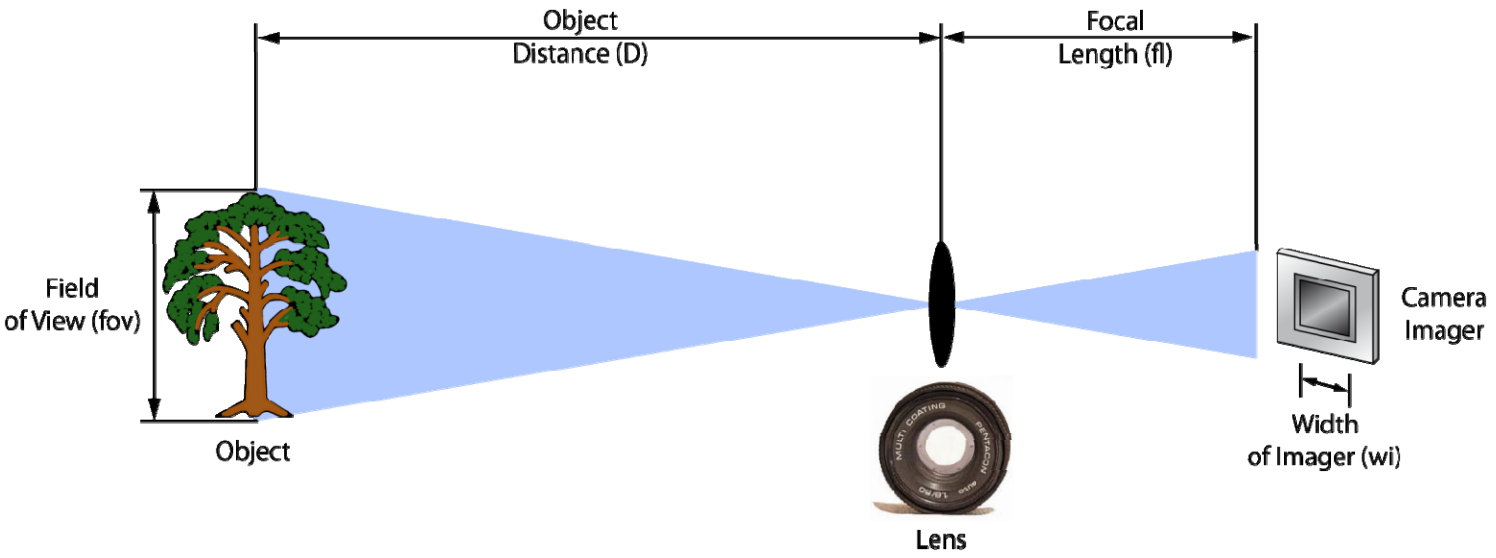
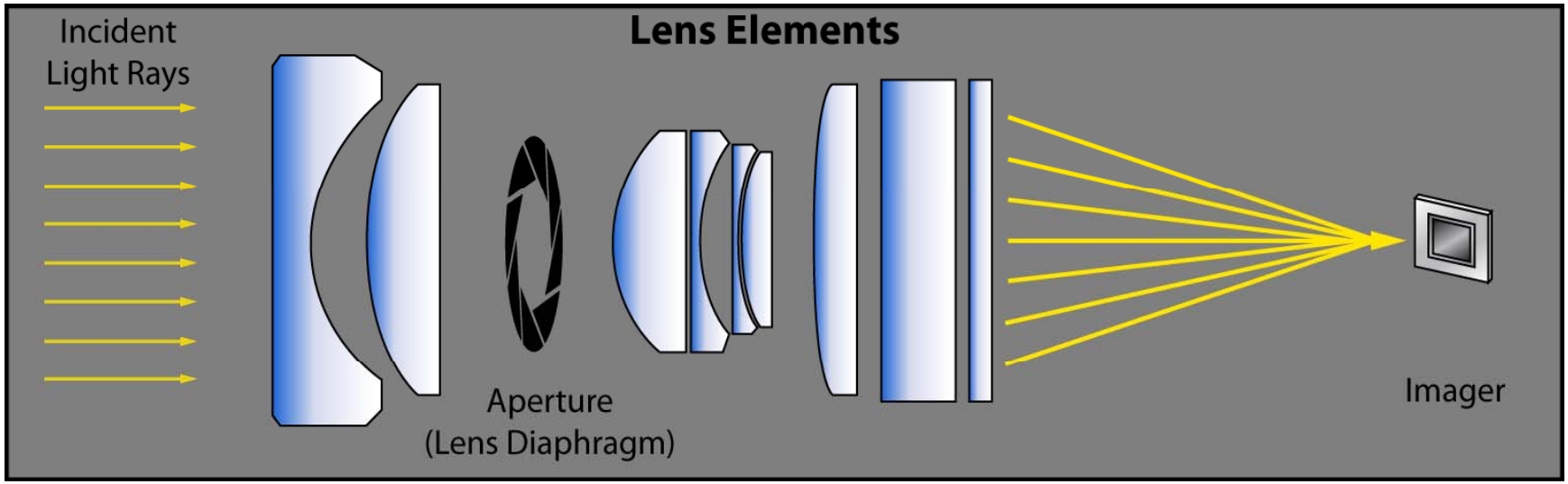
Lenses

Primary Functions of a Camera Lens

- **Lens determines size of scene image projected onto the camera imager at a specified distance behind the lens**
- **Focuses reflected light from the scene on the camera imager**
- **When the lens is focused on infinity, the focal length is the distance between the lens and the imager**



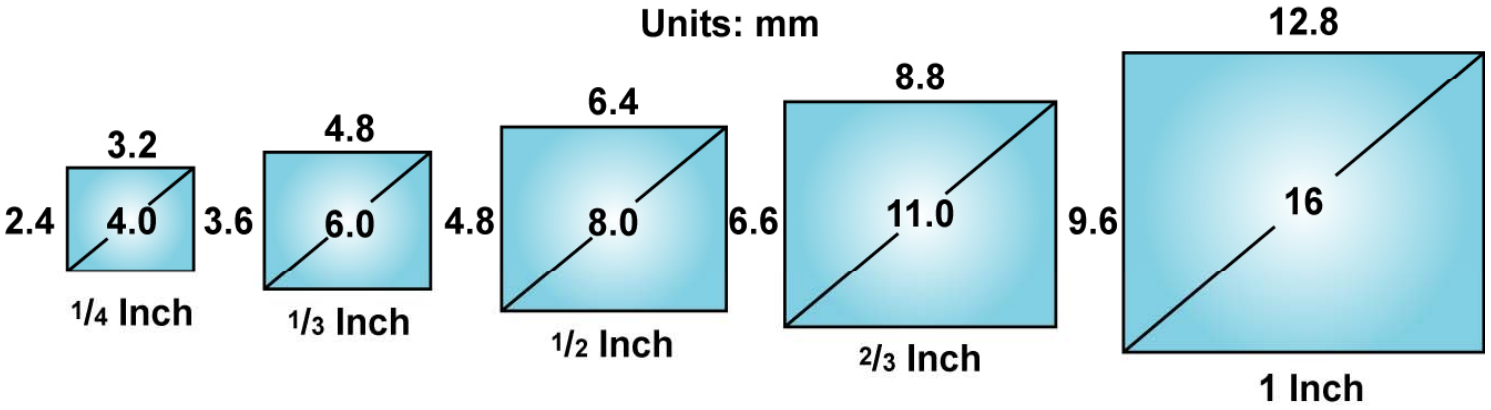
Example of Composite Lens Elements



Lens Format (cont.)

