This Month’s Lesson:
Planning Camera Coverage Areas

Continuing Education
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Part 1 of 4
Welcome to Part I of the latest in SECURITY SALES & INTEGRATION’s acclaimed “D.U.M.I.E.S.” series: “Digital Video Systems Design for D.U.M.I.E.S.” Brought to you by Pelco, this four-part series has been designed to educate readers about recent advances in technology and systems that are likely to shape this decade’s progression of the video surveillance industry. “D.U.M.I.E.S.” stands for dealers, users, managers, installers, engineers and salespeople.

The 2011 series will explore areas of concern for using equipment that meshes today’s surveillance system parameters and needs/expectations, with particular attention to hybrid approaches. The first installment covers analog output equipment and IP, including megapixel cameras.

As procedures and products for video surveillance systems continuously advance, the overall designs and many of the applications remain the same. Video surveillance systems can be divided into three basic avenues: provide safety for property and personnel; enable remote viewing; and provide high quality permanent records.

Surveillance systems can provide safety for property and personnel by just the presence of cameras, which in many cases offer a deterrent to would-be burglars or physical attacks. The incorporation of networked cameras offers greater coverage by remote viewing of these areas. The development of intelligent cameras and software also lessens the need for constant viewing by individuals of these scenes, as well as adding greater efficiency against missed activity.

What Designing Minds Must Know

How many cameras are enough? What type of camera configurations should be considered? Shall fixed or pan/tilt/zoom (p/t/z) cameras be implemented or would a virtual p/t/z work just as well for my application?

There are a few key areas to examine that will help determine the number, type
and configuration of cameras that will work best for your application. The first step to consider is the degree of security. Usually the people selling equipment recommend that the more cameras the better, but in most cases this is not true.

Let’s explore the different degrees of security protection. A single p/t/z camera can only view a limited area at any given time. In automatic mode a p/t/z device can move in excess of 250° per second; however, there will be a loss of visible information as the device moves from one location to another.

What about a virtual p/t/z? Many security professionals have seen where a single camera and super wide-angle lens can operate as a virtual p/t/z system. These systems incorporate megapixel cameras, special software and must have the capability to provide a recording system that can handle megapixel information.

In addition to megapixel technology with very wide-angle lenses, there are new technologies that can stream multiple images from either multiple cameras and lenses or cameras into a single lens that can cover a 360° view of the area.

The next step to increase the degree of security of your system can be obtained by using multiple fixed cameras. This method greatly increases the number of cameras and associated equipment, and is often limited by the overall costs. So usually a balanced combination of fixed position cameras backed by p/t/z cameras is the best method to offer a high degree of security to any application. However, the system is still not complete.

To obtain a complete surveillance package, cameras cannot be the only ingredient. Integration with other technologies will be required to enhance the performance. Tying into systems such as card access, e-fields, fence protection and analytic software will all play an important part in a successful video security package. The result will be an almost 100-percent coverage system.

**Indoor Vs. Outdoor Applications**

Whether to incorporate IP cameras, megapixel cameras or analog output cameras usually depends on the application.

(Note: Many printed articles state that analog cameras are obsolete. However, today’s surveillance cameras are NOT analog, they are digitally processed. The sensor is digital, the circuitry for the video processing is digital. The major difference between IP networked cameras is the method the camera uses to transmit the signal. One type uses coaxial cable, the other a Category-5e or Cat-6 networked cable. There are other differences that could be discussed, but this article will only cover requirements needed for indoor or outdoor system applications, and determining the proper camera equipment for each of these applications.)

When designing a surveillance system the first question should be: Is the application indoors, outdoors or both? For the most part, indoor applications require less preparation. The amount of light available is usually well within the parameters of all high quality cameras. The need for special housing consideration is limited. Yet there are some areas for concern, such as cosmetics, vandals and angles of view. The cabling distances and layout of the cables can also be minimized by the close proximity of the equipment.

Indoor applications would be a perfect place to start with IP/network camera deployment. The use of power over Ethernet (PoE) and proper positioning of wiring closets can make this type of installation even more appealing.

