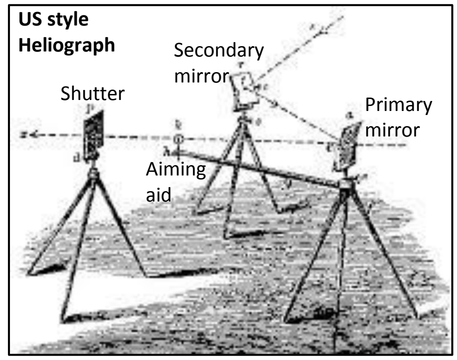
N5IB Heliograph Project (27 October 2017, revised 11 June 2020)

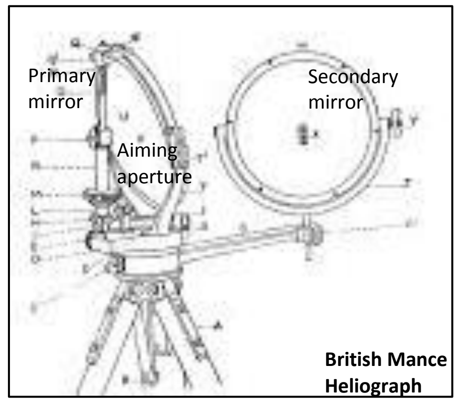
If the Sun won't cooperate and provide a decent ionosphere for radio propagation, we can still make use of the Sun for messaging. The ***Heliograph*** was widely used in the late 19th and early 20th centuries. In the US southwest, from mountain peaks, distances of over 100 miles were achieved at times.

Any heliograph will include a mirror to reflect the sun, some sort of device to assist in aiming the reflected beam at a target, and a means to interrupt the beam in order to signal in Morse. To allow for signaling when the sun is behind the sender, a secondary mirror is generally included.



The primary mirror has a small unsilvered spot at its center. By sighting, from behind the mirror, through this clear spot the user can align the reflected beam onto the desired receiving target. Usually a sighting aide such as a post or peg is positioned a short distance in front of the mirror to assist placing the beam on target.

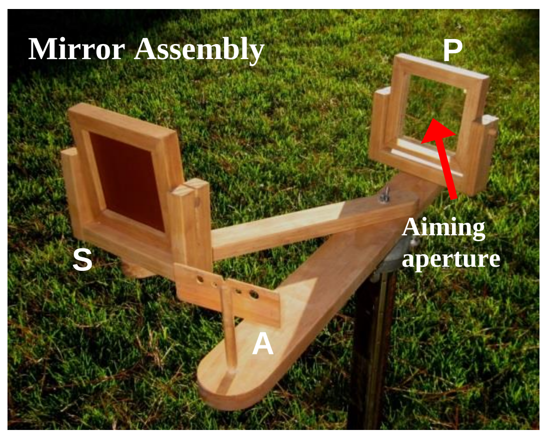
There were two different schemes employed for interrupting the beam to form the Morse characters. In Great Britain, the Mance Heliograph used a primary mirror that would be deflected slightly off target by pressing a lever. The action of pressing and releasing the signaling lever could, unless the apparatus were very firmly supported, cause the aiming alignment to be upset. Because of this, the heliographs used in the US generally employed a fixed mirror and a separately supported lever-operated shutter assembly to interrupt the beam.



Of the three home-made heliographs described here, two are of the US style, with separate mirror and shutter assemblies. The third is in the British style, with the deflectable mirror. All three employ a form of Morse key to produce the signaling flashes.

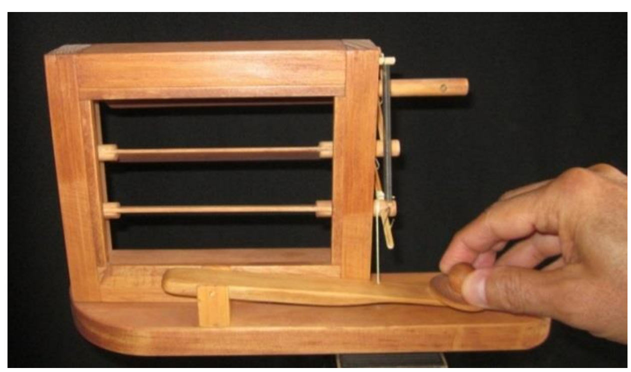
In the first version of the US style heliograph the 3.5" square primary (P) and secondary (S) mirrors are mounted in two-axis gimbals. The aiming aide (A) can be sighted through the aiming aperture, an unsilvered spot (arrow) at the center of the primary mirror.