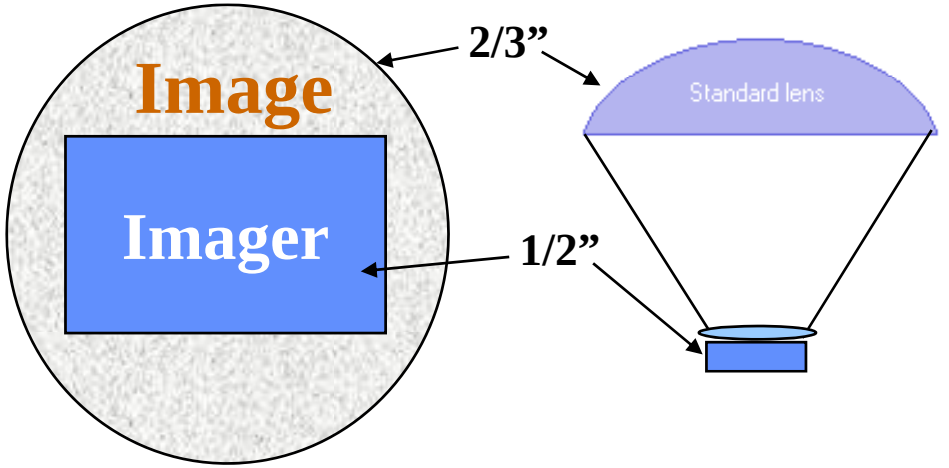
- The lens has a format specification similar to the camera imager
- Lens format must match the camera format size to optimize video image display on camera sensor
- Standard format sizes are:

Lens Format	1/8"	1/6"	1/4"	1/3"	1/2"	2/3"	1"
Imager Width *(Wi)*	1.6 mm	2.4 mm	3.2 mm	4.8 mm	6.4 mm	8.8 mm	12.8 mm

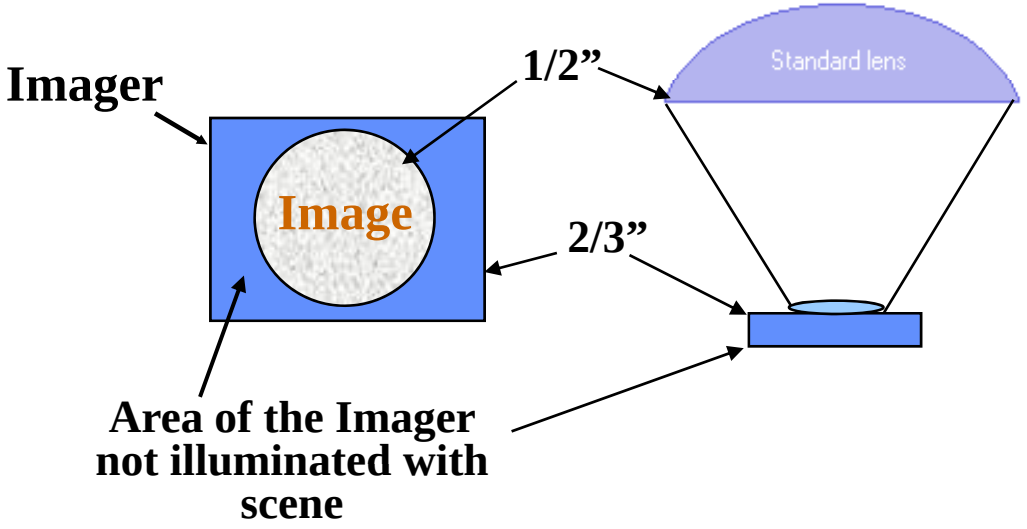


Lens-Imager Format Mismatch

- **Lens format <u>larger</u> than camera format**
  - Area larger than 100% of imager exposed
  - Imager not exposed to part of scene

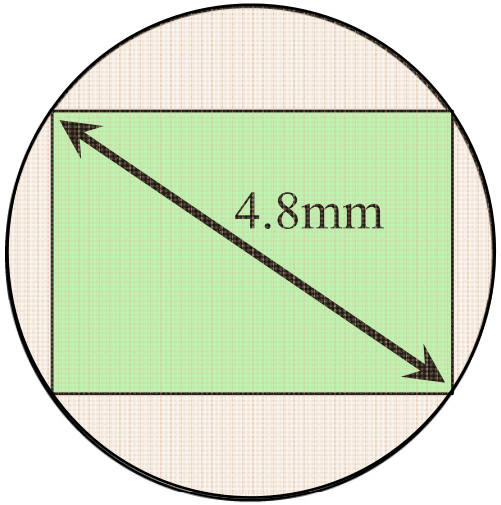


- **Lens format <u>smaller</u> than camera format**
  - Imager not fully illuminated with scene
  - Circular “keyhole” effect



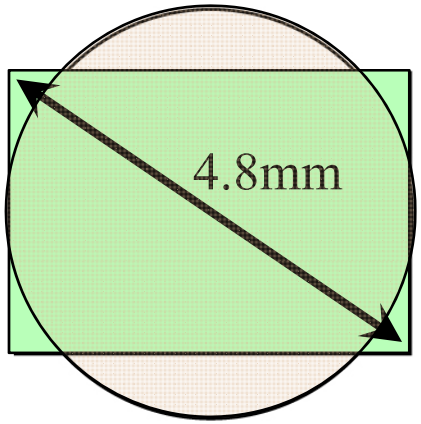
Lens and Camera Imager Format Match & Mismatch Examples

