IPVM

2016 SECURITY CAMERA

Basics

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Welcome!

This book represents the findings of 10,000+ hours of testing on more than a hundred different surveillance cameras. We have taken those lessons, summarizing them and showing you dozens of images to convey the issues and tradeoffs involved.

IPVM is the world's only independent video surveillance testing and research organization. We do not accept any advertising or sponsorships, supported instead by small payments from 9,000+ members across 100+ countries.

We hope this book helps educate you, making you better at selecting and using video surveillance. If you find it useful and would like to learn more, consider becoming an IPVM PRO Member to access 300+ tests, breaking news and personal help.

Have questions? Email us: help@ipvm.com

Enjoy the book!

Security Cameras 2016 Review

In 10 minutes, this note explains the current state of security / surveillance cameras in 2016, reflecting new technology changes and market shifts. This will help you to avoid mistakes based on out of date information.

We cover:

- Resolution - SD, SD+, 720p, 1080p, 4MP, 4K, Higher
- IP vs HD analog
- Image quality - WDR, Low Light, Integrated IR
- Video analytics
- Cost Falling

At the end of this article, you should have a solid appreciation of those options / issues.

Resolution

Whether or not resolution is the most 'important' criteria in selecting security cameras, it is certainly the most commonly cited. Also, there have been notable changes in resolutions offered recently that are important to understand.

SD and SD+ (700TVL, 960H, 1000TVL, 1280H, etc.) Dead

Over the past few years, a variety of SD 'Plus' offerings emerged, with 960H the most widely marketed, as low cost improvements on legacy NTSC / PAL.

As of 2016, all of these are essentially dead, being rapidly end of life'd by manufacturers. The reason is HD analog (offerings like AHD, CVI, TVI) are replacing them (which we examine later).

Just avoid SD and SD+ unless you are locked in to them by your existing system.

720P and 1080P Most Commonplace

Going into 2016, 720p and 1080P security cameras are the most common offerings on the market. 720p is now perceived as 'budget' but the visible quality difference between 720p and 1080p images are typically moderate (despite the doubling of pixels). On the other hand, the price premium for 1080p over 720p is generally minimal.

It is important to remember pixel count / resolution is only one element of video quality. In particular, low light and WDR can vary even for cameras with the same 'resolution'. We examine this more later in the quality section.

New - 4MP

Moving up from 1080p (2.1MP) are new 4MP cameras, which will be an emerging category in 2016. These cameras are still ‘widescreen’ 16:9 aspect ratio but have double the pixel count of 1080p. In our testing, the visible difference is modest over 1080p, however, many of these 4MP cameras are being sold for roughly the same price as 1080p. These cameras are worth considering for general coverage.

New - 4K (8.3MP)

4K cameras, quadruple (4x) the pixel count of 1080p ones, have been broadly released in 2015.

However, in our 4K testing, 4K camera performance varies widely with some models being fairly terrible and others delivering major improvements over 1080p. Be careful when selecting 4K cameras as the first generation offerings now available are not all mature. In particular, if you are using 4K without integrated IR for current models, the risk of very poor low light performance is high.

Many 4K cameras also support a 12MP mode, typically with taller 4:3 field of view (vs 4K's 16:9 aspect ratio). This extra coverage might be useful and is worth checking for. However, 12MP mode in current cameras almost always delivers significantly lower frame rate than 4K stream.

Though 4K is supposed to be at least 24fps, many manufacturers are marketing models as 4K with frame rates in the 6 - 12fps range. If frame rate is important to you, make sure to check this.

More Than 12MP

There are a handful of security cameras with greater than 12MP resolution. Be careful when selecting them as frame rate is often low, low light is often poor, bandwidth consumption and cost can be much higher. We recommend testing such cameras on site versus 4MP and 4K cameras to truly see if the difference is worth it.

IP vs HD Analog

In the past year, HD analog has emerged as a credible contender to IP for high definition video. This is perhaps the biggest and most important new decision.

HD analog's 3 biggest advantages are (1) low cost and (2) setup simplicity and (3) partial backwards compatibility.

- The cost of HD analog cameras, for similar feature sets is regularly ~30% less than IP.
- HD analog cameras do not require any IP configuration, firmware upgrades, network discovery, etc., working like SD analog cameras do.
- Finally, HD analog often allows reusing existing coaxial cabling (though cable age and length can limit that).