The shutter assembly consists of three vanes, mechanically linked together so that they move in unison. The normally closed shutter is activated by pressing the Morse key to open the vanes.



Shutter assemblyCLOSED

Click for video of shutter operation



Morse key pressed, shutter OPEN

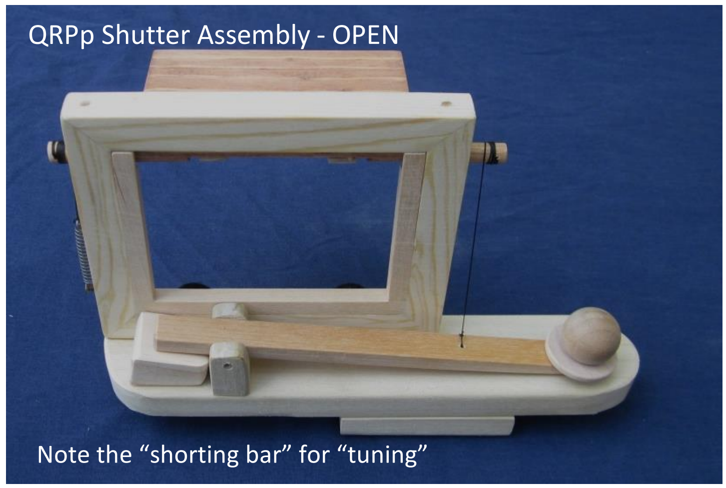
The second US-style heliograph is a miniature version. The mirrors are 2” square, mounted in the same type gimbals. The shutter assembly is simplified to use a single vane, again operated by a Morse key. The aiming aid is at the end of detachable dowel rod that inserts into the front of the mirror assembly.

Since the shutter must be held open in order to make final aiming adjustments, a wooden wedge serves as the “shorting bar” for the Morse key to maintain the system is “transmit” state.


QRPp Shutter Assembly and Morse key - CLOSED

A QRPp Heliograph

[Click here for demo video of received signal]


QRPp Shutter Assembly - OPEN

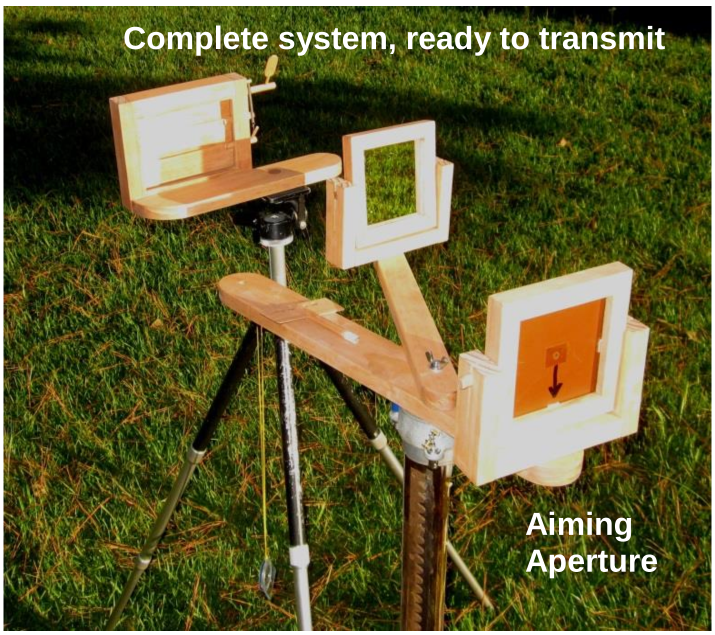
Note the “shorting bar” for “tuning”