Correct



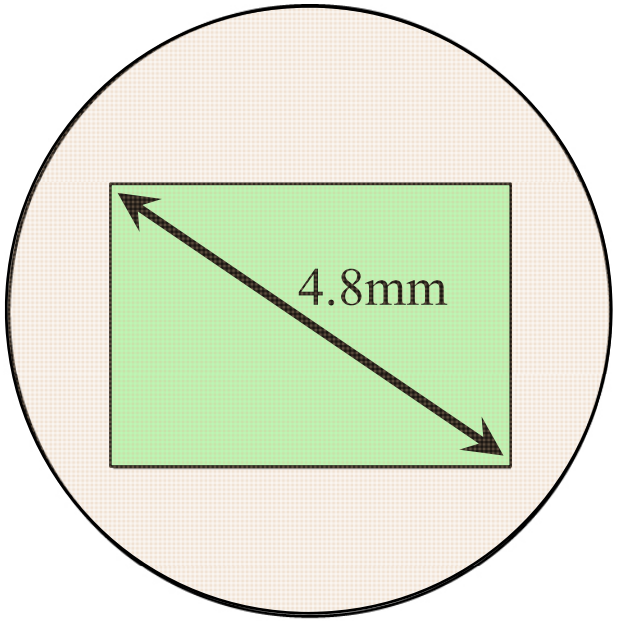
4.8mm lens

Example 1 Mismatch

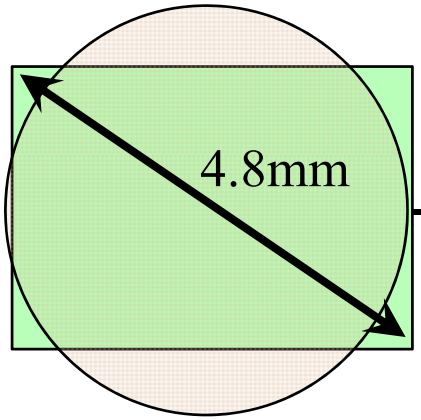


3.2mm lens

Example 2 Mismatch

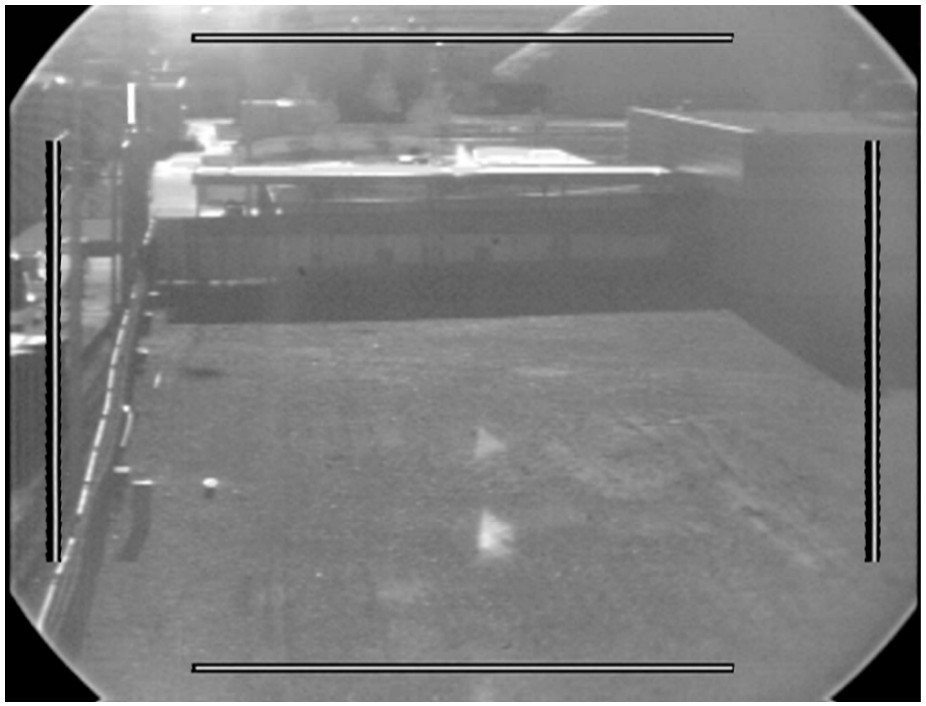


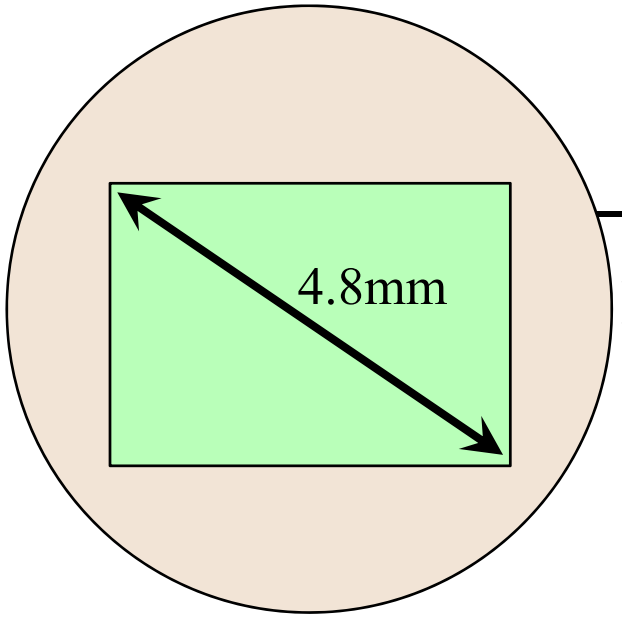
6.4mm lens



Format Mismatch Example 1

Examples of lens format smaller
than imager format





Format Mismatch Example 2

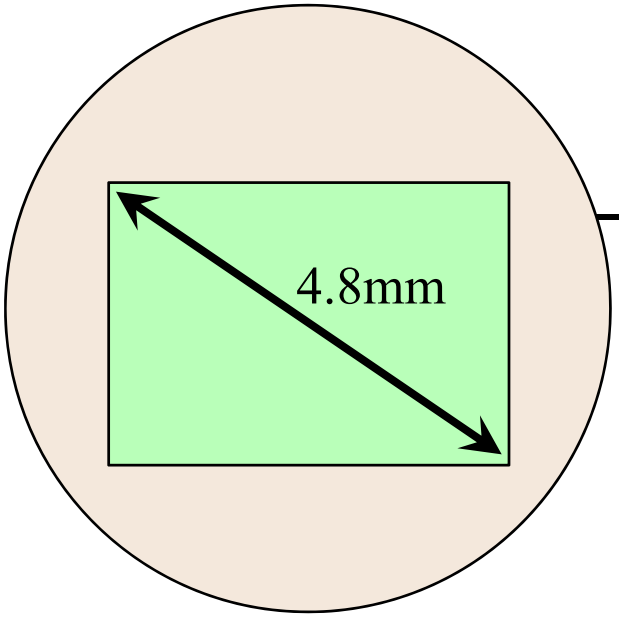
Examples of lens format larger than imager format

- Field of view is smaller than specified for the lens
- Portion of field of view is focused outside the imager

Interior Examples

View with Matched Format

View with Mismatched Format



Format Mismatch Example 2 (cont.)

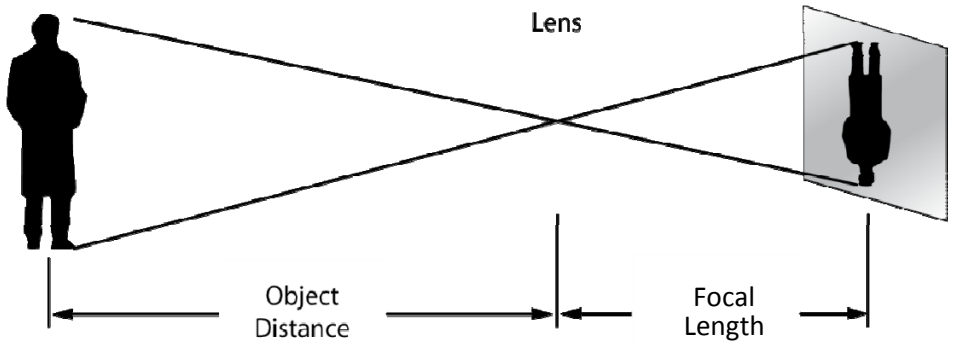
Exterior Examples

View with Matched Format

View with Mismatched Format

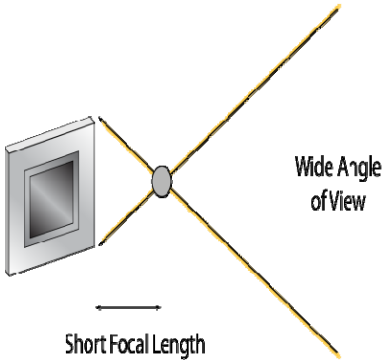
Lens Focal Length

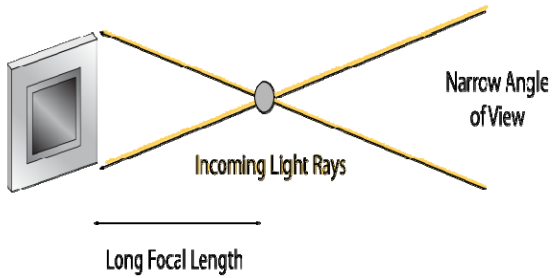
Focal Length is the distance from the lens to the camera imager when the lens is focused at infinity



Lens focal length determines angle of view, and image magnification

- Wide angle lenses have small focal lengths for near views
- Telephoto lenses have large focal lengths for distance views

