

# Ocular and Luminance Issues Pertinent to Optimum Sight Utilization

By Daniel S. Lambert, PA-C

## INTRODUCTION

Whether or not a firearms shooter is consciously aware of it, the use of firearms sights in hitting a target involves, to a great extent, certain involuntary ocular and luminance issues of eyesight. Further, these issues determine whether a given firearms sight is a help or a hindrance to the shooter.

Three questions:

- (1) Why is this an unavoidable fact, not just a theory?
- (2) How can simply understanding this fact enable a shooter to choose a firearms sight that improves consistency in target strikes?
- (3) How does the newly-patented HexSite™, in contrast with all other sights presently on the market, positively and demonstratively address these two issues?

This paper answers all these questions. Read on.

Note: All Figure references herein are found in a separate section at the end of this text.

## GENERAL ORIENTATION

The human eye, having a close side-by-side position, allows each eye a view of the same area from a slightly different angle. While each eye has a great deal in common, each will pick up information that the other doesn't. Each eye captures its own view, and the two separate images are sent to the brain for processing. Binocular vision results when the occipital cortex of the brain (located at the back of the brain and has functional responsibility for sight) combines these disparate images to determine true stereoscopic depth. Additionally, electrical impulses, generated by photon strikes on the retina, have a summative effect on the occipital cortex. In a sense, an object is seen in clearer detail at any ambient light value.

Basically, the farther away an object is from you, the more similar the view in your two eyes, and the closer the object to you the more disparate the two images. The two images are united into one 3-D picture. With stereovision, we can more precisely see WHERE objects are in relation to us, especially when those objects are moving toward or away from us. We can see a little bit around solid objects without moving our heads and we can even perceive and measure "empty" space with our eyes and brain. With monocular vision all of these capabilities are severely compromised or eliminated completely.

In general, because of the properties of stereoscopic vision, we tend to distinguish objects as either standing out from the background or, alternatively, in contrast relief from its surrounding area. Fig. 1 shows the relative optimal functional range of human vision within the "normal" ambient light spectral range. That capability may not hold in situations where the lighting situation is sub-optimal. Thus it is always best, wherever possible, to present an object so that it, and it alone, holds the eye's attention.

Image contrast is a capability that has evolved in the human eye over the millennium. This is a direct function of the rods of the retina-photo that can perceive only thirty shades of gray of light. In LOW LIGHT (less than 500nm) it is that capability that allows for the determination of light intensity, depth of field and shape perception; albeit degraded from that of cones in "normal" light situations. The cones of the retina allow us to see colors but function poorly in low light conditions as displayed in Fig. 1. The Fig. 2 illustrates optimum light wavelengths for maximum luminosity while the right demonstrates the point about the rods. (Ref.5 p3.3.2)

Compare differences of the area under each curve to gain a quick visual appreciation of the magnitude of differences involved.

With this introduction, the following concepts will be examined:

The nature of light and its properties. The pupils' effect on visual acuity and the effects of age-related changes in the human eye. Each will be dealt with as a separate issue to aid in understanding the concept, but it should be kept clearly in mind that all work in concert.

## PROPERTIES OF LIGHT

Light can be described as radiant energy traveling in the form of electromagnetic waves and having a wavelength proper for evoking visual sensation. In general, and illustrated in Fig. 2, the optimal spectral range for the eye is taken at 400nm to 800nm. This encompasses most of the components in the spectrum more popularly known as "white light" -- the light we see by. (Ref. 5,p.3.2.1)

The term Photometry is reserved to apply to measurements within the spectral region that evoke sensitivity in the human eye. The reader should become familiar with the following photometric terms described next.

Luminous power is radiant power weighted according to the spectral sensitivity of the eye. The basic unit is the lumen.

Illuminance, formerly called illumination, is the luminous power per unit area (density) incident upon the surface of an object. Units are lux (1 unit/sq meter) and footcandles (1 lumex/foot).

Luminance is the luminous power per unit solid angle leaving, passing through, or arriving at a unit surface area in a specified direction. Common units are candles/square meter (cd/m<sup>2</sup>) and footlamberts (fl).

Of these Luminance is the most frequently used in discussions of imagery displays. Like the response of the eye to a luminous surface, the definition of luminance involves:

The apparent size of the luminous surface.

Angular size of the bundle of light rays reaching the eye from that surface.

The direction the light is traveling when it strikes the luminous surface and then is reflected to the eye.

The term brightness has been used to refer to both luminance and to the visual sensation associated with a given luminance. Preferred usage at present is to restrict the term "brightness" to the latter meaning.