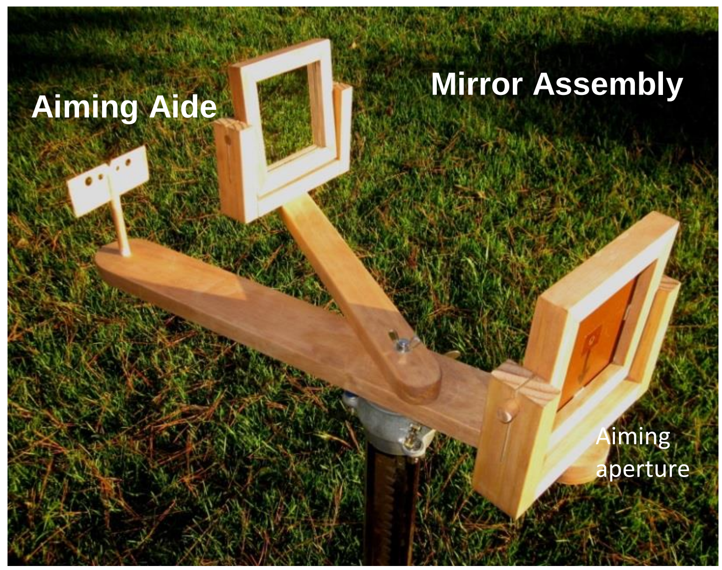

Mirror Assemblies Comparison

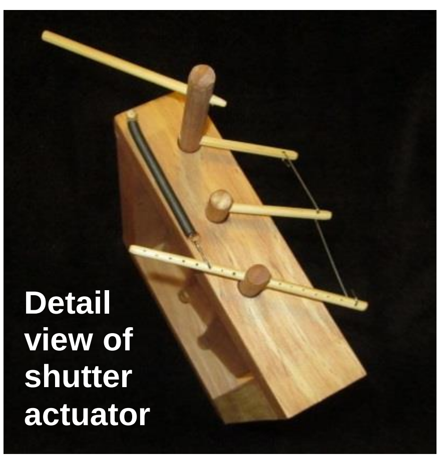

Shutter Assemblies


Shutter Assembly - CLOSED

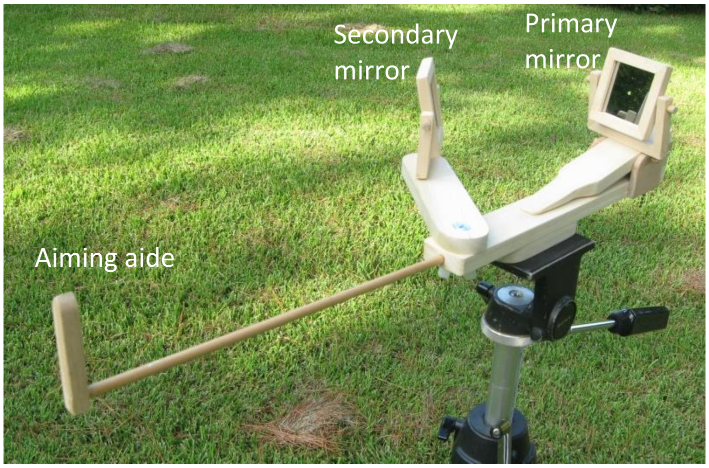

Shutter Asssembly - OPEN

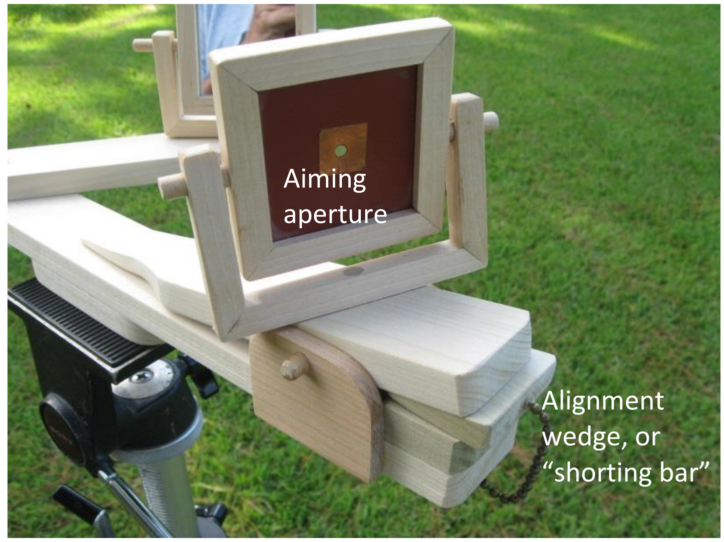

Complete system, ready to transmit
Aiming
Aperture

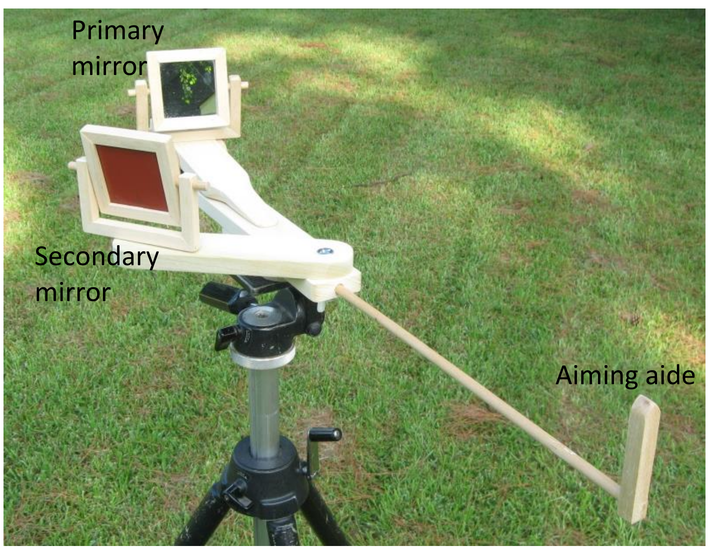

Aiming Aide
Mirror Assembly
Aiming
aperture

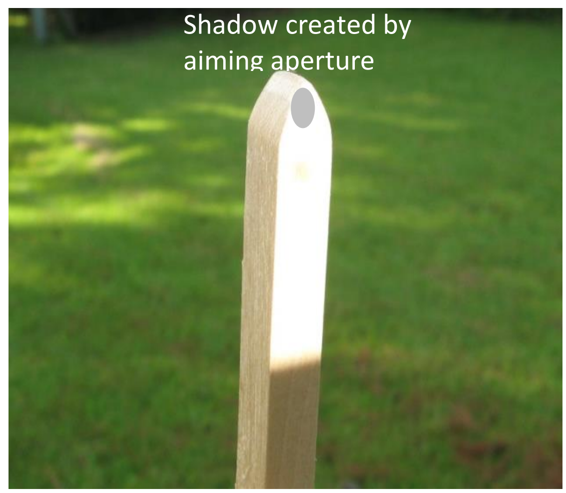

Detail
view of
shutter
actuator

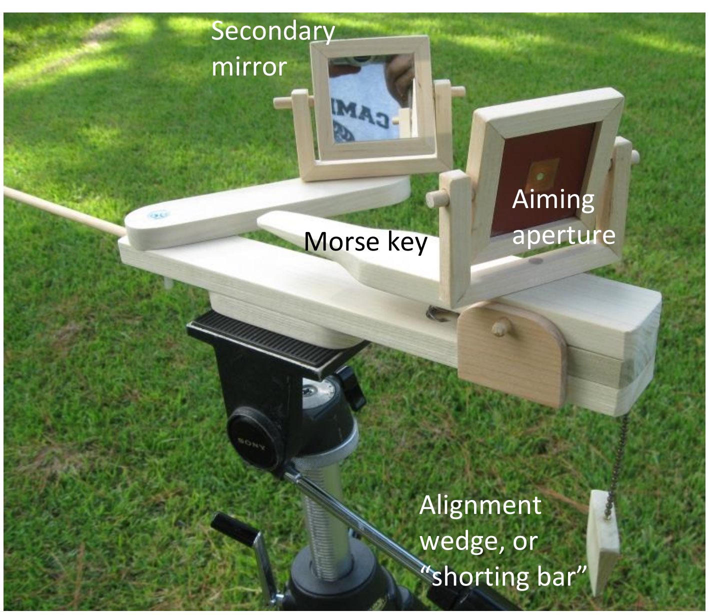
The third heliograph is in the British style. The primary mirror is mounted in its gimbal directly over the pivot of the Morse key. The key is held depressed against a spring by a wedge (the “shorting bar”) while the beam is adjusted onto the target. When the key is released the mirror is deflected upwards and away from the target by about 5 degrees. This deflection is sufficient to move the beam away from the target receiver and “extinguish” the beam as seen by the recever. To minimize any disturbance to the aiming alignment by the mechanical keying action, the end of the key lever is carefully positioned directly above the tripod support point. In this way the downward keying force does not produce a torque about the support point and the beam remains on target.



