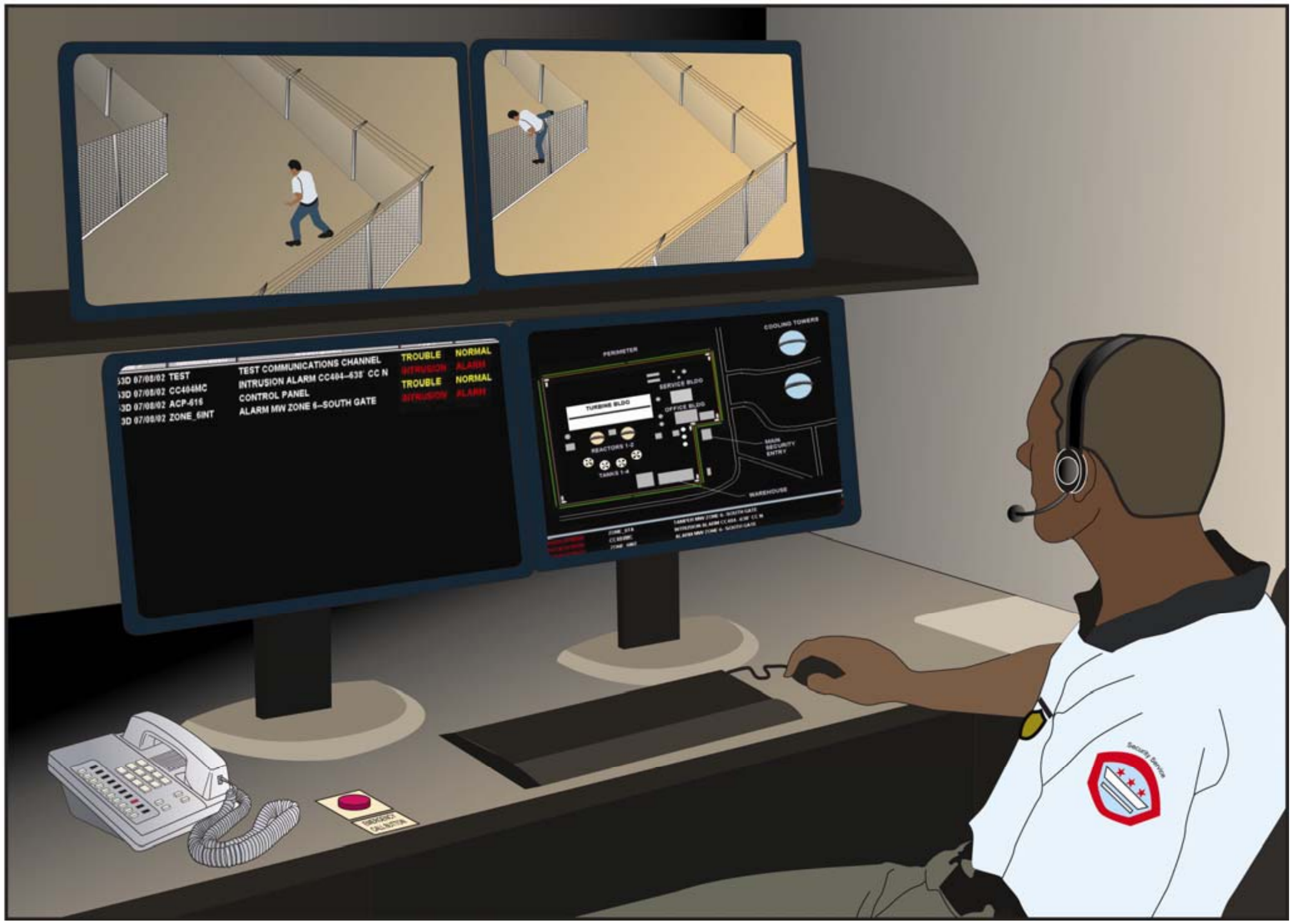
SAND2009-5406P

# Module 13

# An Introduction to Alarm Assessment

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# Classification

- All material in this module is unclassified
- In this module, photos of equipment are included as examples only. Sandia National Laboratories does not endorse or recommend any specific equipment.

# Module Objectives

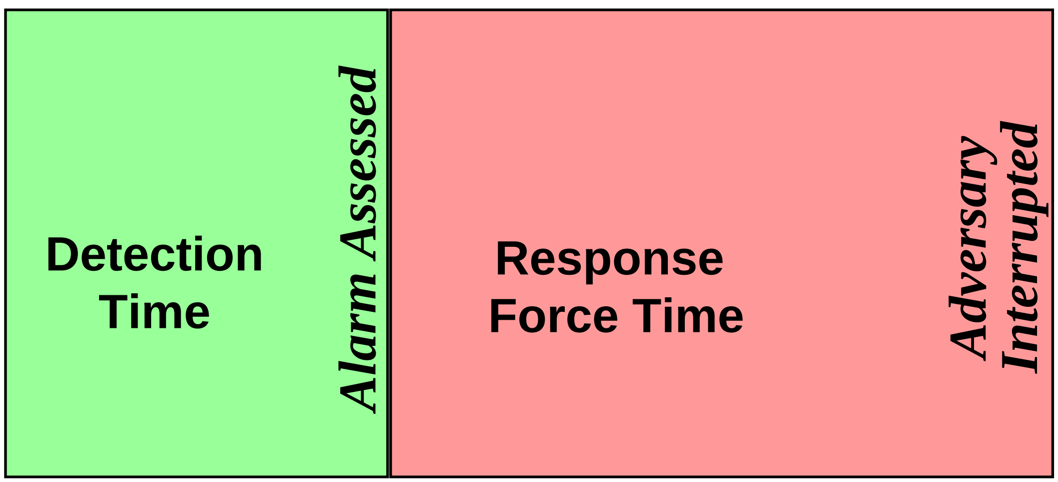
- **Review the basic fundamentals of alarm assessment**
- **Understand the purpose and importance of alarm assessment for a physical protection system**
  - **People vs. technology**
- **Understand the differences between assessment and surveillance**
  - **Key points**

# Module Outline

- Purpose
- Methods – people, technology
- Definitions
- Key points
  - Assessment
  - Surveillance
- Overall goal

# Purpose of Alarm Assessment System

- **Determine cause of each sensor alarm**
- **Provide information about an intrusion – relay to response force**
- **End detection time**

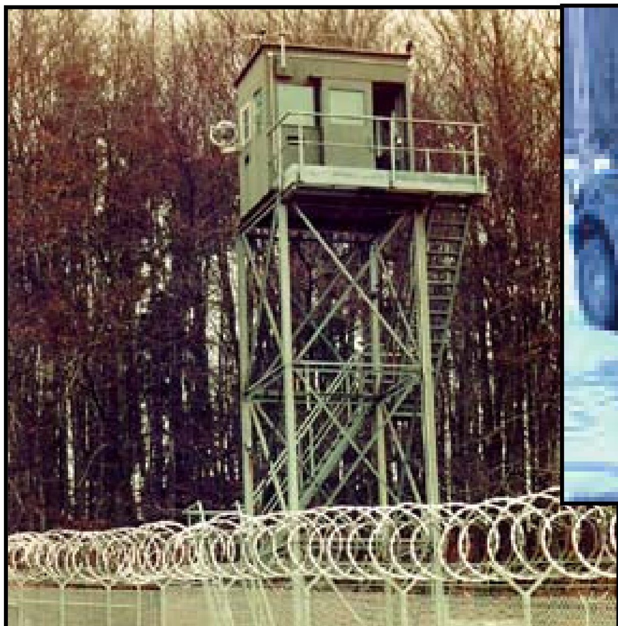


# Class Question #1: Detection Time

## Question: Which step ends detection?

1. Sensor alarm signal is generated
2. Alarm signal is transmitted to console
3. Operator is alerted by incoming alarm
4. Operator scans images on a monitor of the alarmed detection zone
5. In searching for cause of alarm, operator observes an unauthorized person in that area
6. Operator calls up response force, identifying nature and location of intrusion
7. Response force interdicts intruder

# *People* Determine the Cause of an Alarm



# Determine Cause - Technologies

- **Video cameras and appropriate lighting must provide full coverage of indoor & outdoor sensored areas**
- **Thermal cameras must provide full coverage of sensored areas without illumination**
- **Images are displayed to an Central Alarm Station (CAS) operator for assessment**

# Class Question #2:  Detection Time

## Question:  Which step ends detection?

1. **Sensor alarm signal is generated**
2. **Alarm signal is transmitted to console**
3. **Operator is alerted by incoming alarm**
4. **Operator sends roving patrol to investigate since the video system is offline**
5. **The patrol radios to the operator that they have arrived at the sensored area**
6. **After 1 minute the operator sends another patrol to investigate why the first patrol has not responded**

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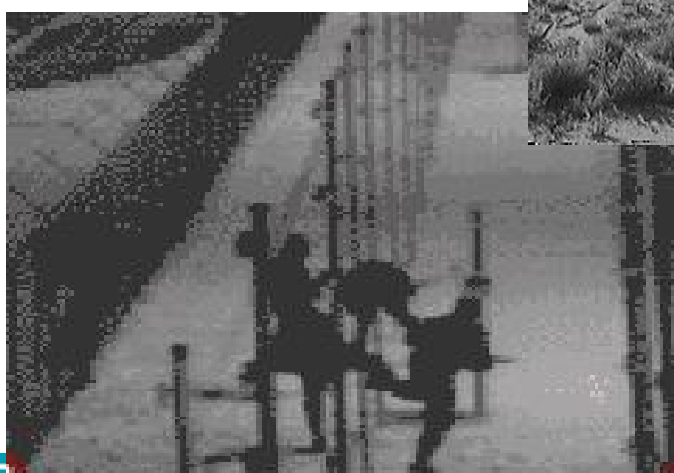
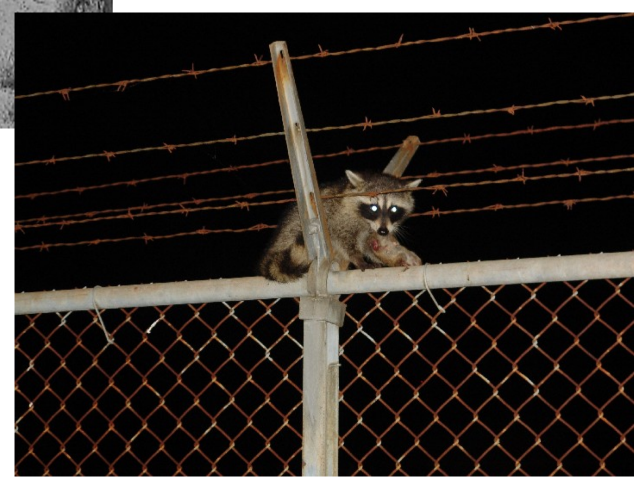
# Provide Information

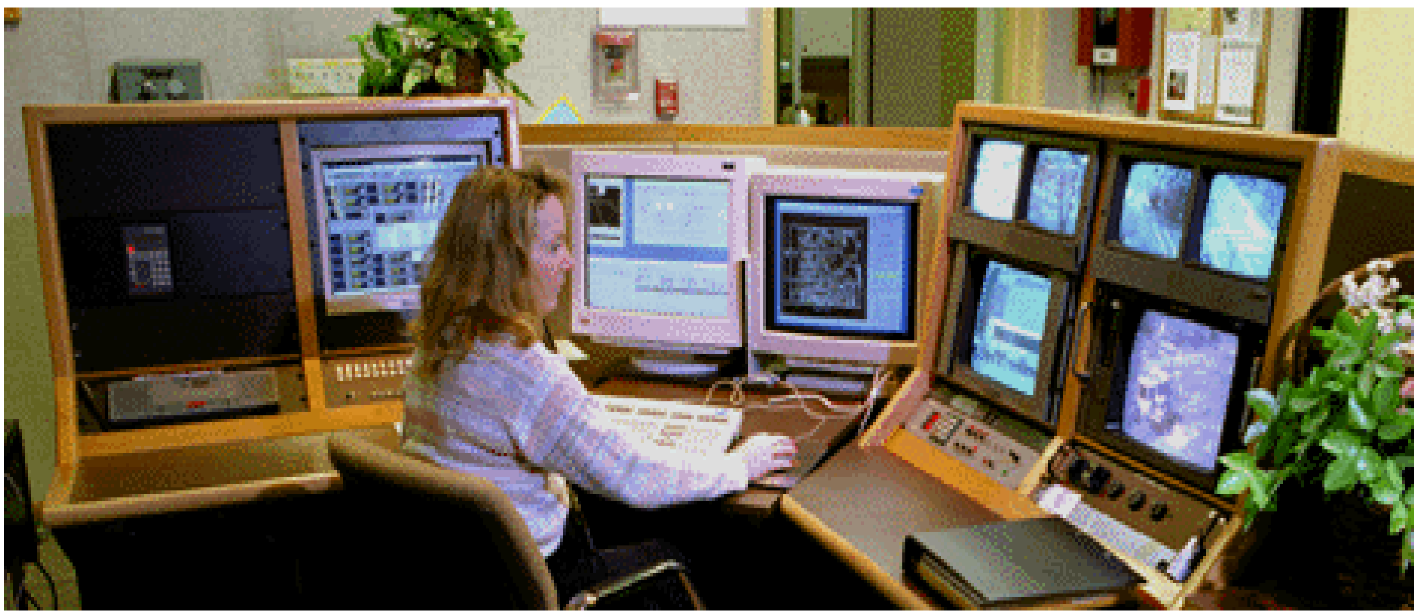
- **Detection, Classification, and Identification**



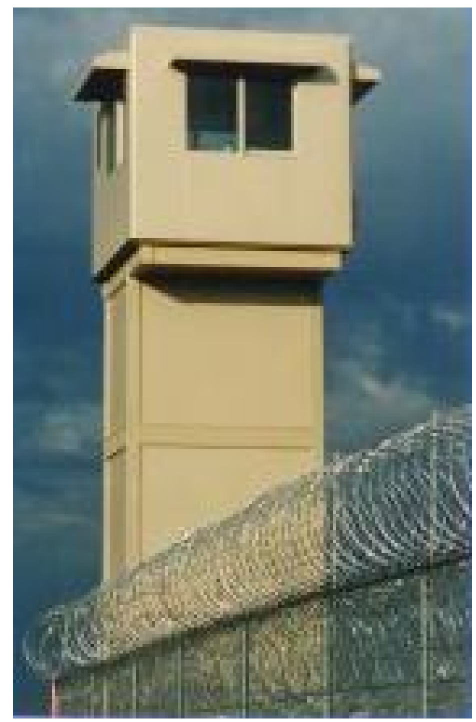
# Assessment vs. Surveillance

- **Definition of *ASSESSMENT***
  - **Video information caused by an alarm activation transmitted to a security operator at the CAS so that operator can determine if an intruder has penetrated a sensored area**



# Assessment vs. Surveillance *(cont.)*

- **Definition of *SURVEILLANCE***
  - **Continuous use of a human as an intrusion detector to monitor areas that are <u>NOT</u> sensored to create intrusion alarms**



# Assessment – Key Points

- The efficiency or accuracy of reporting events by a video technology does not significantly change; slow degradation, catastrophic (lightning strike).
- Technologies can be a force multiplier
- Humans are alerted to alarmed events for video assessment
- Proper application of sensor, video, & AC&D technologies can assist the CAS operator in making quick and accurate decisions

# Surveillance – Key Points

- Video cameras are usually visible to the public and can be used as a deterrent
- Using a human as an intrusion detector has a low $P_D$ (Probability of Detection)
  - Generally believed to be a $P_D$ of 0.1 to 0.2
- Surveillance is used when time is not critical to an event
- Loss of video leaves a single point failure in the assessment of an intrusion

# Overall Goal

- At the end of this series of alarm assessment modules, you will be able to
  - Design and / or evaluate an effective alarm assessment system
  - Understand the use and limitations of surveillance
  - Evaluate a design of an alarm assessment or surveillance system for effectiveness
  - Performance test an alarm assessment system to determine its adequacy and effectiveness

# Summary

- **Detection is not adequate or complete without assessment**
- **Humans make poor detectors but are good at assessment**
- **For an effective on-site response, the time between alarm notification at the CAS and assessment must be short**

**Alarm + Assessment = Detection**

# Introduction to Alarm Assessment and Basic Review

***Questions?***

# Module 14

## Overview of Video System Components

# Classification

- **All material in this module is unclassified**
- **In this module, photos of equipment are included as examples only. Sandia National Laboratories does not endorse or recommend any specific equipment.**

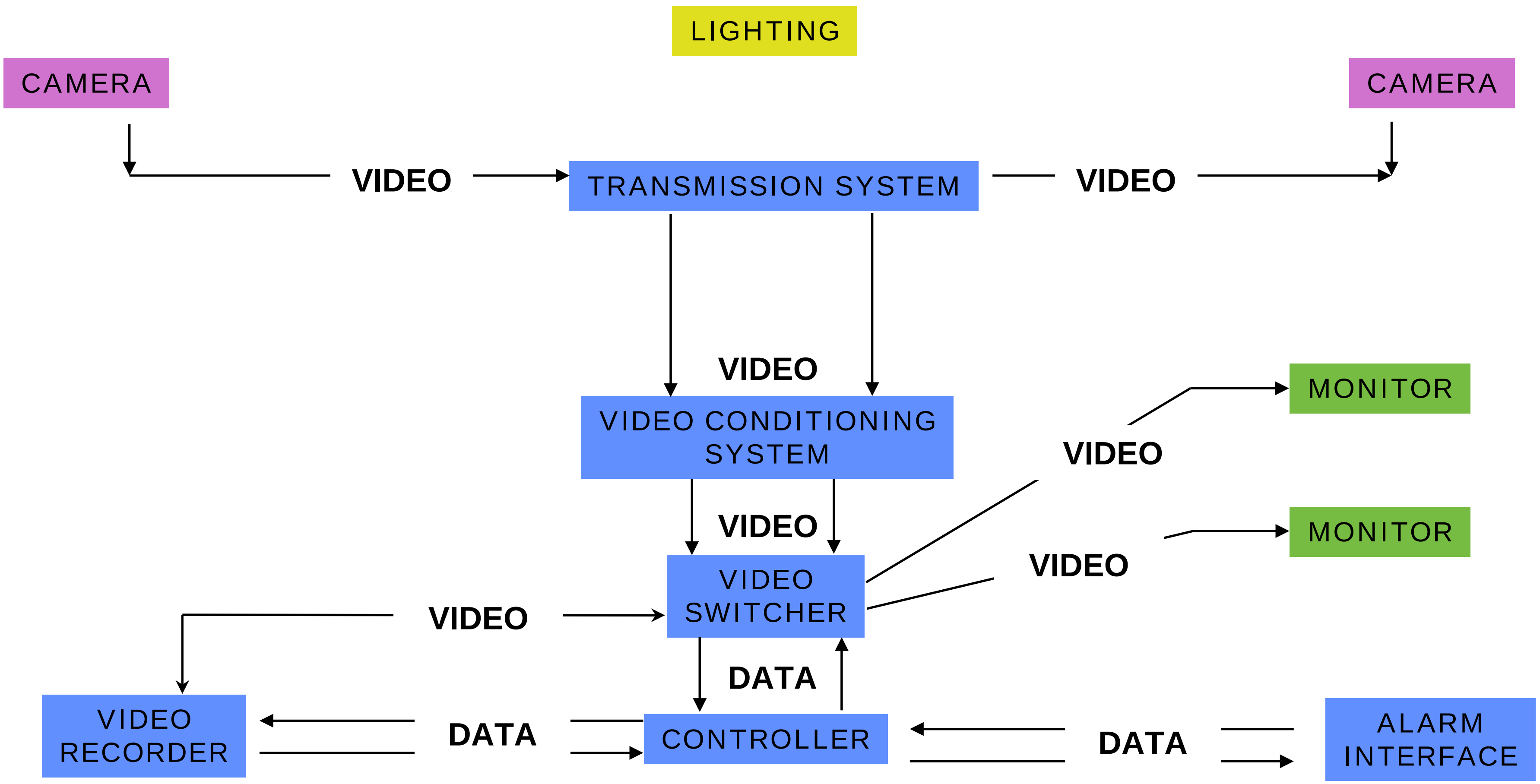
# Module Objectives

- Identify the major components of a video system for alarm assessment
- Compare analog and digital video systems
- Understand the performance requirements of a video system for alarm assessment
- Understand the concepts of detection, classification, and identification of objects in the assessment zone

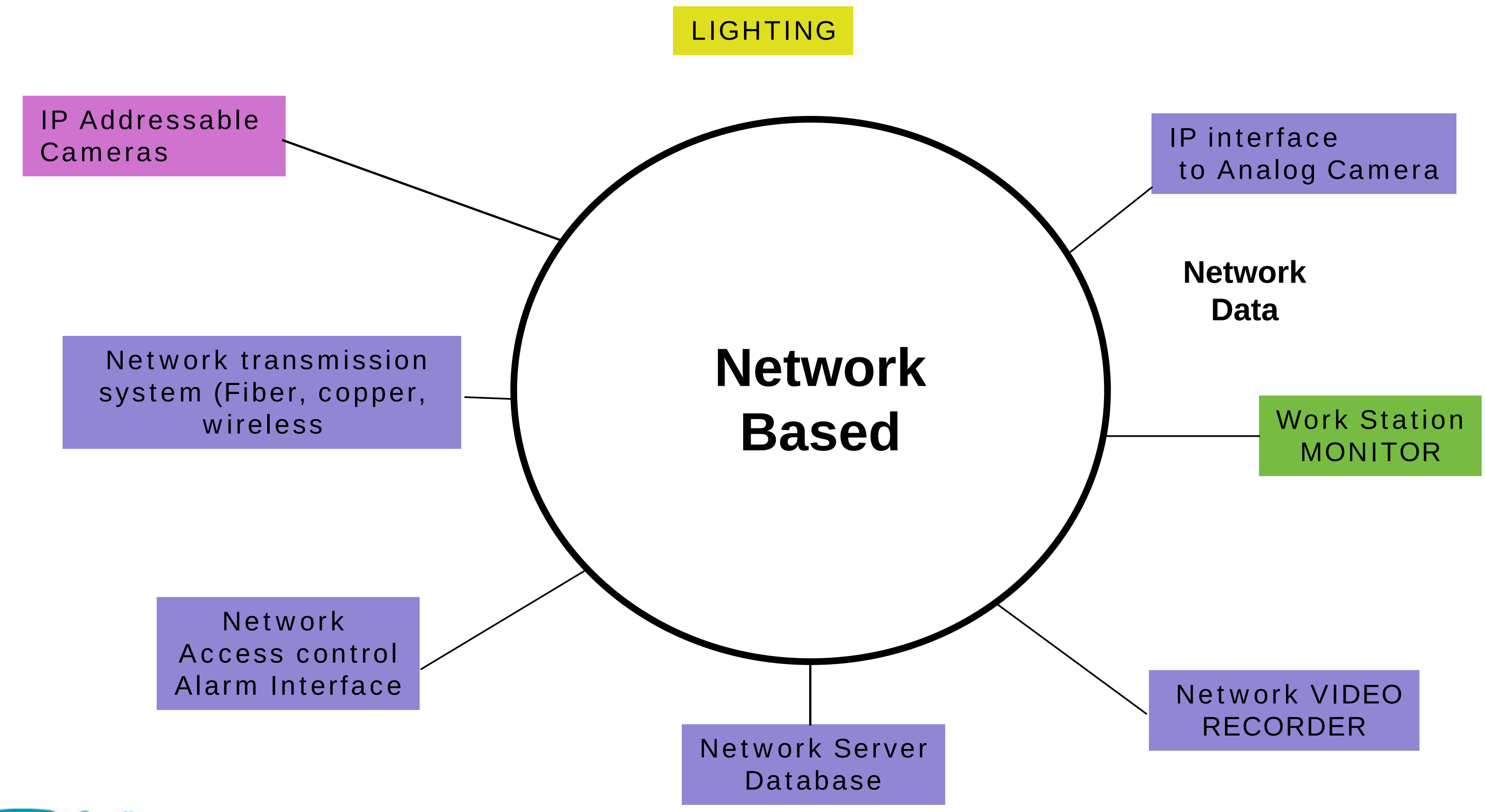
# Module Outline

- Introduction to analog and digital video assessment systems
- Video alarm assessment system performance requirements
- Overview of system components
- Summary

# Analog Video System Diagram



# Digital Video System Diagram



# Compare Analog to Digital

- **Analog**
  - Camera, mount, and lens
  - Lighting system
  - Video transmission
  - Video conditioning
  - Video switching
  - Video recording
  - Video monitor
  - Video controller

- **Digital**
  - Network camera, mount, and lens
  - Lighting system
  - Network transmission
  - Network conditioning
  - Video / database software
  - Network recorder
  - Workstation
  - Network server

# Performance Requirements

- **Assessment System**
  - Camera and lens
  - Lighting system
  - Video transmission / conditioning
  - Video switching
  - Video recording
  - Video monitor
  - Video controller

# Performance Requirements of Video Assessment

- Minimum time between sensor alarm and video display
- Complete area coverage of intrusion detection zone / sensors
- Classify 1 ft (0.3 m) target at far edge of detection zone
- Camera field of view covers entire sensored area;  no blind spots
- Cameras view at least two feet above outdoor fences and sensors
- Continuous operation 24/7
- Minimal sensitivity to adverse weather conditions

# Video / Thermal Camera

- Video camera converts visible or infrared illuminated scene to a video signal for viewing at the CAS
- Thermal imager converts thermal radiance to video signal
- Solid-state image device
- Contrast
- Sensitivity
- Resolution
- Filters

# Lenses

- Format
  - Size (1/2”, 1/3”, . . .)
  - Spherical / Aspherical
- Focal length
  - Relative magnification of an object
- F-stop (F-number)
  - Measure of the ability to gather light
- Transmittance (T-number)
  - The amount of light that can pass through the lens
- Material
  - Glass, plastic, germanium for thermal imagers
- Coatings
  - IR correction, filter, reflective

# Levels of Resolution

| Detection | Classification | Identification |
|---|---|---|
|  |  |  |
| **Determine the presence of an object** | **Determine Class of Object** | **Determine Identity of Object** |

# Requirements for Camera

- High sensitivity ⟶ Low light requirement (.05 lux or less)
- High signal to noise ratio (> 50dB)
- Automatic gain control (AGC)
- Automatic iris control
- Electronic shutter
- High resolution (640 x 480 or greater)
- Environment specifications

# Requirements for Perimeter Camera Tower

- Stable in wind
- Does not interfere with detection sensor performance
- Minimum obscuration to camera view
- Can see through it; tri-pole tower doesn't provide a hiding place
- Steel, reinforced concrete
- 25-30 foot in height

# Lighting System

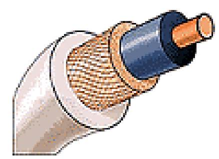
- **Function**
  - **Illuminates indoor or outdoor scene for 24-hour alarm assessment**
- **Major types**
  - **Incandescent**
  - **Mercury vapor**
  - **Sodium vapor**
    - **High or low pressure**
  - **Very near infrared (VNIR)**
  - **Light-emitting diode (LED)**

# Lighting Requirements

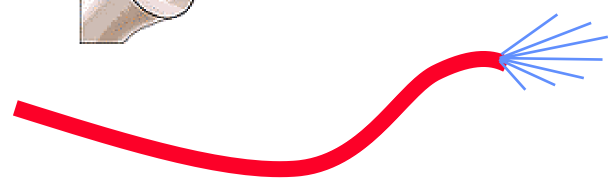
- Minimum average lighting intensity:
  1.0 *foot candle* or 10 *lux*
- Uniform illumination for exterior assessed locations
  - 6:1 light-to-dark ratio, maximum
  - 4:1 design goal
- Extent of coverage
  - Must illuminate all of area to be assessed
- Exterior perimeter assessment ground cover
  - 30% reflective round grey river rock
- Illumination & reflectance measured with a light meter

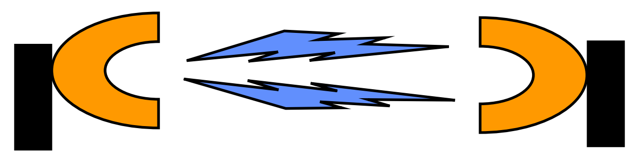
# Transmission System

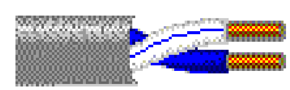
- **Function**
  - **Path for video signal from camera to monitor**



- **Major types**
  - **Coaxial cable**
  - **Optical fiber**
  - **Microwave link (wireless)**
  - **UTP (Unshielded Twisted Pair)**
  - **Network Data System (Ethernet, LAN)**







# Video Conditioning System

- Function
  - Reduce video signal degradation in analog copper cable transmission system
- Major types
  - Transient protection
    - Lightning, high current
  - Equalization
    - High Frequency
  - Isolation Transformers
    - Hum

# Video Switching System

- **Function**
  - To connect cameras to video recorders and display monitors to record & view camera video
  - To connect video recorders to display monitors to play back recorded video
- **Major types**
  - Manual switching
  - Sequential scanning
  - Alarm activated – automatic display of pre- and post-alarm video for alarming zone