Since camera selection is based on sensitivity, resolution and special camera features, indoor camera selection is fairly straightforward. Whether the cameras selected are analog output devices or networked models, all quality cameras will produce an image that will be acceptable in enabling satisfactory system performance.
How low can the surrounding lighting conditions go before the cameras no longer produce a useable image? This challenging low light condition is what we face when we turn to outdoor applications. Outdoor applications therefore can and will become very frustrating for many first-time system designers.

The main considerations for any outdoor or low light application will be: the amount of light available, other environmental conditions, and the overall operating distance requirements for both the video signal and camera power.

These variables apply to all cameras whether they are analog output, IP/networked cameras or even megapixel.

For most of us, indoor applications usually become old hat — placement of cameras, lens angles and cosmetics are your main concerns. However, when turning to the low light world these applications become more difficult.

The video surveillance industry has no standards pertaining to camera sensitivity specifications. This makes it very difficult to determine if the camera selected for an outdoor application is the right choice or if it even will produce an image the end user deems acceptable. Outdoor applications require more information in order to select the proper camera or to ensure quality video images.

Understanding Camera Specs

Following is a guide on how to read and understand today’s camera minimum sensitivity specifications by major manufacturers. Three sets of examples will be presented and analyzed. They will serve as launching pads to investigate and explain various data as it pertains to imaging devices. These sample specifications are from three major manufacturers and appear here unaltered.

Camera Specifications Example 1

- Imaging device 1⁄3-inch imager
- Horizontal resolution 480 TV lines
- Iris control electronic/passive
- Minimum illumination 0.5 lux, 40 IRE, 0/1.2, AGC on, 75% reflectance

- ESC 1⁄40,000 second
- Signal-to-noise ratio 52dB (AGC off)
- Backlight compensation selectable by DIP switch setting
- Auto iris lens type DC/video control, selectable by DIP switch

<table>
<thead>
<tr>
<th>Outdoor Light Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illumination</td>
</tr>
<tr>
<td>Direct sunlight</td>
</tr>
<tr>
<td>Full daylight</td>
</tr>
<tr>
<td>Overcast day</td>
</tr>
<tr>
<td>Dusk</td>
</tr>
<tr>
<td>Twilight</td>
</tr>
<tr>
<td>Deep twilight</td>
</tr>
<tr>
<td>Full moon</td>
</tr>
<tr>
<td>Quarter moon</td>
</tr>
<tr>
<td>Moonless night</td>
</tr>
<tr>
<td>Overcast night</td>
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</tbody>
</table>

It is, at first glance, apparent that this camera was designed for low light application, but how low? Referring to the “Outdoor Lighting Level Chart,” it appears this camera should produce a video image during low light levels equal to a deep twilight condition. The question now arises, will the quality of the image be acceptable? Let’s find out.

The data sheet gives the amount of light required, but how was that number calculated? This is where things change between manufacturers. Since there are no standards, each manufacturer has its own idea on the method to determine and list the sensitivity of cameras.

Using Example 1, it states a light level of 0.5 lux will produce a video image. However, what are the test parameters to obtain that number?

Demystifying the I.R.E. Unit

An I.R.E. unit is a measurement designed by the Institute of Radio Engineers that has integrated with the IEEE, the Institute of Electrical and Electronic Engineers. The measurement indicates the amount of output signal strength generated by a camera. Or in the case of an IP camera, it’s the signal strength of input required by the compression circuitry and Ethernet interface in order to process the video image.

Typically, there are 140 IRE units associated with a 1V peak-to-peak full strength video signal (1 IRE = .00714V). The introduction of the IRE unit makes luminance level values much easier to understand and communicate. The greater the listed IRE value, the greater the image output quality of that camera for the given light level.

A video signal is divided into two sections. The first section is the vertical and horizontal synchronization signals. This unit is used in the ITU-R BT.470 that defines PAL, NTSC and SECAM EIA-170A standards. It is used to lock up the video equipment in order to produce a stable image. The standard level that supports a full sync signal is listed as 40 IRE units.

