How Far Can I See?

The Need to See Far….

Customers want to be certain that the camera system they select is the right one for their needs. One of the most frequent questions customers ask in the video surveillance industry is How far can I see?

Many variables affect, and usually degrade, the answer to this question. Many of the variables that affect the answer are beyond the scope of this document, such as scene/object contrast ratios, lighting conditions, atmospheric attenuation, and optics quality, and will not be considered here.

But you should estimate how far you can see under ideal conditions, to ensure you understand the best case scenario limitations. If the best case scenario is insufficient, then it's back to the drawing board. If the best case scenario is right at the distance you want to see, you may want to increase your design to cover the degrading variables described above. If you far exceed your design goal, you may want to consider reducing how far your design can see.

This paper describes the main elements used in determining how far the camera can see.

Main Elements

In order to get started, you must determine the answers to the following questions, which will be used in the mathematical formulas used to calculate the answer.

- Object Size [Size and Level of Detail You Expect]
- Camera Field of View [At the Object's Distance from the Camera]
- Image Resolution [The Camera's Image Resolution]

Object Size

The first element you must determine is, what is the size of the object (target) that you want to see? For instance, do you need to see a person or an aircraft carrier?

The next question is what level of detail you need to resolve about the object?

Different applications require different resolution levels. Having more pixels on target, results in higher resolution, increasing the probability of accurate assessment. The levels of assessment are:

- Detection: An object is present [of size you want to detect]
- Recognition: The class to which the object belongs (e.g., building, truck, man, etc.).
- Identification: The object can be described to the limit of the observer's knowledge (e.g., motel, pickup truck, policeman, etc.).

For the purpose of this discussion we will use a common standard, The Johnson Criteria [http://en.wikipedia.org/wiki/Johnson's_criteria], which defines DRI (Detection Recognition Identification) in terms of the number of pixels required on the object in order to make an accurate assessment.

- Detection – 2 vertical pixels on target.
- Recognition – 8 vertical pixels on target.
- Identification – 14 vertical pixels on target.

The above is based on a 50% probability of positive assessment

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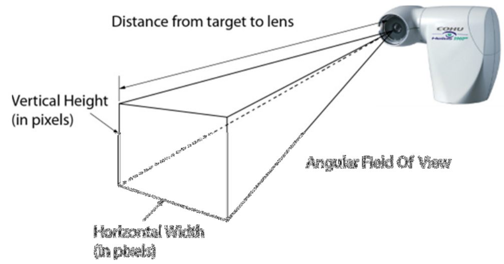
Camera Field of View

The field of view (FOV) is an important parameter that affects how far the camera can see. FOV is the amount of a given scene captured by the camera. It is also referred to as the angle of view or angle of coverage. FOV is determined by three elements: lens, sensor format within the camera, and the camera zoom position in relation to the scene. A larger FOV generally results in the target object being relatively smaller.



CohuHD™ provides a tool located at http://www.CohuHD.com/Files/software_download/PoTCalc.zip to assist you in calculating what the FOV is at a defined target distance from a camera/lens system. The result of this determination is the camera system's FOV in feet (or meters) measured at the target location.

Camera Image Resolution

Image resolution is a term that describes the detail an image holds. Higher resolution means more image detail. Common image resolutions used today are:

Resolution Term	Image Resolution		
	Width		Height
D1	720	x	480
720p	1280	x	720
1080p	1920	x	1080

Now we need to determine the Pixels on Target (PoT), which is calculated using the camera's image resolution, the camera/lens FOV, and the object size.

With this calculation, you can then apply the results to the Johnson Criteria DRI levels to determine the answer to, How Far Can I See?

How to Calculate How Far Can I See?
For the purpose of explanation, the following criteria are used to demonstrate how to perform the calculations:

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- Object Size : 6 ft. (V) x 2 ft. (H) [Person]
- *Camera Field of View : 259 ft. (H) x 145 f.t (V) [Measured @ 4,560 ft. from camera]
- Image Resolution : 1280 (H) x 720 (V) [720p, High Definition]

*The Camera Field of View is based on a 720p 18x camera system calculation. The calculations assume that the target is under ideal lighting conditions.

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Step 1: Calculate Pixels per Foot in Image

Pixels per Foot = Image Resolution / Field of View

- HPF = [1280 / 259] = 5 Pixels per Foot
- VPF = [720 / 145] = 5 Pixels per Foot

Step 2: Calculate Pixels on Object

Pixels on Object = Pixels per Foot x Object Size

- HPoT = 5 HPF x 2 ft. = 10 HPoT
- VPoT = 5 VPF x 6 ft. = 30 VPoT

HPF = Horizontal Pixels per Foot
VPF = Vertical Pixels per Foot
HPoT = Horizontal Pixels on Target
VPoT = Vertical Pixels on Target

Step 3: Compare to your DRI Definition

Here, we use the Johnson Criteria

- Detection – 2 vertical pixels on target (VPoT)
- Recognition – 8 vertical pixels on target (VPoT)
- Identification – 14 vertical pixels on target (VPoT)

Step 4: Result

This example shows that you will have 30 VPoT on a 6 ft man 4,560 ft away, and will be able to Identify him with better than 50% probability

The Johnson Criteria is optimistic. That is, it represents the least number of pixels at which it may be possible to be 50% accurate in DRI assessments. In reality, due to the degradations previously mentioned, the number of pixels needed on target is typically more.