Research regarding light contrast for targets of different size demonstrated that target detection improves with both target exposure and with background luminance; i.e., the greater the luminance gradient the easier to identify and acquire the target. (Fig. 3) (Ref.5,p.3)

Another study demonstrated that as maximal visual performance level is approached, ever-increasing levels of luminance are required to obtain additional improvement. It was also discovered that the amount of light reaching the retina resulted in corresponding performance changes; however, there is a limit at which increasing luminance levels do not increase acuity performance. (Ref.5,p.3.1.4)

## PUPIL PROPERTIES

The contribution of the pupil has significant impact on visual acuity because all light, in order to reach the retinal rods and cones, must first pass through it.

The pupil (the iris) is a dynamic aperture and, through a complex neurological feedback process that is light initiated, the iris will automatically change its aperture to optimize the quantity of light reaching the retina. As shown by the graph, (Fig.7) increasing pupil diameter corresponds to an almost linear increase in retinal luminance with evenly corresponding luminance increases.

Serious consideration should be given to pupil response rate to sudden changes in light intensity. Figure 8 illustrates reaction rates in pupil diameter in situations where the environment changes from dark to light and from light to dark. As can be seen, dark

adaptation time requirements are equal to or greater than 15 seconds as compared to 2-3 seconds in the dark to light scenario.

Comparing monocular to binocular pupils in monocular vision there is a noticeable lag in correcting for luminance changes when compared to binocular vision. This has real, not hypothetical, effects on rapid target identification and location. Such reaction time delays, due to monocular vision, are graphically illustrated in the graph. (Fig. 9)

Age-related reaction time delays are predictable. With increasing age, the distance at which the eye can discern a target as a single object increases. Any object presented to the eyes at a point closer than this begins to blur. This condition is called Accommodation and is a consequence of increasing age. In many cases the Accommodation Point may be at, or even beyond, arms reach. (Ref.4)

The prediction of the effects of aging on ocular performance is fairly straightforward. As the eye reaches approximately forty years of age progressive accommodation errors are seen. Further, pupillary reaction times begin to slow or become erratic and the rods become less sensitive to low luminance levels. This latter effect is a function of both a decrease in the number of rods as well as a decrease in the pupil's capacity to react to changing luminosity levels. (Ref.4,7,&9)

## FIREARM FUNCTION RELATIVE TO LIGHT PHENOMENA

We now focus the discussion of firearms sight optimization by utilizing the previous data regarding the interactive nature of light and the human eye. This can be used as a platform to discuss, with clearer understanding, the changing nature of light perception in the aging eye; the nature of light in its own context and the ramifications of monocular vs. stereoscopic vision in various light conditions. This is directly related to such issues as accurate determination of depth of field, peripheral vision preservation and speed of target acquisition and identification.

A discussion of the technology of firearms sight utilization would benefit from an understanding of the function of the human eye as well as an understanding of the mechanics of light as it enters the eye.

The practical basis of accurate sight alignment (aside from proper grip, body stance, trigger-squeeze, and follow-through) requires a complex balance of visual-motor cues occurring on both a conscious and unconscious level. Such visual-motor coordination is readily perceived in excellent wing shots whose only need is to focus on a target that appears to reside in one focal plane; whereas the pistol marksman is concerned, simultaneously, with near and far perceptual issues. It follows, therefore, that the shooters' task would be simplified if they only needed to concern themselves with issues in one focal plane. This paper will explain how this can be achieved in the context of our current foundation in optical physics and physiology.

Some of the variables impinging on sight performance include the light intensity (including high/low contrast variables), its relative angular incidence to both sight and target and, to no small extent, the quality of the shooters' vision.

Such vision problems as Presbyopia, vertical and horizontal Astigmatism (resulting in lateral impact variance and vertical variance respectively), and refraction errors are some confounding variables that must be addressed. Likewise, a solution must be found to accommodate those individuals who simply cannot shoot with both eyes open without experiencing double vision or tunnel vision. (This leads, in various degrees, to a degradation of depth perception and angular field of view.) (Ref.p.2,3,4 & 7)

The incidence, or direction, of light in the shooting environment can lead to not only errors in depth perception but an unconscious judgment as to the object's relative position to the right or left. Under most circumstances, with considerable training, the visual cortex adapts to these problems. Unfortunately, not all shooters can afford the luxury of the considerable time investment necessary to achieve such a skill level.