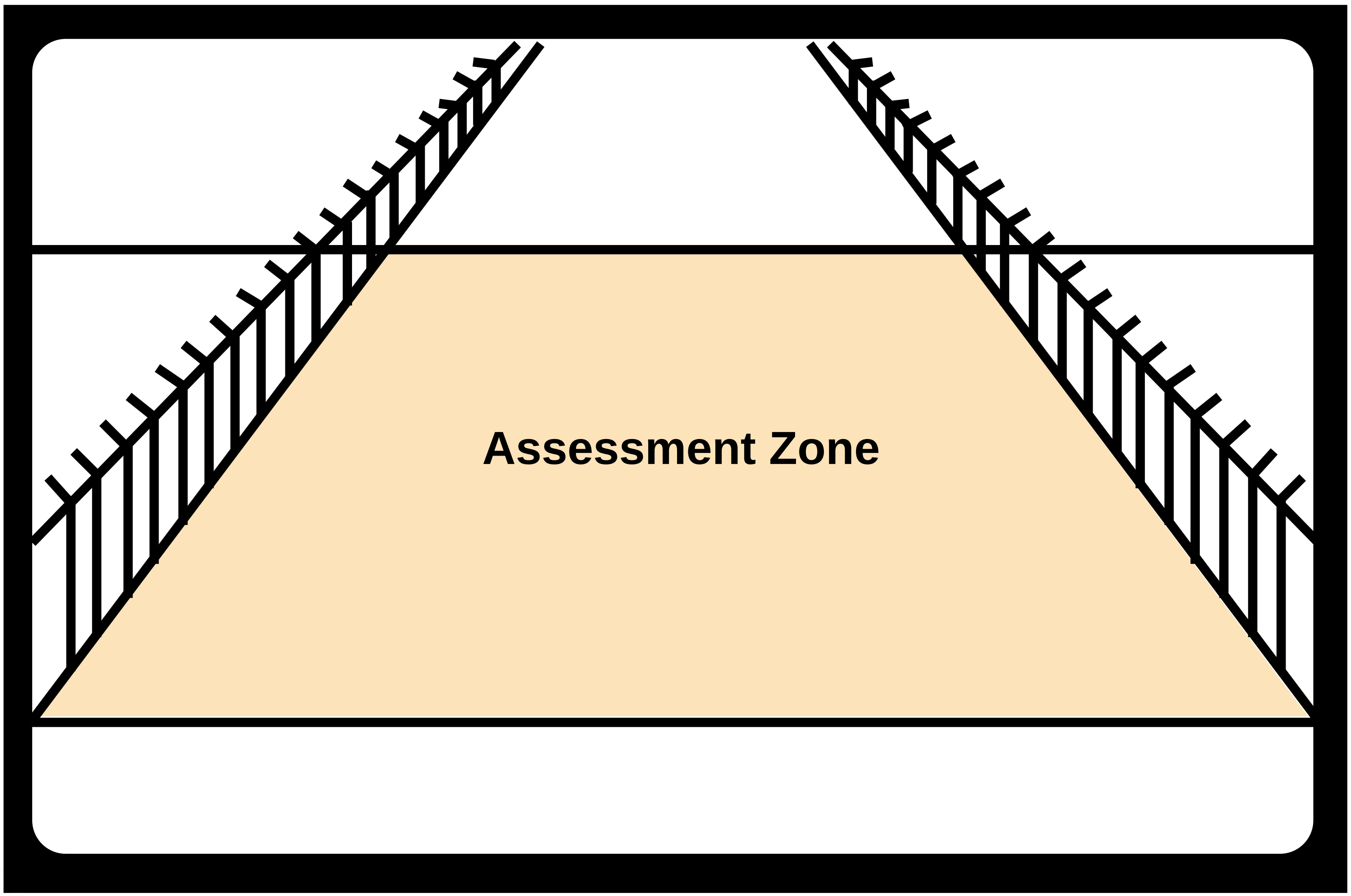
# Video Recording System

- **Function**
  - **Record video signal for instant replay, or historical information**
- **Major types**
  - **Video cassette recorder**
  - **Digital video recorders (DVRs)**
  - **Network video recorders (NVRs)**
  - **Digital cameras with onboard storage**

# Video Monitor

- **Function**
  - **Convert video signal to visual image**
- **Major types**
  - **Black and white**
  - **Color**
    - **CRT**
    - **Flat Screen**
      - **LCD,**
      - **Plasma**

# Monitor View of Exterior Assessment Zone



# Video Controller

- **Function**
  - Electronic control (switching) interface between sensor alarm system and video assessment system
  - Controls display and recording of multiple video signals from cameras and recorders
  - Functions performed directed by AC&D computer or programmed as stand-alone

# Summary

- Components of video system
  - Camera and lens
  - Lighting system
  - Transmission system
  - Video switching equipment
  - Video recorder
  - Video monitor
  - Video controller

# Overview of Video System Components

***Questions?***

# Module 15

## Cameras

# Classification

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# Module Objectives

- Understand how a video camera and lens create images
- Understand the major functional signals of a standard camera

# Module Outline

- Introduction to video signals
- Comparison of various types of cameras
- Measurements of camera performance
- Summary

# Camera Function

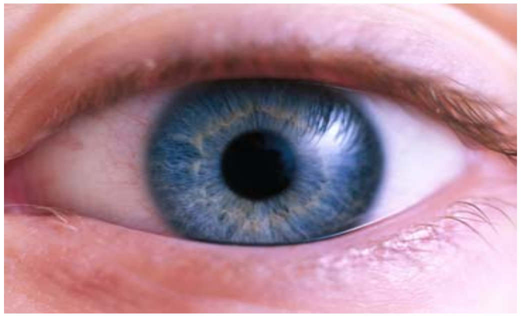
- **Camera converts visual image to an electrical signal for transmission**
- **Major types**
  - **Solid state imagers**
  - **Thermal imagers**
- **Camera placement depends on selection of proper lens to adequately assess a defined area, zone, or sector**
- **Camera field of view must observe entire area covered by a detection sensor (no blind spots)**
- **If one camera cannot observe entire area sensored, then multiple cameras must be used to view entire area**

# Video Composite Signal

- Horizontal lines are displayed from the top to the bottom of the monitor screen
- Two standards for TV pictures in general use
  - 525 lines in the USA (NTSC) and Japan (30 frames)
  - 625 lines elsewhere (PAL) (25 frames)
- The number of lines is a measure of the monitor display resolution video
- In the USA, a video picture is composed of 30 still pictures displayed per second
- Motion pictures display 24 still pictures per second
- 30 pictures per second chosen to synchronize with light flicker

# Persistence of Vision (Human Eye)

- **Human eye retains an impression of an image for a fraction of a second after it has disappeared**
- **A series of still images presented at 14 images per second gives the human eye an impression of continuous movement**
  - **This would present a very distracting flicker**
- **A rate of 30 images US (25 images European and elsewhere) per second eliminates flicker**



# Composite Video

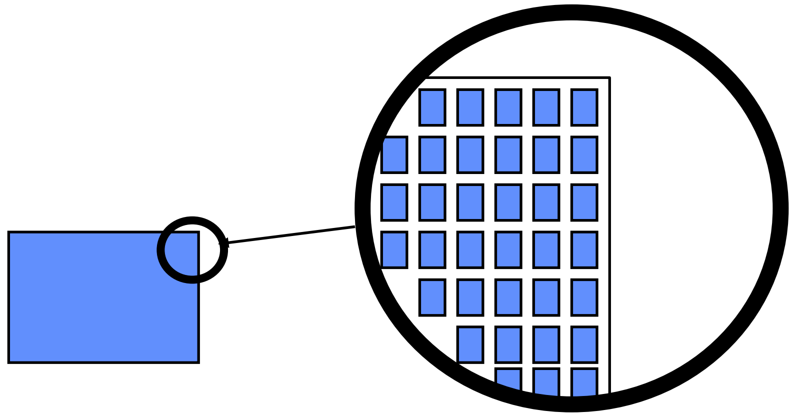
- To transmit 30 complete images per second, the television industry's solution was interlaced scanning
  - Small bandwidth, less expensive
- Instead of scanning the full 525 lines 30 times a second, the scanning speed is effectively doubled and so is the vertical spacing of the lines
- One scan (odd field) produces 262 1/2 lines from the top to the bottom of the picture
- Second scan (even field) starts precisely between the lines of the first scan, so that the lines of the second field interlace with the first
- 33 ms of time elapses between the start of odd & even field display
- This causes jagged edges on fast-moving targets in video scene

# Monitor Picture – Interlaced and Progressive Scan

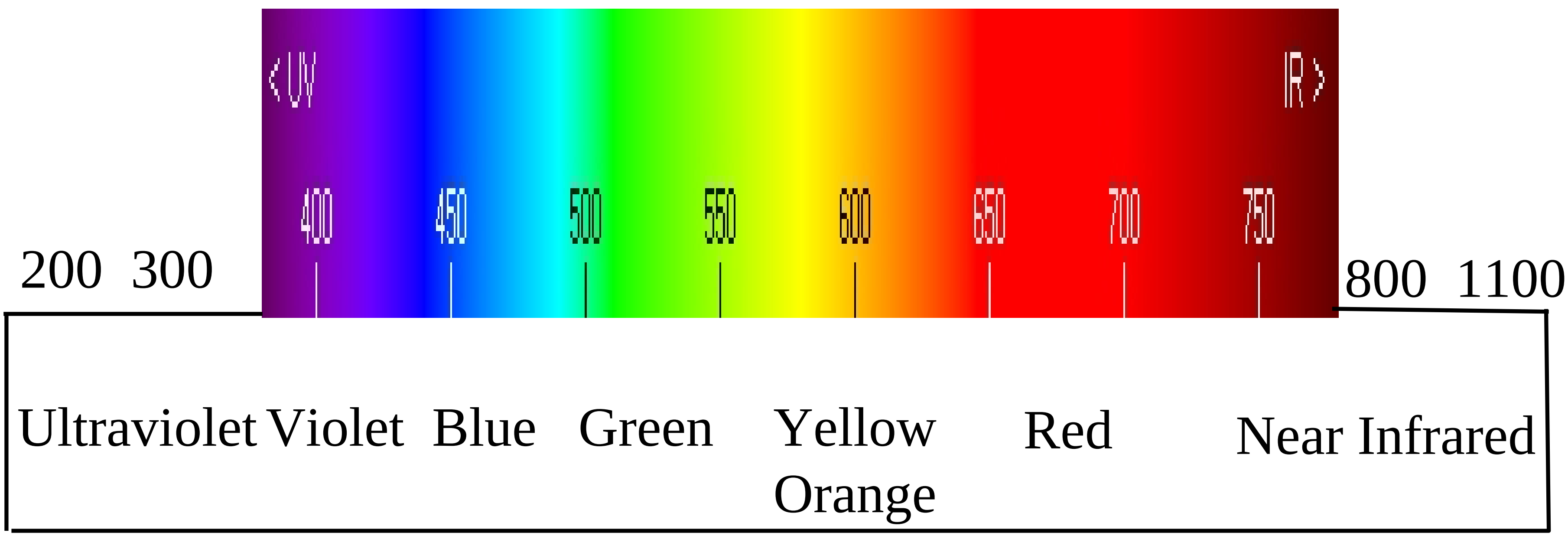
- On a CRT monitor the phosphor continues to glow from the first scan while the second scan is being displayed
- Although only 30 complete pictures (frames) are presented per second the screen is scanned 60 times (fields) per second
- If the lines are scanned sequentially, one after another, it is known as “progressive scanning”
- Progressive scanning accepts movement better than interlaced
  - Movement between fields creates blur

# Solid State Imagers

- **Imager is a photo-to-electron converter**
- **Responds to reflected light from assessed scene**
- **Current solid state cameras**
  - **Charge Coupled Device (CCD)**
  - **Complementary Metal Oxide Semiconductor (CMOS)**
- **Two dimensional arrays of discrete point light sensors that produce pixels (horizontal-vertical resolution) that produce the resulting image**



# Wave Length Chart




Wavelength [nanometers]

# CMOS Imager

- **Each pixel in a CMOS sensor array can have its own amplifier and output circuitry**
- **Manufactured on standard semiconductor production lines versus Charge Coupled Devices (CCDs) on dedicated production lines**
- **CMOS traditionally suffer from poor dynamic response and poor low-light sensitivity**
  - **Significant amount of research and development to remedy deficiencies**
- **CMOS images improving with time**

# Charge Coupled Device (CCD)

- Light charges that build up on all of the array pixels
- Pixels are linked or "coupled" together so that they can be transferred out of the array
  - Directly (digital output)
  - Processed into a time-varying video signal (analog output)

# Solid State Imager Cameras

- Major types
  - Black and white (B&W)
  - Color
  - Day / night
    - Higher resolution at night
    - Color during day and B&W at night
  - Infrared
    - Near - IR, 800 – 1100 nm
  - Intensified

# Examples of Interior Camera Types

# Exterior Type

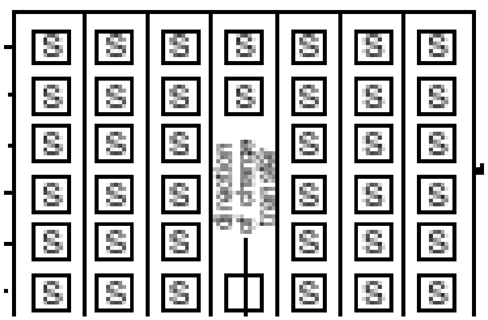
- **Many are interior cameras (with no housing) mounted in an environmental enclosure**

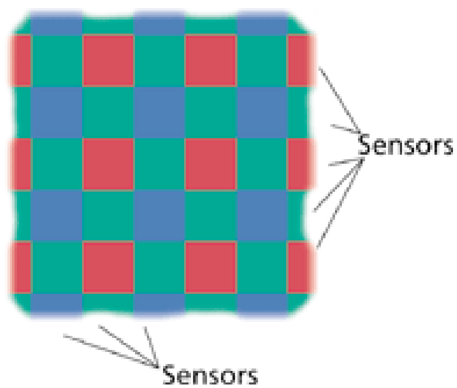
# Color vs. Black & White

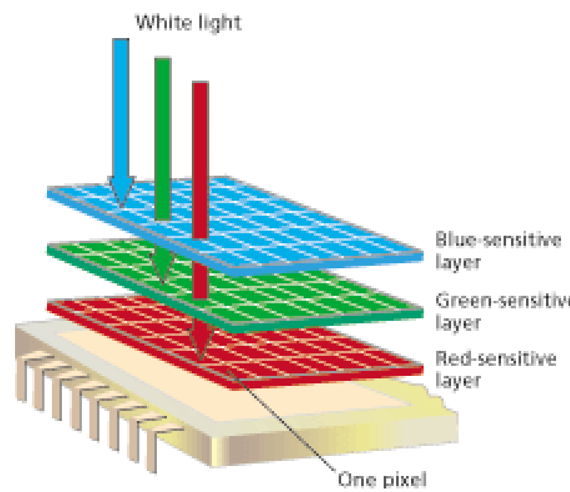
- **Color enhances daylight scenes – more natural image to the human eye**
- **Color at night is problematic; sodium vapor lamps produce gold-orange images**
- **Resolution of color cameras 18% less than B&W cameras**
- **B&W provides sharper image at night due to higher resolution**
- **Does the alarm assessment requirement need color cameras?**


# B&W vs. Color Resolution

- **B&W uses all of the pixels in grey scale**
- **Color uses a pattern of blue, green, and red pixels**



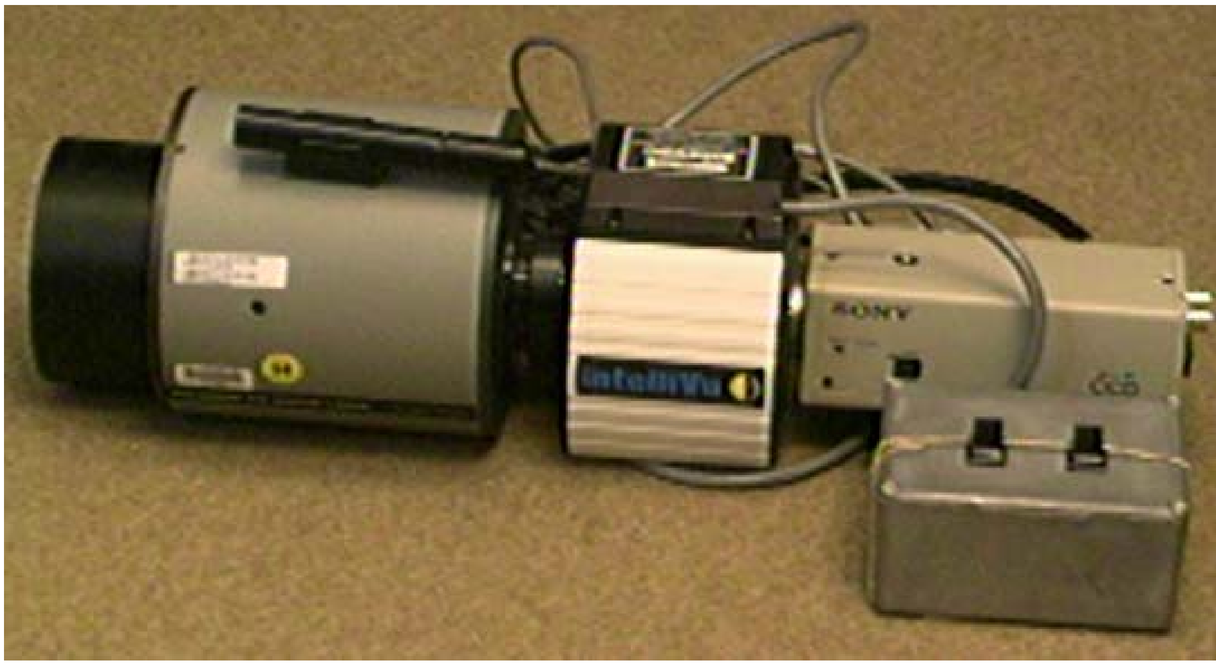


# Day / Night

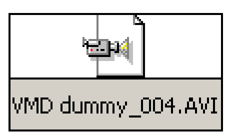
- **Some cameras provide color images during the day and black & white during the night**
  - **Sensor in camera to determine switchover illumination level**
  - **Camera monitors video level and switches when scene reaches switching threshold**
  - **Removes IR cut filter for gathering what is termed enhanced or IR camera (near - IR)**

# Example of Day / Night Camera




# Integrating Cameras

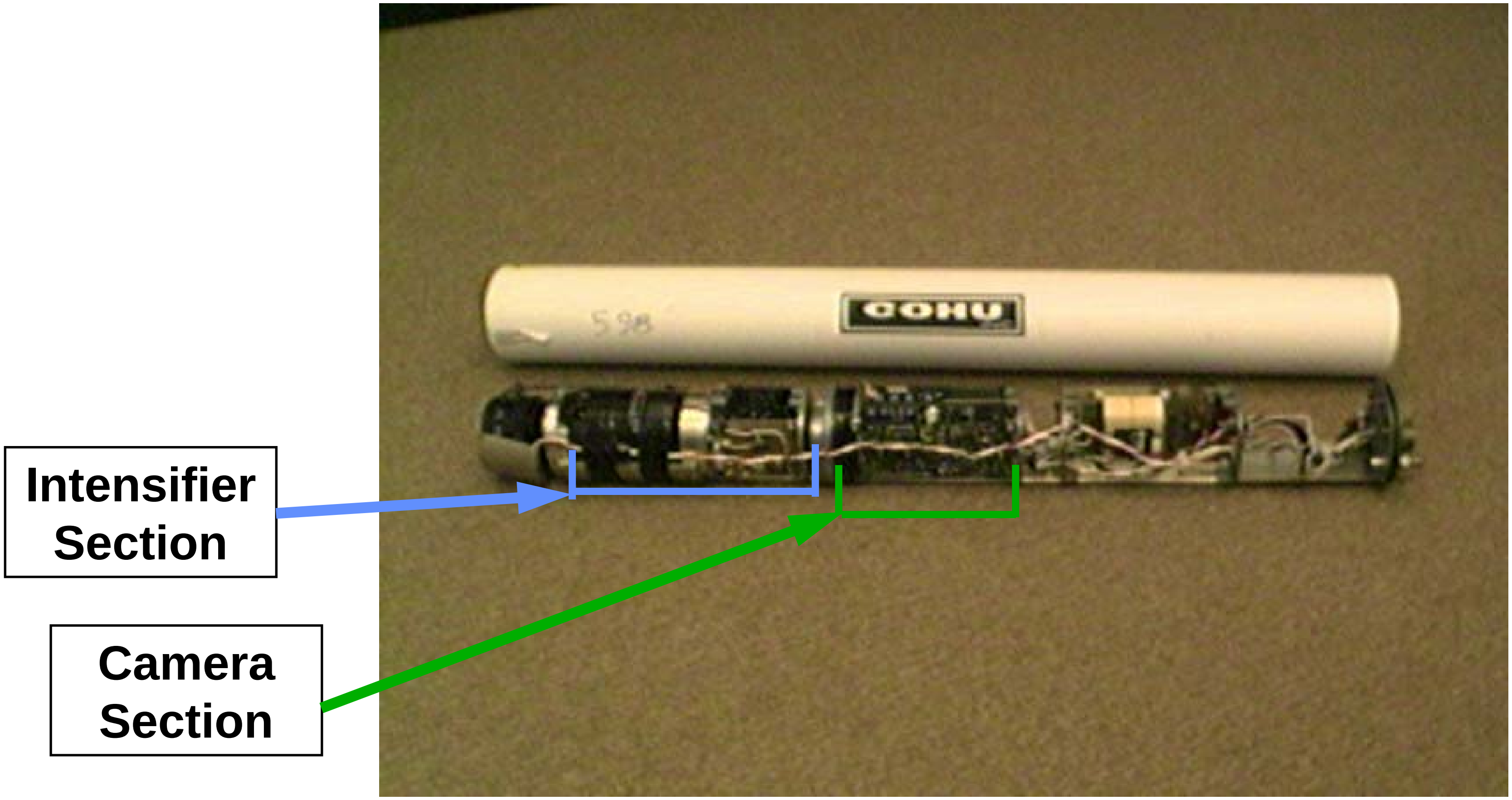
- **Some cameras integrate frames at night to obtain enough scene illumination**
- **This is like leaving shutter open longer on a still camera**
- **Cause the camera imager to gather more photo energy**
  - **Some delays up to 128 frames (~ 4 seconds)**



# Intensified Cameras

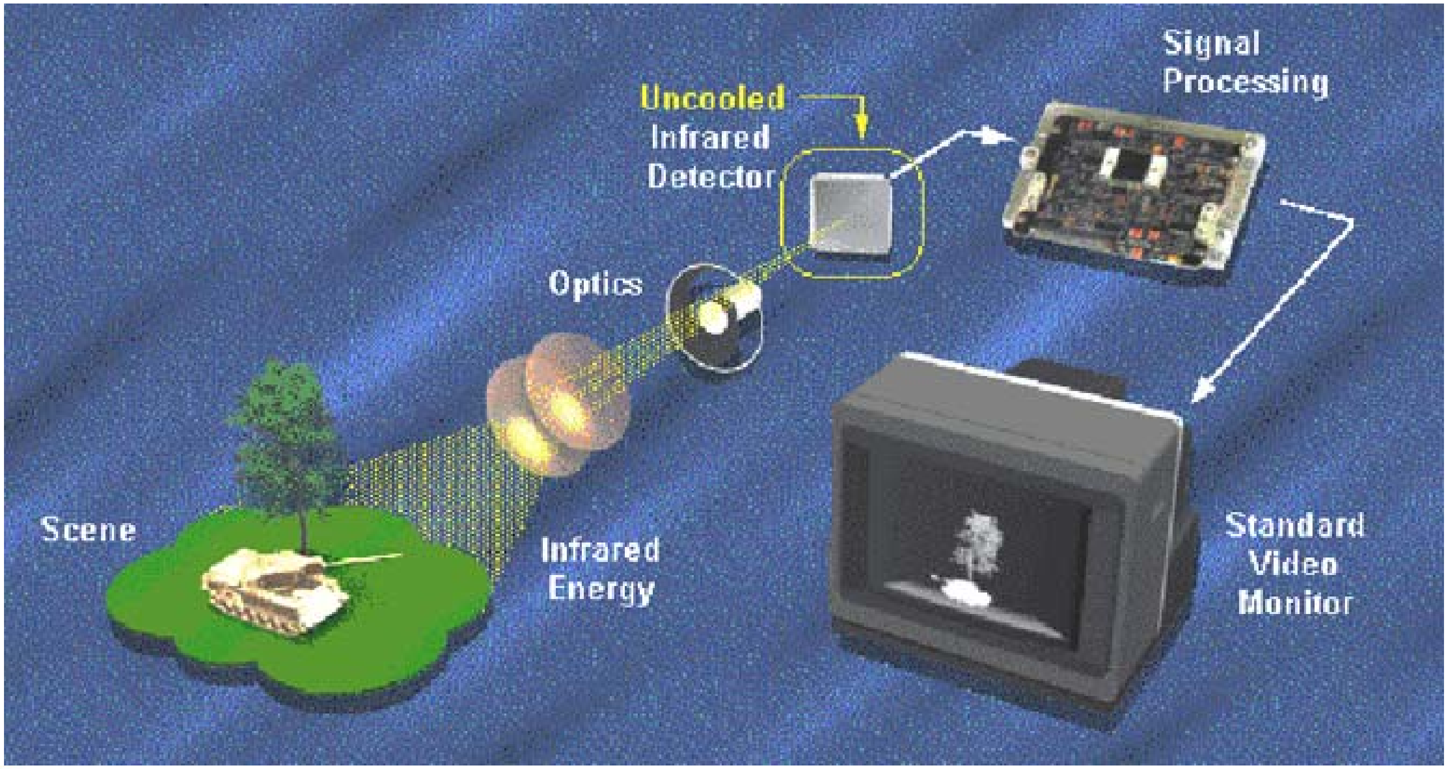
- A photon amplifier bombards luminescent (green) screen that a standard camera views
- Illumination from stars, moon and artificial lighting
- More expensive than standard camera
- Intensifier is a tube type of device
  - ~ 2500 - 3500 hrs
- Bright light sources in scene can distort images
- Because of long phosphor persistence, moving bright lights cause smears in images

# Example:
# Intensified Low-light Camera



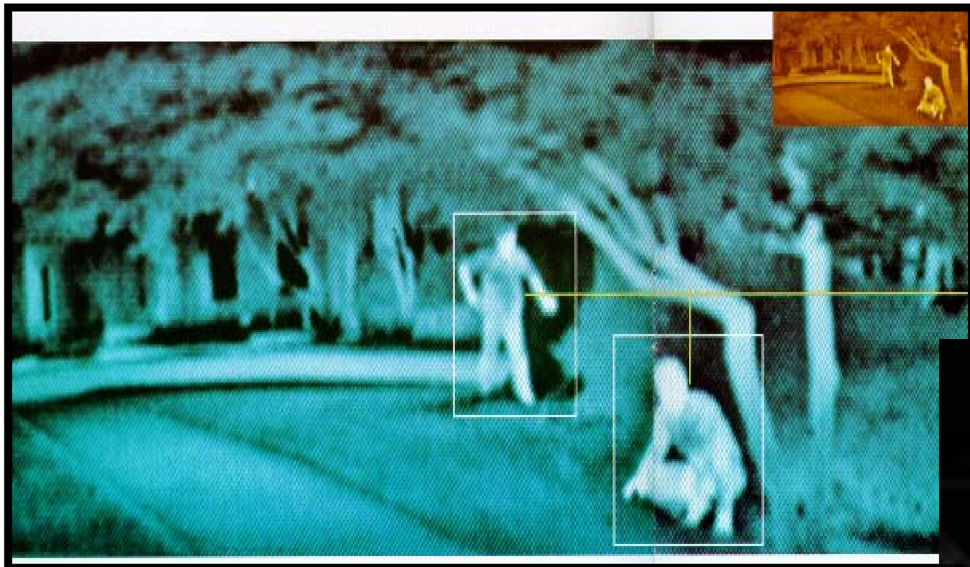
# Thermal (Specialty Camera)

- **Uses emitted thermal / infrared energy**
  - **(3 - 5) or (7 - 14) micron waveband**




VIDEO

# Thermal Camera Image Examples



# Infrared vs. Visible

# Requirements for Camera

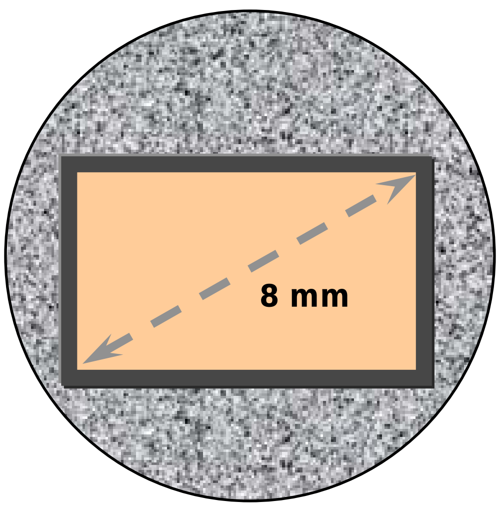
- High sensitivity
- Good contrast, intra-scene dynamics
- High Signal-to-Noise Ratio (SNR)
- Automatic Gain Control (AGC)
- Automatic iris controls / electronic shutter
- High resolution
- Environmental specifications, high reliability

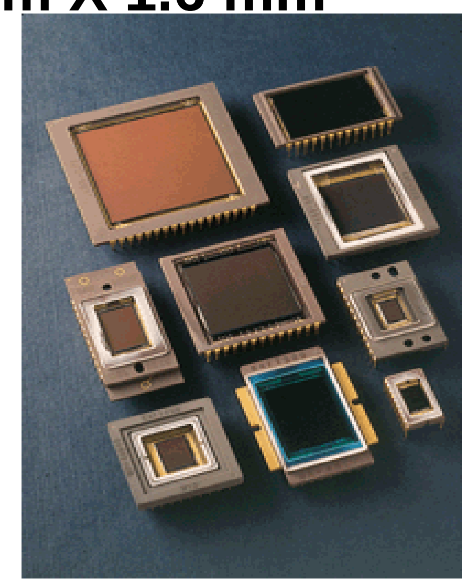
# Camera Functions

- Imager
- Contrast
- Sensitivity
- Resolution
- Signal-to-Noise Ratio
- Automatic Gain Control
- Auto-iris or electronic shutter
- Filters
- Back-light compensation

# Image Device Formats

- **Current formats**
  - **1/2 inch = 8 mm diameter = 4.8 mm X 6.4 mm VARIES**
  - **1/3 inch = 6 mm diameter = 3.6 mm X 4.8 mm VARIES**
  - **1/4 inch = 4 mm diameter = 2.4 mm X 3.2 mm**
  - **1/8 inch = 2 mm diameter = 1.2 mm X 1.6 mm**



*Courtesy of Kodak*

# Contrast

- **Difference between the white and black levels in a video**
- **High contrast is a large difference between the white and black levels**
- **Low contrast is a small difference between the white and black levels and appears gray**

**High**

**Low**

# Sensitivity

- **Amount of signal a camera produces from a particular sensor illumination at a particular SNR**
- **Specified as camera imager face plate illumination**
- **Sometimes expressed as scene illumination (lux / foot-candles) at a**
  - **Defined reflection**
  - **Signal strength**
  - **Particular lens transmission aperture**
  - **Particular SNR**