HD analog's biggest disadvantages include (1) limited high-end feature sets, (2) limited vendor selection, (3) limited resolution and (4) incompatibilities, though these will change (at least somewhat) in the next year or two.

- HD analog started with the very low end - low cost, fixed focal, basic cameras. Vendors are starting to add true WDR, super low light, smart IR, autofocus, etc., but it is important to check if those features are available in the vendors you are considering.
- Likewise, many of the biggest Western and Japanese brands are simply ignoring HD analog - e.g., you will not find any HD analog from Axis, Avigilon, Bosch, Panasonic, Pelco, Sony, etc. and most likely not start in 2016 as they are focused on IP.
- Resolution to date is limited to 1080p, though TVI anticipates shipping 3MP and 5MP in 2016 and CVI as well as AHD have been showing prototypes of future 4K offerings.
- Many HD analog offerings are not compatible with others, plus some use different names for the same technology (e.g., CVI is sometimes branded as MPX or HQA, etc.). This increases the risk that different cameras might not work recorders.

For more, see HD Analog vs IP Guide 2015.

Image Quality

More pixels does not guarantee better image quality. Indeed, as resolution increases, the risk that WDR and low light performance increases (how much varies by camera but it is an accurate general guide).

WDR

True WDR has become far more commonplace in the past year as lower cost sensors have added it 'standard', expanding true WDR availability from only premium priced products to broader availability. However, true WDR is still not available in most low cost cameras and manufacturers often try to trick buyers with confusing WDR marketing terms. What you want to verify is that the camera has multiple exposure WDR and this is tracked in our Camera Finder (see: WDR Camera Tracking Feature).

If you have concerns of capturing details (e.g., faces) that have sunlight behind them (e.g., sunrise or sunset), true WDR can be quite useful.

Low Light

Over the past few years, advances in image processing have significantly improve low light performance without adding any light (such as IR or street lights). Plus, in 2015, quite a number of new cameras with 1080p 1/2" imagers plus advanced image processing have come on the market. In our 1/2" testing, that combination has provided a significant increase in best in class low light performance.

The main downside is that these 'super' low light cameras, especially with 1/2" imagers tend to be some of the most expensive in the market.

Integrated IR

Integrated IR is the most common low cost way to deliver low light images without having to add in any external illumination. Over the past few years, integrated IR has moved from a fringe feature on 'cheap' cameras to be an offering for essentially every camera manufacturer, 'high' end or low.

Integrated IR quality can vary significantly. Range (distance IR will illuminate from camera) routinely varies from 5m to 50m or more (see our Camera IR Range Tool). Also, the beam width (how wide the IR covers can vary) and some cameras will cause hotspots if the IR beam width does not match up with the camera / lens' FoV. Finally, some integrated IR cameras have 'smart' capabilities that detect objects and automatically adjust IR power to not overexpose them. For more, see our IR guide.

Video Analytics

Video analytics have been the next big thing for security cameras for more than a decade and continues to be so.

Unfortunately, most video analytics (especially outdoors where they are typically most desired) work insufficiently, suffering from significant false alerts. Even new offerings, like Axis video analytics, just released, are weak. It is possible to get video analytics that work well, but even in 2016, one needs to be careful about validating performance in one's own applications and for one's own needs (factoring in weather, lighting, ability to handle / respond to false alerts, etc.), as the technology is not broadly mature.

Cost Falling

Last but certainly not least is cost. Going into 2016, security camera pricing is essentially in a downward spiral, as rivals continue to cut costs, in a 'race to the bottom'. What is causing this is debatable, but it is certainly being lead by Chinese manufacturers, from the mega government run one (Hikvision) to the small assemblers in Shenzhen. When this stops is not clear but the trajectory is likely to lead quite a number of manufacturers out of business.

The good news is that decent security cameras can be bought incredibly inexpensively ($100 or less is commonplace). Combine that with sensors having gotten much (e.g., true WDR and 4MP and 1/2" 1080p sensors, mentioned above) and it has never been better to buy security cameras. On the other hand, it has never been more dangerous to make or sell them.

Pixels

The most damaging misconception in surveillance is that pixels = resolution = quality.In fact, pixels determine potential quality, limited by many other important factors. In this note, we explain why you will make much clearer and better decisions recognizing this.