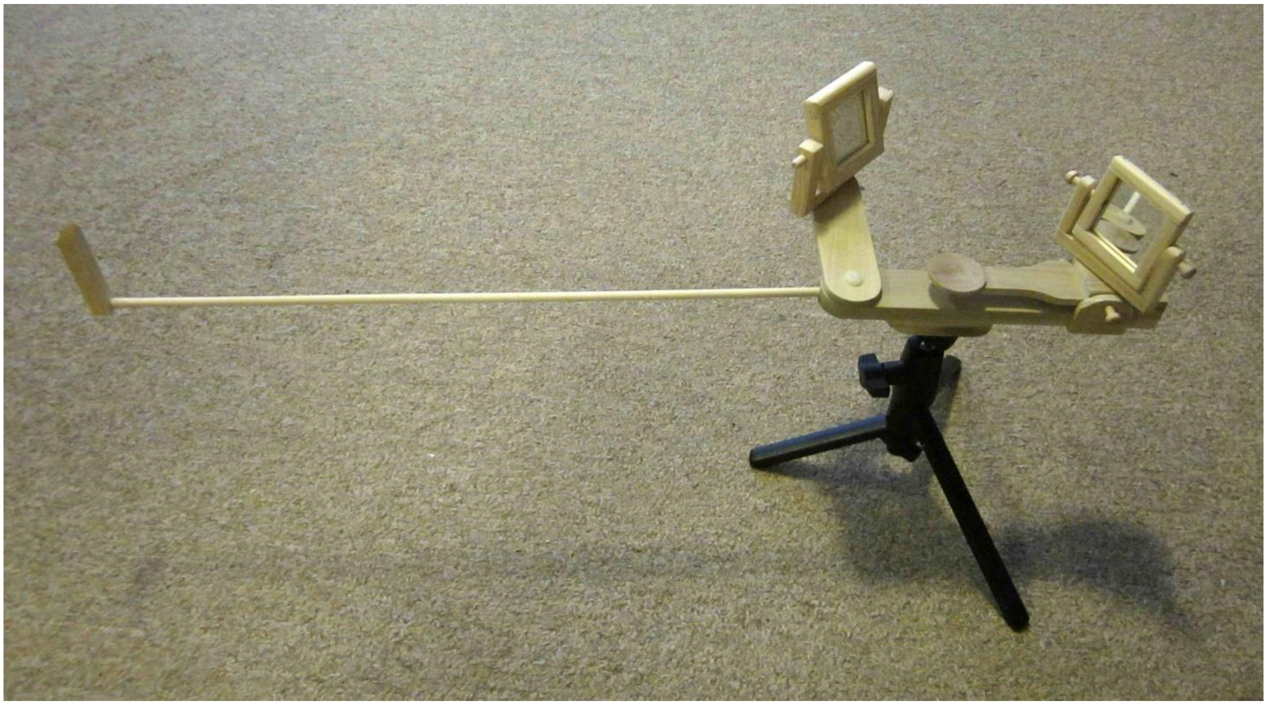


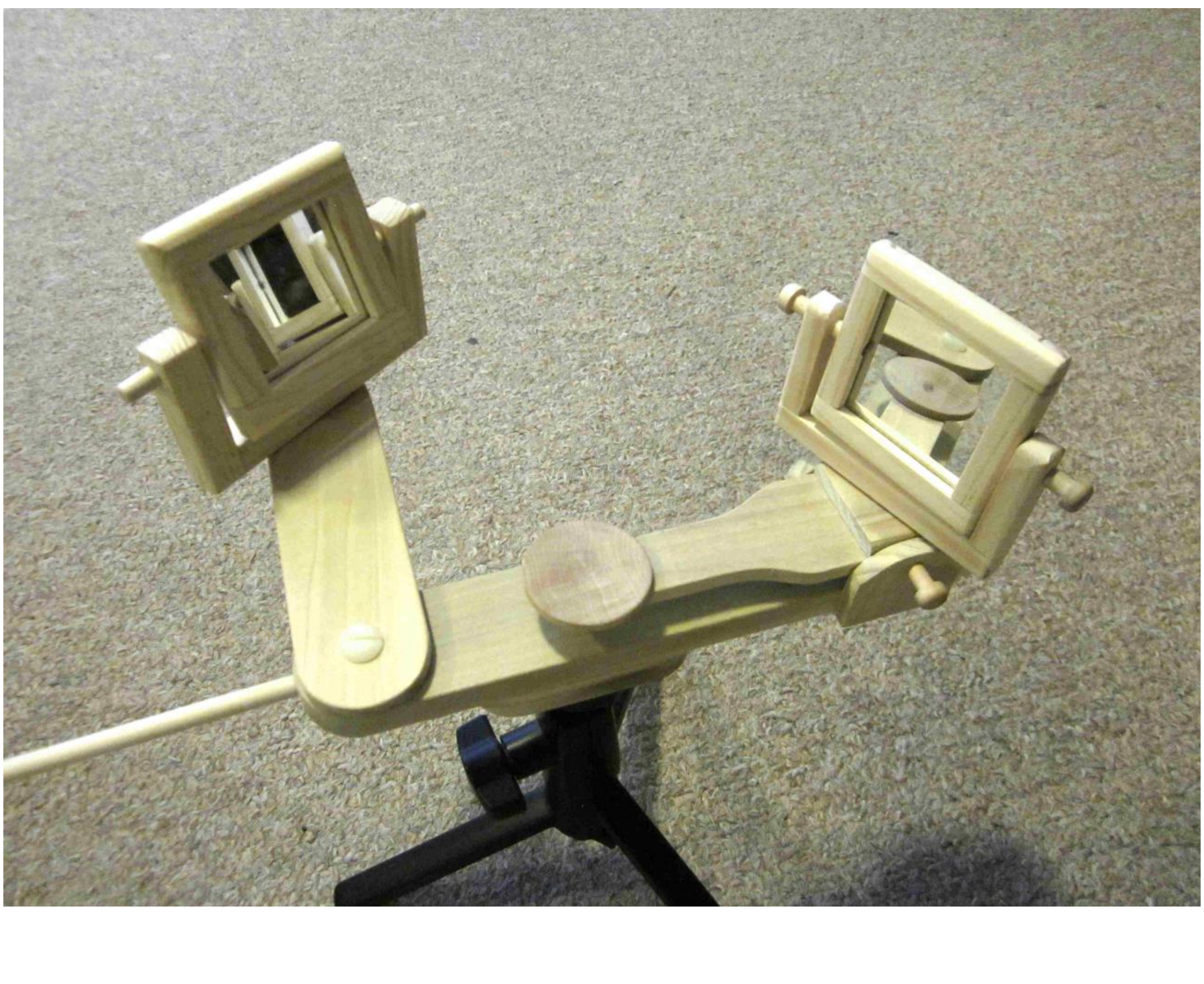