# Sensitivity Example

Sensitivity (faceplate) @ 2850 K, Please see Table 1

**ELECTRICAL**

**Image Area**
6.4 x 4.8mm (corresponding to 1/2" format tube)

**Active Picture Elements**
RS-170: 768 (H) x 494 (V)
CCIR: 752 (H) x 582 (V)

**Imager Type**
On-chip microlens sensor interline transfer CCD

**Cell Size**
RS-170: 8.4 x 9.8 microns
CCIR: 8.6 x 8.3 microns

**Resolution**
RS-170: 580 (H) x 350 (V) TVL
CCIR: 560 (H) x 450 (V) TVL

**Sensitivity (faceplate) @ 2850 K**
Please see Table 1

**Electronic Shutter**
Eight steps from 1/50 or 1/60 to 1/10,000 second (1/50 or 1/60, 1/125, 1/250, 1/500, 1/1,000, 1/2,000, 1/4,000, 1/10,000 second)

**Integration**

**Auto Lens**
Separate lens video ratio tracks AGC peak/average adjustment to eliminate AGC/auto lens interaction
Power: +15V, 35mA maximum

**Synchronization**
Genlock, revert to variable phase line lock with zero crossing detector
Genlock, revert to crystal
Crystal Lock
H & V Drive
Asynchronous Reset
Internal Clock Speeds
RS-170: 28.6363 MHz
CCIR: 28.375 MHz

**Power Requirements**
12V AC or DC (standard)
24V AC or DC (optional)
115V AC (optional on RS-170 models, includes wall transformer and connector)
230V AC (optional on CCIR models, includes wall transformer and connector)
4.2 Watts DC power consumption
LED Power Indicator, Green

**Lens Mount**
"CS" mount, 16mm format
"C" mount with adapter (furnished)

**Camera Mounts**
1/4 - 20 threaded holes, top and bottom

**Connectors**
Video (BNC)
Power (2 circuit screw terminal)
Lens (3 pin mini-DIN)
External Sync (8 pin DIN)

**ENVIRONMENTAL**

**Ambient Temperature Limits**
Operating: –20° to +60°C (-4° to +158°F)
Storage: -30° to +70°C (-22° to +187°F)

**Humidity**
Up to 95% relative humidity

**Vibration (less lens)**
Sine vibration from 10 to 2,000 Hz, 5g peak, all 3-axis, 1/2 hour per axis per MIL-E 54007, para. 3.2.24.5.1.2, fig. 2, curve IIIA
Random vibration from 10 to 2,000

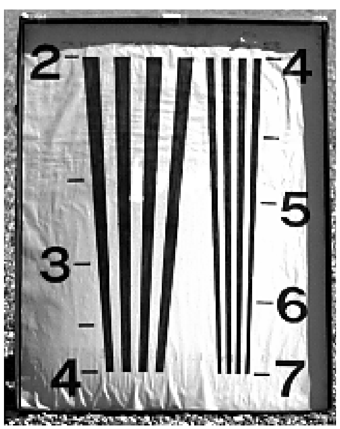
Table 1:

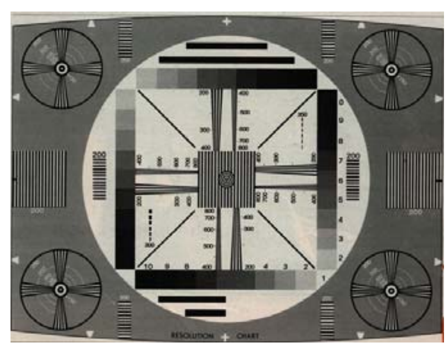
**SENSITIVITY**

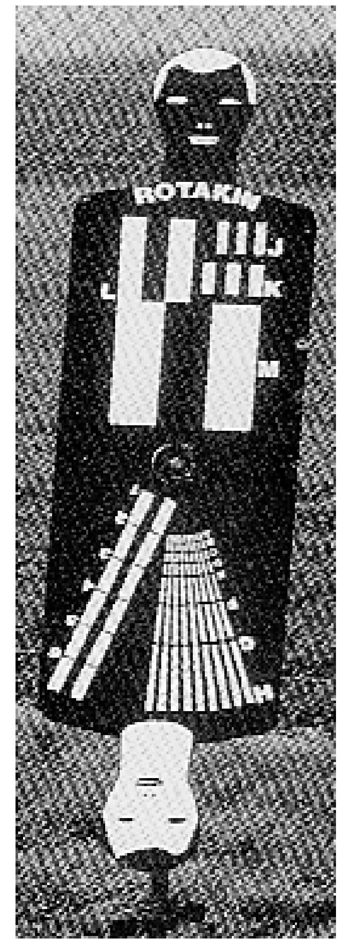
| | Full Spectrum | With IR Filter |
|---|---|---|
| Full Video, No AGC | 0.039 fc (0.39 lux) | 0.15 fc (1.5 lux) |
| 80% Video, AGC On | 0.001 fc (0.01 lux) | 0.006 fc (0.06 lux) |
| 30% Video, AGC On | 0.0002 fc (0.002 lux) | 0.0009 fc (0.009 lux) |

# Resolution

- **Degree to which you can see fine details in viewed image**
- **Measured using IEEE or RETMA resolution chart**
  - **200 - 1600 lines**
- **Units of measure are pixels or line pairs/mm**
  - **Stated as “horizontal or vertical TV lines”**





# Resolution *(cont.)*

- The higher the resolution, the more details can be resolved in an image
- A camera's far field of view is limited by design criteria of requiring a certain amount of horizontal TV lines of resolution to fall on a target
- Design criteria change for the assessment function required (detection, classification, or identification)

# Signal-to-Noise Ratio (SNR)

- Signal-to-Noise Ratio (SNR) is expressed in decibels (dB)
- The higher the SNR the better rating
- With low SNR, the picture can appear grainy, snowy, and sparkles of color may be noticeable
- Sometimes video control and display equipment will not be able to synchronize to extremely noisy signals
- A good SNR would be >35 dB;  >50dB is fairly common

# SNR Details

- When no light shines on a CCD's sensor, do they generate electrons?
  - Thermal and electrical effects always produce electrons
  - CCD manufacturers call these "dark" currents
  - Dark currents cause some electrons to get trapped in charge wells
  - In capturing an image, the dark-current electrons add to those produced by any incident light, adding noise
  - This noise reduces the CCD's dynamic range, reducing its ability to accurately resolve changes in light levels

# Dynamic Range

- **A CCD's maximum output signal ratio to the output signal due to dark current is defined as the SNR expressed in decibels (dB)**
- **Examples:**
  - **A dynamic range of 48 dB indicates accurately resolving light levels for a range of one part in 256 (28)**
  - **A dynamic range of 60 dB's accuracy is one part in 1024 (210)**

# Automatic Gain Control (AGC)

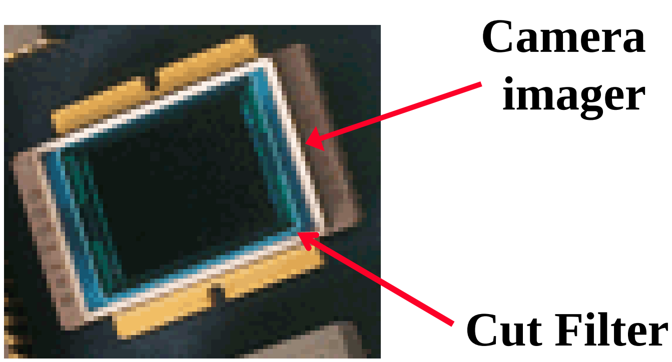
- Circuitry used to ensure that camera output signals are maintained at preset constant levels over widely varying input signal levels
- AGC is typically used to maintain a constant video signal level by amplifying weak (low light) picture signals electronically
- Substantially increasing the amplified gain can increase the video noise associated with an image

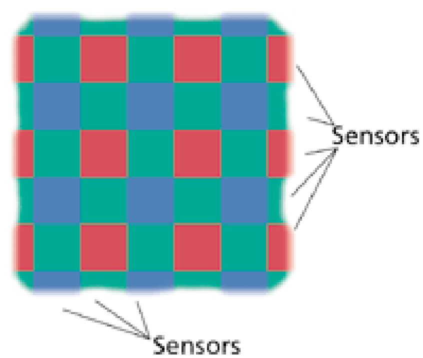
# Auto-Iris and Electronic Shutter

- Automatic Iris – signal generated within a camera to automatically adjust the lens iris setting that allows the imaging device to perform under optimum conditions
  - Video level – based on the video signal from camera; control circuit inside lens assembly
  - DC – based on voltage signal generated by camera; voltage from camera to control iris opening
- Electronic shutter – adjusts the amount of time the imager “collects” light over range of illumination levels

# Filters

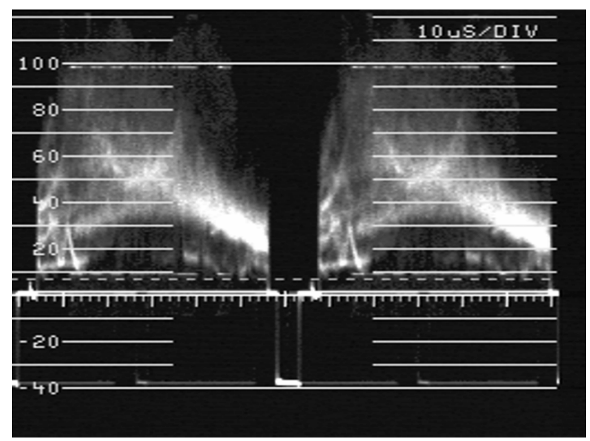
- **IR cut files are generally placed in front of the imager chip**
- **A detector acquiring color images separates colors by placing a small color filter over individual sensors**



# Summary

- **Camera**
  - **Imager, sensitivity, contrast, resolution, format**
- **Waveform measurements**
  - **Black and white level**
  - **Intra-scene dynamics**
  - **Full video**
  - **Usable video**



# Cameras

***Questions?***

# Module 16

## Camera Lenses

# Classification

- **All material in this module is unclassified**
- **In this module, photos of equipment are included as examples only. Sandia National Laboratories does not endorse or recommend any specific equipment.**

# Module Objectives

- **Learn how to choose the appropriate camera equipment to meet minimum performance criteria for an effective assessment system**
  - **Understand the parts and functions of lenses**
  - **Match a lens to a camera to properly view a designated target area of coverage**
  - **Understand resolution and minimum resolution criteria**

# Module Outline

- Introduction
- Characteristics and performance of lens
- The assessment zone and resolution
- Summary

# Primary Functions of a Camera Lens

- **To collect the reflected light from the scene and focus the light onto the camera's imager**
- **To magnify objects within the viewing angle**
- **To create a viewing angle that is adjusted by changing the focal length of the lens**

***A clearer and sharper image will be produced when more light is properly focused on the imaging sensor***

***AND YOU GET WHAT YOU PAY FOR!***

# Examples of Camera Lenses

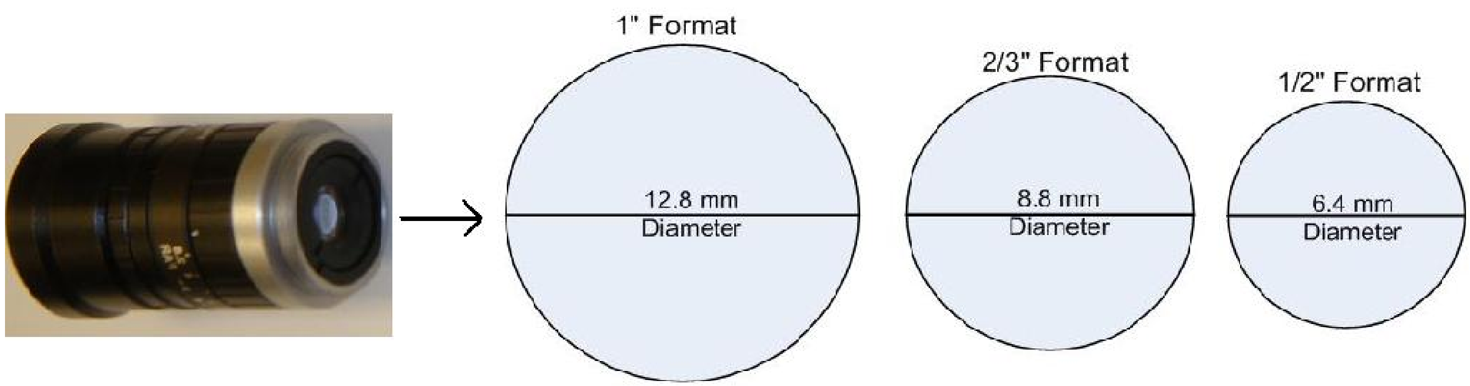
# Parts and Functions

**Complexity and cost of the lens will depend on the following:**

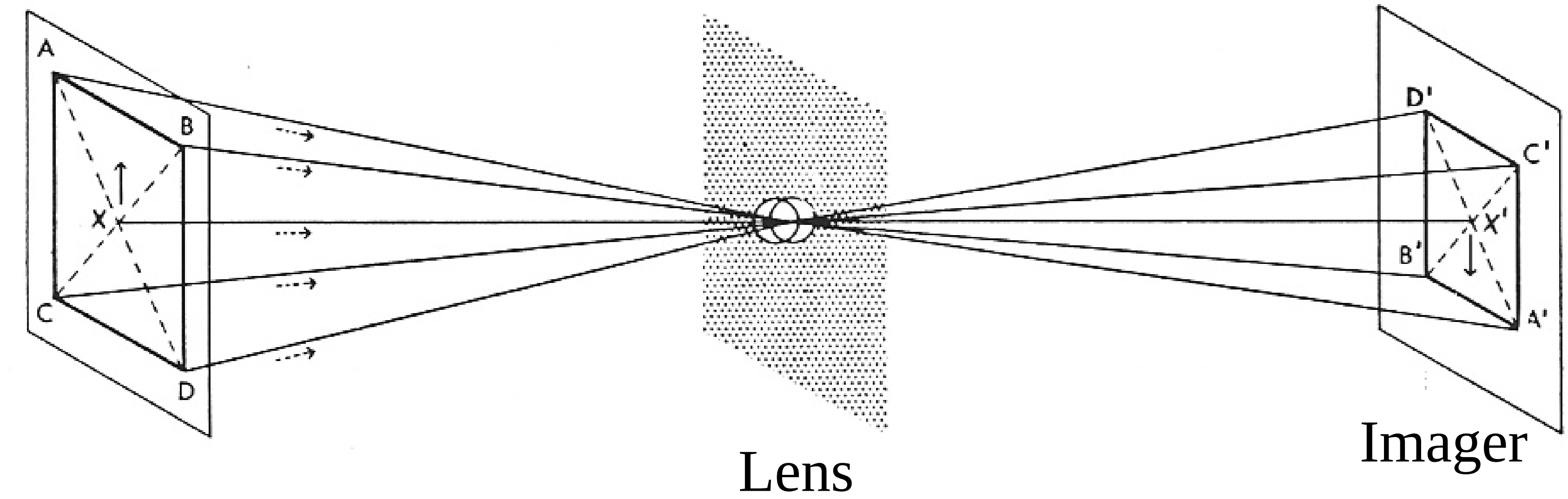
- Field of View
  - Lens Format
  - Focal Length
    - Fixed
    - Variable
    - Zoom
- Max Aperture (f-stop)
- Depth of Field (DOF)
- T- number
- Lens Type
  - Spherical/Aspherical
  - C–Mount
  - CS-Mount
  - Other
- Focus ring

# Lens Format

- **The format of the lens must match the camera's sensor format to optimize the video image**
- **Standard sizes are:**
  - **1/2", 1/3", 1/4", 1/6", 1/8"**

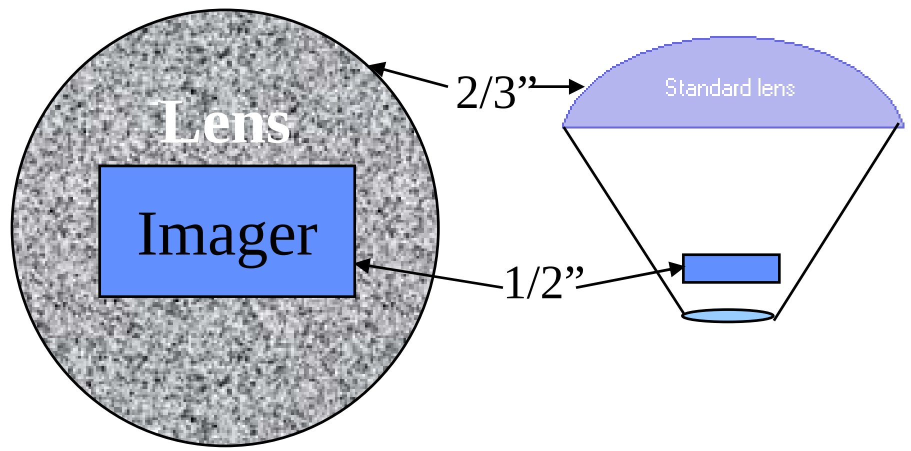


# Lens Basic Function

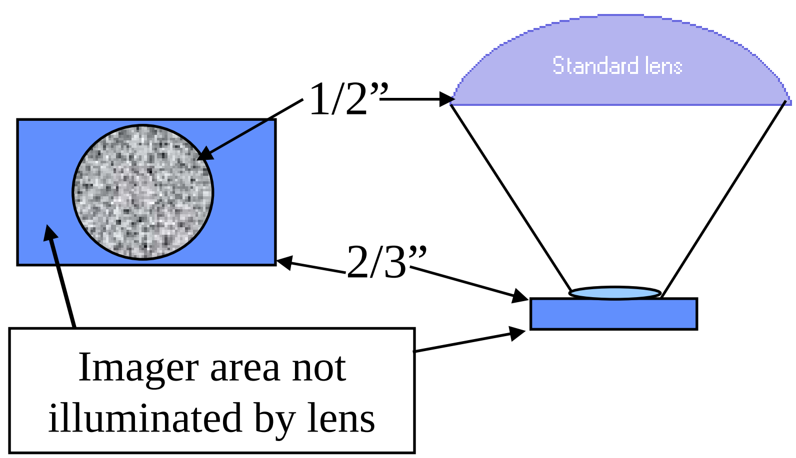


# Format Mismatch

- **Larger lens format than camera format**
  - **Imager sees only part of scene from lens**
  - **Field of view is changed**

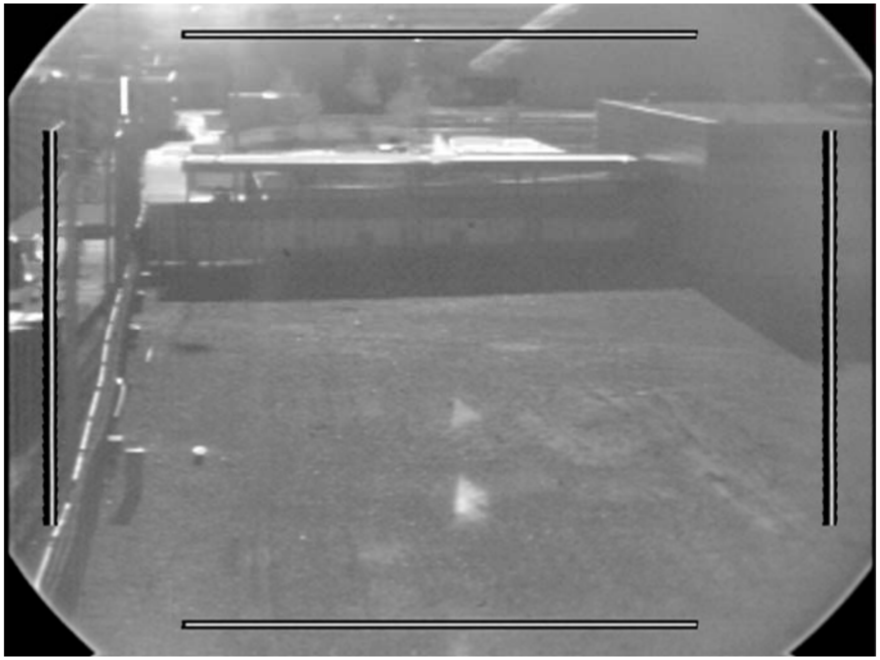



- **Smaller lens format than camera**
  - **Tunnel vision**
  - **Imager not fully utilized**

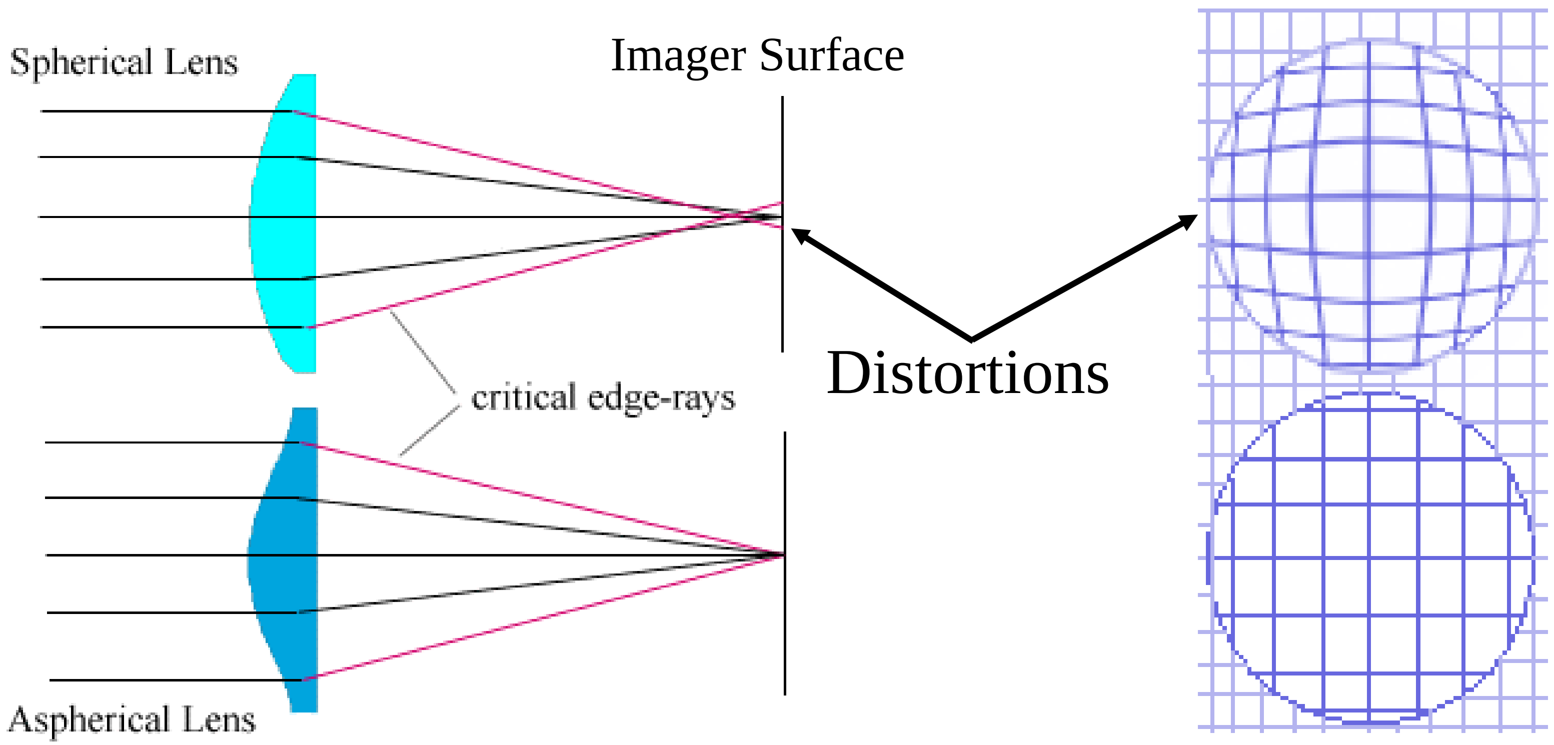


# Format Mismatch Example

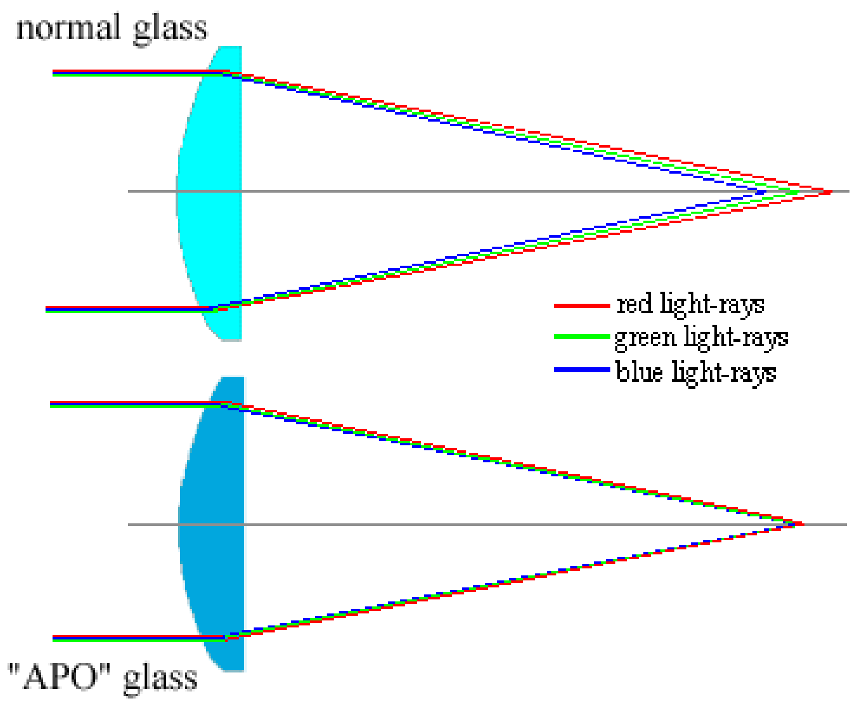
## Lens format smaller than the imager



# Spherical & Aspherical Lens Grinds



# Specialized Glass / Coatings



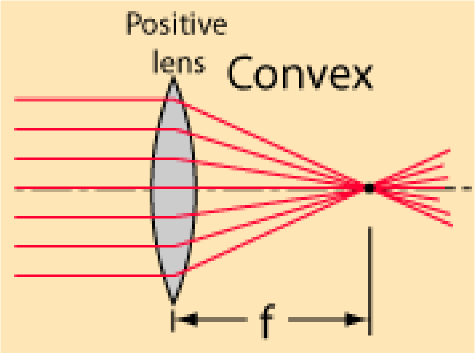

***Apochromatic Elements – to more accurately focus different wavelengths***

# Lens T- Number

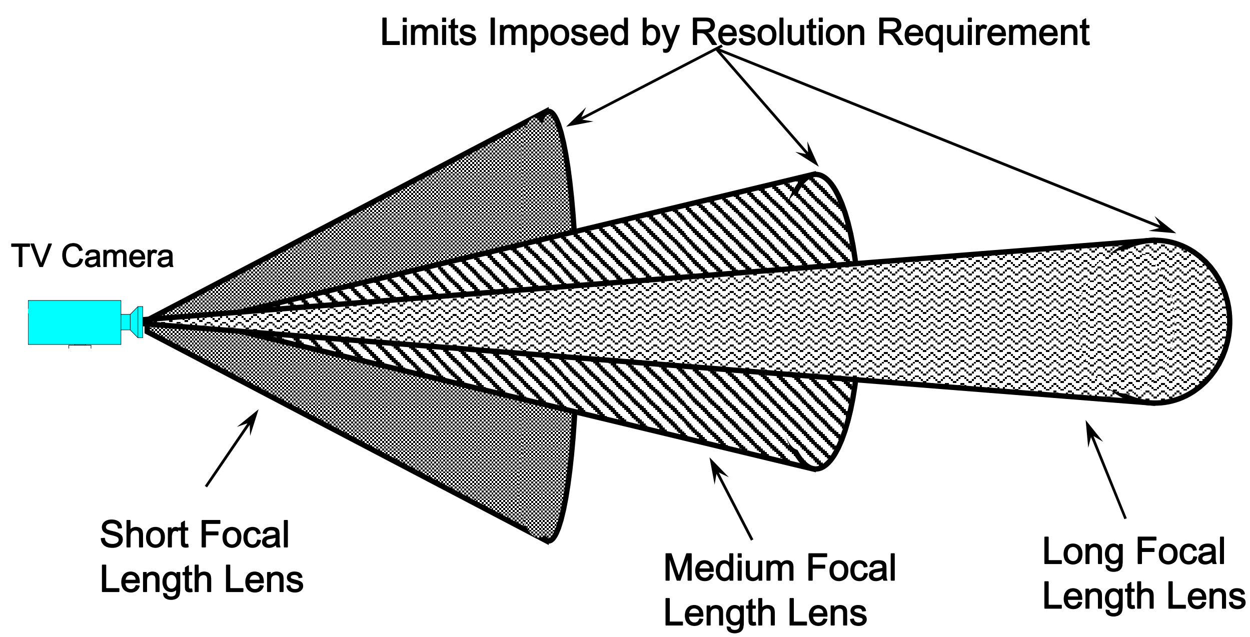
- The spectral transmittance of the lens describing effectiveness of light passing through the lens material
- The transmittance of a lens is not generally 100%
- Lenses with two different T-numbers would let a different amount of light pass through
- Glass elements in the lens provide slight diffusion of light from front to back of lens assembly
- Some lenses have gray spot at center of lens to further reduce light transmission through lens at high light levels

# Focal Length

- **Definition (convex): distance from center of the lens to the focal point**
- **Relative magnification of an object and width of field of view**
- **Distance from focal point to CCD chip**
- **Smaller numbers indicate a wider field of view**
  - **e.g., 4mm, 6mm**
- **Larger number indicates a more narrow field of view**
  - **e.g., 50mm, 75mm**