Demonstrating This With Images

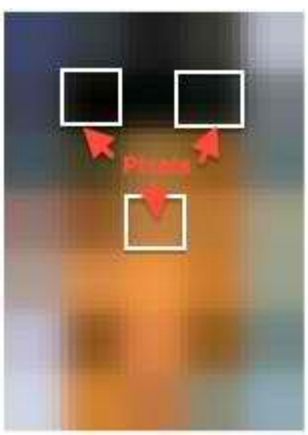
Here's a relatively high quality, high 'resolution' image:

It's 161 pixels wide across a small area of 1 - 2 feet, delivering a high ~100 PPF.

Now contrast this with this low quality, low resolution image:

This is 5 pixels wide and a total of 35 pixels covering the same exact area as the image above (enlarged so you can see it). This is clearly low quality.

Why? The pixels are being forced to cover areas wider than the details desired. You can see it the blockiness of the image. Those blocks are the limits of the pixel.

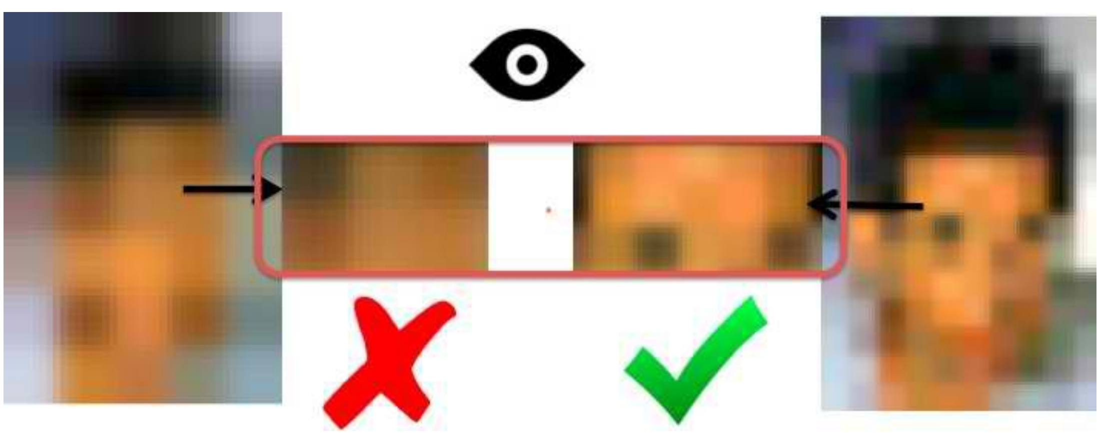


The image calls out 3 of the 35 pixels but you can make out pretty much all the individual pixels.

Now let's increase the pixels / resolution for this image.

A lot more details are being revealed now, as the number of pixels increases from 35 total to 140 and each pixel now can cover a smaller area.

Let's compare the two images to see key details in the image improve:

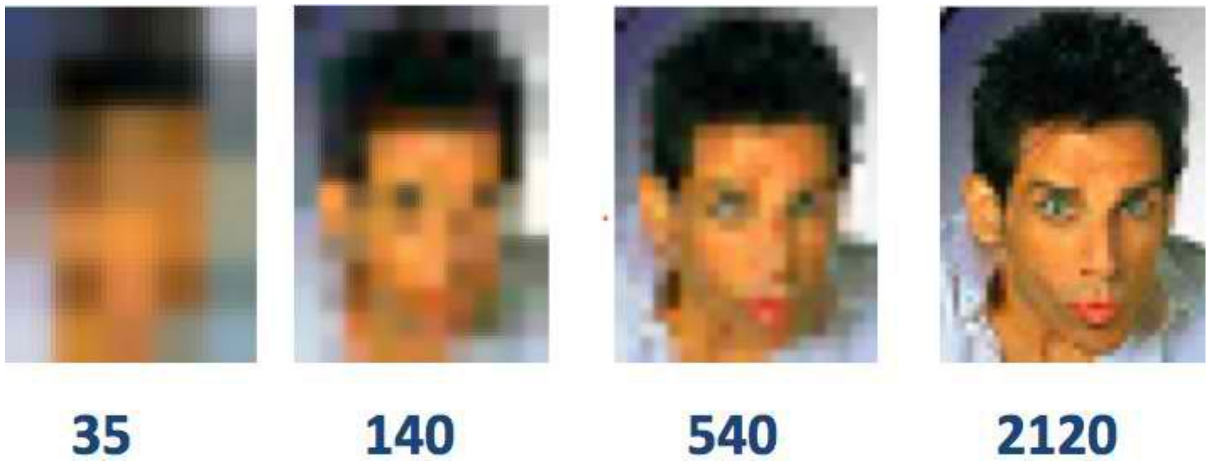


In the former image, the eyes were bigger than the pixels and therefore could not be captured. However, in the latter one, with pixels cover an area smaller than an individual eye, allows the eyes to be captured as two black dots.