## BINOCULAR vs. MONOCULAR VISION

The HexSite™ sighting system, designed to be used with both eyes open, preserves stereoscopic vision. This has utility in preserving depth perception, enhancing peripheral vision and, because of the enhanced light-gathering ability of both eyes, greater contrast definition of the target in all lighting scenarios. (Ref.p.1 & 3)

We will now look at the issue of monocular v. binocular vision and follow with a discussion of High-Low contrast luminescence.

Figure 10A clearly demonstrates the effect of monocular vision in judging the accuracy of the position of objects in the same plane, while Figure 10B demonstrates how a High-Low light contrast situation affects target acquisition. (Ref.6)

Look at Figures 11A & 11B, and alternately close each eye, noting that the wineglass in the scene appears to shift right or left. Individuals who close one eye while shooting, experience the same effect. This places an additional burden on the brain's optical interpretive area to spatially correct for the apparent object displacement.

This experiment lends itself to a demonstration of the effect of monocular sight on peripheral vision. Fix your gaze at an object several feet in front of you, and then close either eye. You will note your peripheral vision is decreased by roughly 50%. While not quite as apparent, monocular depth perception is also affected with a concomitant degradation of its quality in failing light. Figures 11A and 11B provide examples of how differences in light intensity values affect the initial "choice" of both eyes in seeking out an object of regard. This will also affect how the visual cortex perceives depth of field. (Fig. 1) (Ref.p.6 & 8)

In Figures 10A & 10B, the areas of highest contrast are visually acquired first. In Figure 10A the eye is led first to the distant object because its contrast value is higher than the foreground. The reverse occurs in Figure 10B. In Figure 12, as one initially views the system of pipes, the eye is drawn to the lighter areas first, then to the darker, and back to the lighter again. The key point is that in any field of regard the eye focuses first on the higher contrast area. An example is seen with colored or "marked" rear sights. With such sight configurations the distant object (target) will appear to blur because the brain is attempting to visually clarify the brighter (higher contrast) rear sight first. The "trade-off" in such situations is that a clear sight picture is obtained at the expense of a sharply-defined visual background. Logically, in a mission-critical situation, the clearest field of regard should be the target, not the sight.

Discussion of the concept of High-Low light contrast leads next to an examination of the effects of Brightness and Incident Luminescence in target acquisition. These factors also have effects on depth perception, object acquisition rate, and accuracy of object definition. Light contrast is not only a function of the difference in intensity of reflected light to the pupil but also of the angular direction, or the incidence, of the light striking the target before being reflected to the viewer. The "direction" of perceived depth depends on the direction of the luminance gradient. The viewer automatically assumes that only one light source is striking the object in view and if an object is brighter on one side the perception of its relative size and depth can be altered. In Figure 13, the light is from above which creates the illusion that objects, (like the "eggs" in Fig. 13) are convex and form an "X" in the picture.

If the same object (Fig. 14) is illuminated from below this image is altered. If the viewer looks at Figure 14 with head cocked to the right the "X" disappears. This is not a representational change in accurate perception of an image (all "circles" are truly concave). Rather, the perception is illusionary; a result of the brain's inability to accurately interpret the viewed geometry owing to the confounding influences of incident light.

To summarize, in the shooting environment a variety of independent variables operate in concert to allow the brain to correctly interpret what it sees. It is important to understand these variables in order to optimize visual acuity, target acquisition rate, and correct target identification. (Fig. 14) (Ref.8)

## SIGHT TYPE ANALYSIS

In Summary: In the shooting environment, there are diverse independent variables operating in concert, which can allow the brain to correctly interpret what it sees. The shooter then takes the necessary steps to optimize his visual acuity, to shorten his target acquisition rate, and to accomplish correct target identification. Certainly one of these steps is shooting with both eyes open.

The study by Ben Evans and Ken Lamb, presented earlier, demonstrates that the HexSite™ sighting system is 41% faster, and just as accurate, as the conventional post-

and-notch sight configuration in target acquisition and accuracy. In comparison, the ghost ring sight was nearly as fast in target acquisition as the HexSite™ sighting system but distinctly inferior to both the HexSite™ sight and the conventional sight in terms of accuracy.

Those conversant with statistical analysis are no doubt aware of a small flaw in the study in that only one shooter was involved in the testing, thereby bringing into question the power of the statistical test used. However, this issue is mitigated to a large extent by the significant (statistical) differences in observed outcomes. Clearly this study should encourage a follow-on study with greater power of test. Review of the data thus far indicates that these outcomes may be confirmed.