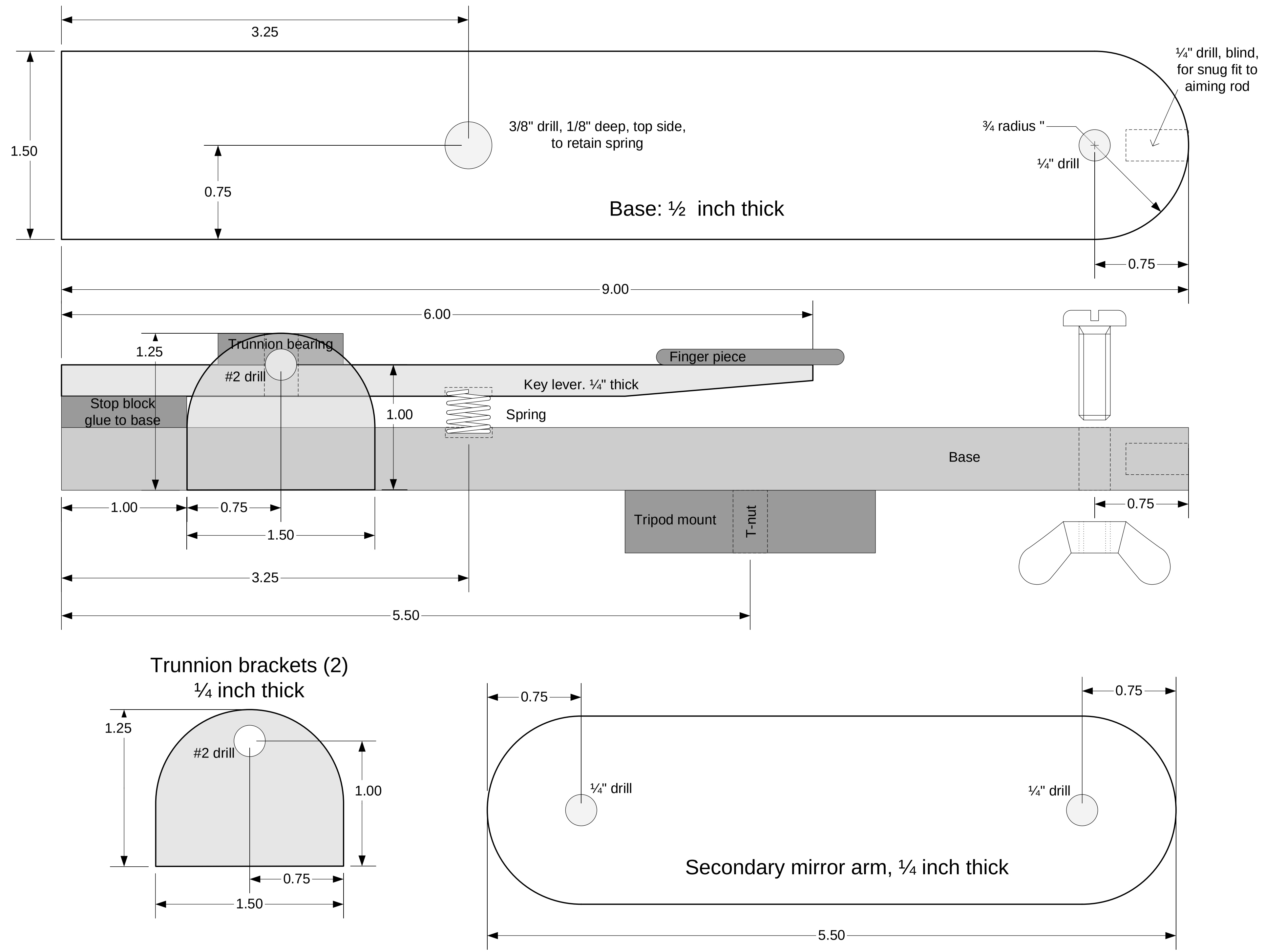




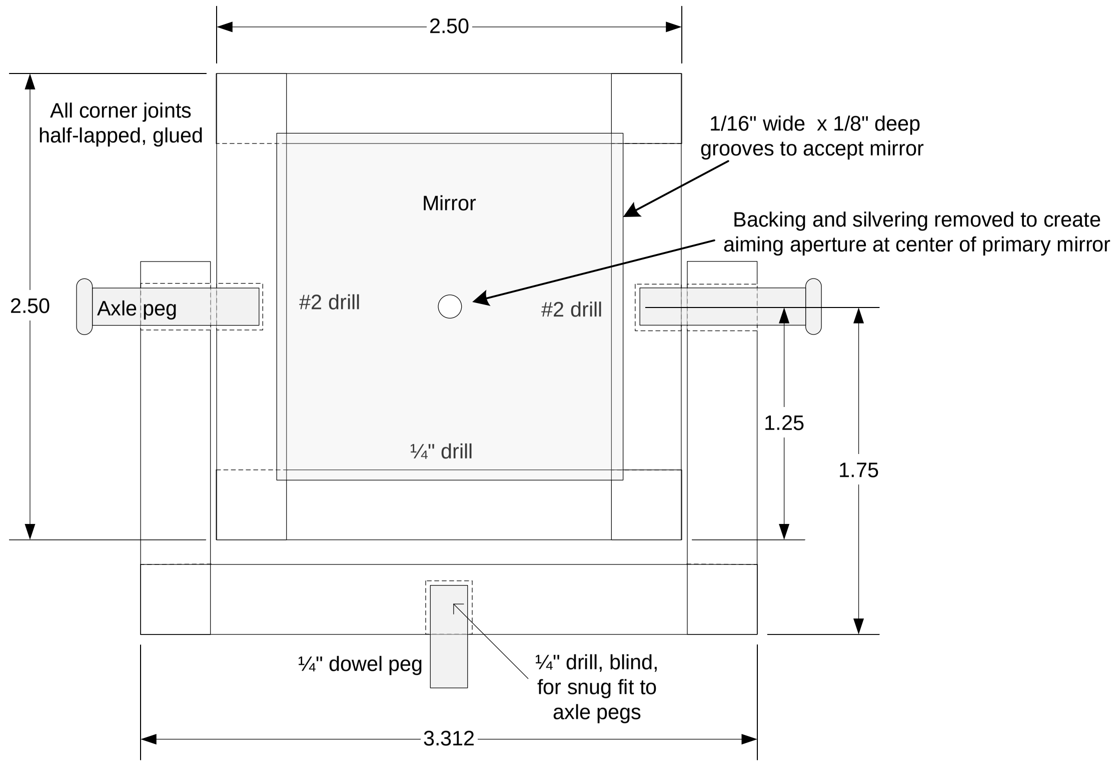
Another British style heliograph, with a measured drawing that can be printed actual size for use as a template.