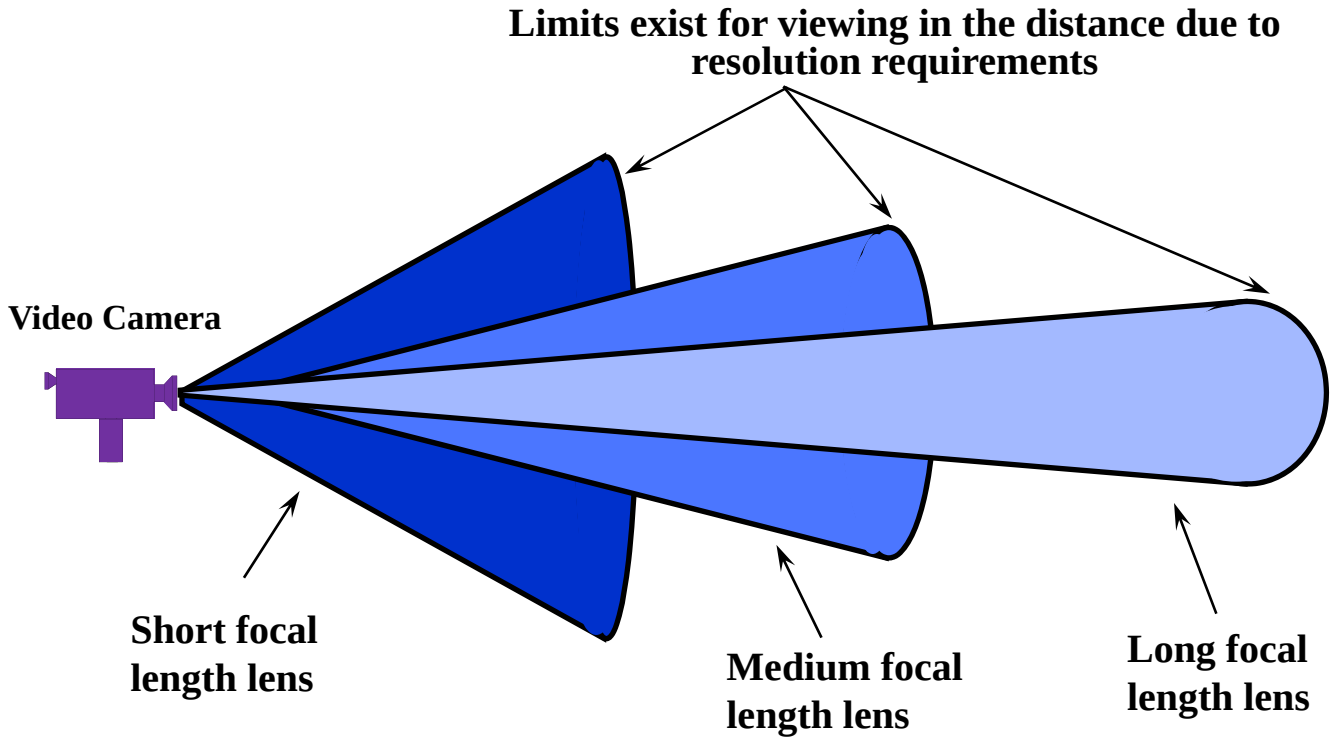




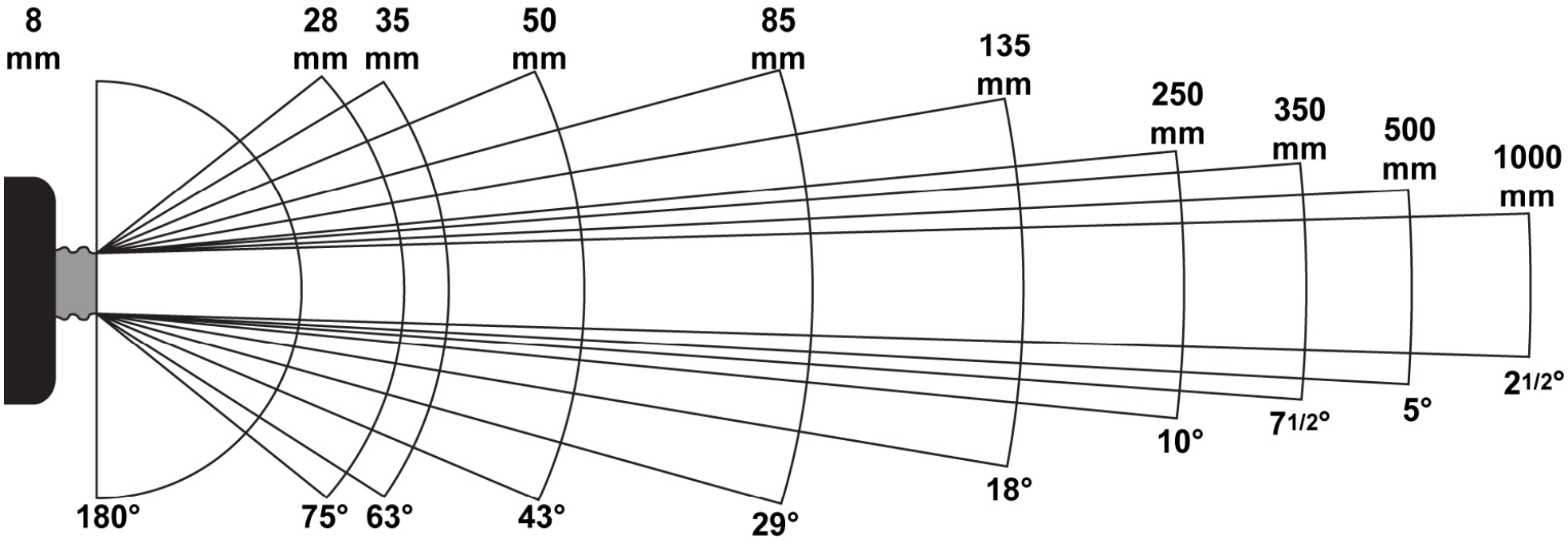
Lens Focal Length

Relative magnification of an object and the size of field of view

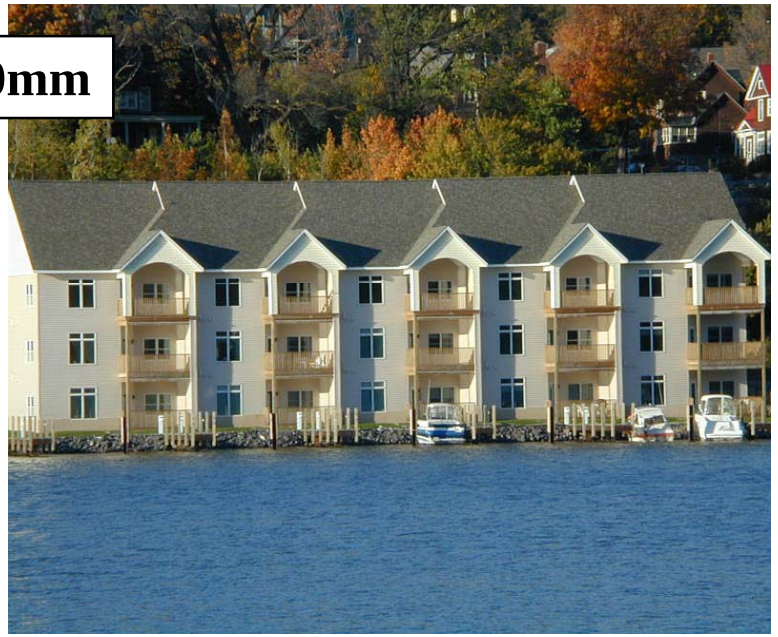
- Smaller numbers indicate a shorter distance & wider field of view (e.g., 4mm, 6mm)
- Larger numbers indicate longer distance & more narrow field of view (e.g., 50mm, 75mm)



Examples of
Lens Focal Length Relationships



Examples of an Image at Four Different Focal Lengths



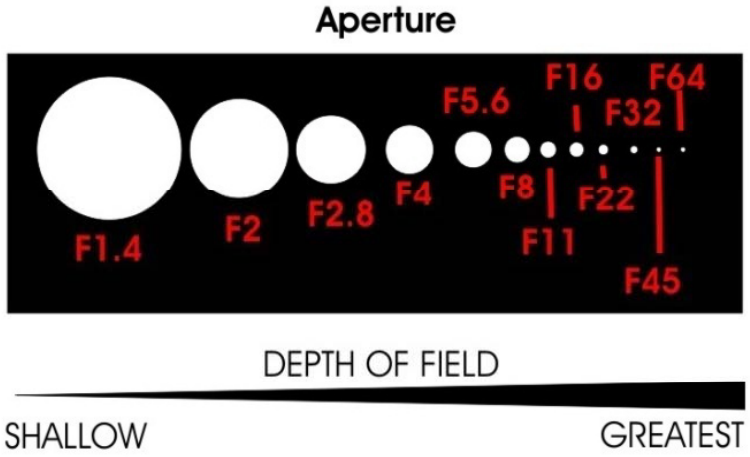
Courtesy of Michigan Tech

Lens Aperture

Aperture for a manual iris - The adjustable diaphragm opening controls the amount of light entering through the lens



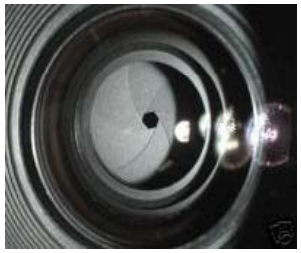
- **Regulates the amount of light that passes onto the imager**
- **Can be fixed or adjustable**
- **Calibrated in *f-numbers* or f-stops**



