag{10}$$

$$Y = a_y + \Delta_y^{\text{align}} - \Delta y_{\text{cant}} + h_{\text{hold}} + \Delta_y^{\text{click}}, \tag{11}$$

where $a_{x,y}$ is the aim point including wobble.

9 Scoring Model

9.1 ISSF Decimal Scoring

The score is a function of the radial distance $\rho = \sqrt{X^2 + Y^2}$ of the shot centre from the target centre, interpolated linearly within each ring so that a decimal value 1.0–10.9 is produced; the innermost zone is the *inner ten* ("mouche"). Ring spacing is 8 mm at 10 m and 25 mm at 25 m.

9.2 Implementation

```
const dist = Math.hypot(x_mm, y_mm);
// 10 m: inner ten within 2.5 mm; rings every 8 mm
const ringIndex = Math.floor((dist - 5.75) / 8.0);
const fraction  = (dist - (5.75 + ringIndex*8.0)) / 8.0;
return { score: Math.max(1.0, 9.9 - ringIndex - fraction), isMouche: false };
```

10 Implementation Notes

10.1 Coordinate System

All physical quantities are in millimetres on the target plane; the origin is the target centre, x to the right and y upward. The left viewport draws the sight picture at `PX_PER_MM_SIGHT = 25` px/mm; the right viewport draws the target face at the per-target `scale_right`.

10.2 Physical Constants and Defaults

Symbol	Code	Default
Sight radius b	`L_SIIGHT_RADIUS_MM`	220 mm
Sight height h	`sightHeightOffset`	45 mm
Click value δ	`click_value_mm`	1.0 / 2.5 mm
Wind factor k	`wind_factor`	0.5 / 1.5 mm/(m/s)
Muzzle velocity v	`muzzle_velocity_mps`	175 / 330 m/s

The identifier `L_SIIGHT_RADIUS_MM` retains its original (misspelled) spelling from the source for fidelity to the code.

References

[1] International Shooting Sport Federation, *ISSF Official Statutes, Rules and Regulations*, ISSF, 2024 edition.

[2] National Rifle Association, *NRA Guide to Pistol Marksmanship*, NRA Publications, 2014.

[3] R. L. McCoy, *Modern Exterior Ballistics*, 2nd ed. Schiffer Publishing, 2012. ISBN 978-0-7643-3825-0.

[4] R. A. Rinker, *Understanding Firearm Ballistics*, 6th ed. Mulberry House Publishing, 2005. ISBN 978-0-9645598-3-4.