The second section of the measurement is the actual video signal strength from the camera. The reason IRE is a relative measurement is because a video signal may be any amplitude. A value of 100 IRE is defined to be the range from black to white in a video signal producing a high quality full video signal. A lesser value corresponds to a poorer image quality. A value of 50 IRE is usually a minimum requirement for most inputs to digital equipment for proper operation.

With all of that stated, the simple fact is that since the video strength measured in IRE units is linear, the greater the IRE level the stronger the video signal.

Let’s return to the camera Example 1. With a given rating of 0.5 lux @ 40 IRE for minimum illumination in order to produce the higher quality image (100 IRE), more than 1.2 lux of light would be required and not the 0.5 lux posted on the datasheet. Some of you might be thinking, “So what? The video image is still acceptable, so what is all of the concern?” However, it is not just the reduced quality of the video but also what this loss of IRE units will do to the overall scheme of things.

First, for the systems that incorporate individual encoders, each encoder must convert the analog video sig-
nal into digital. This is accomplished using an A/D converter (analog to digital). Each encoder has a set of input parameters and many of them require a minimum of 50 IRE units in order to function properly.

Secondly, in the case of an integrated IP camera, the encoder circuitry may try to amplify the video signal up to the 100 IRE level. This can cause a grainy or noisy image and increase the transfer file size on a network.

**Lenses and F-Stop Ratings Defined**

The camera specification sheet also lists the minimum f-stop rating of the test lens used in producing the camera performance specifications. For our sample a test lens rated at f1.2 was used in order to obtain the minimum illumination figure.

Typically, outdoor scene illumination measured in lux can vary from 100,000 (sunny) to 0.00001 (overcast, moonless night). To handle this, light range lenses with adjustable irises are incorporated. However, all lenses have a rating to specify their ability to pass light at low light levels. The term indicating the lens’ performances is known as the minimum f-stop rating of the lens.

Let’s look at the human eye as an example illustrating the f-stop concept. As light becomes brighter, the iris of your eyes closes to allow only the proper amount of light that causes your retina to react and produce a quality image. It is the same with the lenses used in cameras. However, a growing concern in lens selection is the minimum f-stop rating of the lens or how well it operates at low light levels. With the increased use of cameras for outdoor applications this has become a very real issue.

To start, the f-stop rating of any lens is determined by the ratio of the focal length of the lens divided by the actual mechanical diameter of the iris opening of that lens:

\[
F\text{-stop rating} = \frac{F}{D}
\]

Where:
- \( F \) is the focal length in millimeters
- \( D \) is the diameter of the iris opening in millimeters

The lower a lens’ f-stop rating, the greater its light-gathering capability or speed. The normal minimum f-stop rating of a typical lens is between f0.75 to f1.8.

Since every camera requires a lens to produce an image, the specification sheet will list the f-rating of lenses used in the testing phase of the camera. In this case a fixed lens was selected with an f-stop rating of f1.2. If an integrator selects a different lens compared to the specification sheet, he/she must ensure that the minimum f-stop rating of the lenses is equal to or less than that on the datasheet. If not, the video output strength from the camera will suffer. The end results could mean poor low light video images.

Another fact worth noting is that the f-stop rating of lenses is logarithmic. This means that for every single f-stop increase in a lens, the amount of light passed through that lens will decrease by 50 percent.

In addition, the test lens used for the specification is a fixed f-stop rated lens. The incorporation of a zoom lens can add an additional one to two f-stops to that specification when in the zoomed position. This can reduce the amount of light to the camera sensor by a factor of two to four times.

Summary to this point, the selected camera in Example 1 will produce only a 40-percent video output signal when using an f1.2 fixed iris lens with an available light source of 0.5 lux (deep twilight).

**Cost of Automatic Gain Control**

For those who are unfamiliar with the function of automatic gain control (AGC), a quick update is in order. The purpose of AGC is to increase the...
sensitivity of the camera during low light level applications.