Lens Iris

Manual Iris

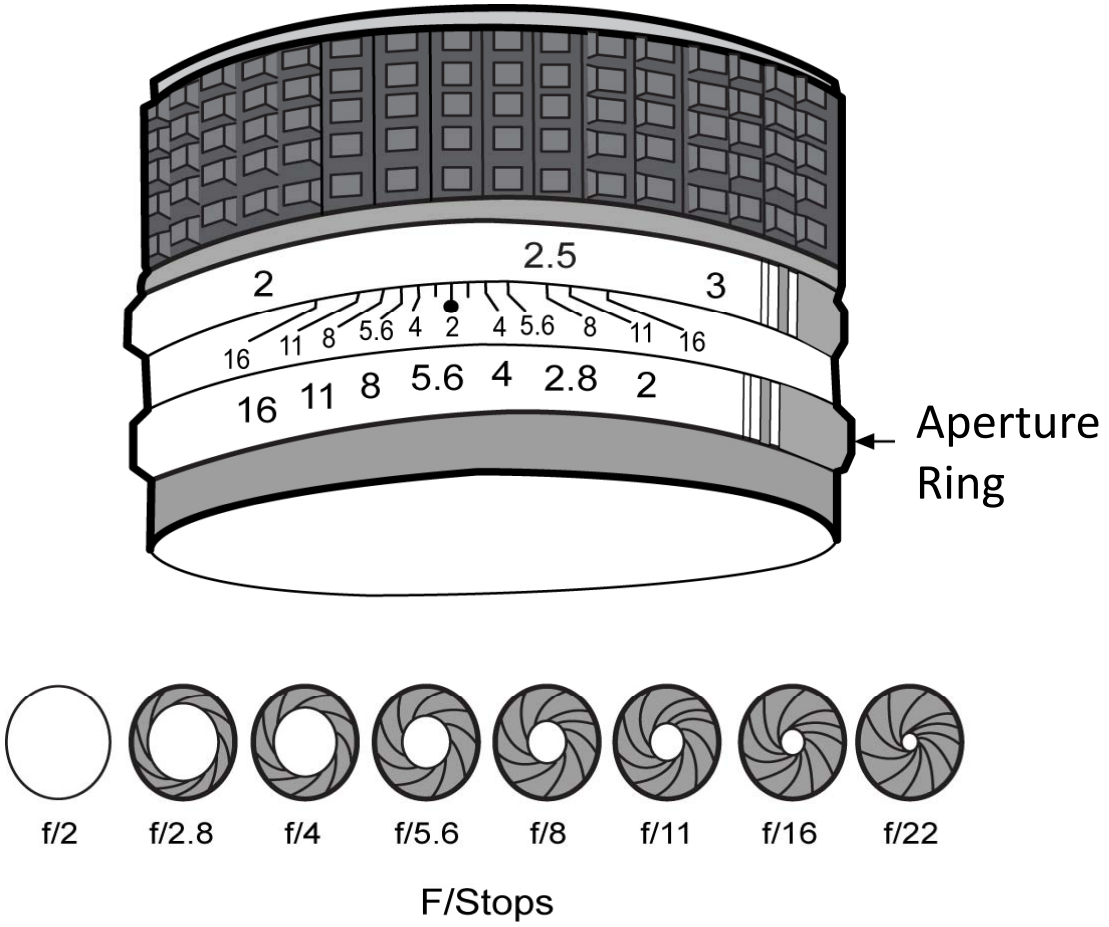
- For use in environments where the amount of light is constant



Automatic Iris

- For use in environments where the amount of light is not constant
- Controlled by signal from camera

Manual Aperture Ring Relationship to Iris Opening



Lens f-stop

f-stop is the focal length divided by the diameter of the lens opening

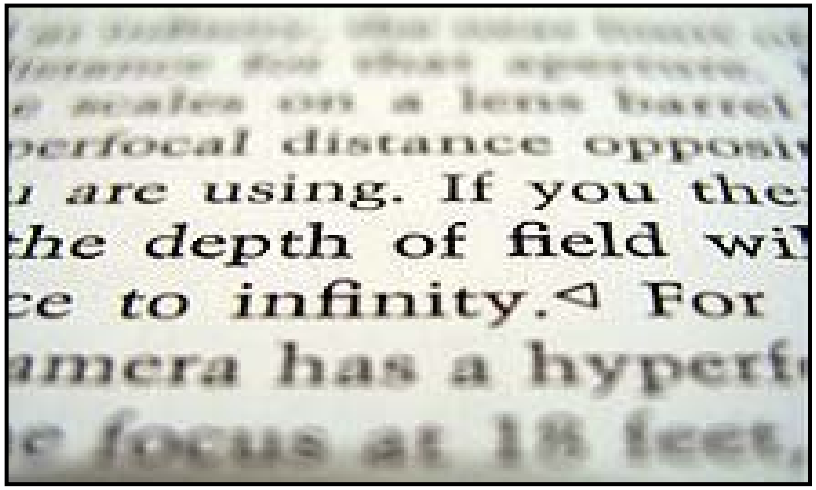
- Indicates the relative amount of light that can be delivered to imaging device (smaller numbers allow more light through)
- 25mm focal length, f/1.4 lens is 17.9 mm wide
  25mm/17.9mm = f/1.4
- The progression of f-stops for security cameras is:

1	1.4	2	2.8	4	5.6	8	11	16	22

which are all powers of the square root of 2

Depth of Field

The Depth of Field is that portion of the image that is in sharp focus

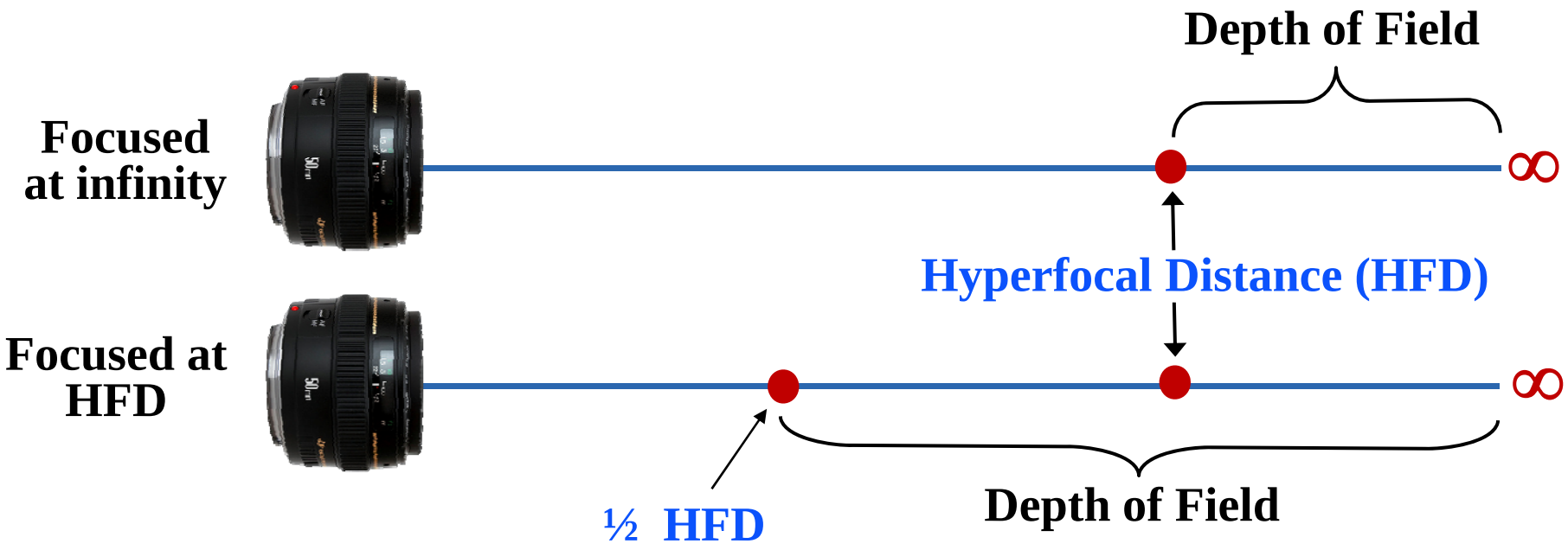


- **Amount of scene in focus is greatest when focused at the hyperfocal distance**
- **The Depth of Field is greater**
  - When higher f-stops used
  - When smaller focal lengths used
  - When subject distance from camera is larger