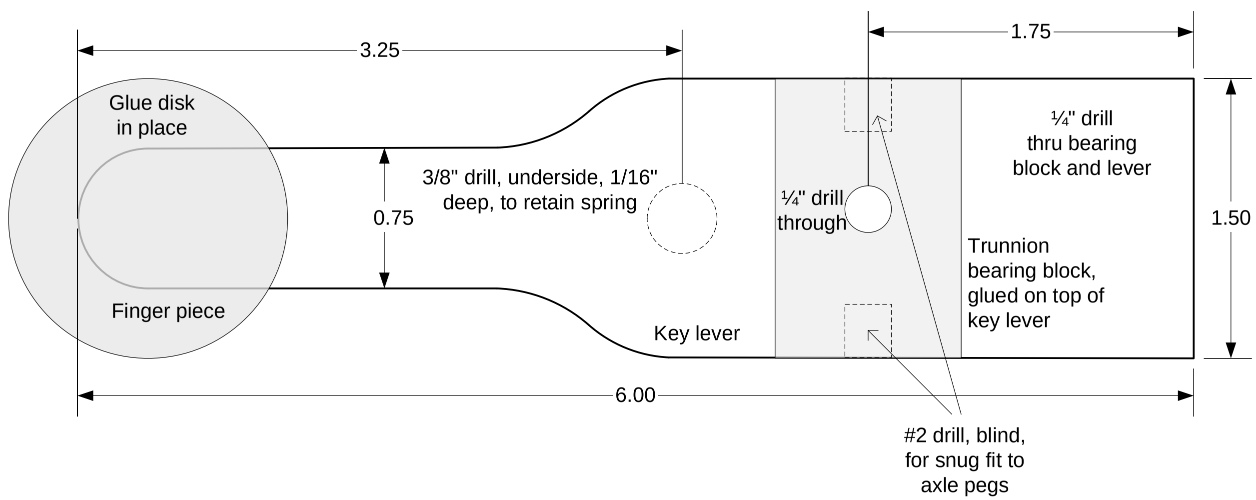






Can be used as actual-size template if printer scaling is verified





Bill of Materials:

Parts made from 1½" wide, ½" thick stock:
Base - 9" long
Tripod mounting block - 3" long

Parts made from 1½" wide, ¼" thick stock:
Key lever - 6" long
Secondary mirror arm - 5 ½" long
Trunnion brackets (2 pieces) - 1 ¼" long
Stop block - 1" long
Trunnion bearing block - 1" long
Aiming wedge - 2" long

Parts made from 3/8" x 3/8" square stock:
Mirror frames (8 pieces) - 2 ½" long
Mirror gimbal sides (4 pieces) - 2" long
Mirror gimbal bottoms (2 pieces) - 3 5/16" long
Airming target

Parts made from ¼" round dowel:
Aiming aid extension rod - 18" long
Mirror gimbal pivots (2 pieces) - ½" long

Hobby Lobby craft parts:
Mirrors (2 pieces 2" square) SKU: 507061
¼" (nominal) axle pegs (6 pieces) SKU: 210997
1½" round disk SKU: 165654

Hardware:
¼" x 20 tpi T-nut
¼" x 20 tpi x 1" long nylon screw
¼" x 20 tpi nylon wing nut
3/8" diameter compression spring

Tools and supplies:
Drill bits: ¼" #2 19/64" 7/8" Forstner
Router bits: 1/16" 3/8"
Wood glue, fine sandpaper, clamps, square
Acetone, Q-tips

Fun with Math, or A solar *transmitter power* calculation:

Near sea level, the sun provides an irradiance which averages, within the visible spectrum (roughly 380 nm to 780 nm wavelength) of about 1.2 $W{\cdot}m^{-2}{\cdot}nm^{-1}$. Or in other words, about 1.2 watts onto each square meter of surface, for each nanometer of bandwidth. At these wavelengths, one nanometer of bandwidth is a little less than 900 GHz wide.

Since the visible spectrum is about 400 nm wide , that means each square meter of surface will receive about 480 W of visible solar power.

The mirror of the smaller heliograph measures 4.8 cm x 4.8 cm (2" x 2"), for a surface area of 23 cm^2, or 0.0023 m^2. The mirror will intercept, at most, about 1.1 W of visible solar power (0.0023 m^2 x 480 W/m^2). Definitely falls within the 5 W traditional definition of QRP operations.

In fact, if the efficiency of the mirror (80-85% for a second surface mirror) is taken into account (rather like the efficiency of a final amplifier) the visible solar power reflected by the mirror will be about 0.94 W or less. Easily QRPp !

Now comes the interesting part. The light reflected by the mirror is actually an image of the sun, which is circular, and about a half degree wide. So the transmitting *antenna* (the mirror) has a *beamwidth* of half a degree. The directive gain of an antenna depends on its *beamwidth*. Half a degree corresponds to an astonishing 42 dBi (decibels of gain relative to an isotropic source). Applying that gain to the 0.94 W gives an effective radiated power referenced to an isotropic source of an amazing 15 KW ERPi !

A corresponding calculation applied to the larger Heliograph, whose mirror measures 9.8 cm x 9.5 cm (3.5" x 3.5"), gives us, assuming the same efficiency and beamwidth, 3.8 W of reflected visible solar power, and an ERPi of 60 kW. The military units generally used 5" mirrors, for an ERPi of over 100 kW.

So, the larger Heliograph qualifies as QRP, the smaller one as QRPp. By the way, the *band* can be tagged as the *half a micrometer band* corresponding to a frequency in the vicinity of 600,000 GHz. And in case you wondered, hams have access to everything above 300 GHz – any mode permitted.