In conclusion, any sight system should inherently possess the following capabilities:

- (1) The ability to be used with both eyes open.
- (2) Function equally well in low and bright light situations.
- (3) Not be an issue for those with Accommodation or ocular refractive error difficulties.
- (4) Be rugged enough not to be disabled by inadvertent rough treatment.
- (5) Be applicable to pistols, rifles, and shotguns.
- (6) Be affordable to users; and
- (7) Require less time than other sights to attain user proficiency.

With the information in hand thus far it would seem that only the HexSite™ sighting system fulfills these requirements. The direct effect of this will be a significant increase in time saved by the sight's speed and accuracy.

The attributes of a functionally "ideal" set of firearm sights ought to include provisions for binocular vision, for preservation of peripheral vision, and for realistic assessment of depth of field. The sight should provide these provisions simultaneously, and without creating "distractions" that require the brain to make multiple decisions, thus slowing the shooter's ability to acquire and engage the target. As an example, sights frequently are marked with dots/paint/colors, presumably to enable the shooter to acquire faster sight alignment. But, in fact, these create a visually confusing picture described in an earlier paragraph.

With focus drawn to sight marking, the brain has two mutually exclusive choices:

- (1) Settle for a clear sight picture at the expense of target clarity and peripheral vision; or

(2) Take time to fight through the distraction to gain a clear and accurate target acquisition.

If this "trade-off" is complicated by visual acuity problems, such as Accommodation, Astigmatism, and/or Presbyopia, the shooter's problems are compounded.

At its best, the post-and-notch sight allows target refinement, but its bulk prevents an unobstructed view of the target area. A ghost ring sight allows unobstructed view of the target area, but at the expense of target refinement.

Enter the HexSite™ sighting system, a hexagonal aperture sight, designed for point-of-aim shooting, rather than a 6 o'clock hold, owing to its unobstructed view of the target area. In a defensive shooting situation, instead of employing the age-old conventional and unnatural instruction to "focus on the front sight", the HexSite™ sight allows the shooter to effectively employ a natural inclination to focus on the target. It is not a difficult conclusion to accept that this "unconventional mind set" of always keeping the target in optical focus, not the sight, equates to significant increases in speed.

Target acquisition is facilitated in large part by the geometry of the HexSite™ sighting system. The shooter's visual perception of the rear sight is of three consecutively smaller hexagons, each centered inside the other, creating 16 intersecting-angle reference points. The sketch of the HexSite™ sighting system (Fig. 15) portrays these reference points, which involuntarily draw the eye to the precise optical center of the rear sight. In other words, the eye spontaneously is centered on the target without effort. The HexSite™ sight is all black, thus the attention of the eye automatically is guided to the object of highest value beyond the sight -- to the target.

Another distraction is eliminated by an angled interior-face concavity, which reflects any incidental light away from the eye. This creates a "shadow", further embellishing its "blackness", giving the eye a maximum-value contrast in any light, drawing its attention quickly and naturally to the always-higher-value target area.

The HexSite™ sighting system (Fig. 15) also shows dotted lines connecting the vertices. This symbolizes the principle of "implied line" (A-B-C) conceived by the brain as a result of the geometric reference points 1 - 16. The top center of the front sight post just touches and exactly bisects these lines. As a result, the shooter need only reference the desired impact point and shoot. This eliminates time-consuming consideration of extraneous variables, thereby significantly reducing target acquisition and engagement times.

Here we note that the "implied lines", the 30-degree angular (B&C) and the horizontal (A) lines, conceived between vertices of the geometric reference points, also are used in refining elevation and windage, and in "leading" moving targets. In executing these variables, the shooter experiences similar improvement in target acquisition and engagement times.

## BIBLIOGRAPHY

1. B De Bruyn, The effect of stereoscopic depth on the perceived speed of transparent motion. Dept. Of Psychology, University of Surrey, Guildford, UK. INTERNET Access:  
<http://www.pion.co.uk/perception/ecvp98/p88b.html>
2. Bailey, Freund, MD & Scott Agnosta, MD, Anatomy of the Eye.  
<http://www.vrmny.com/anatomy.htm>
3. Building Technologies Program, Impacts on Visual Performance, 1994 Annual Report  
<http://eande.lbl.gov/gov/BTP/pub/annrep94/Lsivp.html>
4. Eye Care Associates of East Texas, On Line Information Request,  
<http://www.eyecareassoc.com/knowmore.htm>
5. Farrell, Richard J & Booth, John M., Design Handbook For Imagery Interpretation, Boeing Aerospace Company, Dec. 1975. D180-19063-1
6. Illusion Works, [http://www.illusionworks.com/html/hall\\_of\\_illusions.html](http://www.illusionworks.com/html/hall_of_illusions.html)
7. University of Alberta, Transduction at the Retina,  
<http://wel.psych.ualberta.ca/-p267/parents/marise3.gif>
8. University of Toronto, PSY280F Homepage,  
<http://server.esc.cquest.utoronto.ca/psych/psy280/ch7/shadding>
9. Youngman, Melissa, Presbyopia & Perceptual Change Topics,  
<http://hubel.sfasa.edu/courseinfo/SLtopics.html>