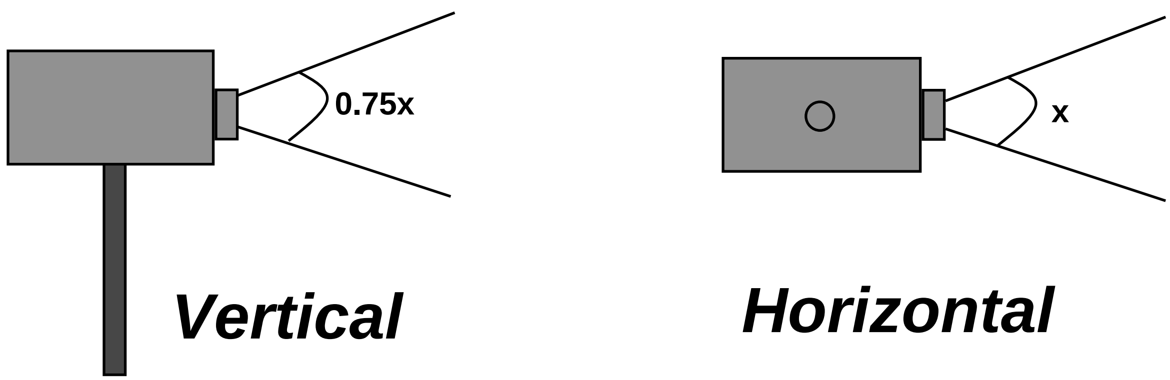


# Focal Length of Lens



# Camera and Lens

- **Field of View**
  - Horizontal angular field of view = $2\text{Tan}^{-1}(W/2F)$ where W = width of imager and F = camera focal length
  - Vertical field of view = .75 x horizontal angular field of view



# Long vs. Short Lengths

- Short focal lengths only allow for short distance fields of view due to pixel distribution at the far field of view
- Longer focal lengths provide for longer distance fields of view
  - Environmental effects on long distance views can distort the image, e.g., fog, thermal waves

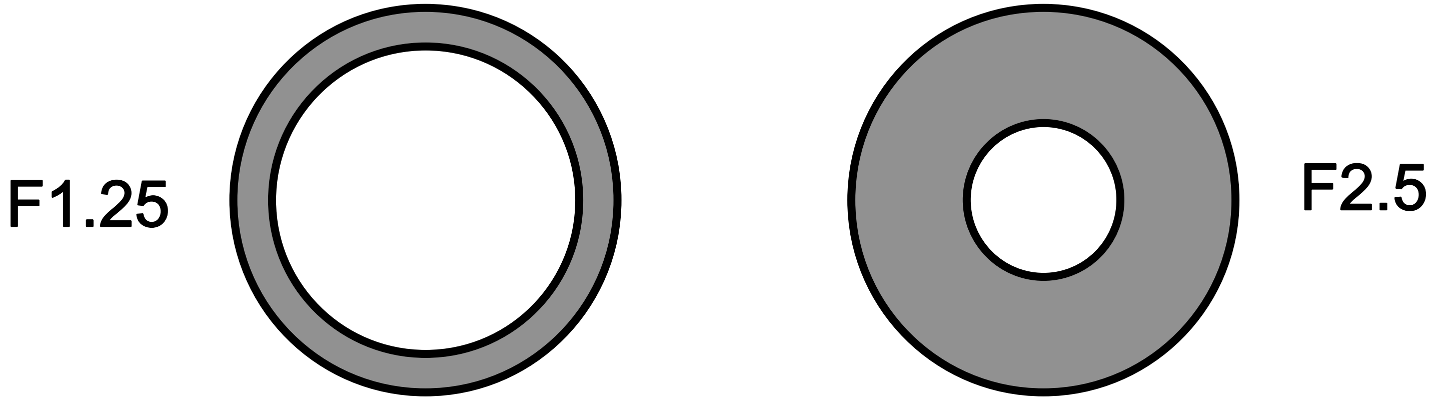
# Aperture

- Adjustable opening that controls the amount of light entering a camera

- Iris
  - Manual
    - For use in environments where the amount of light is constant
  - Auto
    - For use in environments where the amount of light is constantly changing
      - Iris controlled by signal from camera (DC or Video)

# Iris Setting (F-Stop)

- **Ratio of the focal length divided by the aperture opening**
- **A smaller F-stop number corresponds to a larger opening that passes more light**
  - **25mm lens / 20mm opening = F1.25**
  - **25mm lens / 10mm opening = F2.5 (1/2 light)**

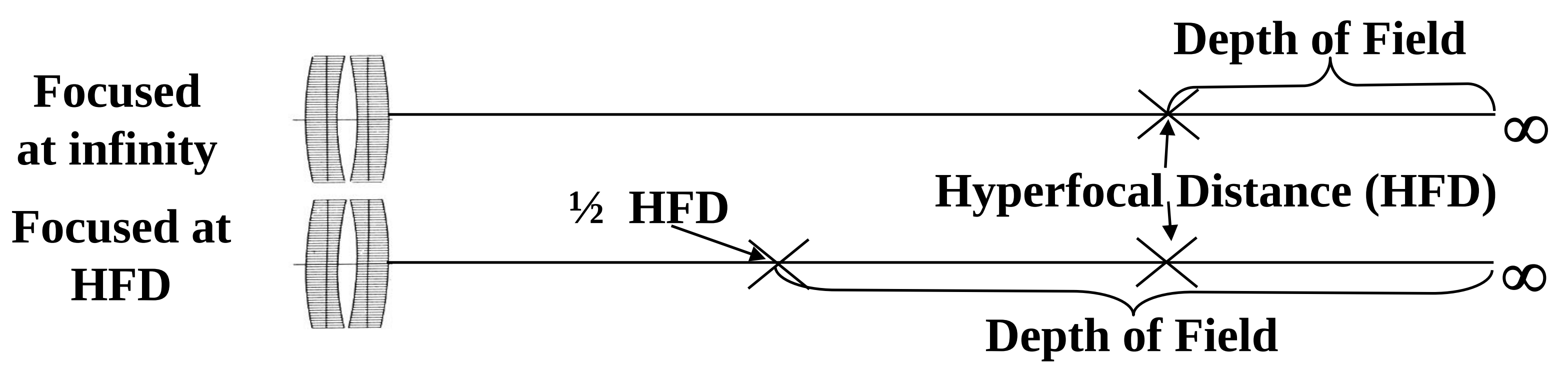


# Depth of Field

- Amount of scene that is in focus, greatest at ½ hyperfocal distance
- Greater
  - When higher F-stops used
  - When smaller focal lengths used
  - When subject distance from camera is greater

# Hyperfocal Distance (HFD)

- Nearest point at which you can focus and have objects at infinity in focus
- Setting focus of lens to hyperfocal distance allows objects half that distance to infinity to be in focus
  - Largest depth of field



# Hyperfocal Distance Formula

**H (meters) = [ L$^2$ / F x D ] / 1000**

**where**

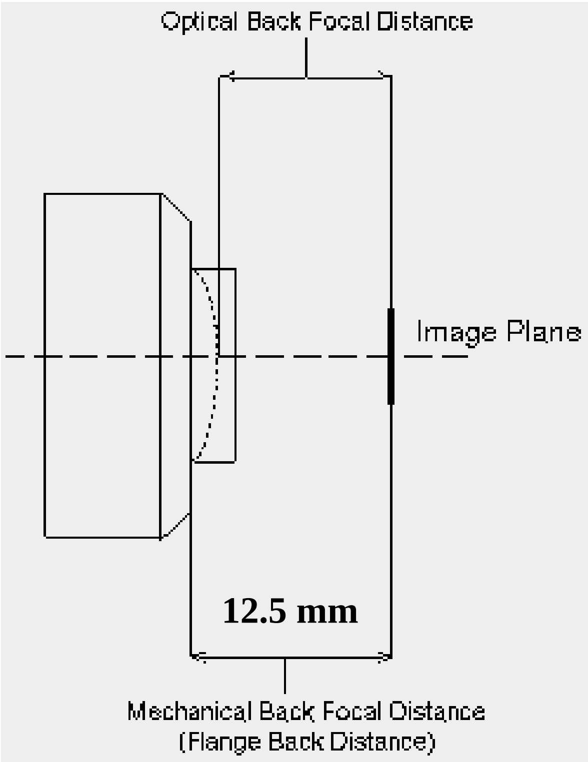
- **H = Hyperfocal distance**
- **L = Lens focal length (i.e., 50mm)**
- **F = Lens F-Stop setting**
- **D = Diameter of circle of confusion**

***Diameter of circle of confusion can be estimated by 1 / (500 / diameter of imager in millimeters)***

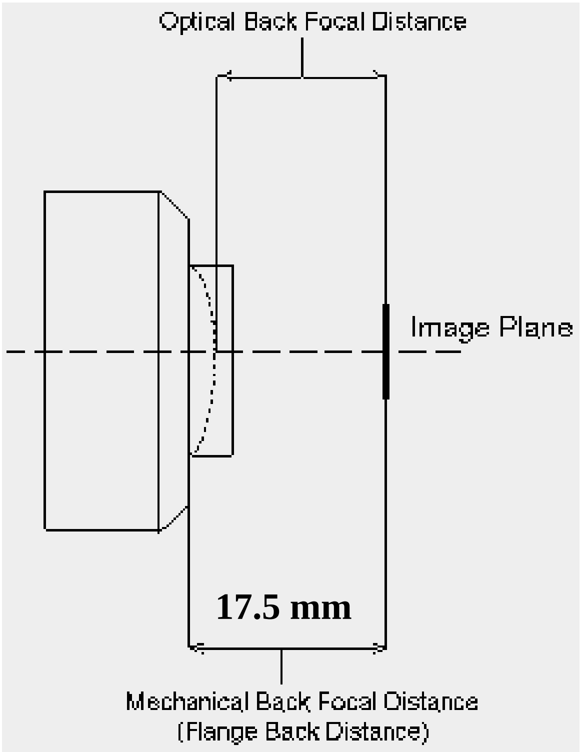
# Lens Mounts

- **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**

# C and CS Mount



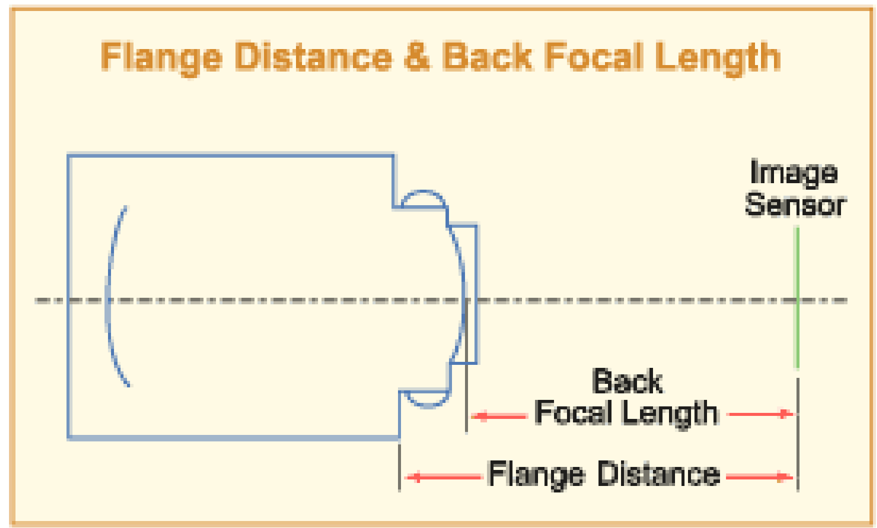

CS - Mount




C - Mount

# Focus

- **Mechanical**
  - **Adjustment of flange distance from camera housing**
- **Optical**
  - **Using focusing ring on lens to move back of lens closer or farther away from image sensor**



# Back Focus (Mechanical)

- Sometimes a camera cannot be focused by the optical focusing ring on the lens or on a zoom lens at either end of the zoom range
- May indicate a back focus problem, usually from one manufacturer to another
- It means that the flange back is not at the proper distance from the imager

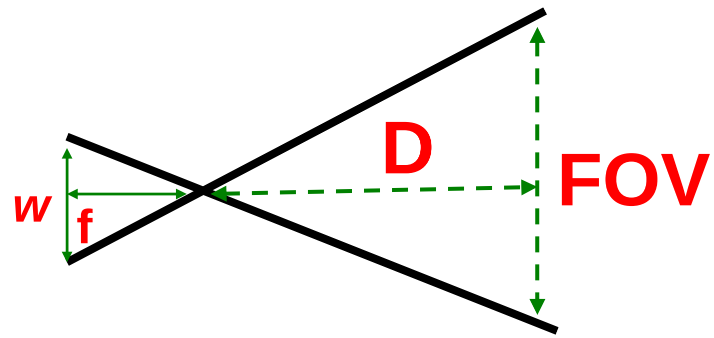
# Back Focus Fixed Focal Length

- Focus target is positioned to fill most of image area
- Set iris wide open
  - Neutral density filters
- Set focus ring on lens to minimum (nearest) setting
- Move camera imager plane with adjustment screw or mechanical adjustment ring so focus goes from blurred through clear to slightly blurred again
- Check that focus ring adjustment on lens can now go from blurred to focus to blurred again
- Lock imager or mechanical ring set screw

# Field of View (FOV) Formula

**Use to calculate Horizontal (HFOV) and distance to camera**

**D = W (f / *w*)     D = FOV (FL/ Wi)**




where

» D is distance from camera (m)

» FOV is width of field of view (m) at distance D

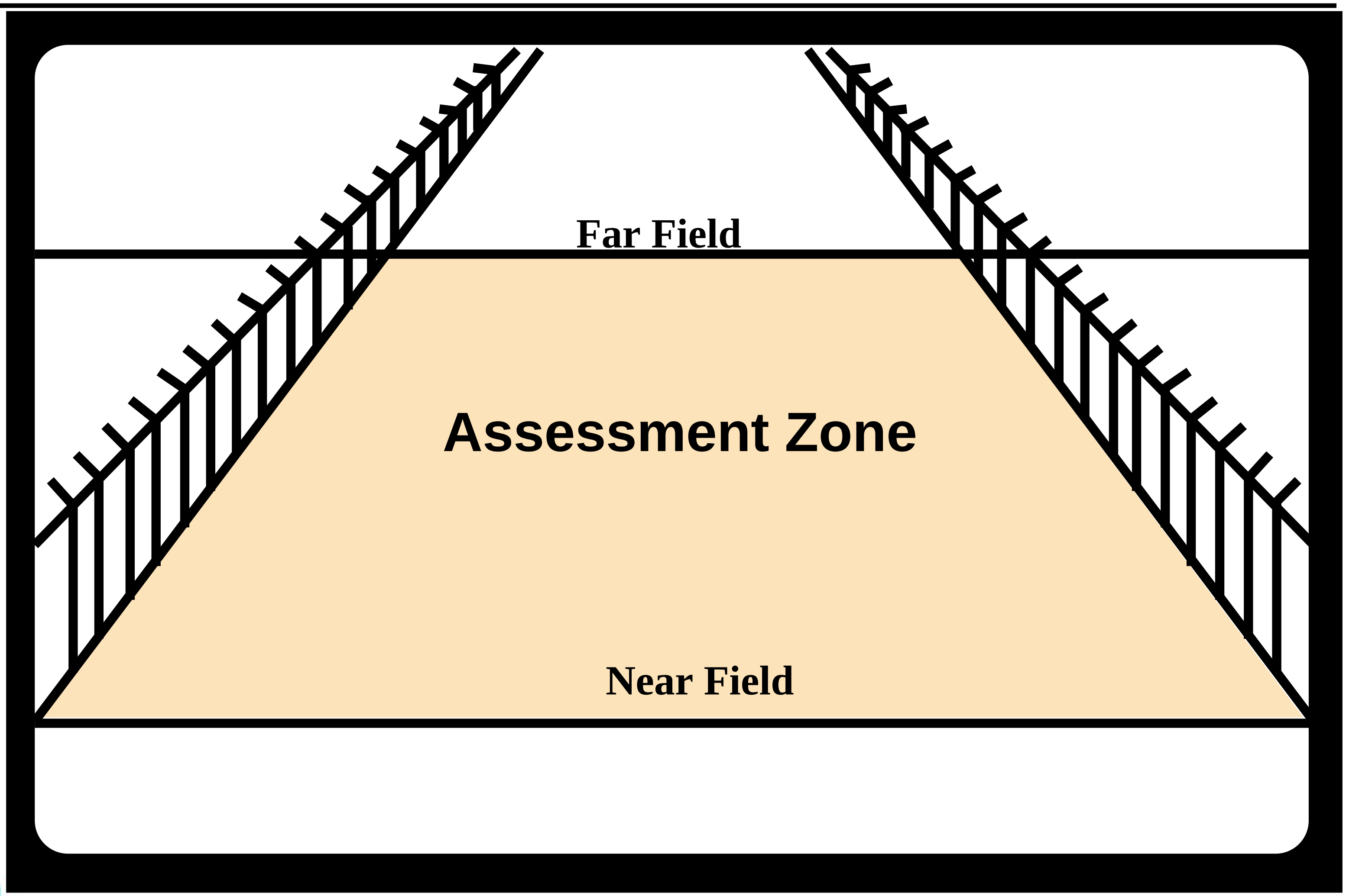
» FL is focal length of lens (mm)

» Wi is width of imagers sensitive area (mm)

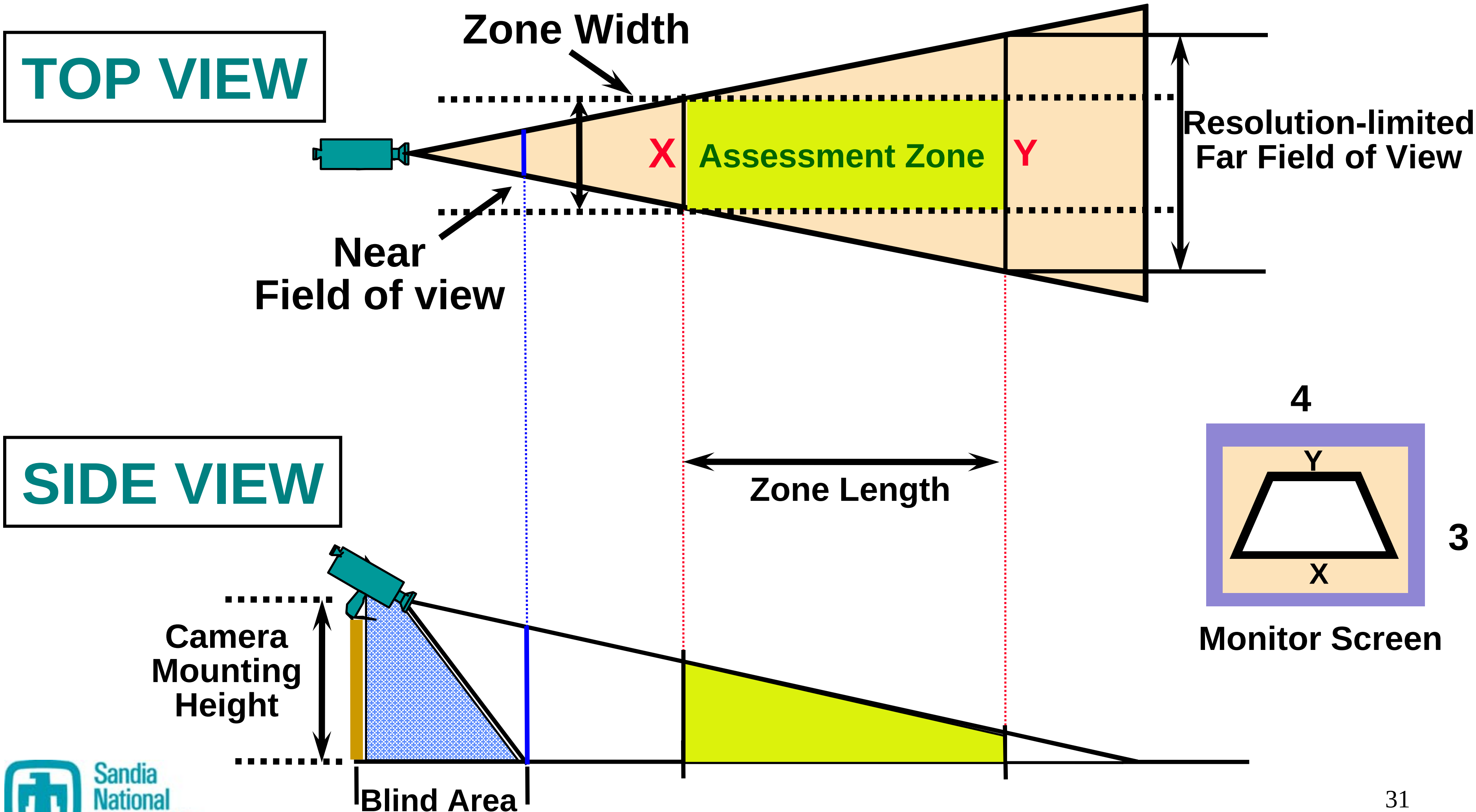
**Vertical FOV = HFOV * .75**

| |
|---|
| *Wi* = 6.4 for 1/2" |
| *Wi* = 4.8 for 1/3" |
| *Wi* = 3.2 for 1/4" |
| *Wi* = 2.4 for 1/6" |
| *Wi* = 1.6 for 1/8" |

# Schematic of Monitor View



# Geometry of Assessment Zone



# Exterior Monitor View


Day

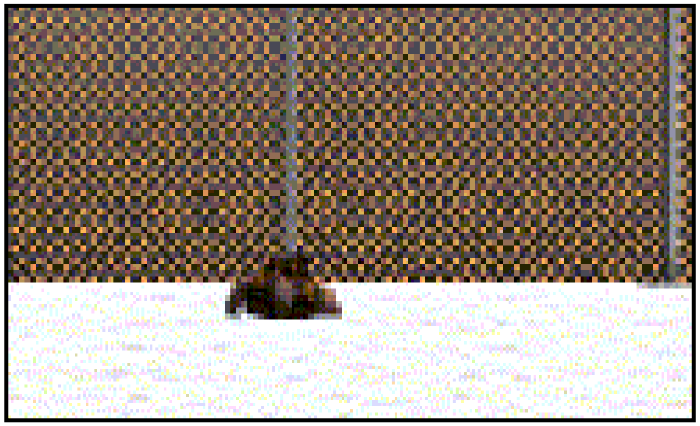

Night

# Levels of Resolution

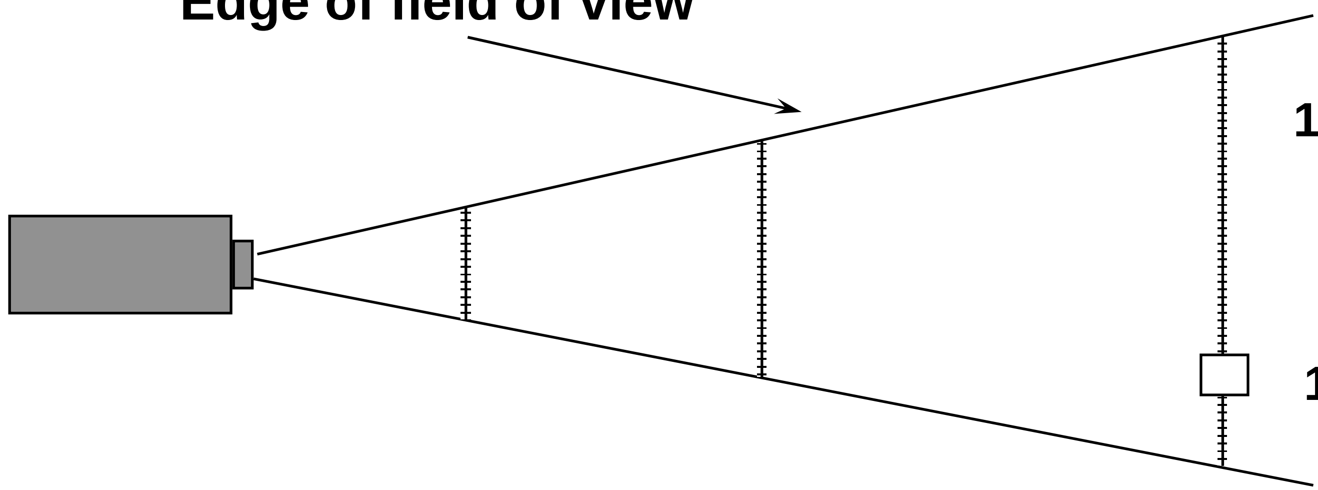
| Detection | Classification | Identification |
| --- | --- | --- |
|  |  |  |
| Determine Presence of Object | Determine Class of Object | Determine Identity of Object |

# Assessment Resolution

- **Classifying an object depends on camera resolution, lens focal length, size of object, object contrast to background, and motion**
- **Alarm assessment distinguishes between nuisance and real**
  - **Small animal and smallest human profile to camera**
- **Testing has indicated 6 HTVL or 8 pixels**

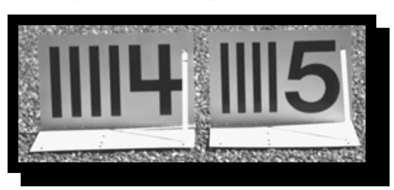


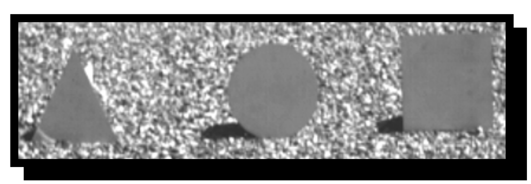
# Lens Selection and Resolution




**Horizontal view**

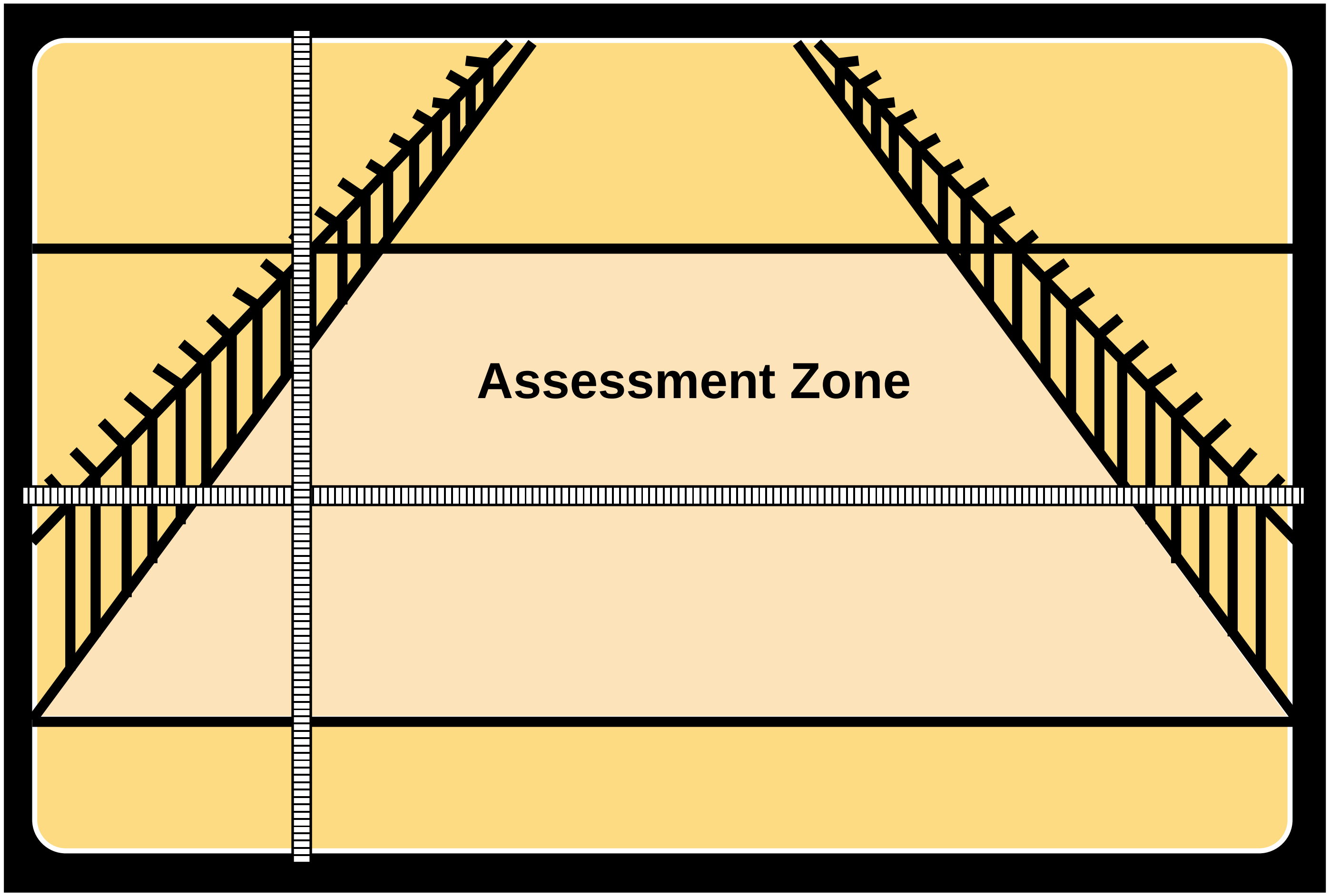
- Camera specification 600 horizontal TV lines of resolution
- Minimum target size for classification is 6 HTVL (8 pixels) of resolution for a 1 square-foot target





# Camera Resolution and Field of View Testing

# Resolution



# Classification Examples

Video Clip

Bird

Video Clip

Shadows

Video Clip

Airplane

Video Clip

Coyote

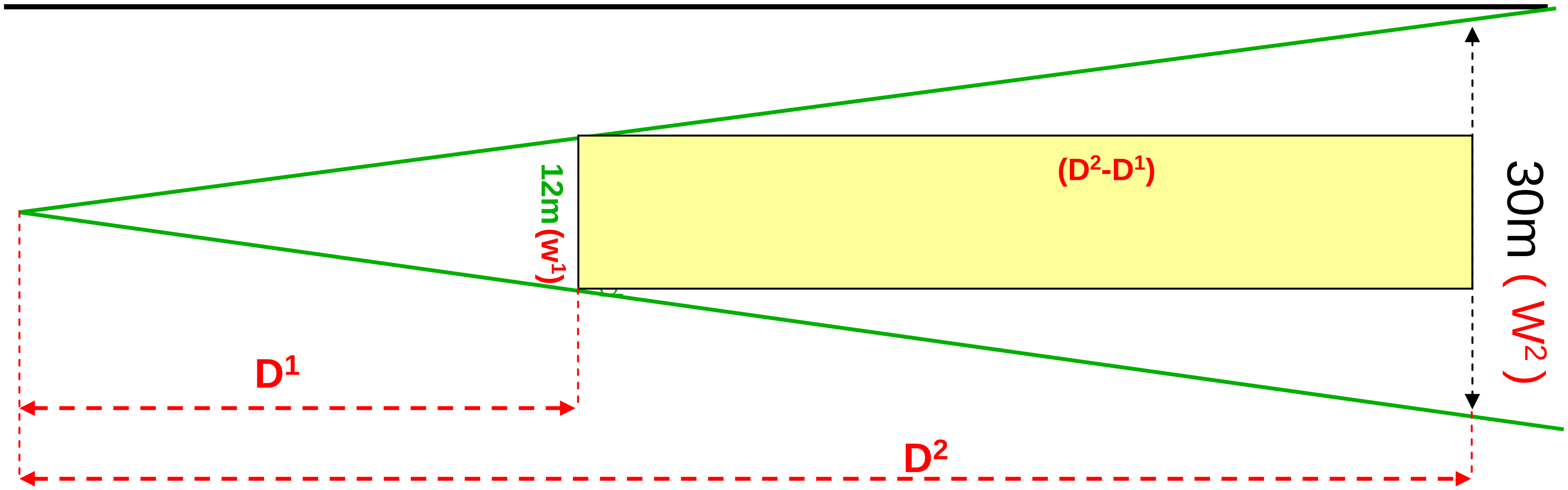
Video Clip

Walker Dark

Video Clip

Fog

# Calculation for Zone Length




**F**ocal Length of lens

$w$ – width of imager format

**W**idth of f.o.v. at a distance (D)

**D**istance

$$D = \frac{W\,F}{w}$$

$w$= 6.4 for 8mm format

$w$= 4.8 for 6mm format

$w$= 3.2 for 4mm format

$w$= 1.6 for 2mm format

$$D^1 = \frac{W^1\,F}{w} \qquad D^2 = \frac{W^2\,F}{w}$$

$D^2 - D^1$ = zone length

# Resolution at Far-Field

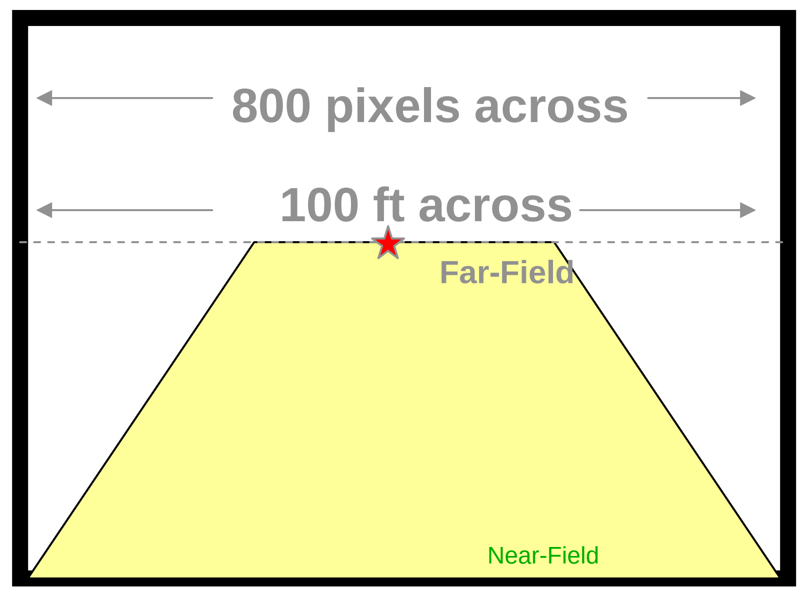
**12 in. at 8 pixels** = no more than **1.5 in. per pixel (line pairs)**
If a camera/monitor provides **800** pixels of horizontal resolution (*600 HTVL) then maximum field of view width is : 1.5 in. *800 **pixels** = 1200 in. = 100ft

Another way to reach this is using ratios:
8 pixels to 12 in. = 800 pixels to X.

$$\frac{8}{12 \text{ in.}} = \frac{800 \text{ pixels}}{X}$$

Solve for X = 1200 in. or 100 ft.