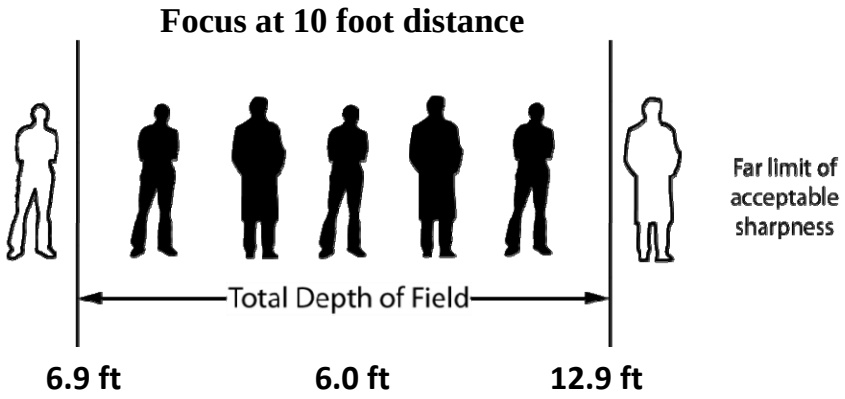
Focus at Hyperfocal Distance (HFD)

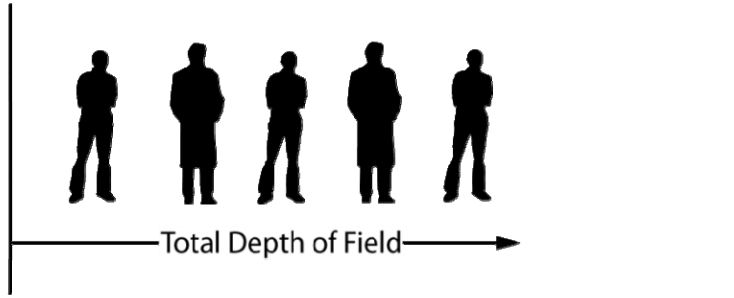
Hyperfocal Distance is the lens focus distance that allows objects over the largest distance to be in focus

- Setting the focus of lens to the hyperfocal distance allows objects 1/2 that distance to infinity to be in focus
  - Gives largest depth of field



A Physical Example of Hyperfocal Distance (HFD)





Depth of Field Extends from 15 feet to Infinity

Hyperfocal Distance Charts

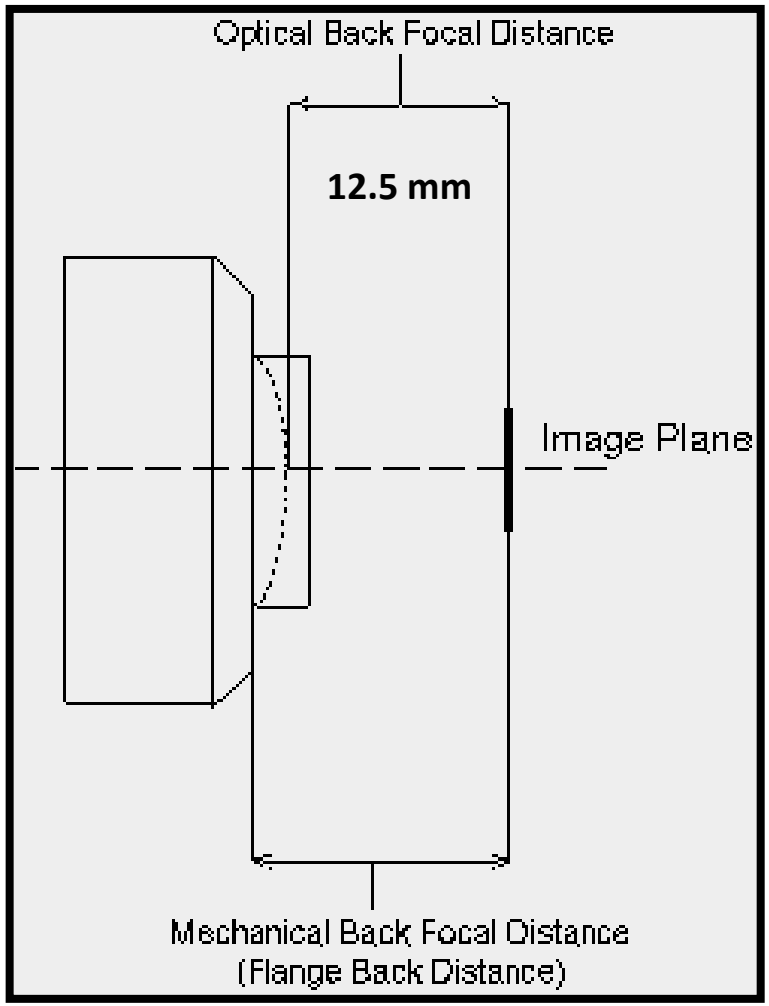
Hyperfocal point in feet from camera

	15 mm	17 mm	20 mm	24 mm	28 mm	35 mm	50 mm	100 mm	150 mm	200 mm
f 2.8	8.79	11.29	15.62	22.50	30.62	47.85	97.64	390.58	878.80	1562.30
f 5.6	4.39	5.64	7.81	11.25	15.31	23.92	48.82	195.29	439.40	781.15
f 8	3.08	3.95	5.47	7.87	10.72	16.75	34.18	136.70	307.58	546.81
f 11	2.24	2.87	3.98	5.73	7.79	12.18	24.85	99.42	223.69	397.68
f 16	1.54	1.98	2.73	3.94	5.36	8.37	17.09	68.35	153.79	273.40
f 22	1.12	1.44	1.99	2.86	3.90	6.09	12.43	49.71	111.85	198.84
f 36	0.68	0.88	1.22	1.75	2.38	3.72	7.59	30.38	68.35	121.51

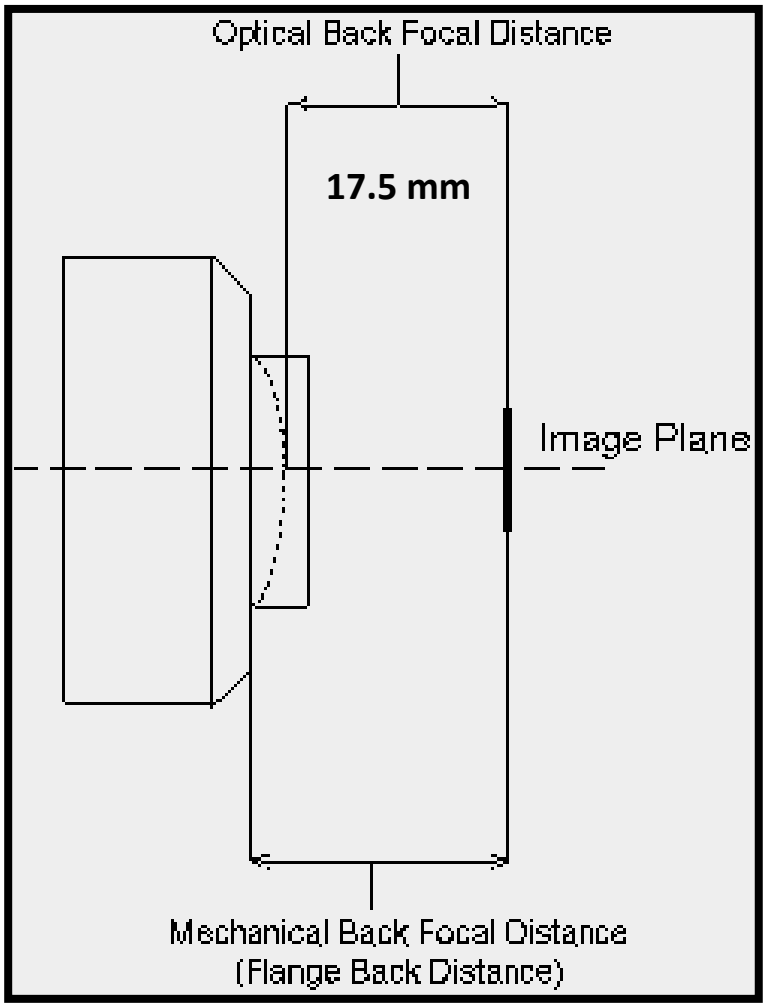
Lens Mounts

- **Flange back distance is between the flange of the lens and the focal plane of the lens**
- **C – flange back distance is 17.5mm**
- **CS – flange back distance is 12.5mm**
- **CS camera to C mount adapter (5mm spacer)**
- **C mount camera to CS lens not possible**
- **Others – normally still image photography**