## ABOUT THE AUTHOR

The nearly 20 years as a practicing, Board Certified, Physician Associate has provided me with an extensive science background which includes a double bachelors degree in Molecular Biology and Biochemistry in addition to the extensive medical training in human physiology. I obtained my medical background at Emory School of Medicine and went on to do residencies in both surgery and emergency medicine.

In drafting this paper I called heavily upon that training but also on my shooting experience as well. While I can not claim extensive mastery with the pistol, being, as I am, only two years into this art, I can state without any hesitation that I have practiced extensively with sight systems discussed. The binding of these two factors permitted me an unusual perspective from which to generate my evaluation.

I would like to encourage the reader, if he has any interest in the subject at all, to avail himself of the opportunity to shoot these sight configurations and then draw his/her own conclusions based on that experience.

Dan Lambert, PA-C, BMsc, BSci

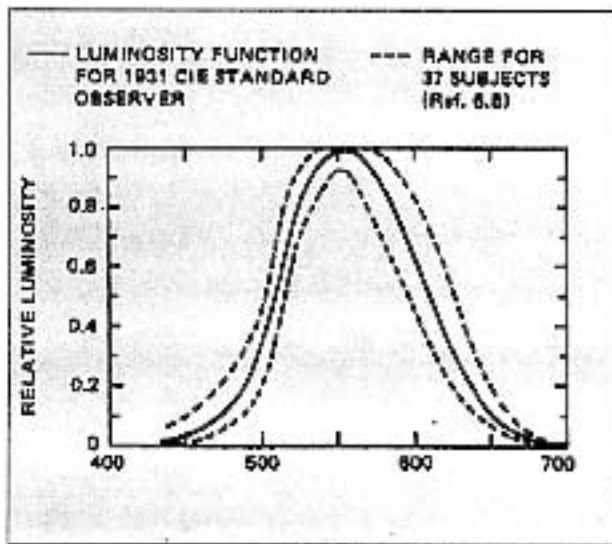


Fig. 1  
 (ref. 5, p.3.3.2)

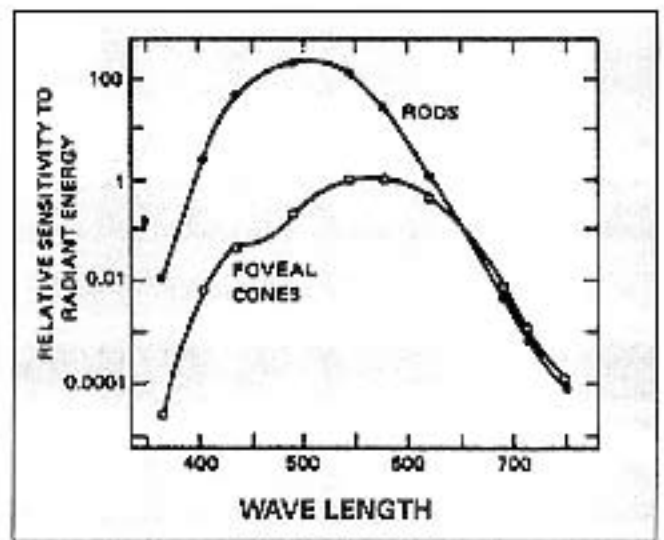


Fig. 2  
 (ref. 5, p.3.2.1)