What if camera was **400** pixels?



# 6mm Format Camera Example

**A 1/3" (6mm) format 800 pixel camera has an imager width of 4.8mm.**
**For a 100m zone length at 12 m width:**

**What focal length lens do we need?**
**How far away from the near field should the camera be placed?**

$$\frac{(30)\,F}{4.8} - \frac{(12)\,F}{4.8} \geq 100$$

$$(6.25)\,F - (2.5)\,F \geq 100$$

$$(3.75)\,F \geq 100$$

$$F \geq 26.7\text{mm lens}$$

What lenses are available?

$$\frac{(12)\,(26.7)}{4.8} = D_{\text{from near field}} = 66.8\text{m}_{\text{ from near field}}$$

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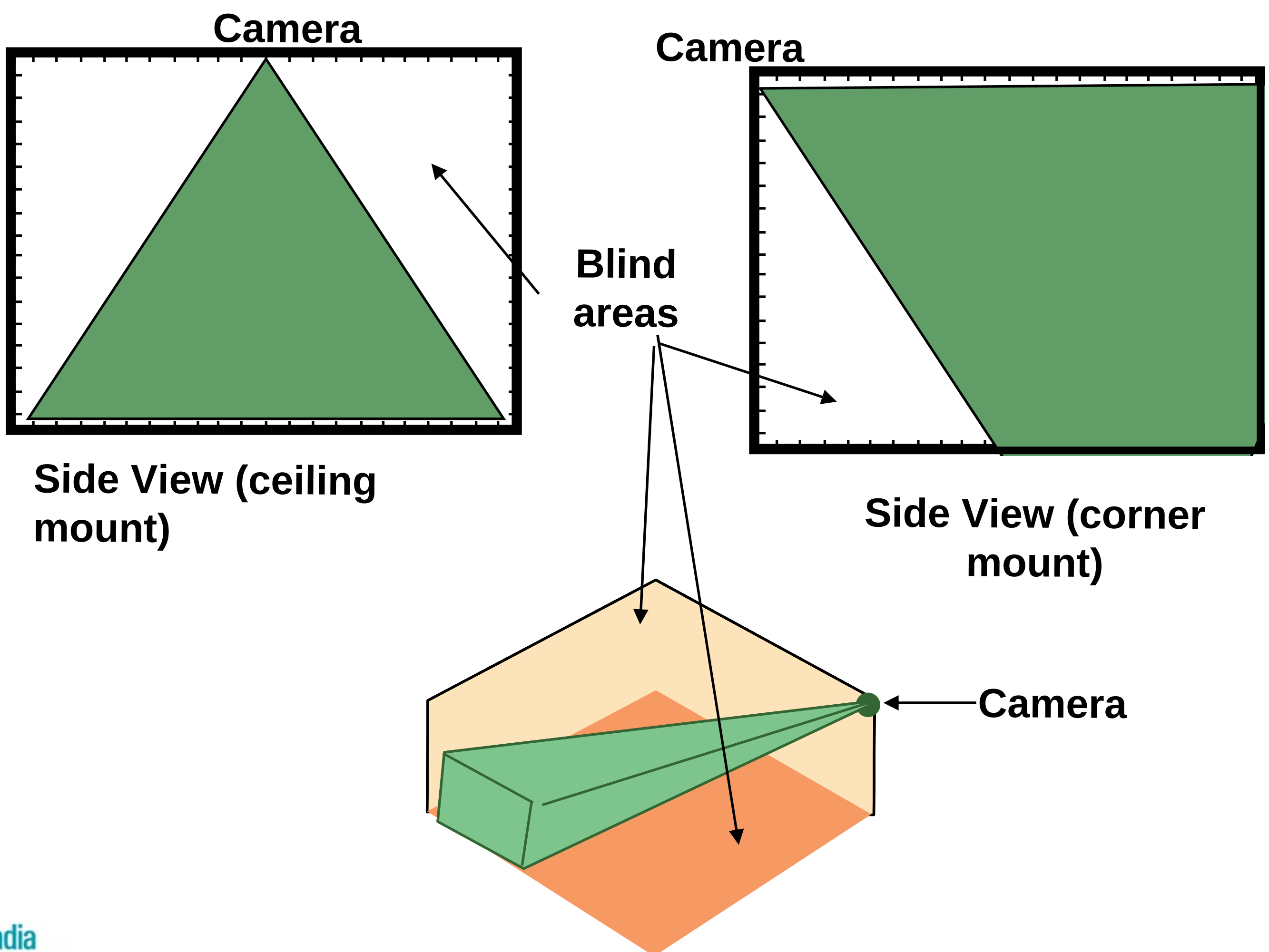
# Geometry for Interior Assessment



# Interior Assessment

- **Extreme wide angle can cause fish-eye effect, making identification difficult**


# Summary

- Camera video signals may be influenced by lens adjustment
  - Out of focus during day or night reduces assessment
  - Depth of view for full area coverage to be in focus
  - Different wavelengths of light may influence the focus if lens coatings are not used to compensate
  - Poor aperture settings for auto-iris cameras can make the camera electronics work harder or not produce a full video signal

# Summary *(cont.)*

- **Evaluation of assessment capabilities includes technical personnel training on camera / lens setup**
- **Have maintenance personnel indicate how they set-up and service the cameras to determine their performance level**

# Camera Lenses

***Questions?***

# Module 17

# Camera Mounts and Towers

# Classification

•**All material in this module is unclassified**
•**In this module, photos of equipment are included as examples only. Sandia National Laboratories does not endorse or recommend any specific equipment.**

# Module Objectives

- Understand the roles of the different camera mounts and camera towers for a stable camera image.

# Module Outline

- Introduction
- Camera mounts
- Camera towers
- Summary

# Introduction

- **Camera mounts and towers are important for camera stability**
- **Camera must be rigidly mounted to maintain a stable image to the CAS operator during windy conditions**
- **Camera mounts and towers come in a wide variety of configurations**

# Camera Tower Examples

# Camera Mounts

- **Tower – mounts camera to top of platform of tower**
- **Pole – mounts to cylindrical pole**
- **Parapet – top of wall at roof line**
  - **Comes over top of wall**
  - **Made to swing onto roof for safer servicing**
- **Pedestal – flat surfaces like roof, overhang**

# Camera Mounts *(cont.)*

- **Corner – outside corner of intersecting walls**
  - **Usually wall mount with 90° adaptor plate**
- **Ceiling – horizontal overhang surface**
  - **Can use pedestal mount or wall mount**
- **Wall – vertical surface, wall, or column**
  - **Many "J" shaped or "L" shaped**

# Mount Criteria

- Must be sturdy enough for all environmental effects
- Ice, wind, snow must be factored into load rating
- Rated by amount of load safely supported
- Attach with proper hardware and anchors to support weight
- Break-away features
  - Special mounting brackets
- Minimize vibrations to camera to lessen camera movement
- Many mounts are weak at single contact points

# Camera Mount Examples

# Mount Vibration

# Camera Tower Requirements

- Stable in wind
- Tower does not interfere with sensors
- Minimum exploitability by an adversary
- Not on wooden pole
- About 10 feet lower than lighting poles
- High enough to avoid pointing at camera above horizon

# Camera Tower Examples

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# Summary

- Determine if camera mount and tower selection are appropriate for application and environment
- Determine is camera movement comes from the tower or the camera mount

# Camera Mounts and Towers

***Questions?***


HRTD Human Resources Training & Development

# Module 18

## Alarm Communication & Display Sys and "No Single Act"

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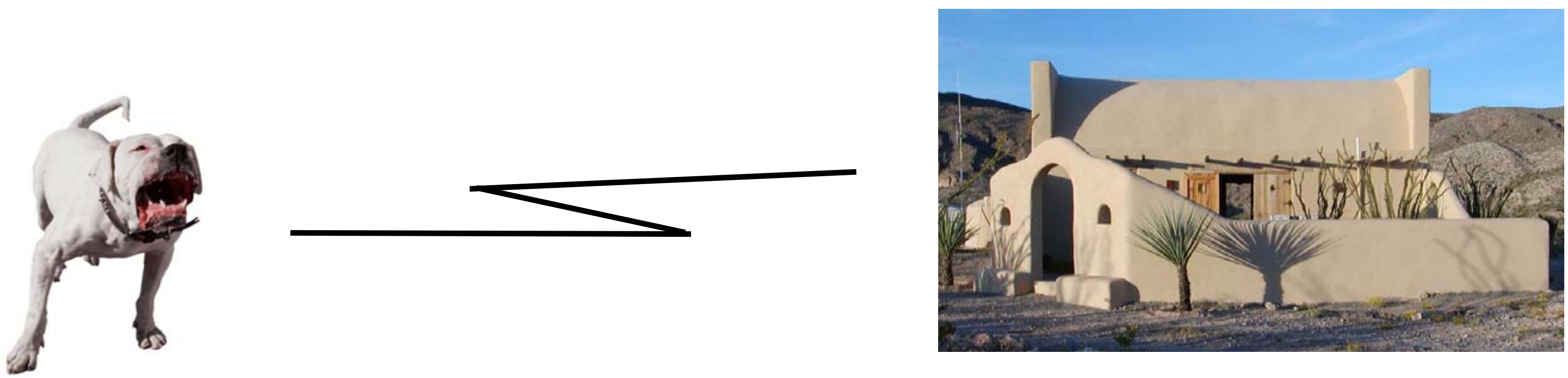
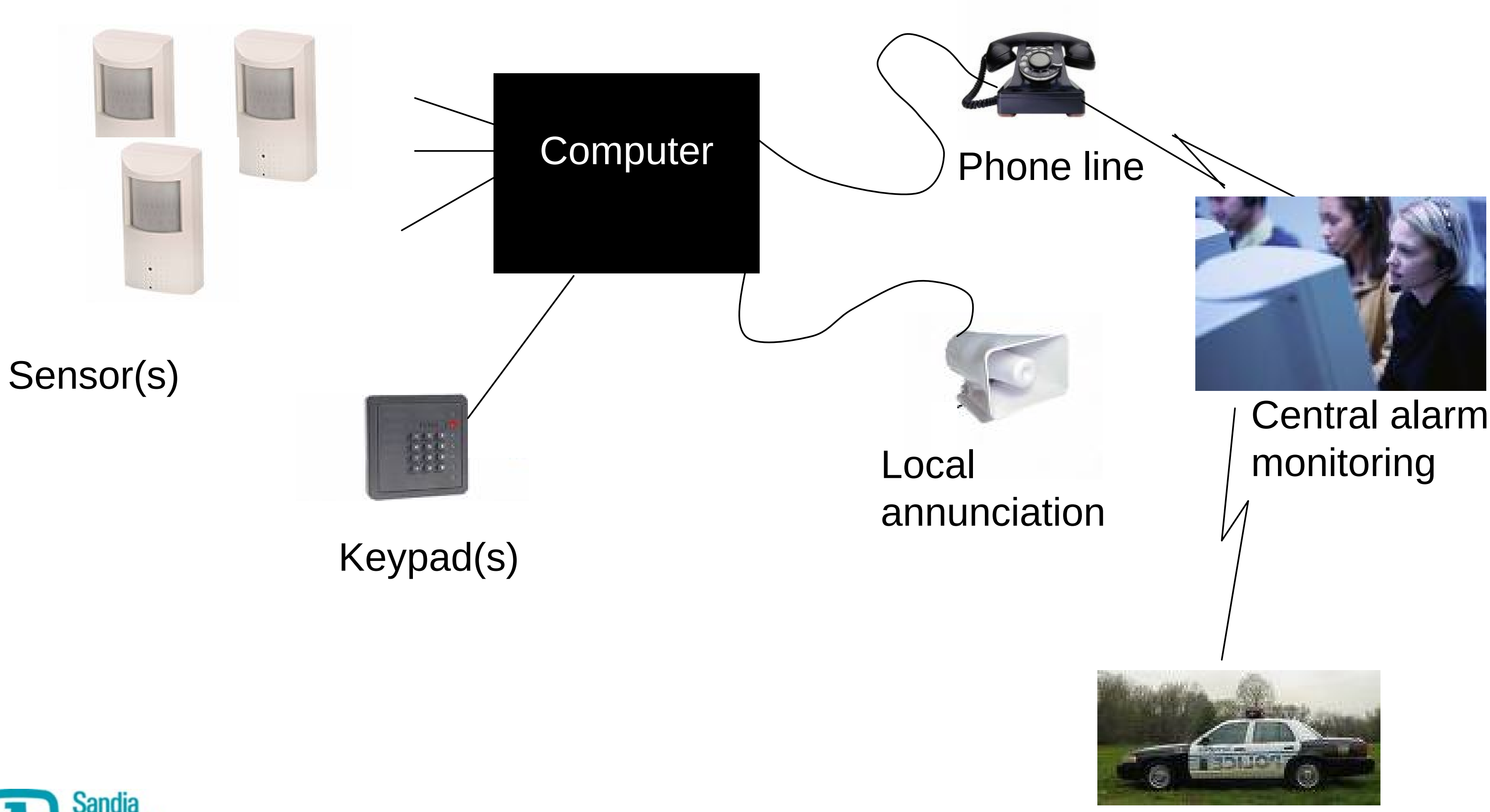
# Classification

- **All material in this module is unclassified**
- **In this module, photos of equipment are included as examples only. Sandia National Laboratories does not endorse or recommend any specific equipment.**

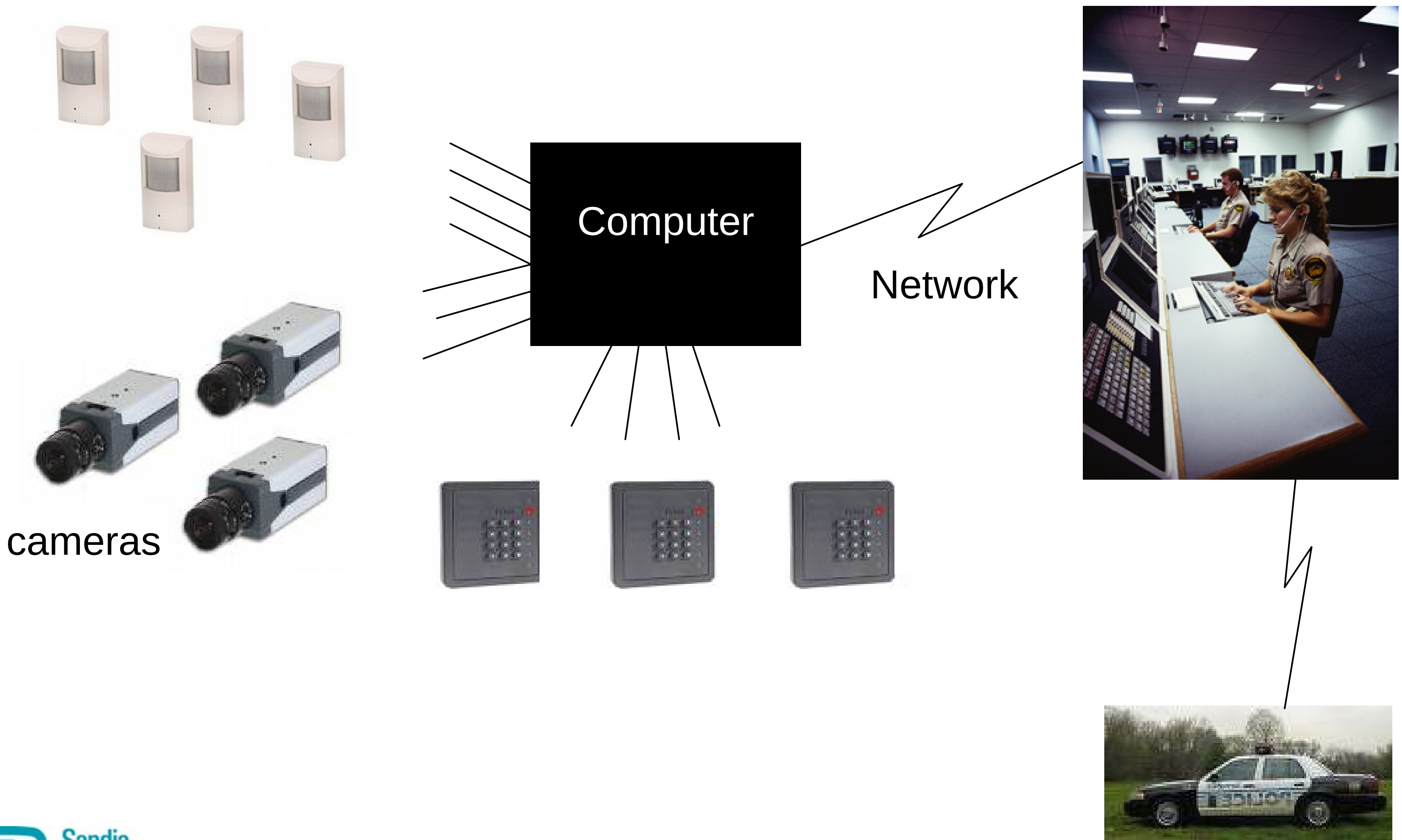
# A very old and rudimentary alarm system:



# Basic modern alarm system for a home or very small business:



# Alarm system for a small to medium-sized business or government office:



## Alarm system for a large business or government facility:

Computer

Own central alarm/ monitoring station

Own response team

# Is this an Effective AC&D System?

# 10 CFR 73.55

## No Single Act

– **10 CFR 73.55 Section (i)(4)**

**(4) Alarm stations.**

**(i) Both alarm stations required by paragraph (i)(2) of this section must be designed and equipped to ensure that a single act, in accordance with the design basis threat of radiological sabotage defined in § 73.1(a)(1), cannot disable both alarm stations. The licensee shall ensure the survivability of at least one alarm station to maintain the ability to perform the following functions:**

**(A) Detect and assess alarms;**

**(B) Initiate and coordinate an adequate response to an alarm;**

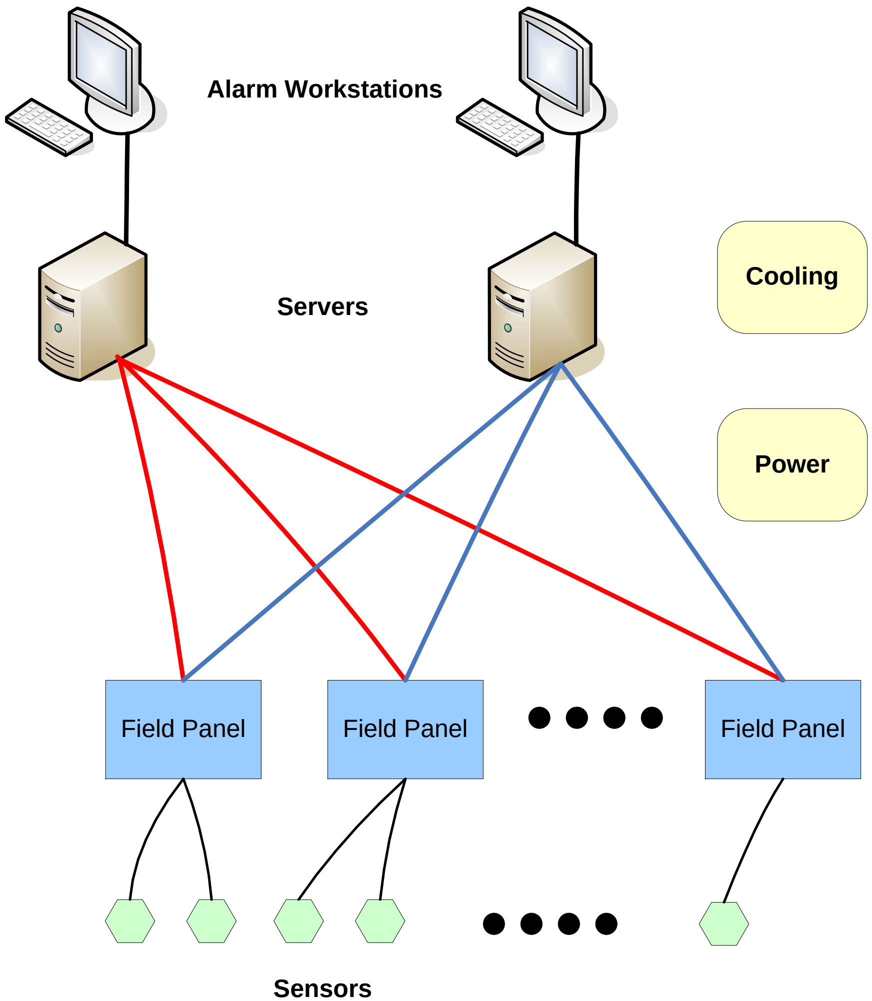
**(C) Summon offsite assistance; and**

**(D) Provide command and control.**

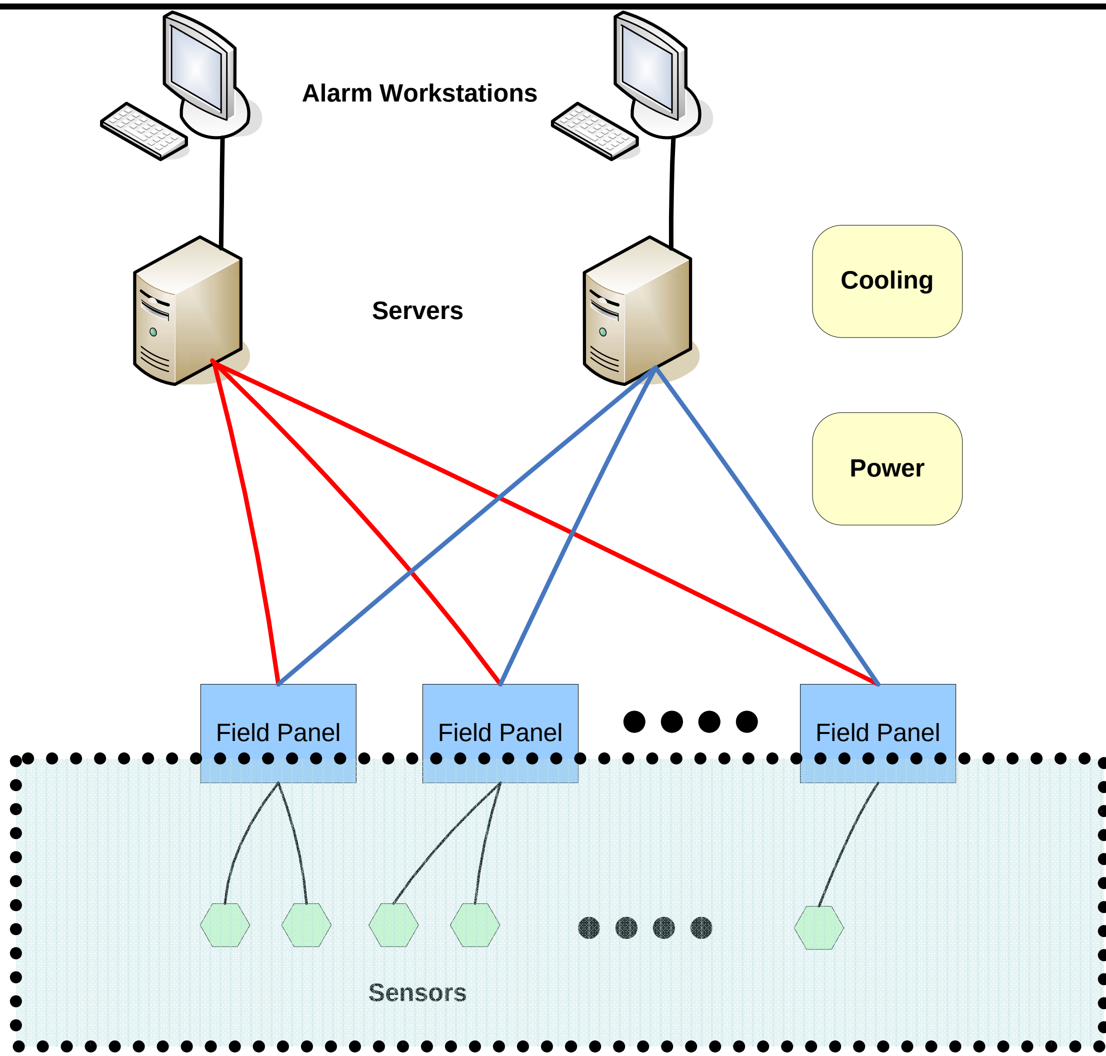
# Analysis of Requirements

- *Single Act*
- **The requirement mandates at least two “alarm stations”, but other redundancies may be required to ensure security personnel can handle alarm events.**
- **The regulations do not specifically define the term “single act”. For presentation purposes, a single act is defined as an event caused by the defined threat that occurs at a single time and at a single location.**
- **We place no restriction on the duration of a single event.**

# Typical IDS Architecture



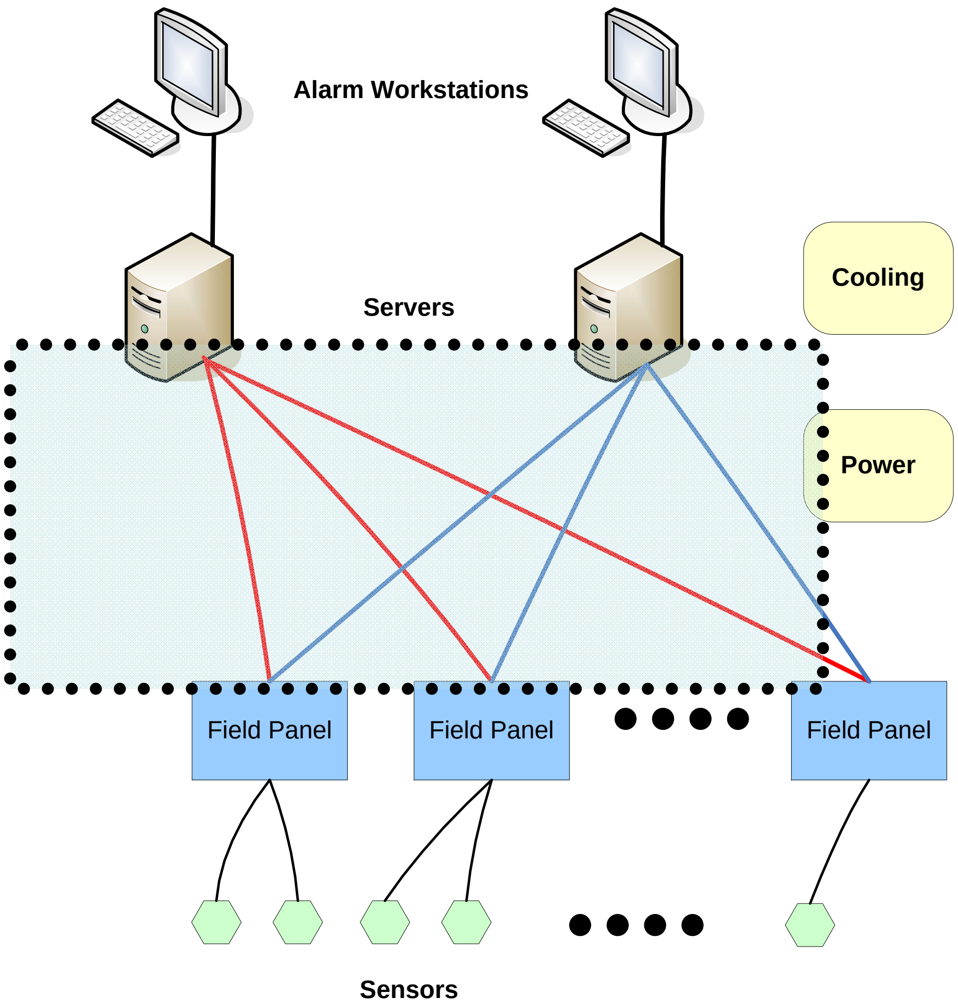
# Sensors & Sensor Communications



# Sensor Communications

- System must detect failures of its components
- Failures can be tolerated in single sensor zones as long as compensated by human detection (post a guard)
- Two or fewer adjacent sectors down at any one time