C and CS Mount



CS - Mount

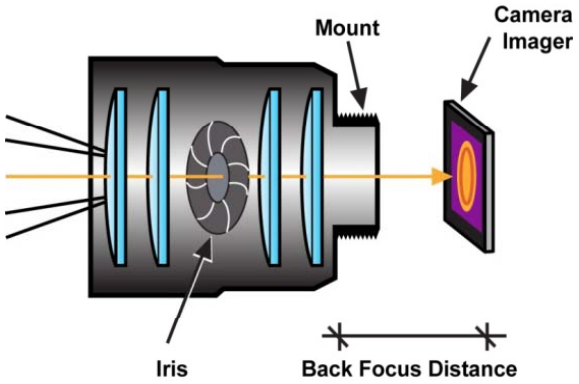


C - Mount

Lens Mechanical Focus

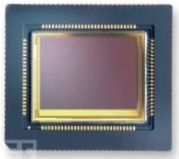
Lens Focus -- There are two focus adjustments

- **Back Focus -- this adjusts the distance between the back of the lens and the imager**
- **Front Focus -- This adjusts the focusing lever or focus ring on the lens assembly to provide a clear image at the camera imager**

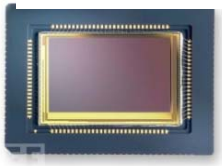


Field of View

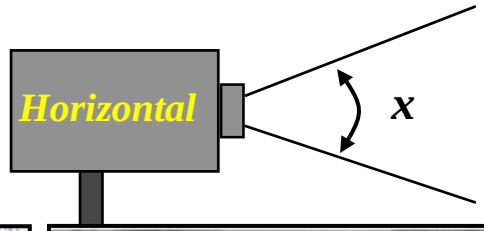
Field of View – the horizontal and vertical distances visible in the camera image at a linear distance from the camera

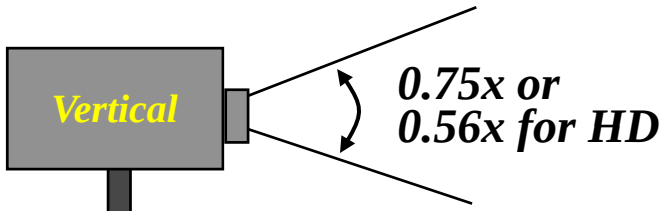


– For a standard camera, the vertical field of view is 0.75 times the horizontal field-of-view dimension

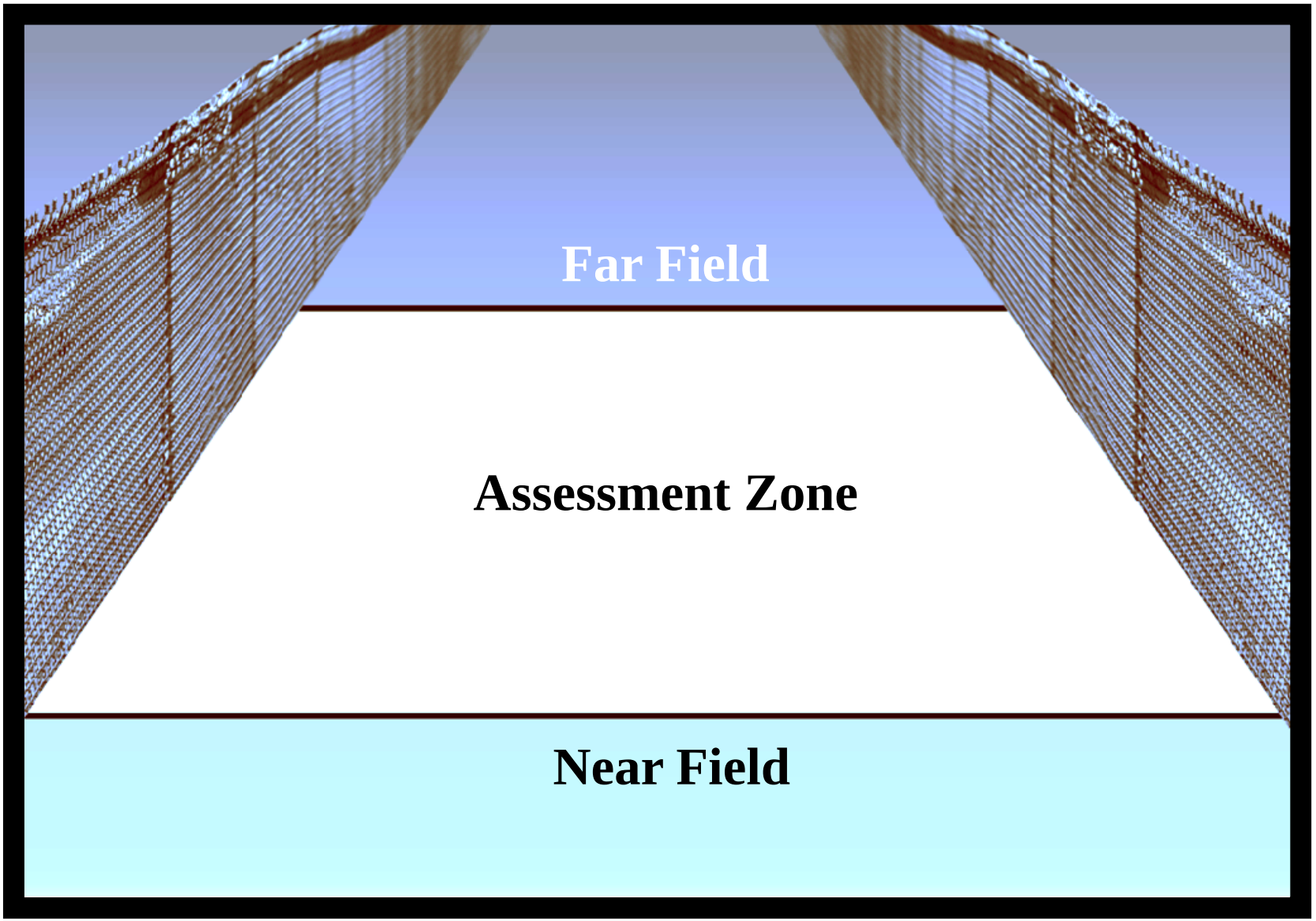


– For a High Definition camera, the vertical field of view is 0.56 times the horizontal field-of-view dimension