This feature is a compromise because it will amplify the video signal to improve image strength, but at the same time it also amplifies the random noise generated by the circuitry within the camera. This amplification of noise causes a grainy image that randomly moves about the scene and will increase the bandwidth requirement for networked cameras. AGC is incorporated to improve camera sensitivity but it requires a tradeoff.

Without AGC the camera used in Example 1 would require more than 5 lux of light to produce a 40 IRE signal output.

**How Reflectance Factors In**

The last factor associated with the parameters for minimum illumination is reflectance. Some manufacturers publish the exact procedures and criteria they use to provide their cameras’ sensitivities while others assume everyone is already knowledgeable on how specifications are determined. Well there is a little known fact about camera specification that packs a wallop.

Camera manufacturers list the direct amount of light that the camera requires to produce an image. Many give you the f-stop rating of the lens that is used, the output signal strength (measured in IRE units) and whether the AGC is incorporated to produce the numbers listed on the datasheet. However, there is one test parameter item missing. What is the reflectance factor of the test pattern used in the procedure?

Reflected light in the real-world set of parameters, especially in the low light surveillance arena, varies from 5 percent to 95 percent depending on the viewed scene. The test reflectance percentage used by most manufacturers is either 75 percent or 89.9 percent and is determined by the test pattern used when testing the camera’s sensitivity.

After reviewing a reflectance chart, it does not take long for most people to realize that real-world surveillance operates with a great deal less reflectance than that offered by a camera’s specifications.

This difference between the actual and specification reflectance indicates that the minimum light level printed on the datasheet will actually be much greater when used in normal surveillance applications.

Example 1 was based on a 75-percent reflective test pattern. Locating this camera in an outdoor asphalt parking scene (5-10 percent) the camera would require at least 2 to 3 lux of light to perform within the limits set by the datasheet.

In summary, for Example 1, the specification sheet lists are the parameters used in the test procedure. Understanding this information is a must for anyone to properly design and select the optimal camera for low light outdoor applications.

The “Camera Application Guide” (see next page, top left) shows the amount of light required for the camera specification in Example 1. However, when applying the parameters for an outdoor parking lot scene you can see that the amount of light required by the camera to produce an image is 15 times greater.

Trying to outperform the marketplace, manufacturers have added features to their cameras in order to make them more sensitive for low light applications. This leads us to Camera Specification Example 2 that follows.

### Reflectance Factors

<table>
<thead>
<tr>
<th>Scene</th>
<th>Reflectance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empty asphalt parking lot</td>
<td>5%</td>
</tr>
<tr>
<td>Parkland, trees, grass</td>
<td>20%</td>
</tr>
<tr>
<td>Red bricks</td>
<td>35%</td>
</tr>
<tr>
<td>Unpainted concrete</td>
<td>40%</td>
</tr>
<tr>
<td>Parking lot with cars</td>
<td>40%</td>
</tr>
<tr>
<td>Aluminum building</td>
<td>65%</td>
</tr>
<tr>
<td>Glass windows and hallways</td>
<td>70%</td>
</tr>
<tr>
<td>Snow-covered landscape</td>
<td>85%</td>
</tr>
</tbody>
</table>

**Camera Specification Example 2**

- Imaging device 1/3-inch vertical double density interline CCD
- Horizontal resolution 580 TV lines
- Iris control electronic/passive
- Minimum illumination 0.0006 lux, 50 IRE, f/1.2, sens-up x256
- Dynamic range 52dB
- Backlight compensation BLC/HLC/Off
- Auto iris lens type DC/video control, selectable by DIP switch

In Example 1, we discussed all of the normal parameters governing the listed minimum illumination figure for cameras. In Example 2, we are going to add an additional parameter called sens-up. This is a technology that provides higher camera sensitivity in low light conditions. It is also referred to as sensup or digital slow shutter (DSS).

To well-established CCTV professionals or photography pros, this definition makes perfect sense. However, most of you are probably wondering what this definition means in plain English. Let’s take a closer look to make sense of sens-up and review the pros and cons of this technology when used in practical, real-world surveillance applications.