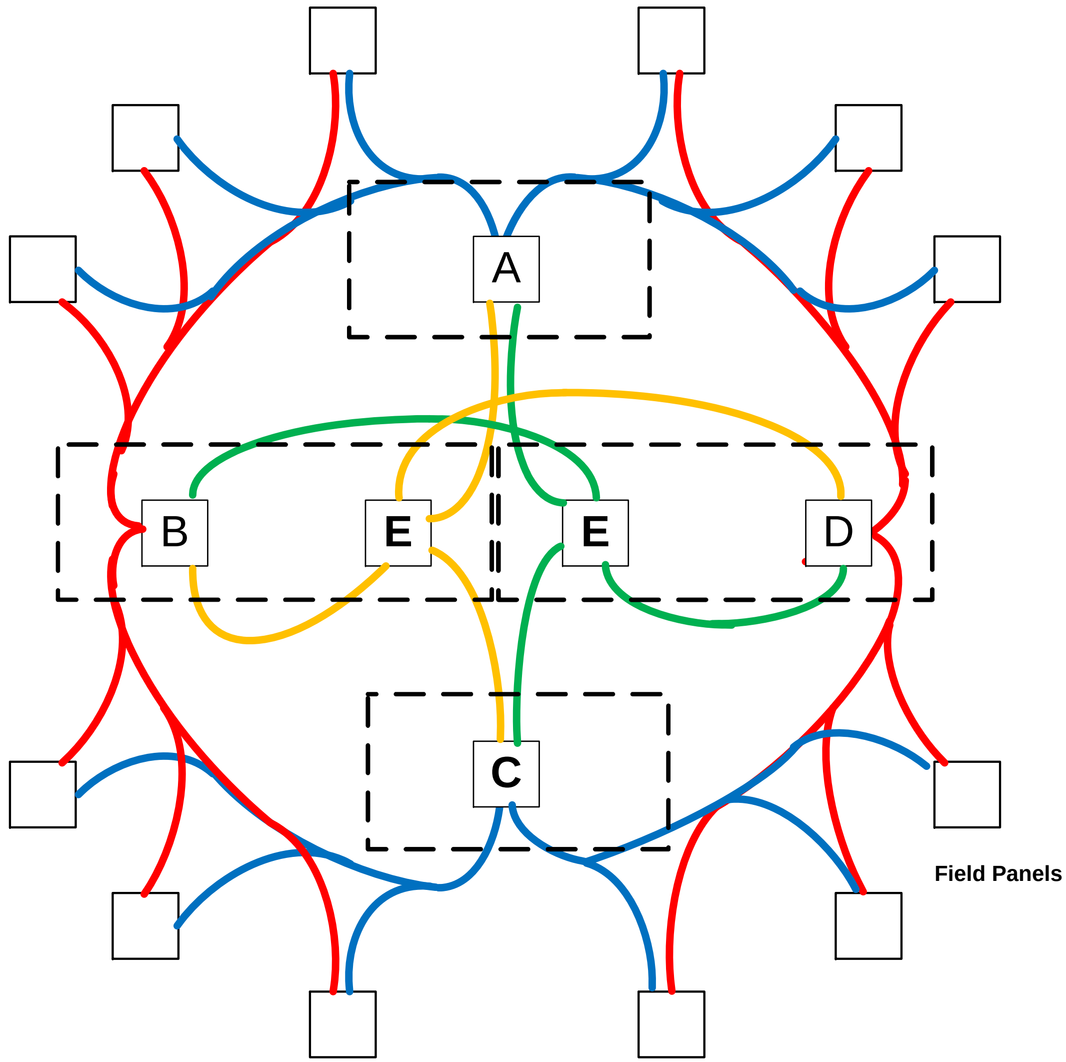
# Communications Circuits



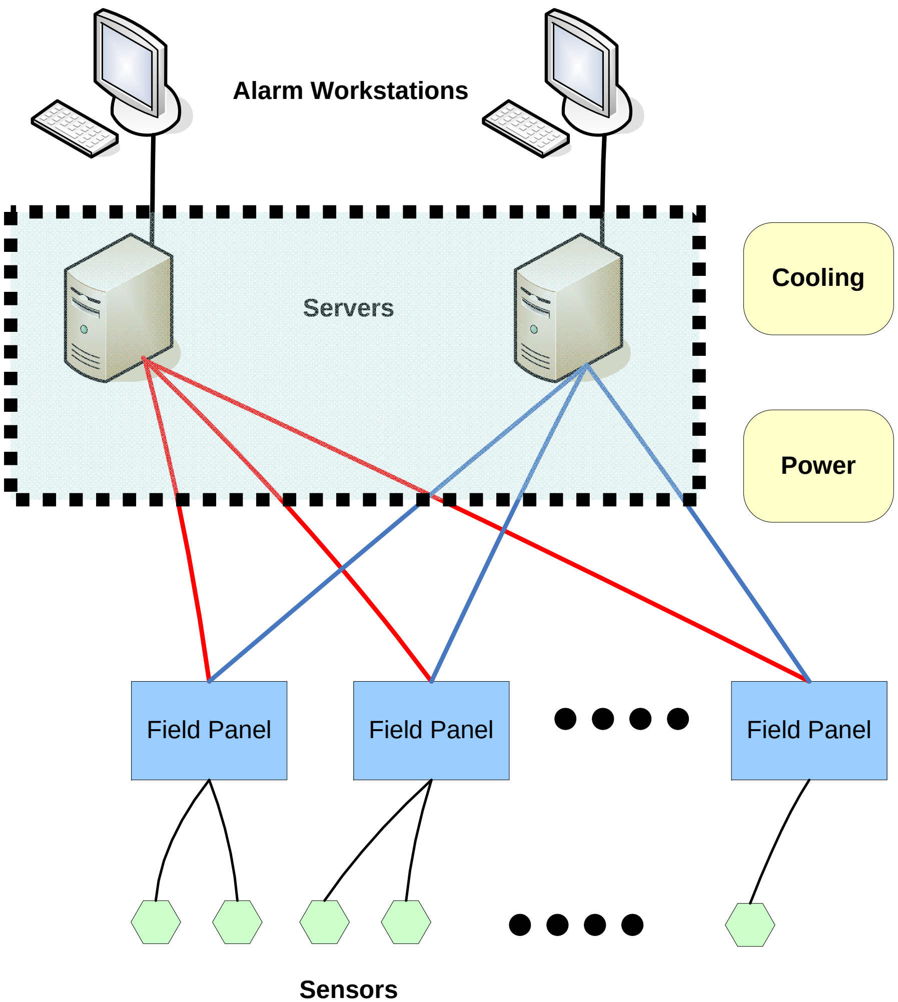
# Alarm Communications Circuits and Equipment

- As faults move to this layer, additional design techniques are required to meet “no single act” requirement
- Equipment and Circuit Redundancy
  - Redundant components placed such that they aren’t in the same place
  - Circuits routed via different physical paths
- Testing should show that disabling single components or circuits has no effect on system detection/assessment capabilities
  - Disconnect devices or circuits
  - Verify continued operation (alarm handling)
  - Verify system detects errors
  - System must restore when faults are corrected

# An Example Network Architecture



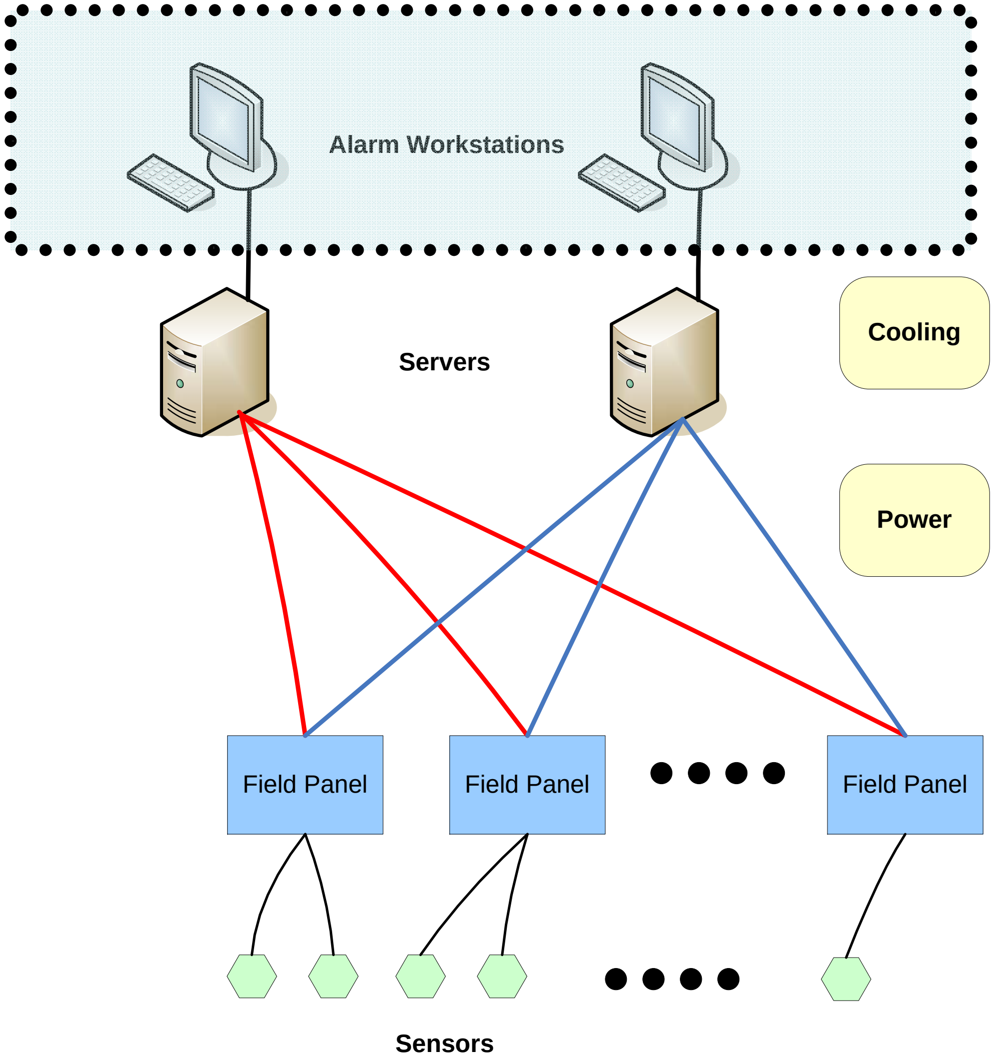
# Server Components



# Alarm System Servers

- Redundancy for servers is necessary
- Separate physical locations
- Testing
  - Cause one server to fail
    - Verify alarms can still be received at one workstation
    - Upon correction of the failure, the system should restore to initial state with no loss of alarms

# Alarm Workstations



# Alarm Workstations

- **May be associated with specific servers**
- **Failure of a server may cause the associated workstation to fail**
- **Some systems have additional redundancy at the workstation level**
- **Testing**
  - **Fail one workstation**
  - **Second should report the failure and continue to process alarms**
  - **The system should restore when the fault is cleared**

# Ancillary Components - Power

- **Power**
  - Each control room powered by separate power circuitry or provide un-interruptible power supplies (UPS)
  - Generators should be located separately from UPS components
  - Attacks at a single location must not cause power failures at both control rooms simultaneously

# Ancillary Components - Cooling

- **Separate cooling systems should be used to cool each control room**
  - **Servers / Workstations cooled independently**
  - **Single failure of cooling should not cause both primary and secondary workstations to fail**
- **Testing for cooling is usually by inspection**

# System Software

- **Commercial systems provide a single source for software**
  - **Measures must be maintained to ensure software has not been tampered with**
    - **Trusted Vendor Sources**
    - **New software tested off-line first**
    - **Proper IA controls**
    - **Security patches**

# Administrator/Maintenance Physical Access

- **Access to physical security equipment must be limited.**
- **No single individual should have access**
  - **Enforce "two-person control"**
  - **Knowledgeable second person**

# Final Thoughts

## Good Questions to ask

- What happens if . . .
  - This component fails?
  - This communications link fails?
  - Everything in this room failed?
- Can alarms continue to annunciate through single failures?
- Does the system report system failures?

# Alarm Communications & Display Systems and No Single Act

***Questions?***

# Module 19

# Digital Video Recorders

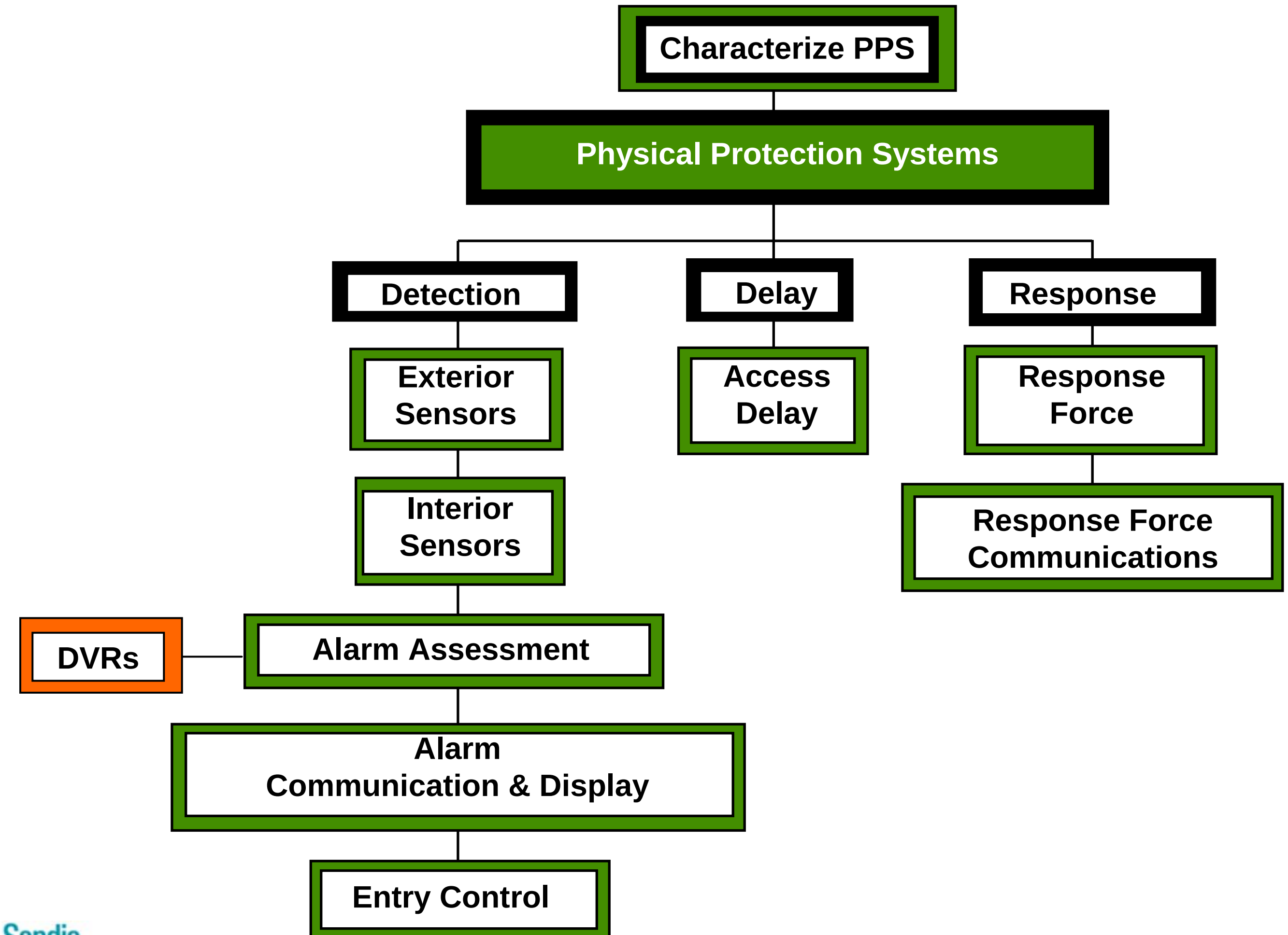
# Classification

- **All material in this module is unclassified**
- **In this module, photos of equipment are included as examples only. Sandia National Laboratories does not endorse or recommend any specific equipment.**

# Module Objectives

- Understand the basics of Digital Video Recorder technology
- Understand the capabilities and interfaces of Digital Video Recorder units

# DEPO – Physical Protection Systems

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# Digital Video Recorder (DVR)

- Has significantly improved the process for security video recording and playback in the past 10 years
- Makes VCR tape recorders obsolete
- Records images from 1-16 video cameras at the same time
- Can adjust the number of frames of video per second and the resolution of video images stored
- Improves speed of recording
- Greatly improves time to access recorded video for playback - do not have to rewind tapes to playback video

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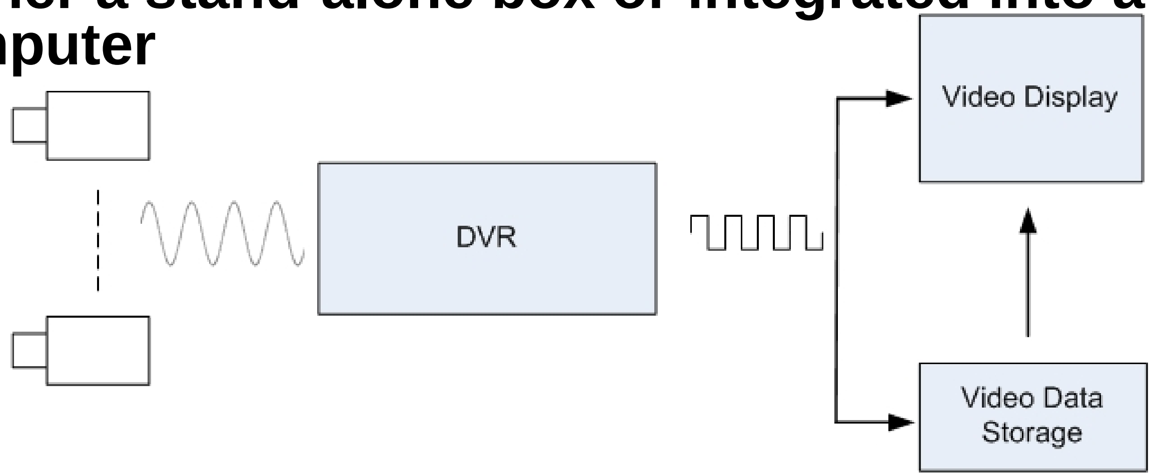
# What is a DVR?

## Attributes of a DVR:

- Digital video capture and storage
- Reasonably fast processor and special software
- Large amounts of disk drive storage space
- Ability to connect to existing video cameras
- Either a stand-alone box or integrated into a desktop computer



# Examples of PC-Based and Integrated DVRs

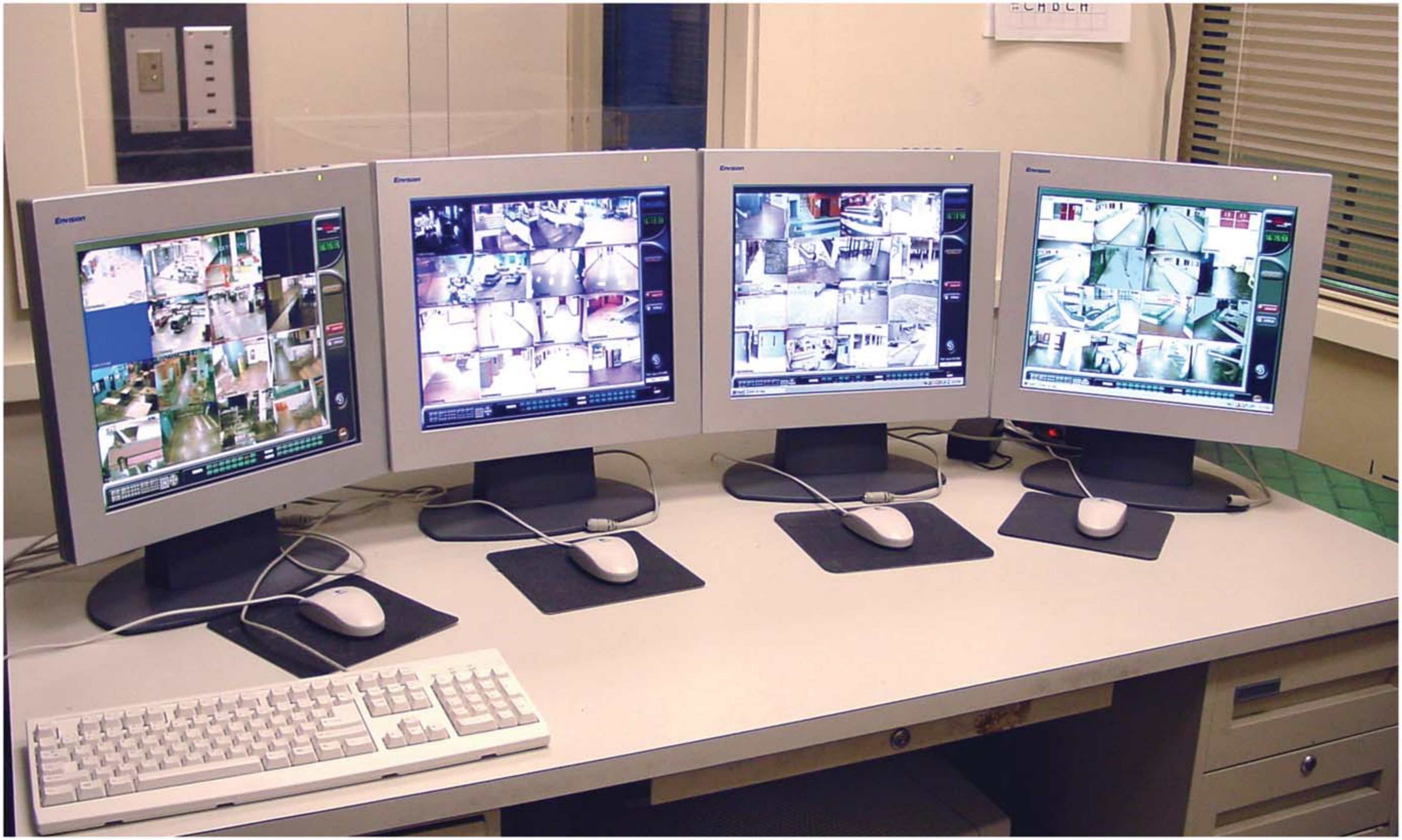
# Features/Capabilities

- DVRs record video on computer hard disk storage devices
  - does not use video cassette tapes
- Can automatically record, organize, and save days, weeks, or months of video, depending on memory storage size
- Can instantly playback video from a specific date and time
- Can copy video clips and images to portable memory devices
- Can send e-mail with alarm video to response force personnel
- Ability to save large amounts of video possible because computer hard drives are very large and not expensive

# Features/Capabilities (cont.)

- Overwrites previously saved video when the maximum memory storage limit reached
- Display configurations: single or multiple camera images can be viewed as separate windows on digital monitors
- Monitor views can be configured to display live and recorded pre-alarm video


Monitor
Search
Camera 1 – E Hall
Camera 9 – C Hall
Camera 8 – B hall
Camera 6 – Guidance
Ergo 1280
Camera 19 – Bronco arena S
Camera 14 – Ag lot
Camera 20 – Int tech bldg
Camera 15 – Aux W lot
Camera 5 – New wing E
Camera 16 – NW lot
Camera 7 – Commons
Camera 17 – Front N lot
Camera 18 – Discus field
07-22-00 04:08:41



# Features/Capabilities (cont.)

- DVRs with Video Motion Detection (VMD) allow the DVR to automatically store video when a movement alarm triggers a recording
- Can be set up to allow secure access to recordings using the Internet
  - – but security issues must be resolved
- User-friendly operation – VCR control commands
- Because the DVR is computer-based, many setup and control parameters can be customized for each application

# What Determines Video Storage Capacity

- **Amount of disk storage space**
- **The number of video channels recorded**
- **The number of frames captured per second (frame rate)**
- **Video image resolution (pixels)**
- **The quality of video saved-compression**

# Frame Rate

- NTSC (National Television Standards Committee) analog cameras provide video at 30 FPS
- The maximum DVR video recording rate is specified in frames per second (FPS)
- Most DVRS can capture video at up to 30 FPS - many can not record at that rate on all channels simultaneously
- The maximum of FPS recording rate (e.g., 480) must be divided among the cameras attached to that unit (usually 16)
- Ideally, want to record as many FPS when an event is triggered
- Record at a reduced rate when nothing is happening in the scene – a minimum of 3-5 FPS

# Frame Rate Example (5 fps)

# Video Storage Resolution

- **Image size can be controlled by reducing the captured resolution**
- **DVR resolution is represented as a pixel count or in terms of CIF**
  - **CIF: Common Intermediate Format is a standard video format used to define resolution in terms of pixel count**

| Format | Resolution | Uncompressed image size (kB) |
|---|---|---|
| CIF | 352x288 | 250 |
| QCIF | 176x144 | 63 |
| 4CIF | 704x576 | 1000 |
| 16CIF | 1408x1152 | 4000 |

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# Playback Resolution Makes a Difference



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# Resolution example: QCIF image (~63 kB)

# Resolution example: CIF Image (~250 kB)

# Resolution example: 4CIF Image (~1000 kB)

# Image Quality

- Image size can be further controlled by increasing the degree to which each captured image is compressed
- A good camera may provide a high-resolution image, but the captured image is compressed to save storage space
- To view a recorded image, the image is decompressed, but resolution can suffer
- Overall image quality is a function of camera resolution, captured resolution, and compression

# Compression example: “low” quality (~10 kB)

# Compression example: "medium" quality (~20 kB)

# Compression example: “high” quality (~40 kB)

# How Much Disk Storage Space Do You Need?

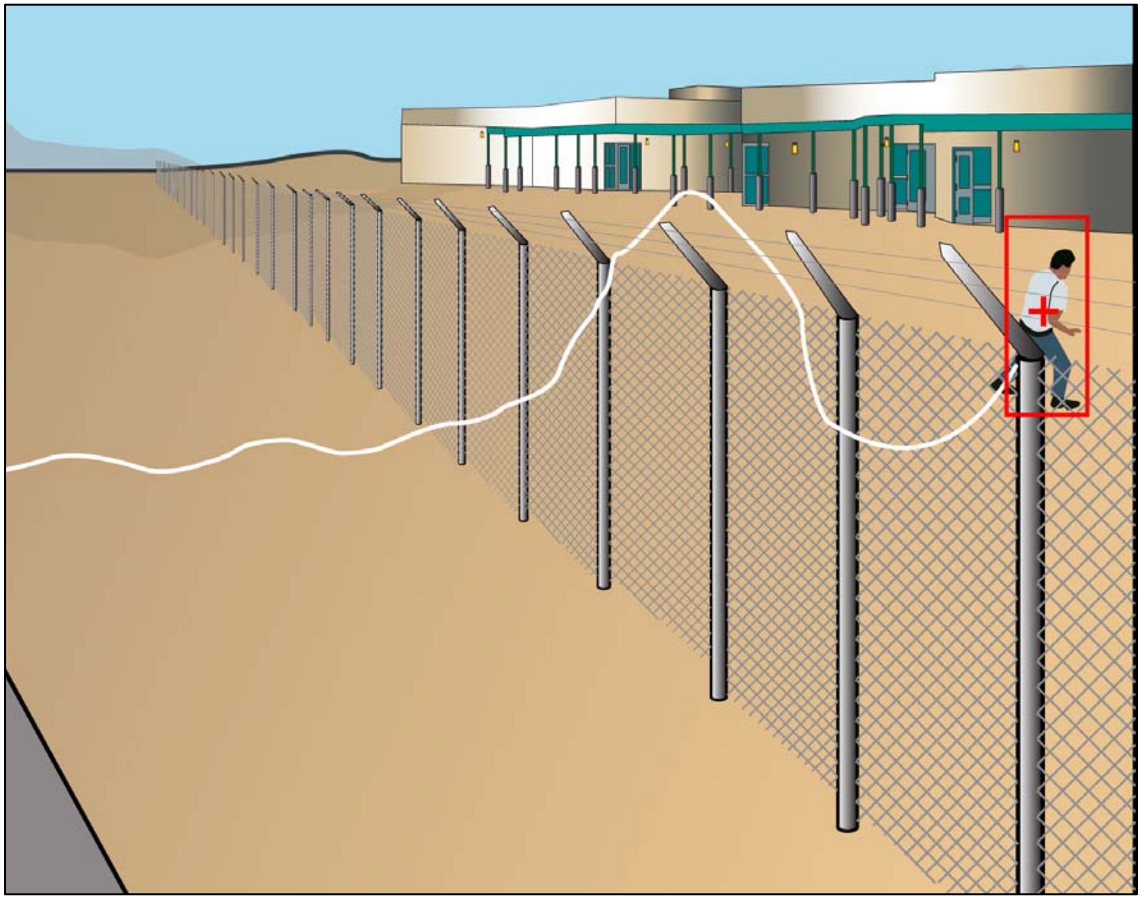
- **As much as you can afford . . .**
- **Vendor manuals and web sites have DVR memory size calculators for estimating the amount of memory needed**
- **Calculator inputs are: number of cameras, FPS, picture quality, and length of storage time needed**