Using increased DRI levels is recommended to achieve more realistic expectations. The chart below is a comparison of different image resolutions, lens magnifications (calculated at maximum zoom) with the resulting distances for detection, recognition and identification of a person. The DRI levels used are 120 VPoT for identification, 30 VPoT for Recognition, and 10 VPoT for detection. Included are images of a 6ft person with the respective VPoT for your convenience.

How Far Can I See?

Object: Human, 6 ft. Tall

CohuHD Camera Solution	Image Resolution	Sensor Format	Zoom Optics	DRI Levels		
				ID	REC	DET
				120	30	10
3920SD, 3960SD	SD 480p	1/4"	35x (119mm)	1,060 ft	4,270 ft	13,650 ft
3920HD, 3960HD	HD 720p	1/3"	18x (84mm)	1,130 ft	4,560 ft	14,560 ft
3920HD, 3960HD	HD 720p	1/3"	30x (132mm)	1,770 ft	7,120 ft	22,730 ft
3920HD, 3960HD	HD 1080p	1/3"	20x (94mm)	1,850 ft	7,440 ft	23,760 ft
8800	SD 480p	1/2"	60x (750mm)	3,760 ft	15,150 ft	48,387 ft
8800HD	HD 720p	1/3"	55x (660mm)	7,310 ft	29,450 ft	94,050 ft
8800HD	HD 1080p	1/3"	55x (660mm)	10,960 ft	44,180 ft	141,000 ft
*8800HD	HD 1080p	1/3"	137.5x (1650mm)	27,895 ft	112,100 ft	358,721 ft

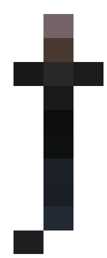
*Lens 2.5x extender inserted

The images below depict the amount of detail an observer would see with the DRI levels and object distances above.

120 VPoT
Identification

30 VPoT
Recognition

10 VPoT
Detection



Analysis of Chart Statistics

A result that is clear from the chart above, is that cameras with higher magnification lenses can not necessarily see farther. When comparing the D1 35x camera with the 720p 18x camera, you can see that in fact the 720p camera, with almost half the optical power, can see further than the D1 camera.

Comparing the 720p 30x camera with the D1 35x camera, you can see that the higher resolution and optical magnification of the 720p 30x camera results in seeing more than 1-½ times further than the standard definition D1 35x camera despite it having more optical magnification. Considering only optical magnification should be avoided.

Beyond this, using 1080p image resolution with powerful 55x optics, the results are astounding, resulting in viewing distances greater than 10x the traditional D1 camera systems. The benefits of seeing farther by using increased image resolution and optical magnifications become obvious from the chart statistics above.

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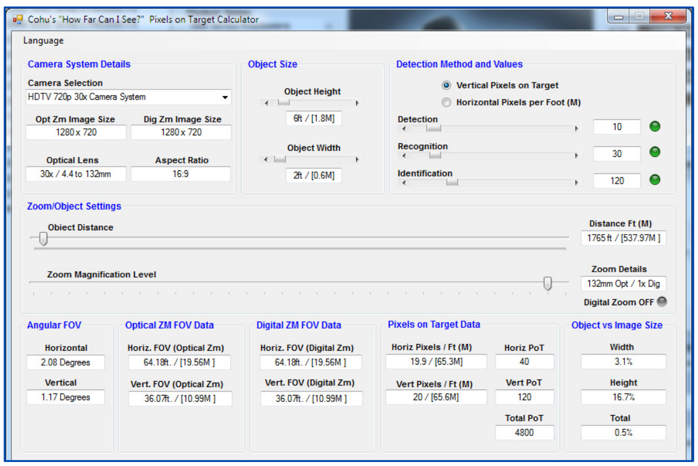
CohuHD Pixels on Target Calculator

CohuHD provides a tool to estimate the distance at which an object can be detected, recognized, and identified. It also estimates the distance at which general, forensic or high detail levels can be observed. The calculation is based on object size, vertical or horizontal detection criteria, pixels on target values, and camera system variables (such as resolution, optical or digital zoom, and aspect ratio). Johnson Criteria are used for target assessment. The factors that influence the accuracy of discrimination such as object/scene contrast ratio, atmospheric conditions, and daytime vs. nighttime, should be taken into consideration, and adjustments to the estimated distance may result. The calculator can be downloaded from the website at: http://www.CohuHD.com/Files/software_download/PoTCalc.zip.



Conclusion – Where Will Your Camera Take You?

So, where do you want your camera to take you? How far away? It depends on several environmental variables and the camera system. The more pixels on target, the more detail can be observed. However, the higher detail level will require greater bandwidth. So, the level of information the camera system needs to provide becomes an important question in determining specifications for the system. CohuHD can help customers define their needs and choose the best camera system to meet those needs. For more information on CohuHD products, please go to http://www.CohuHD.com.