Let's increase the pixels for this scene, from 140 to 240:

As each pixel covers a smaller area, more features continue to emerge - lips, ears, etc. and the eyes become more detailed (eyebrows, iris, etc.).

Finally, here's 4 samples ranging from 35 to 2120 pixels covering the same area:



Clearly, as we increased pixels allocated, the more fine details that can be captured.

The smaller pixel count images, regardless of how 'good' the camera or encoder was could not capture those details because the pixels were covering too large an area for them. This is what we mean by pixels determine potential.

Pixels Limits on Quality

A 1MP camera will never capture the fine details of the face of a subject at a 50' wideFoV. It simply lacks the potential, because the pixels will cover too large an area relative (25ppf) to how small a face is at the same position.

However, a 5MP came covering that same 50' wide FoV may capture the fine details. It has the potential, because the pixels will be covering small enough areas (50ppf).

This potential, though, is a maximum theoretical limit bound by very important factors like:

- Ability to capture in low light scenes (which most 5MP+ cameras are terrible at).
- Ability to handle wide dynamic range scenes (see example).
- Quality of lens, preciseness of focus and eliminating any DoF problems.
- Minimizing compression artifacts / loss of quality (see tutorial).
- Angle of incident of subject to camera (if the camera is too high or the person is looking askew from the camera, more pixels will not help).

Quality vs Pixels

Ultimately, image quality is driven by a half dozen factors combined. While pixel density / count determines the potential quality and the maximum achievable details, those other factors, that are often overlooked and ignored in PPF calculations, routinely and often dramatically constrain the actual image quality achieved.

Resolution

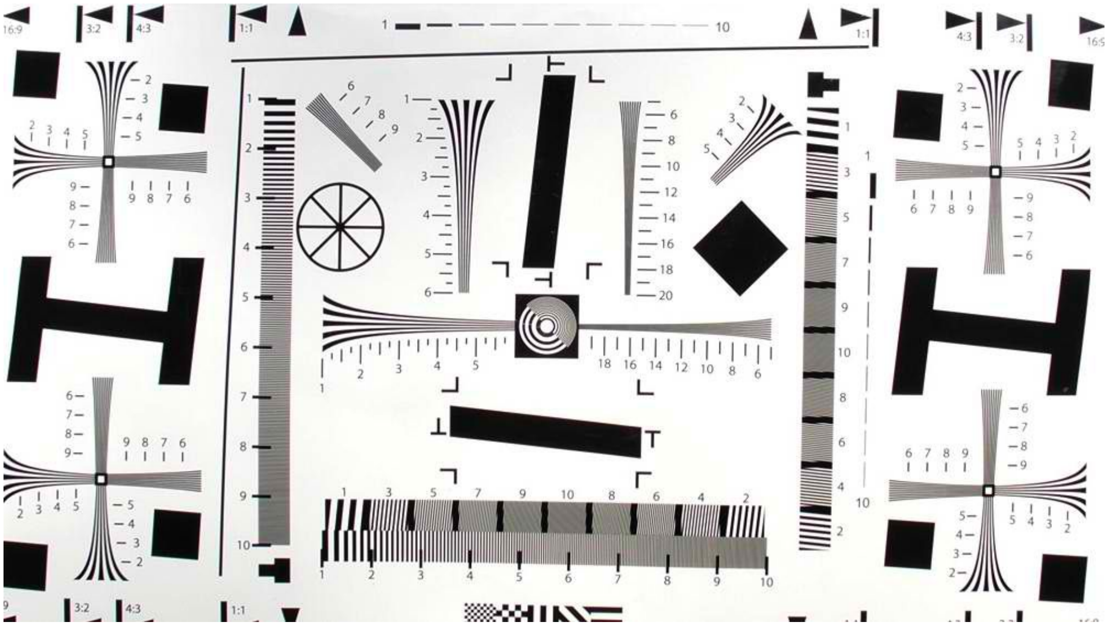
Understanding video surveillance resolution is surprisingly difficult and complex. While the word 'resolution' seems self-explanatory, its use in surveillance is far from it. In this tutorial, we will explain 5 critical elements:

- What resolution traditionally means – seeing details - and the constraints of this approach
- What resolution usually means in surveillance – pixels – and the limits of using this metric
- How sensor and stream resolutions may vary
- How compression impacts resolution greatly
- What limits resolution's value

Resolution – Seeing Details

In normal English and general usage, resolution means the ability to resolve details – to see or make them out. For example, can you read the lowest line on an eye chart? can the camera clearly display multiple lines side by side on a monitor? etc. It is a performance metric focusing on results.