# Digital Video Recorders

***Questions?***

# Module 20

# Video Motion Detection (VMD)

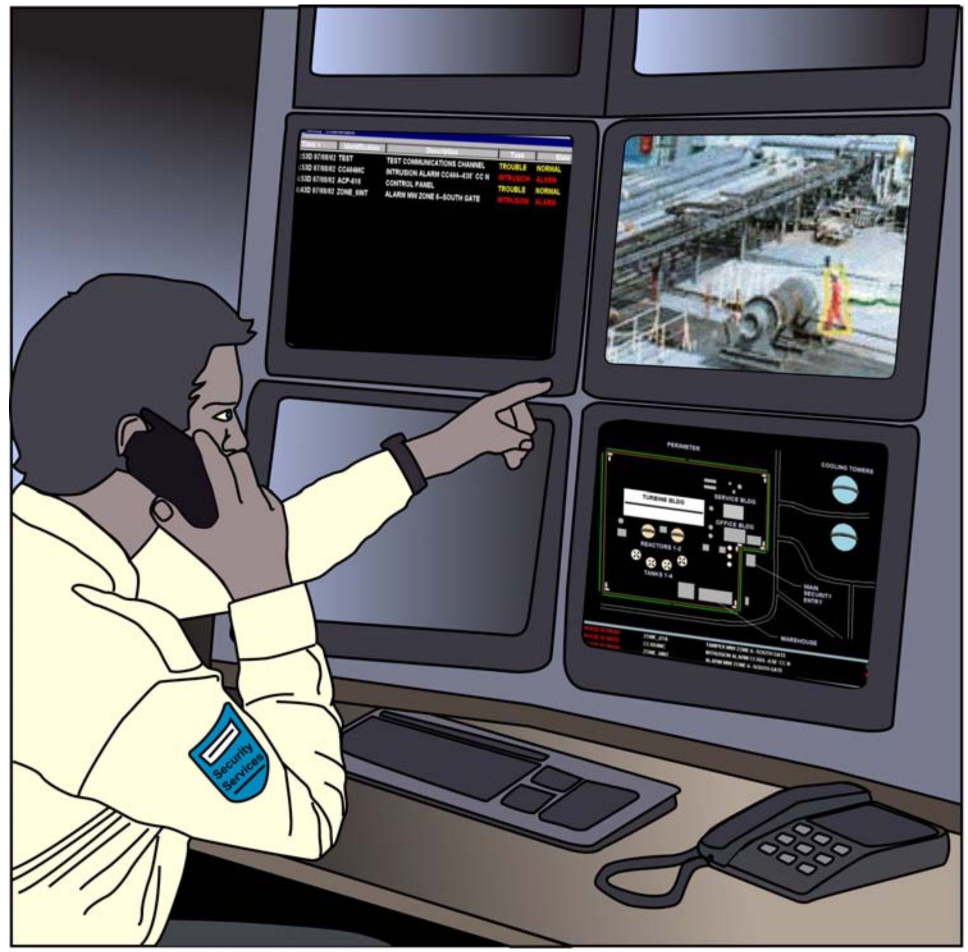


# Classification

- **All material in this module is unclassified**
- **In this module, photos of equipment are included as examples only.  Sandia National Laboratories does not endorse or recommend any specific equipment.**

# Module Objectives

- **Understand the basics of Video Motion Detection (VMD) technology**
- **Understand the advantages and limitations of Video Motion Detection technology**



# Video Motion Detection

- **Also known as:**

  **Intelligent Video**

  **Video Analytics**

  **Video Intrusion Detection**

# What is VMD

- Analysis of video from analog or digital cameras
- Alarm video is captured, marked up, and stored
- Several detection algorithms for specific behavior alarms
- Video from VMD can be stored on a Digital Video Recorder (DVR) or Network Video Recorder (NVR)
- Either a rack-mount module or specific-purpose personal computer

# Video Motion Detection

- Significant advances in the state of the art since 2000
  - A viable enhancement to video assessment
- With VMD, an existing assessment camera can become another intrusion detection sensor
- With alarm assessment cameras, VMD sensor's infrastructure is already installed
- Camera video is analyzed in real time for intrusions
- VMD software provides an alarm to alert the operator of an intrusion and a log of alarm events
- Video is "marked up" with a box around the moving target and may also have highlighted trail

# VMD Technology Attributes

- VMD can be used with analog or digital cameras
- Effective with daylight, near-infrared, thermal imager and 360-degree view cameras
- Requires addition of hardware modules or alarm processing hardware and software
- Modular technology can be implemented at the camera or at the CAS
- In one configuration, VMD software is downloaded into special digital cameras with digital signal processor chips (DSP) and memory

# VMD Technology Attributes (cont.)

- Digital camera can be configured to send low frame rate video during normal operation
- When intrusion detected, camera sends alarm message to CAS and then increases frame rate during alarm event
- Pre-alarm video is stored in camera's memory and transmitted to CAS when alarm event occurs

# VMD Technology Attributes (cont.)

- Most expensive may not be the best technology
- Lower performance modules provide simple movement detection
- Higher performance modules use sophisticated algorithms to detect and categorize moving target
- VMD analysis algorithms generally activated when movement in area of interest in camera field of view

# Three Types of VMD Technology Available

1. **Software running on a personal computer with video capture card**
   - Located at or near the CAS
   - Analog or digital cameras connected to VMD computer

2. **Standalone single- or multi-channel hardware/software modules**
   - Located at the camera or CAS
   - Analog or digital cameras connected to VMD modules

# Three Types of VMD Technology Available (cont.)

3. Software imbedded in a digital camera with on-board digital signal processor (DSP) and memory
   - Inside digital camera at camera location
     - With digital cameras having on-board video processors, analysis can be performed at the camera
     - With analog cameras analysis performed at the CAS

# How VMD Works - Detection Algorithms

- **VMD algorithms make decisions about what is moving and the nature of movement**
  - **Pixel movements are identified**
  - **Pixels in motion are "blobbed" together as a group of pixels with common motion**
  - **Pixel "blob"is analyzed to determine if the pixels fit the classification criteria needed to generate an alarm**
  - **Motion, direction, speed, and other factors analyzed**
  - **If attributes pass analysis tests, an alarm signal is sent to the CAS and the intrusion video is displayed on the video monitor**



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# How VMD Works – Detection Rules

- **Detection based on a set of "rules" and "areas of interest" in the camera's field of view**
  - **Rules can be applied to areas of interest rather than the entire view**
  - **Allows specific detection functions to be active only within portions of the camera's field of view**
  - **Detection function does not have to be active throughout the entire camera's field of view**
  - **Movement in areas of interest triggers an alarm**
  - **Movement in other areas does not trigger an alarm**

# How VMD Works – Detection Rules (cont.)

- Complement of detection rules established by vendors for their hardware and software
  - Kinds of rules, functionality, and reliability vary widely from vendor to vendor and by application
  - During system set-up, the operator chooses a rule and identifies where in the camera view it is to be applied
  - From drop-down menus and graphical tools, areas in the camera view can be highlighted

# How VMD Works – Detection Rules (cont.)

- Each rule has a list of attributes to be selected to calibrate the detection algorithms
- After rule attributes are selected, a rule definition file is saved and sent to the camera or VMD module for update and execution
- Rules can be active only during certain days of the week or during certain hours of the day
  - Entry portal detection can be active during non-operational hours and inactive during normal hours

# How VMD Works - Calibration

- Operator calibrates the camera's field of view, with respect to object size, object type (human, vehicle) speed, size direction, and location
- Example
  - The person stands at 3 or 4 locations from near field to far field
  - At each location, the operator sets markers to the person's height to calibrate detection algorithms
  - Software scales the detection algorithm's function for identifying a human's movement in camera's field of view
  - A human occupies more pixels when closer to camera than when further away

# How VMD Works – Calibration (cont.)

- **VMD algorithm calibration allows identification of movement at the ground or floor level**
  - **Movement above ground level can be exempt from alarm classification**
  - **Assumes targets of interest are humans walking or crawling on the ground**
- **If a person "swinging-in" on a rope is a concern:**
  - **The detection algorithm can be programmed to detect on object either greater than or less than a particular size**
  - **The detection alarm occurs with a human-sized object and not with a bird-sized object**

# How VMD Works - Learning Mode

- Some VMD technologies have a learning mode for detection and alarm algorithms
  - At start-up, for a few 10s of seconds, the VMD software learns scene attributes in pristine condition
  - Later, the software performs comparisons to the pristine scene when alarm-generating movement is detected
- Some VMD packages have an adaptive baseline scene for use during the algorithm decision-making process
  - The pristine scene is modified to account for current illumination conditions
  - Useful in outdoor applications where scene illumination changes 4-5 orders of magnitude



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# How VMD Works – Object Surveillance

- Recently VMD was adapted for observation of objects to ensure they are not moved, removed, or tampered with
  - Effective in locations where personnel are present but detect for object movement or tampering
  - VMD algorithm examines the scene to ensure that items in the scene remain at their baseline positions
  - Usually some specific visual feature of the object under surveillance is observed to ensure it does not disappear
  - A change in the visual feature aspect ratio or being covered up for more than a predetermined time causes an alarm

# How VMD Works – Object Thermal Surveillance

- **Another example is the use of a thermal imager camera and VMD for electrical equipment thermal protection**
  - **Scientific thermal imager cameras provide a video image that has either a black & white or color image proportional to the temperature of items in the scene**
  - **Temperature (color) of object can be calibrated**
  - **Object (e.g. transformer) temperature can be monitored by VMD software**
  - **VMD alarm created when temperature exceeds the calibrated threshold**

# VMD Advanced Capabilities

- **An advanced capability is the VMD tracking function**
  - **Movable (PTZ) camera set to view a static scene**
  - **When alarm-generating movement is detected, the camera zooms in and follows the target within limits of zoom and movement capability**
  - **Applied to static or preset camera (tour) locations**
  - **Tracking can be triggered at any of the camera's tour stop locations**

# VMD Advanced Capabilities (cont.)

- At least one vendor has demonstrated tracking while a camera is in motion
  - While the camera is panning, VMD software identifies the relative movement in the camera's field of view and then tracks that movement
- Tracking the hand-off from one camera to another
  - When one camera reaches its end-of-tracking capability, the object is handed off to another camera to continue tracking
- Forensic data mining of stored video
  - Software locates all observations of target in stored video
  - Video clips arranged in time sequence for operator display



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# VMD for Behavior Detection

- Some VMDs perform physical behavior detection particularly for interior cameras
  - A behavior detection example would be at a door that requires each person to swipe a badge or enter a code into a keypad to enter
  - A behavior-based algorithm creates an alarm if personnel tailgating occurs
  - An alarm is created when a second person enters a door behind a first person without either the badge swipe or code entry

# VMD for Behavior Detection (cont.)

- Another example is detection of a human going into a door that should be used for exit only
  - If a person was observed by the algorithm as entering the exit door, an alarm would occur
  - Example at an airport:  If a person tries to enter the gate area through the gate exit lane

# VMD Sensitivities

- More sensitive to movements across the field of view
- Less sensitive to movements toward or away from camera
- “Across” movements change more pixels for the same movement than does movement toward/away
- As a video sensor, the detection pattern should be across the field of view

# VMD Sensitivities (cont.)

- **Should not be used where there is a large change in scene illumination**
  - **Example – If a camera is oriented so that it views the inside of an exterior door, opening the door on a bright, sunny day causes large changes in scene illumination when the door is opened**
  - **Can cause nuisance alarms or non-detection of personnel entry through the door because of significant perturbation presented to classification and detection algorithms**
- **New camera imagers can mitigate part of the bright light alarm sensitivity**
  - **Cameras with Pixim imagers have independently integrating pixels to significantly reduce image washout**

# VMD Sensitivities (cont.)

- VMD tends to be more sensitive to black & white pixel movements – extremes of color spectrum
  - Easier to differentiate than movements in grey scale or muted colors
- The scene's area of interest must not include areas that experience moving shadows or moving sun glint
- If indoors where windows face east or west, a low angle of sunlight entering windows can cause persons to cast shadows inside the building
- If the area of interest includes an area where moving shadows are cast, this may cause unnecessary activation of detection and classification algorithms, creating the possibility of nuisance alarms



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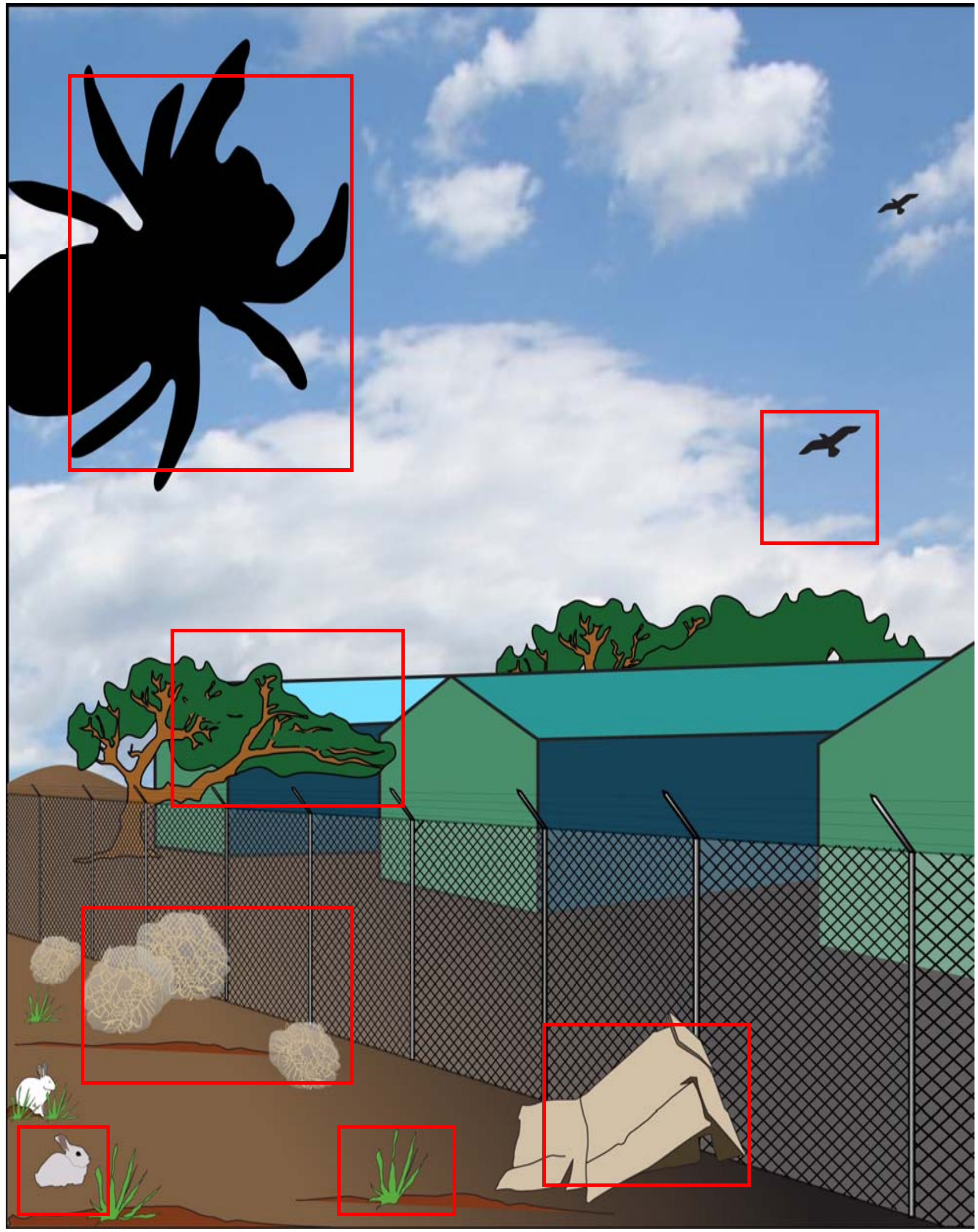
# Sources of Nuisance Alarms

- **Applications can create challenging environments**
  - **Indoor environments produce fewer challenges than outdoor environments**
  - **Large changes in lighting, reflections from shiny objects, shaking cameras, out of focus cameras, low contrast scene, target color near same color as background, target not occupying enough pixels in view, movement of large items in view (trees, large birds), blowing snow & driving rain**



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# Sources of Nuisance Alarms (cont.)

- Some VMDs produced no or very few alarms while others produced significant number of alarms
- Indoor applications have fewer environmental variables
  - Lighting is fairly constant
  - Camera to target distance is usually much shorter than outdoors
  - Cameras tend not to shake in indoor applications
  - Absence of animals & insects to trigger alarms

# VMD Technology Limitations

- **Detection accuracy is affected by:**
  - Clarity of camera image
  - Scene resolution at detection location
  - Scene environment
  - Amount of video compression
  - Scene illumination and illumination evenness

# VMD Technology Limitations

- **Because VMD is an optical process, environments that degrade the ability to see also degrade the ability of the VMD to detect intrusion**
- **Environment examples:**
  - **Heavy rain**
  - **Heavy snowfall**
  - **Fog**



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# VMD Technology Limitations

- Outdoor environments provide more challenges to accurate detection than indoor environments
  - Wind
  - Birds and insects
  - Clouds
  - Shadows that move with the angle of the sun
  - Reflections from shiny objects
  - Lights that cycle on and off at night
  - High light-to-dark ratio nighttime illumination areas
  - Shaking cameras in high wind environments



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# VMD Technology Limitations

- **Indoor environments have:**
  - **Lighting intensity controlled in the daytime or nighttime**
  - **No animal life to affect detection**
  - **No weather-related degradation in detection**
  - **No movement in scene due to wind**
  - **No moving shadows or reflections**



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# VMD Technology Limitations

- Requires precise time synchronization of VMD, recorder and alarm display monitor PC
- Network time server synchronized to GPS satellite time
- Clock time off by seconds can cause missing alarm video clip from recorder

# Operability Degradation

- VMD operability issues are generally the result of:
  - Camera degradation or failure
  - Video transmission system degradation or failure
  - Video system power or secondary power source failure
  - System grounding or ground loops
  - Lightning-induced events
- Operability issues can also be result of changes in detection rules or changes to calendar or time clock scheduler



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# Operability Degradation (cont.)

- Physical changes affecting VMD operability include:
  - Out-of-focus camera
  - Camera moved from initial MVD calibrated position
  - Loss of scene contrast
  - Degradation or failure of camera electronics
  - Loss of or significant change in scene illumination
  - Bright light appearing in the camera's field of view

# Performance Degradation with Compression

- Greater than 20% compression begins to noticeably affect fine detail in video images
  - Performance degradation with increased compression noticed initially at far field of view
  - As compression increased, degradation affects more of the scene toward the camera
  - Compression causes edges of objects to become fuzzy
  - Because VMD analyzes edges of groups of pixels in movement, compression to the extent that images become fuzzy significantly complicates and degrades algorithm analysis functionality

# VMD Installation Criteria

- **Detection across view rather than toward camera**
- **Cameras should be looking down at an angle at the area of interest**
- **Cameras looking straight down are problematic**
  - **Looking straight down causes the top and bottom of the camera view to be the same distance from camera**
  - **Lose perspective – algorithms expect that the top of the view is further away from the camera than the bottom**

# VMD Installation Criteria (cont.)

- Neutral color scene background with a 25 to 35% reflectivity rather than very light or dark color
  - Very light or very dark background makes it easier to blend with background
- VMD cameras on solid structures that do not shake or vibrate
  - Minimizes computation and improves the resolution and the ability to detect intruder
- VMD should not be implemented in locations where shadows move across the detection area
  - Algorithms are most sensitive to black & white pixel movement
  - Moving shadows can cause unnecessary detection alarms



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# VMD Installation Criteria (cont.)

- Cameras should not be installed for viewing inside of exterior doors
  - A door opening on bright, sunny days causes large bright spots in the camera's field of view
  - A bright spot may cause the VMD algorithm to not detect human movement in the area
- The illumination level should be even, at least 2 fc and have a light-to-dark ratio of 4-6

# VMD Installation Criteria (cont.)

- **The VMD should be integrated with a DVR or NVR for instant playback of alarm video**
  - **Processing the camera video through the VMD module prior to recording creates a marked-up video**
  - **Playback will have boxes around the cause of the video intrusion alarm**
  - **Allows the operator to focus on the portion of the video image where the movement occurred rather than having to look for that location in an un-marked video**

# Testing VMD Sensor

- Similar to testing physical sensor
  - Targets of interest move through the scene at a range of speeds an varying aspect ratios
  - If a human is the target of interest, movement includes walking and running at various speeds, and walking and crawling at normal and extremely slow speeds to ensure an alarm is created
  - Tests should include covering a human doing a belly crawl with a fabric cover of about the same color as the background or floor

# Testing VMD Sensor (cont.)

- Alarms should occur when the following occur:
  - Shine a bright light at the camera lens
  - Cover the camera with a black plastic bag
  - Move the camera so it is no longer viewing the intended scene
  - Turn off lights in the area to produce a low-contrast image
  - In locations where sunlight enters an area, observe the scene during daylight periods when alarms are not caused by sunlight and shadows created by persons walking adjacent to VMD-sensored areas


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# Testing VMD Sensor (cont.)

- Disconnect power to the camera
- Disconnect the video cable (analog) or Ethernet cable (digital)
- Disconnect power to each Ethernet switch in the digital transmission network (one at a time) –
  - Should create a “loss of video” alarm for the camera connected to the switch
- Disconnect the uplink cable from each Ethernet switch (one at a time)
  - Should create a “loss of video” alarm for each camera connected to the switch
- Open the camera enclosures and junction boxes that have tamper switch protection



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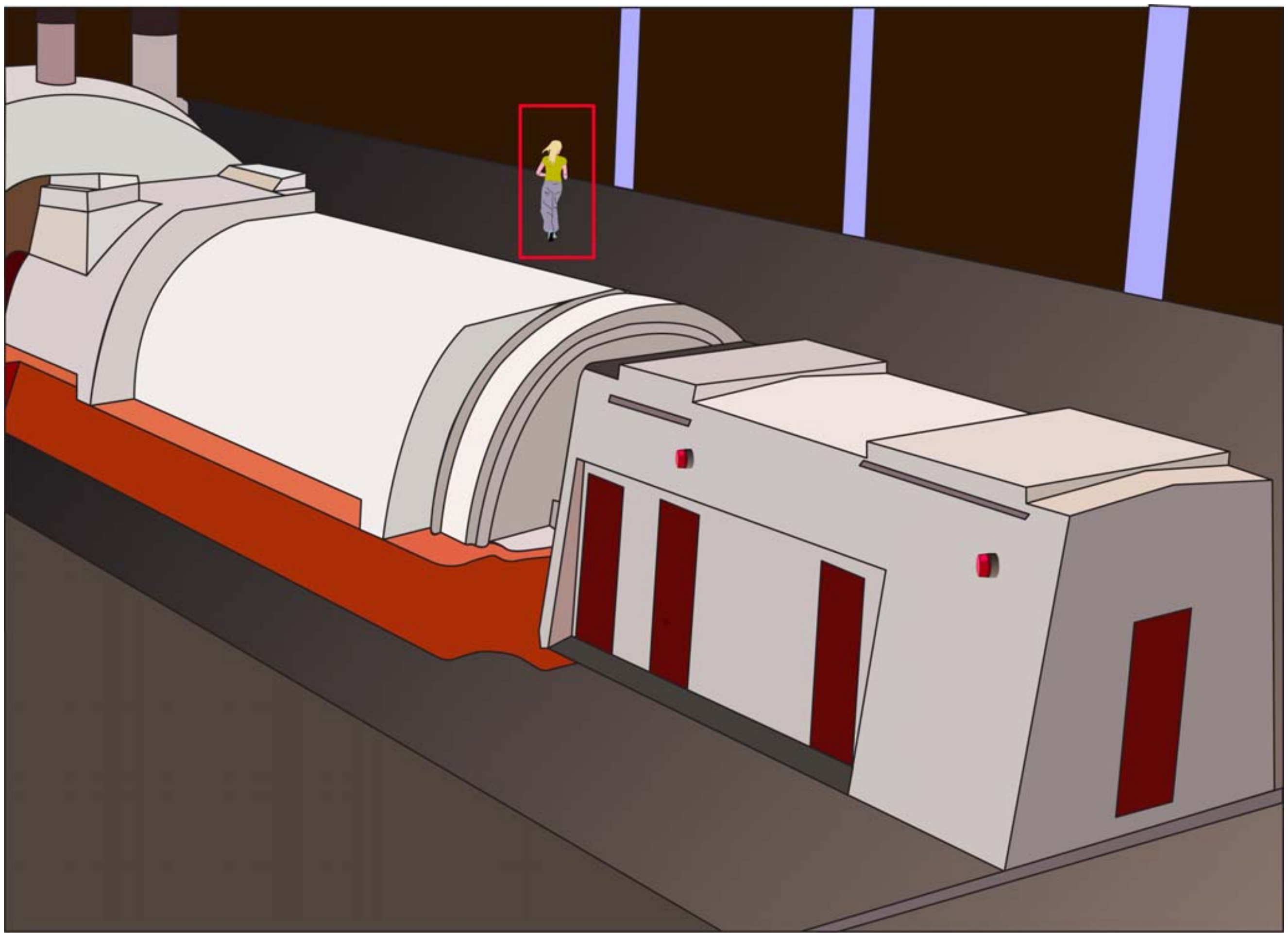
# Video Motion Detection

*Questions?*



# Module 21

# Lighting Systems

# Classification

- **All material in this module is unclassified**
- **In this module, photos of equipment are included as examples only.  Sandia National Laboratories does not endorse or recommend any specific equipment.**

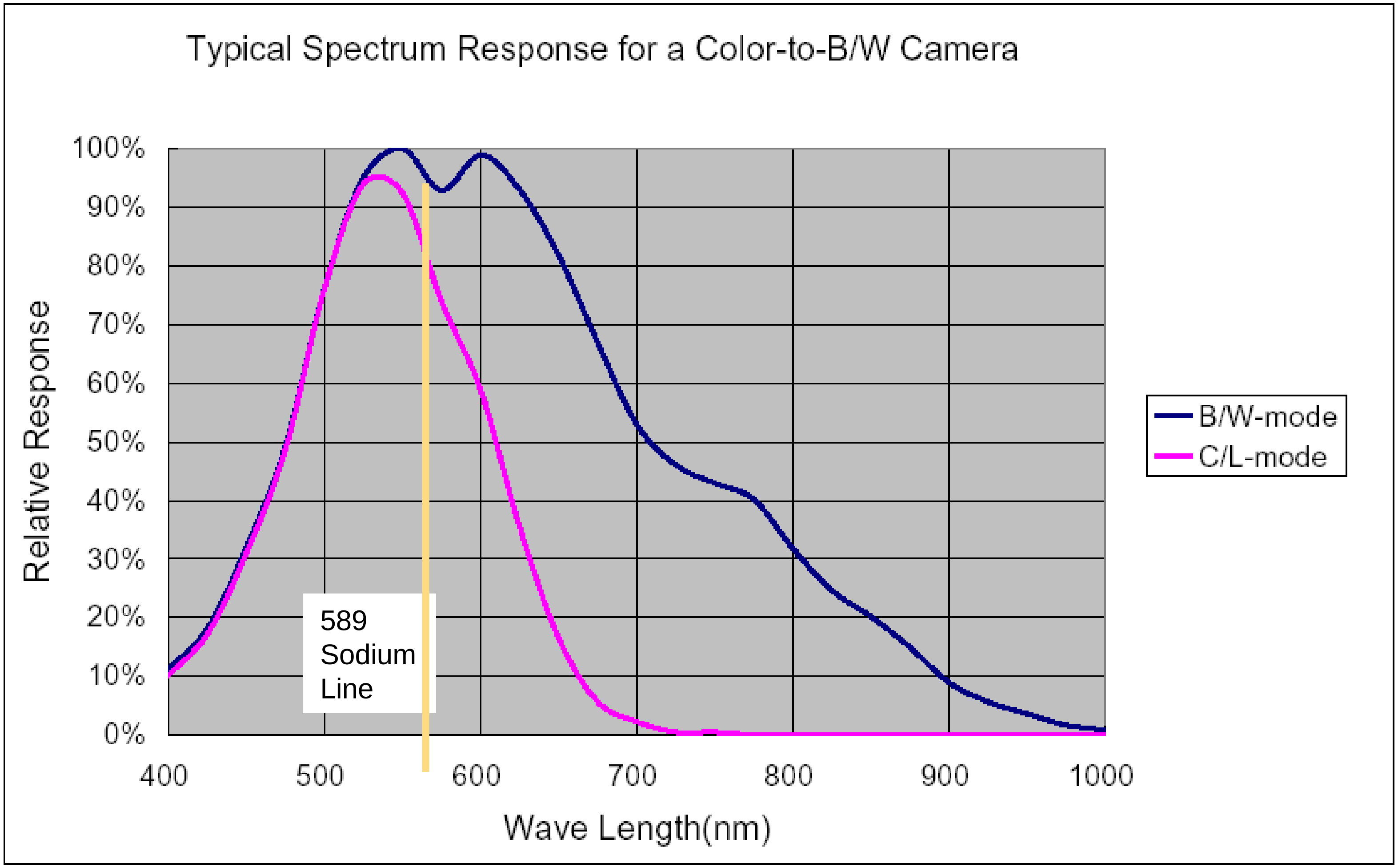
# Module Objectives

- Understand the different types of light
- Understand various lighting instruments and modes of operation
- Determine the correct method to measure light levels