**Getting Up on Sens-Up Pros/Cons**

The main purpose of sens-up is to provide a camera with the ability to see in very low light conditions.

Security cameras equipped with this technology use a circuitry that automatically adjusts the integration timing circuit of the camera’s sensor in order to vary the sensitivity. (The integration timing circuit adjusts the charge and discharge rate of the sensor in order to increase or decrease the sensitivity.) Normal integration rate is 60 times a second for interlaced cameras and 30 times a second for progressive scan cameras. By changing this rate, the camera can be made more or less sensitive.
Let’s review images per second. The words real-time video, real-motion video and time-lapse video now come into play. These are old-school terms; however, they still apply to today’s applications.

Real-time video is described as 60 fields or 30 frames being reproduced per second while real-motion video is listed as only 15 images per second. Of course, time-lapse video was anything less than 15 images per second. Real-time is preferred for its high quality and no loss of video information. This is especially true when movement is involved such as moving vehicles, poker games or people running. Real-motion is a compromise producing acceptable video at reduced image rates to save hard drive space or meet bandwidth requirements on a network. Time-lapse only provided minimum video coverage for simple applications.

In short, as the sens-up value increases to produce an image at low light levels the number of images displayed will decrease. At the extreme limit of sens-up listed in Example 2 (x256) only 0.5 to one images of video will be displayed per second. This limited number of images per second is one of the problems when sens-up is incorporated.

The two variables that affect this sens-up related “blurriness” are the speed at which the object moves (the faster the movement the blurrier the video) and the maximum sens-up limit of the camera settings (the higher the limit, the blurrier the image).

Many applications such as license plate capture cameras, p/t/z cameras or other high movement areas will become streaky and unreadable. That’s not the video image people are looking for especially after reviewing video for evidence of a robbery or other issues. The tradeoff, if the lighting is low, but adequate, a low sens-up limit and a high resolution camera can capture excellent images without blur or distortion. The trick is setting the camera up correctly and taking advantage of whatever ambient light does exist.

The final camera specification example is very similar to that of sens-up; however, it is presented in a different manner.

### Camera Specification Example 3

- Imaging device 1/4-inch (effective)
- Imager type CMOS
- Imager readout progressive scan
- Maximum resolution 2,048 X 1,536
- Signal-to-noise ratio 50dB
- Auto iris lens type DC drive
- Electronic shutter range
  - 1 ~ 1/100,000 second
- Wide dynamic range 60dB
- White balance range 2,000° to 10,000° K
- Sensitivity f/1.2; 2,850° K; SNR >24dB
- Color (33 ms) 0.50 lux
- Color SENS (500 ms) 0.12 lux
- Mono (33 ms) 0.25 lux
- Mono SENS (500 ms) 0.03 lux

Sens-up in Example 2 listed the sensitivity of the camera in the integration of the sensor or how many images per second would be reproduced. This integration factor can also be listed in time. The longer the integration time, the fewer images per second the camera will display. Example 3 lists the sensitivity of the camera at 0.50 lux @ 33ms. The following is a very helpful conversion to determine the number of images per second at listed light levels:

\[
\text{ips (images per second)} = \frac{1}{\text{time (seconds)}}
\]

Using this example, let’s place some values into the formula. Image per second is what we want to find. The camera with 0.50 lux of scene illumination will require the camera to set its time integration circuitry to 33ms or .033 seconds in order to produce video.

\[
\text{ips (images per second)} = \frac{1}{.033} = 30
\]

Thirty images per second, which in old terms is known as real-time video and therefore the image quality will be blurry or jumpy. Now reduce the sensitivity to 0.12 lux and recalculate:

\[
\text{ips (images per second)} = \frac{1}{.50} = 2
\]

In this case the video image will appear blurry or choppy with any movement within the scene at a light level of 0.12 lux and is equal ~ to a 32x sens-up setting.

In closing, as more and more video surveillance applications are expanding to the outdoors and low light environments, more information is required in order to select the proper camera. Whether the camera is an analog output or IP, all require sufficient amounts of light to produce an image that is acceptable to the end user.

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