Historically, video surveillance used this approach. Analog camera resolution was measured with line counts, literally the camera's ability to display more lines side by side in a given area on a monitor.



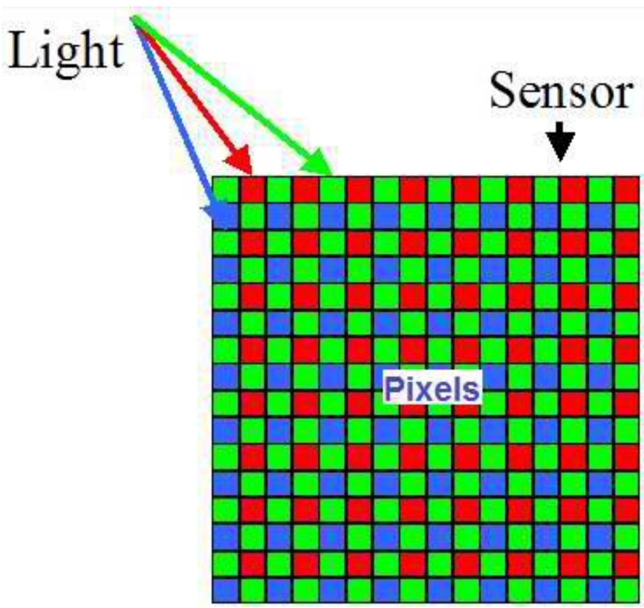
If you could see more lines, it meant you could see more real world details – facial features, characters, license plates, etc.

The main limitation was that resolving power – lines counted – was always done in perfectly even lighting conditions. However, with direct sunlight or low light, the resolving power would change, likely falling significantly. Even more challenging, some cameras fared far worse in these challenging lighting conditions than others.

While this approaches measures performance, it only does so in the most ideal, and often unrepresentative, conditions.

Resolution – Pixel Count

Now, with the shift to IP, manufacturers do not even attempt to measure performance. Instead, resolution has been redefined as counting the number of physical pixels that an image sensor has.



Pixels Determine Potential, Not Quality

Pixels are a necessary, but not sufficient, factor for capturing details. Without a minimum number of pixels for a given area / target, it is impossible. See our tutorial on why Pixels Determine Potential, Not Quality.

Limitations

The presumption is that more pixels, much like higher line counts, delivers higher 'quality'. However, this is far from certain.

Just like with classic resolution measurements that used only ideal lighting conditions, measuring pixels alone ignores the impact of common real world surveillance lighting challenges. Often, but not always, having many more pixels can result in poorer resolving power in low light conditions. Plus, cameras with lower pixel counts but superior image processing can deliver higher quality images in bright sunlight / WDR scenes.

Nonetheless, pixels have become a cornerstone of specifying IP video surveillance. Despite its limitations, you should:

- Recognize that when a surveillance professional is talking about resolution, they are almost certainly referring to pixel count, not resolving power
- Understand the different resolution options available

The table below summarizes the most common resolutions used in production video surveillance deployments today:

Name / Pixel Count	Horizontal x Vertical
VGA / .3 MP	640 x 480
720p / 1 MP	1280 x 720
1080p / 2 MP	1920 x 1080
3 MP	2048 x 1536
5 MP	2592 x 1944
4K / 8 MP	3840 x 2160
10 MP	3648 x 2752
12 MP	4000 x 3000

Everything else equal, you should expect to pay more for higher resolution (i.e. pixel count) cameras. While these cameras can often deliver more details, keep in mind performance variances (low light, WDR).

Resolution – Sensor vs. Stream

While manufacturers typically specify cameras based on the resolution (i.e. pixel count) of the sensor, sometimes, the resolution of the stream sent can be less. This happens in 2 cases:

- The manufacturer uses a higher resolution sensor than maximum stream they support. One common example of this is panoramic cameras where a 5MP sensor may be used but only a 2MP max output stream is available.