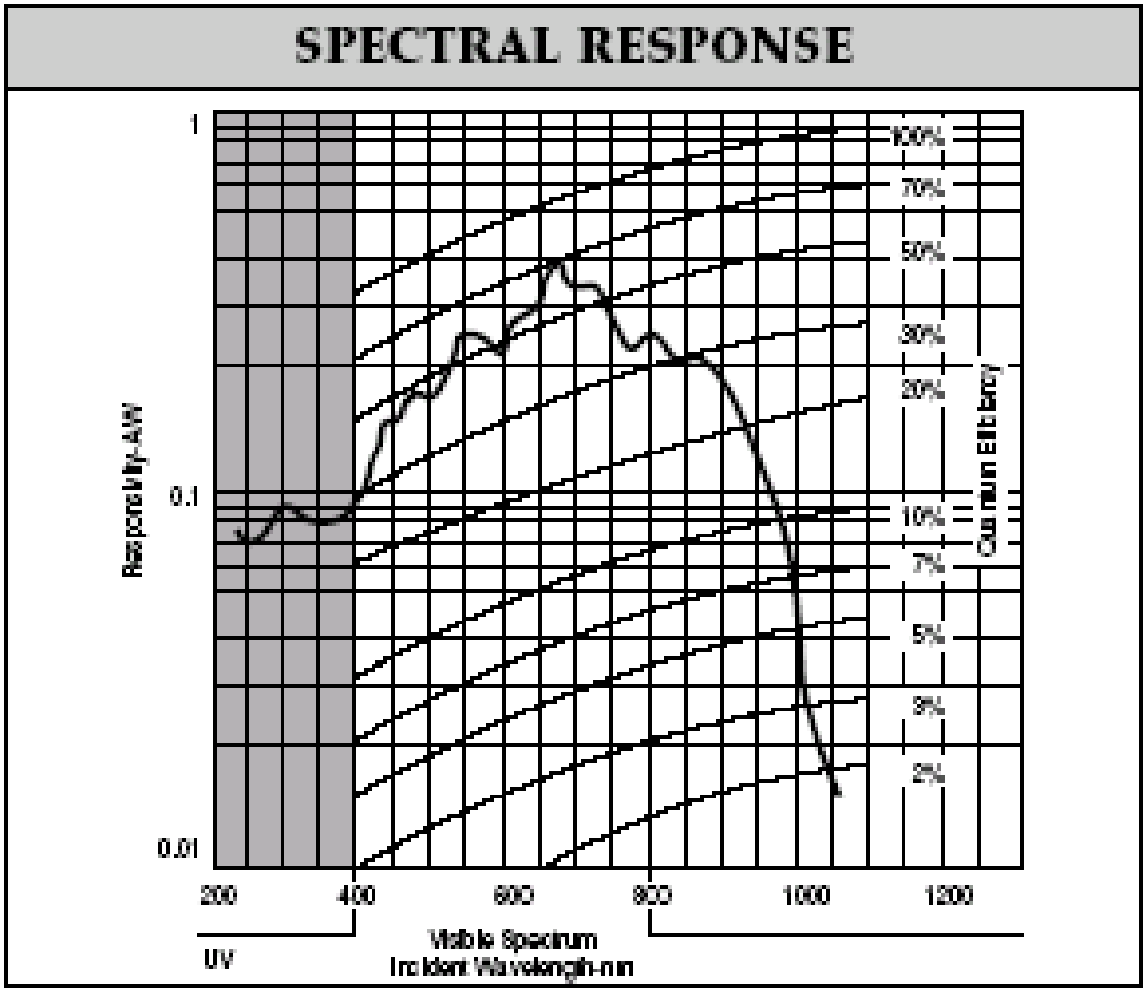
# Module Outline

- Introduction to different types of light
- Lighting instruments
- Lighting requirements and measurements
- Summary

# Camera Spectral Responses



# Standard Black / White Spectral Response



# Function of Lights

- Illuminate scene with sufficient reflected light for nighttime operation
- Produce the amount of illumination needed to produce a usable video output signal
  - Camera-dependant functions
  - Lens-dependant functions
- Provide safety lighting for area personnel

# Natural Lighting

- Natural – sunlight, moonlight, starlight
  – Sun and moon light contain broadband visible and IR light
  – Broadband – all colors and wavelengths of visible light
- Spectral response
  – Changes at sunrise and sunset
  – Intensity and angle changes by the time of day
    - Effects shadows, color rendition, illuminating

# Artificial Lighting

- Incandescent
- Mercury vapor
- High pressure sodium
- Low pressure sodium
- Dual element (HPS / Incandescent)
- Near infrared (uwatts / $cm^2$)
  - Compatible with camera type
  - Color vs. black and white

# Lamp Characteristics

| ***Lamp Type*** | ***Efficiency in Lumens/Watt*** | ***Spectrum*** |
|---|---|---|
| Incandescent | 12-20 | Broad, High in IR |
| Quartz Iodine | 20-23 | Broad, High in IR |
| Mercury Vapor | 40-65 | Blue Green |
| Metal Halide | 80-100 | Broad |
| H.P. Sodium | 95-130 | Gold-Yellow |
| L.P. Sodium | 131-183 | Monochromatic Yellow |

# Conventional Lighting

Mercury Vapor

HPS

LPS

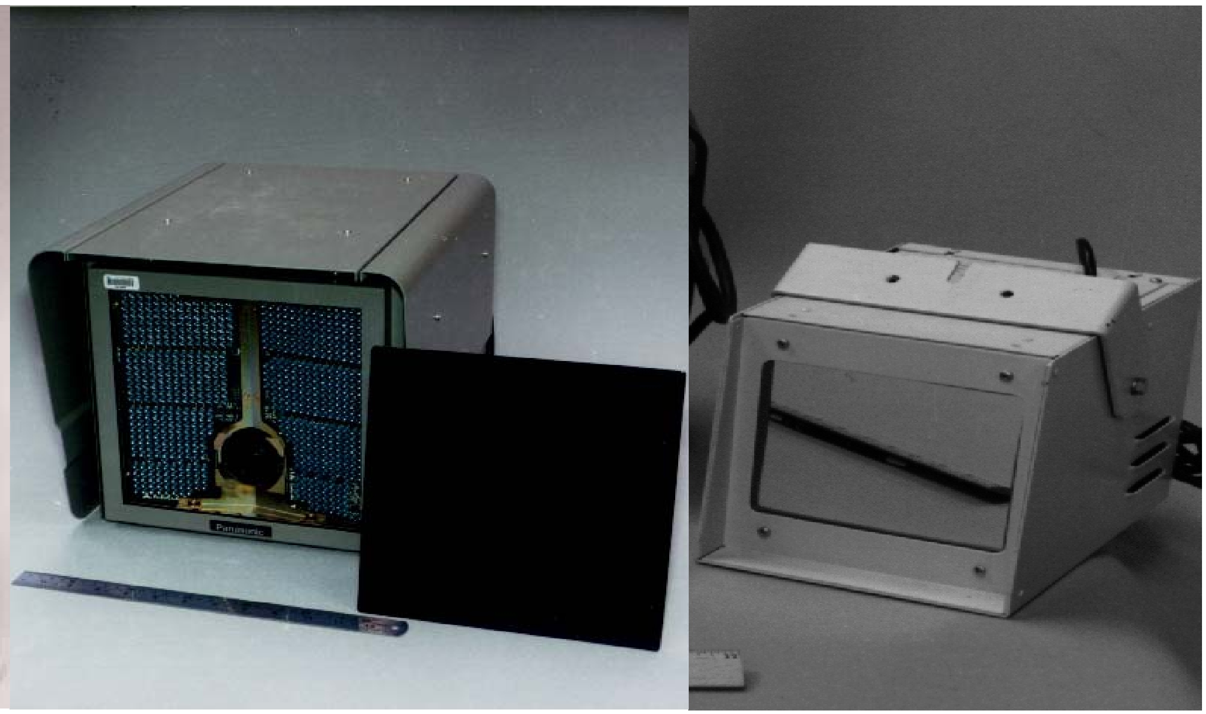
# Low Camera Mount

# High Light Mount

# Unconventional Lighting

- **Black lighting: IR illumination**

**Incandescent Light**

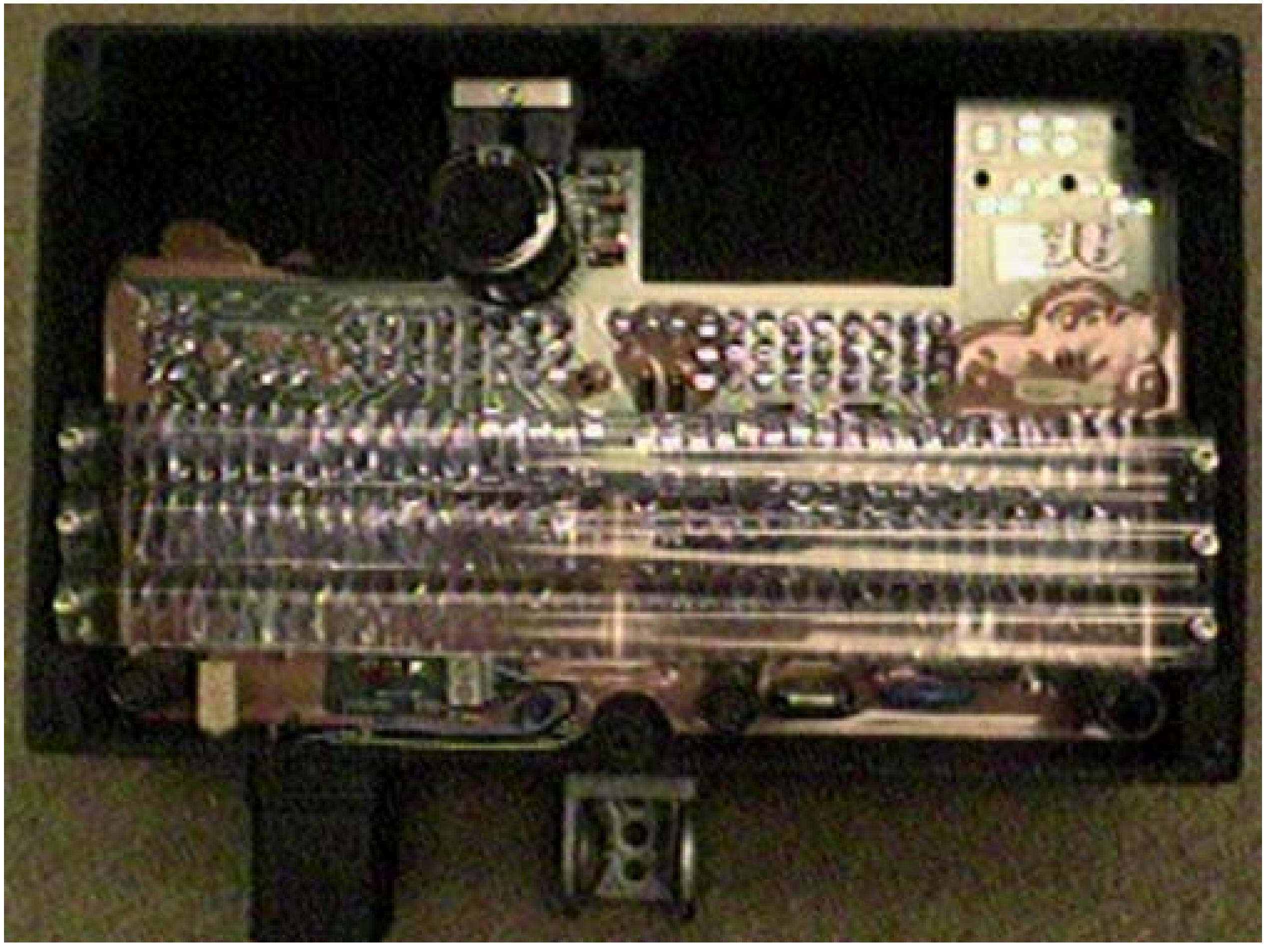


**LED IR Light Sources**

Sandia National Laboratories

# Unconventional Lighting

# Unconventional Lighting



**LED Panel Light**

# General Restrike Times

- **Incandescent, tungsten, fluorescent**
  - **Instantaneous to couple second delay for full output**
- **Mercury vapor**
  - **3 to 7 minutes**
- **Metal halide**
  - **15 minutes**

# General Restrike Times *(cont'd)*

- **Low pressure sodium**
  - **7 to 15 minutes**
- **High pressure sodium**
  - **1 to 2 minutes**
  - **Dual arc, 2 minutes to 80% output**
- **Infrared (IR)**
  - **Instantaneous to 2 minutes (full power)**

# Lighting Modes

- Continuous
  - Always on-indoors
  - On at night-outdoors
- Alarm activated or manually switched
  - Alerts adversary of detection
- Movable – portable illuminators
  - Should meet lighting criteria
- Emergency
  - Immediately on after power outage or if system in restrike mode

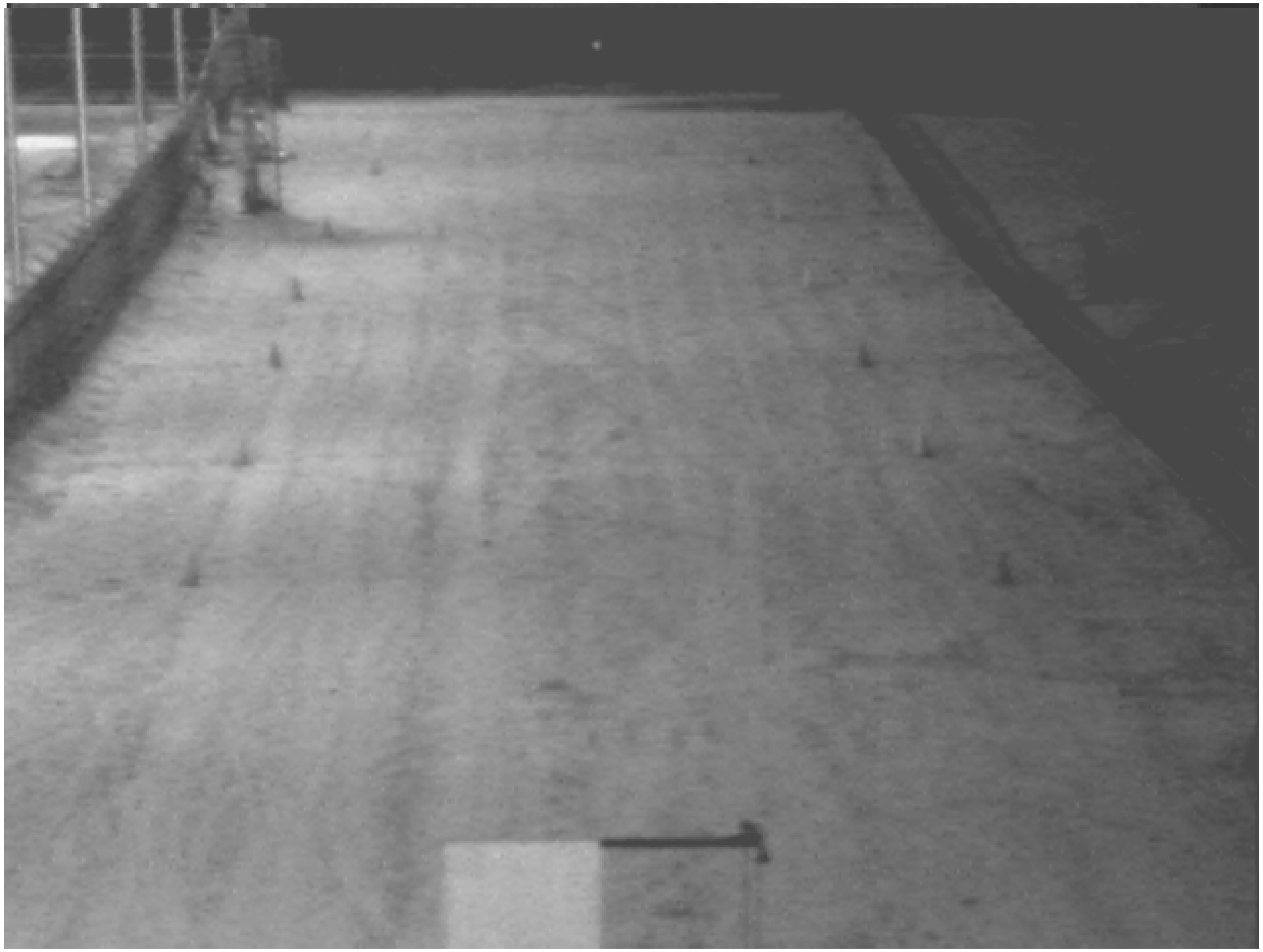
# Lighting Requirements

- **Horizontal illumination:**
  - Min 7.8 LUX (.8 fc)
- **Vertical illumination:**
  - Sufficient to provide good contrast between an object and background
    - Approx. 10 LUX (1 fc)
- **Light-to-dark ratio:**
  - Design to 4 / 1, accept 6 / 1
    - Minimum reflectance, 30% when dry

# Scene Reflectance Values

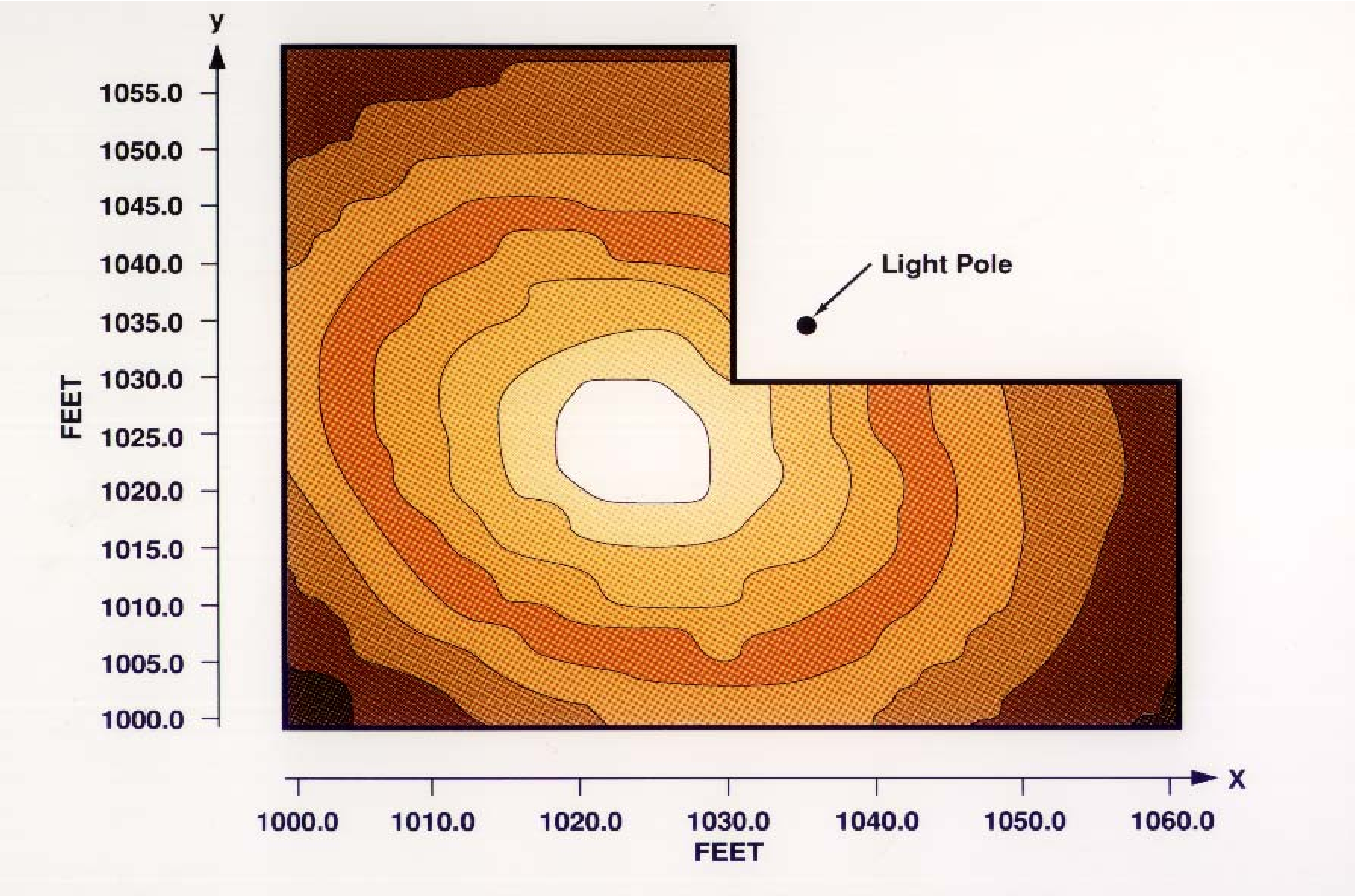
| Surface | Reflectance (%) |
|---|---|
| Empty asphalt | 7 - 10 |
| Sandy wet soil | 15 - 20 |
| Grass covered with trees | 20 - 25 |
| Red brick building | 30 - 35 |
| Sandy dry soil | 30 - 35 |
| Unpainted surface aluminum | 60 - 65 |
| Snow-covered field | 70 - 75 |

# Contrast Ratios - 6 to 1

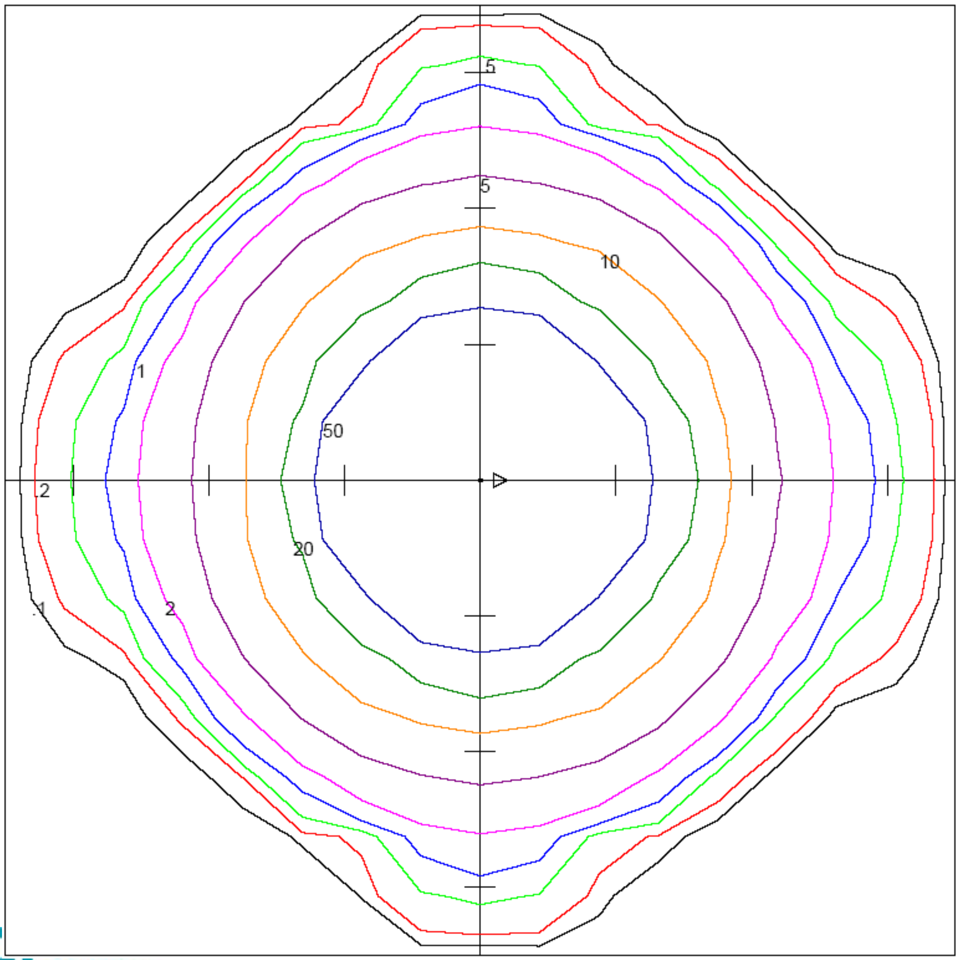


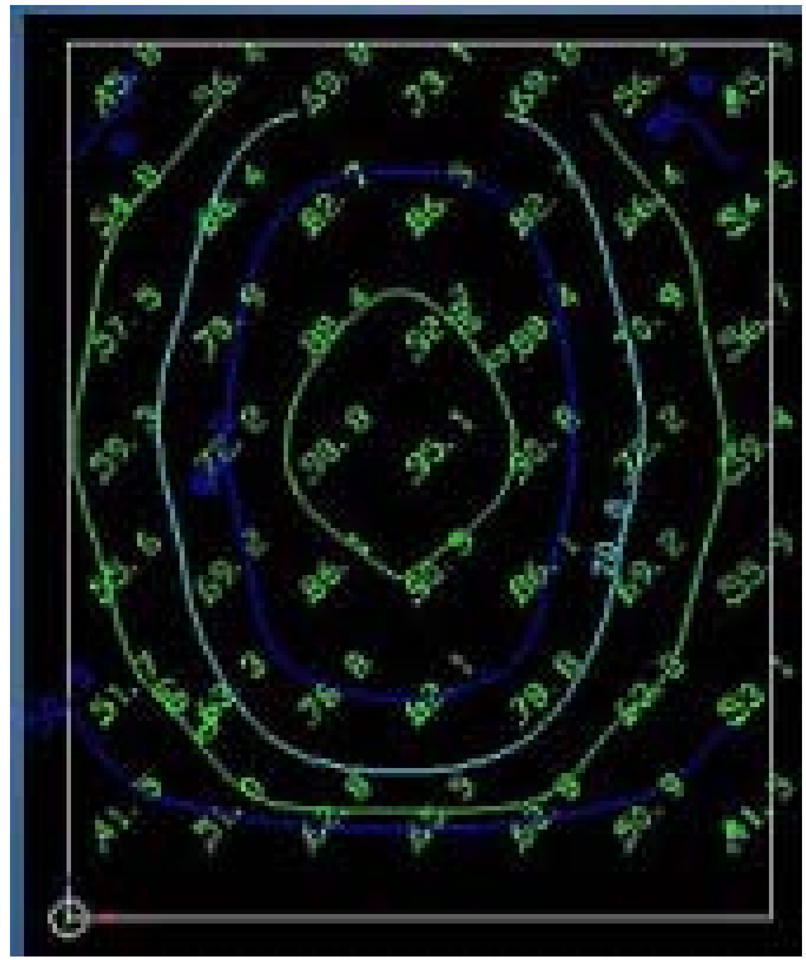
# Contrast Ratios - 24 to 1

# Lighting Program Output



# Isoline Patterns

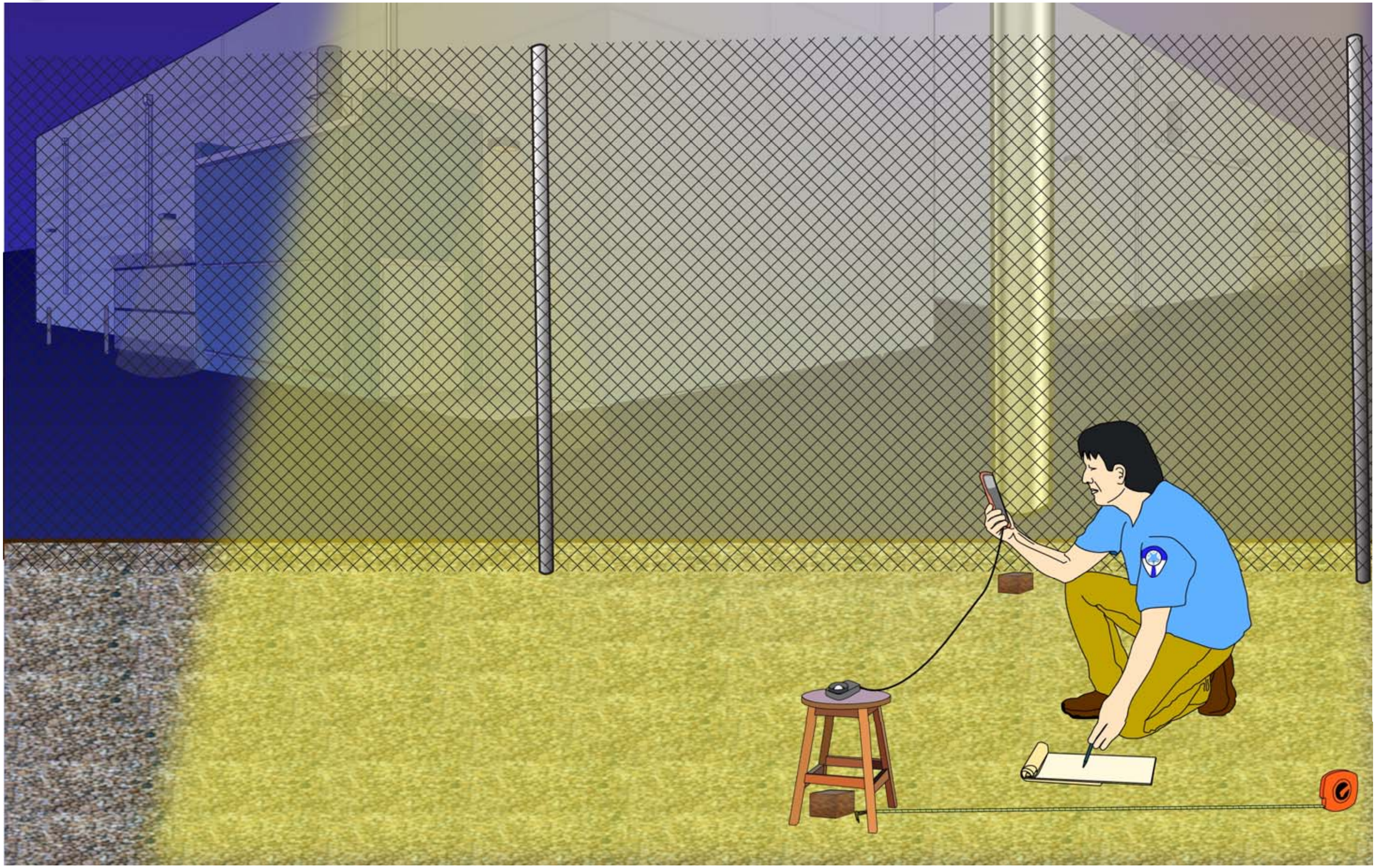


# Measuring Lighting

- Test at night, well after sunset or before sunrise
- Use calibrated light meter
  - Most don't measure IR
- Obtain multiple evenly spaced light readings (one foot from ground), a minimum set includes 70% of cameras field-of-view
  - Light-to-dark ratio (highest value/lowest value)
  - Average light level (sum all readings/number of readings)
  - Reflectance value of the ground cover (1/(meter up reading/meter down))
- Test restrike time

HRTD
Human Resources
Training & Development



# Example 1:  Is this Good Lighting?

# Example 2:  Is this Good Lighting?

Entry Control Point

# Summary

- Lighting is to allow alarm assessment at night
- How much light depends on camera selection
- If using IR light, it must be chosen with care
- Lighting software programs can help for designing or evaluations
- Performance test system by measuring and comparing against requirements
- Poor lighting contributes to other system errors

# Lighting System

***Questions?***