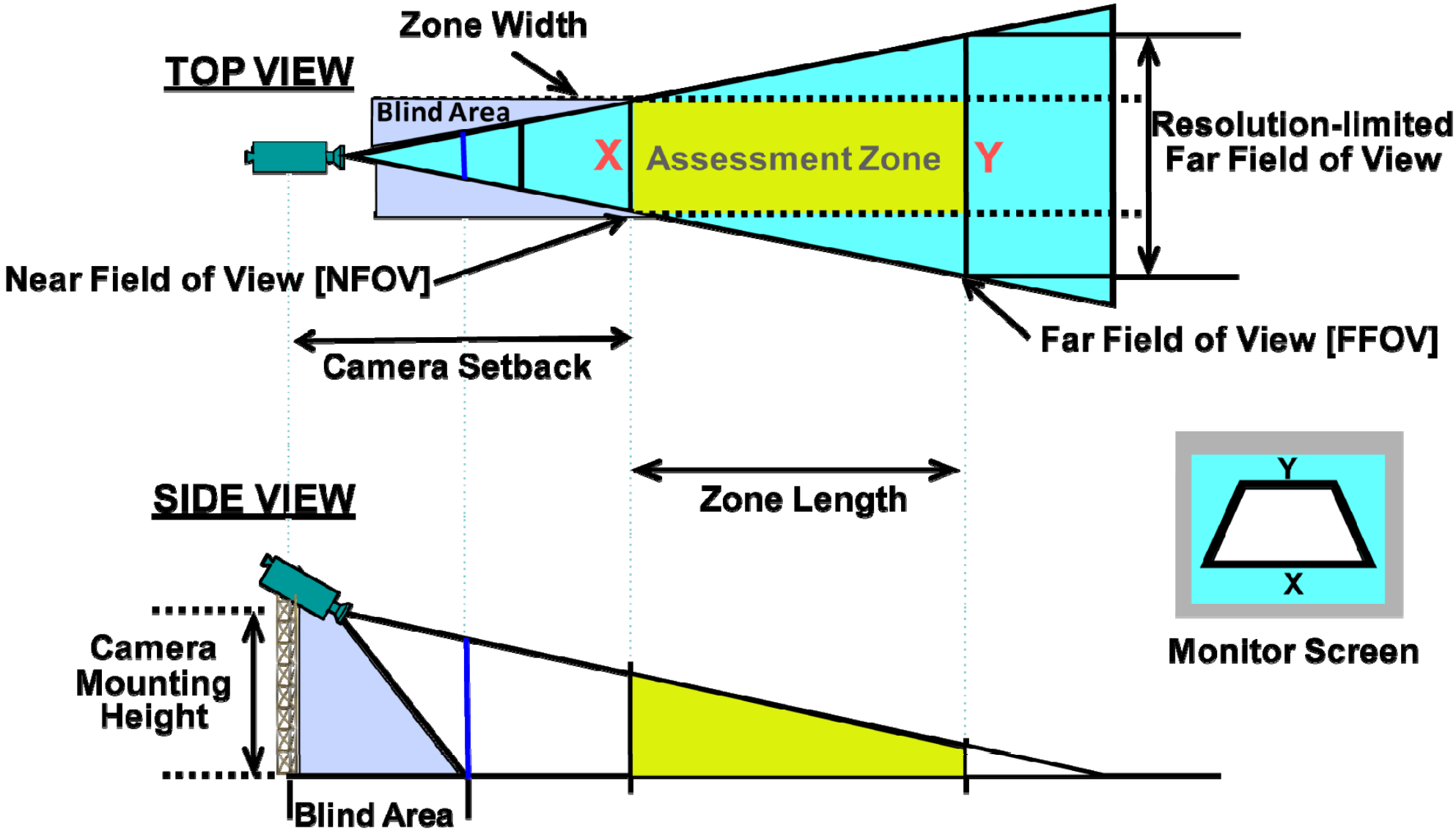




Assessment Area Monitor View



Geometry of Assessment Zone



Levels of Assessment Resolution

Detection	Classification	Identification
		
Determine Presence of Object	**Determine Nuisance or Real Alarms**	**Determine Identity of Object**

Assessment Resolution - *Detection*

Assessment Resolution - *Classification*

Assessment Resolution - *Identification*

Assessment Resolution (cont.)

For assessment, we consider 3 levels of resolution:

Detection	identify the presence of an object in the video image
Classification	identify whether the object is a human, animal, or blowing debris
Identification	recognize the person, know more than that they are human

Sandia believes that the approximate number of pixels in width needed to assess a 1-foot target is as follows:

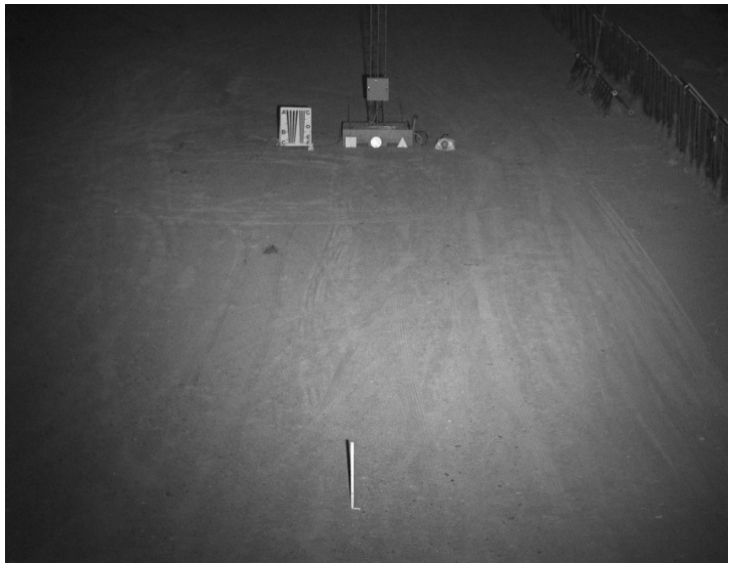
Detection	**2 to 3**
Classification	**6 to 9**
Identification	**10 to 16**

Factors that can aid assessment are:

Contrast, Motion, the Upright Human Figure

Assessment Resolution (cont.)

- Assessment resolution depends on camera resolution, lens field of view, & closeness of object to camera
- Want to distinguish (classify) between an animal and a person crawling with head facing camera
- It is easier to determine that an object is a human if the human is in a standing position




CAMERA 1

Far Field Resolution

760 x 480 pixel resolution

1376 x 1032 pixel resolution

4 times as many pixels!

Field of View and Resolution Testing

Using a Circle, Triangle, & Square to Determine Far Field of View Resolution Adequacy

Horizontal Resolution at Far-Field

To recognize the circle, triangle, and square, 8 pixels are needed on a 1-foot target at the FFOV (far field of view) = 0.125 foot per pixel

- If a camera/monitor provides **800** pixels of horizontal resolution, then the maximum field of view width is:

  0.125 ft x 800 pixels = 100 feet

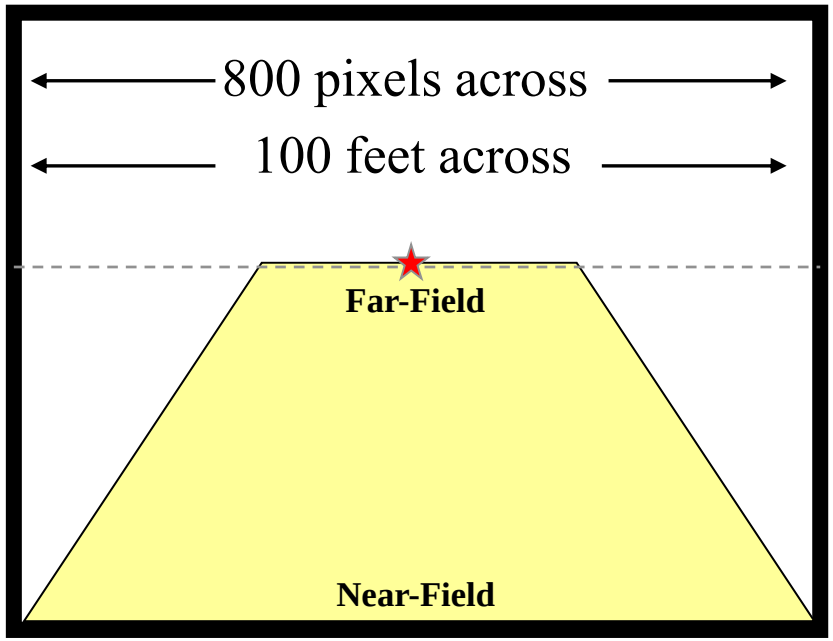
- Another way to calculate is using ratios:

  8 pixels to 1 foot = 800 pixels to *x*

  $$\frac{8 \text{ pixels}}{1 \text{ ft}} = \frac{800 \text{ pixels}}{x}$$

  Solve for *x* = 100 ft

- What if the camera imager was 640 pixels?



Interior Assessment

An extreme wide angle can cause the "fish-eye" effect, making identification difficult