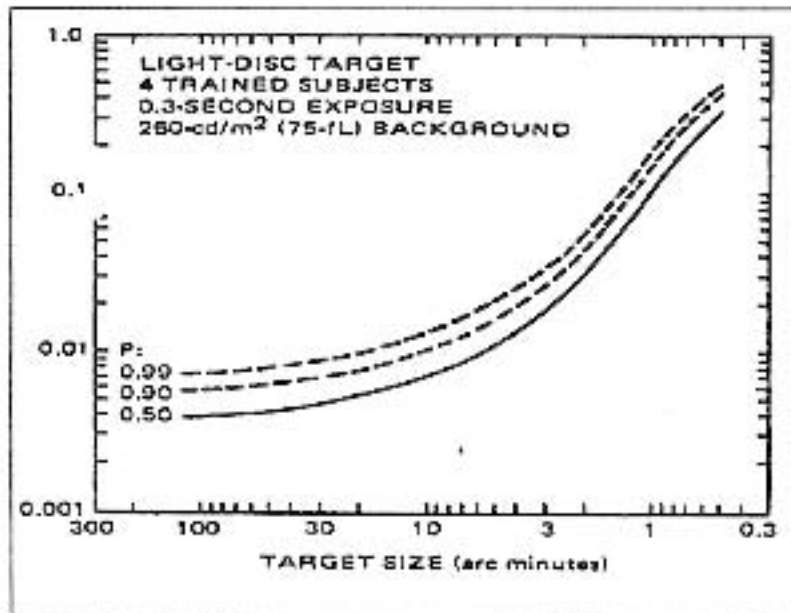


Fig. 3  
 (ref. 5, p.3.2-23)

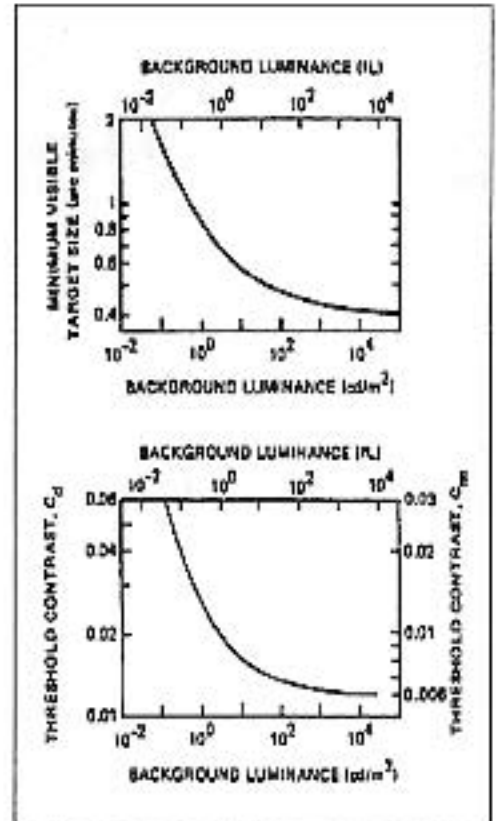


Fig. 4  
 (ref. 5, p.3.2-23)

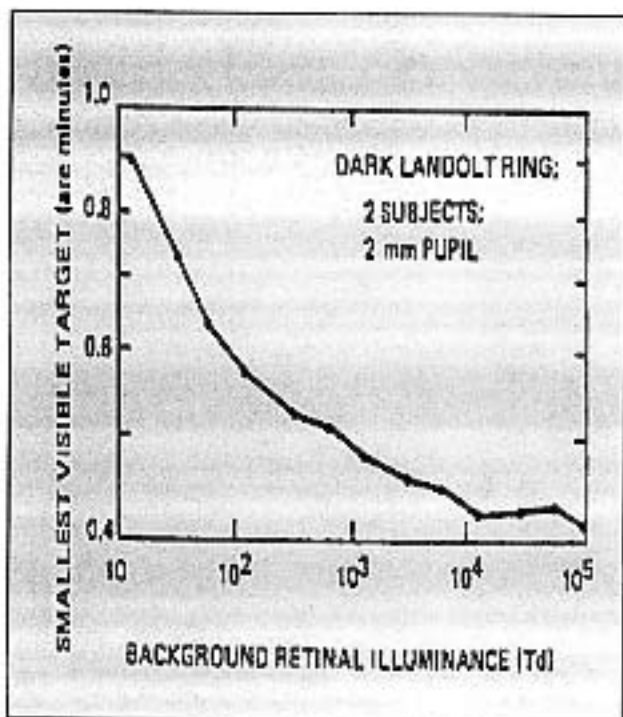


Fig. 6  
(ref. 5, p.3.2-23)

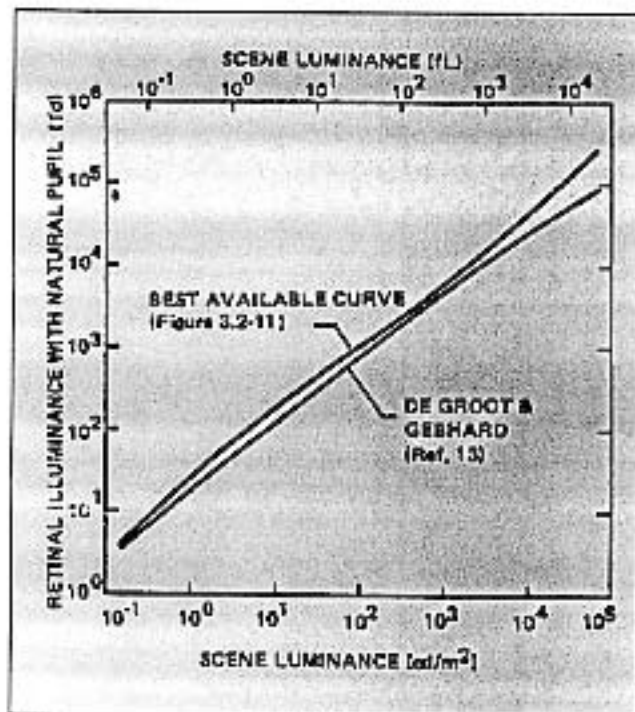


Fig. 7  
(ref. 2,3,75, 3.2-6)

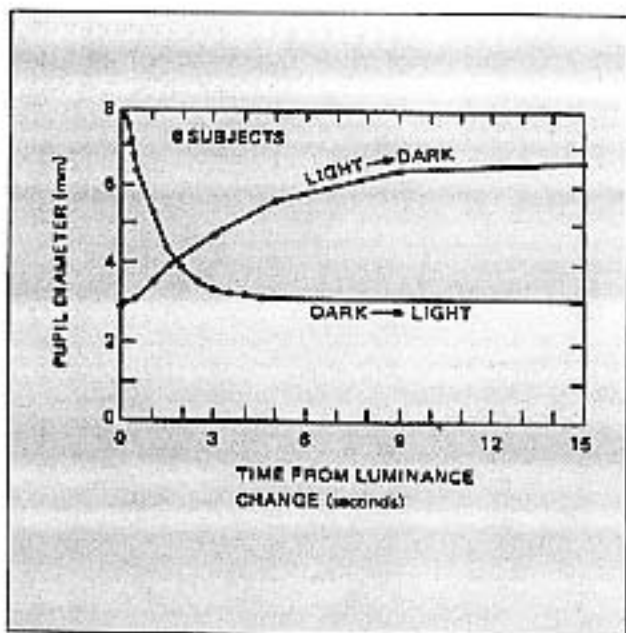


Fig. 8  
(ref. 2, 3, 75, 3.2-6)

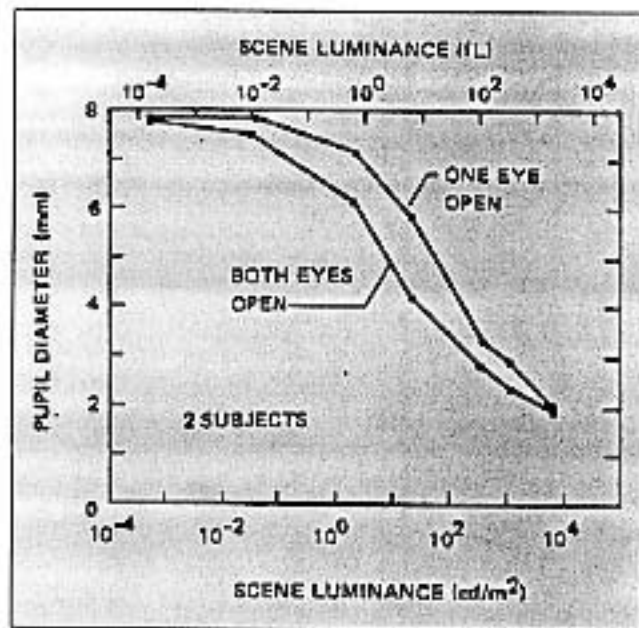
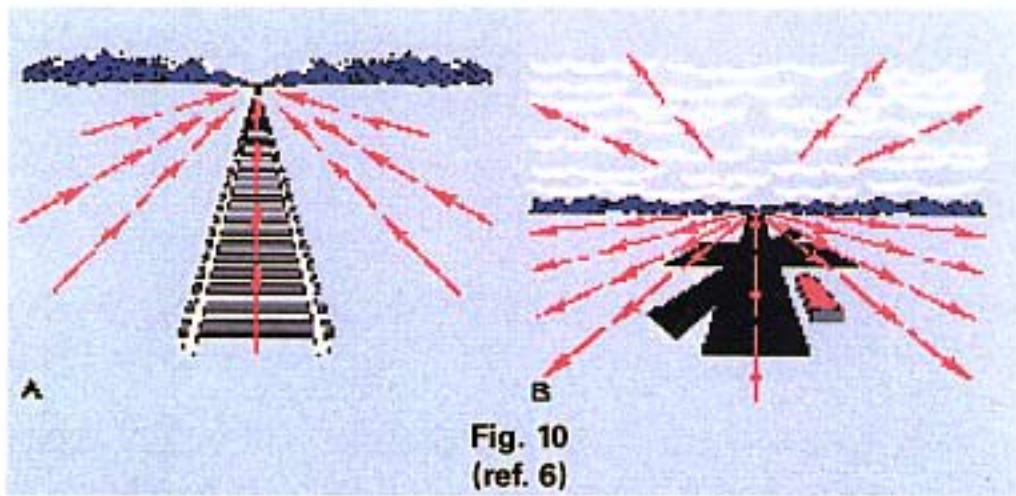


Fig. 9  
(ref. 4)



**Fig. 11a**  
(ref. 6)



**Fig. 11b**  
(ref. 6)



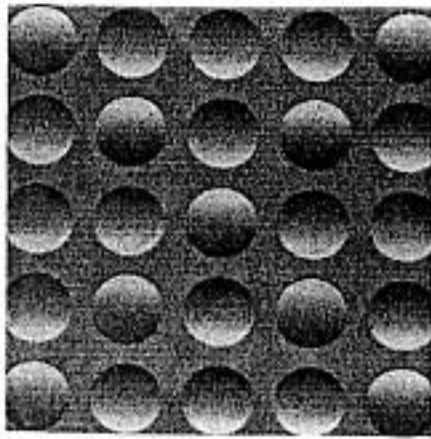


Fig. 13  
(ref. 8)

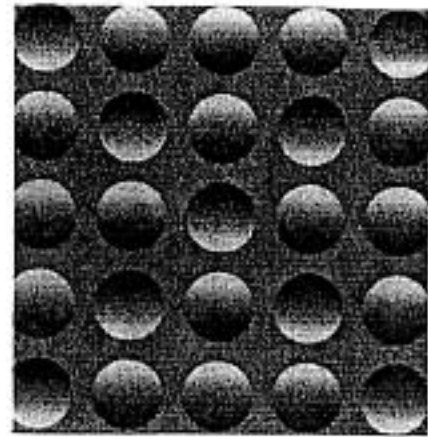


Fig. 14  
(ref. 8)

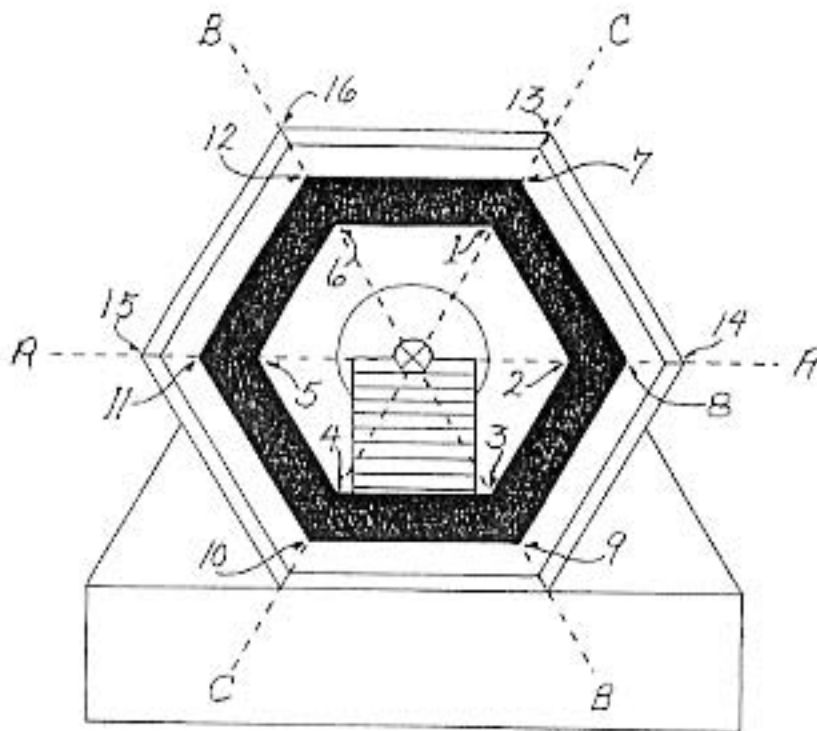


Fig. 15

For further information write or call:

Home of the  **HEXSITE™**  
Sighting Systems  
**GOSHEN**

ENTERPRISES, INC. SINCE 1981

P.O. Box 20489

Sedona, Az 86341-0489

Ph. (928) 284-1483

Fax (928) 284-9108