- The integrator explicitly or mistakenly sets a camera to a lower resolution.Some times this is done to save bandwidth but other times it is simply an error or glitch in the VMS default resolution configuration. Either way, many times an HD resolution may look 'terrible' but the issue is simply that it is not set to its max stream resolution (i.e., a 3MP camera set to 640 x 480).

Make sure to check not only the resolution of the sensor but the stream resolutions supported and used.

Don't Forget Compression

Since resolution now measures physical pixels, it does not consider how much the pixels are compressed. Each pixel is assigned a value to represent its color, typically out of a range of ~16 million (24 bits), creating a huge amount of data. For instance, a 1080p/30fps uncompressed stream is over 1Gb/s. However, with digital video today, surveillance video is almost always compressed. That 1080p/30fps stream would more typically be recorded at 1Mb/s to 8Mb/s – 1/100th to 1/1000th less than the uncompressed stream. The only question – and it is a huge one – is how much doesvideo get compressed?

The positive side is the potential to massively reduce bandwidth/storage without significantly impacting visible image quality. That is why it is nearly universally done.

However, picking the right compression level can be tricky. How much compression loss can be tolerated often depends on subjective preferences of viewers or the details of the scene being captured. Equally important, increasing compression can result in great cost saving on hard drive, switch and server reductions.

Just because two cameras have the same resolution (i.e. pixel counts), the visible image quality could vary substantially because of differences in compression levels chosen. Read our video quality / compression tutorial to dig into these details.

Limitations on Resolution Value

Even if quality increased exactly in proportion to pixel count (which it obviously does not), two other important limits exist in practical usage: angle of incident and resolution needed.

Angle of Incident

Regardless of how high quality an image is, it needs to be at a proper angle to 'see' details of a subject, as cameras cannot see through walls nor people. For instance:

Even if the image on the left had 10x the pixels as the one on the right, the left one is incapable of seeing the full facial details of the subject. This is frequently a practical problem in trying to cover a full parking lot with a single super high resolution camera. Even if you can get the 'right' number of pixels, if a car is driving opposite or perpendicular to the camera, you may not have any chance of getting its license plate (similarly for a person's face).

Resolution Needed / Overkill

Typically and historically, surveillance has been starved for resolution, with almost always too little for its needs. However, as the amount of pixels increases to 2MP and beyond, frequently this can be overkill. Once you have enough to capture facial and license plates details, most users get little practical benefit from more pixels. The image might look 'nicer' but the evidentiary quality remains the same. This is a major consideration when looking at PPF calculations and ensuring that you do not 'waste' pixels.

Factors Impacting Resolution

Unfortunately, many factors impact surveillance resolution, far beyond pixels, such as:

- Low light performance
- WDR performance
- Compression settings
- Camera angle / downtilt
- Lens selection and focus

Do not accept specified resolution (i.e. pixel count) as the one and only quality metric as it will result in great problems. Understand and factor in all of these drivers to obtain the highest quality for your applications.

Test your knowledge

Take this 9 question quiz now

Frame Rate

This is the industry's most in depth guide to frame rates in video surveillance.

As a precursor, you need to know the speed of objects, most typically people.

Speed of People

The faster a person moves, the more likely you are to miss an action. You know the 'speed' of frame rate - 1 frame per second, 10 frames per second, 30, etc., but how many frames do you need for reliable capture?

Here's how fast people move.

For a person walking, a leisurely, ordinary pace is ~4 feet per second, covering this 20 foot wide FoV in ~5 seconds:

Note: Click here to view the comparison on IPVM

For a person running, our subject goes through the 20' FOV in ~1.25 seconds, meaning he covers ~16' in one second:

Note: *Click here to view the comparison on IPVM*

For example, if you only have 1 frame per second, a person can easily move 4 to 16 feet in that time frame. We need to keep this in mind when evaluating frame rate selection.

In this guide, we cover:

Note: *Click here to view the comparison on IPVM*

- What speed do people move at and how does that compare to frame rates.
- Walking: What risks do you have capturing a person walking at 1, 10 and 30fps.
- Running: What do you have capturing a person running at 1, 10 and 30fps.
- Head Turning: How many more clear head shots do you get of a person at 1, 10 and 30fps.
- Playing Cards: What do you miss capturing card dealing at 1, 10 and 30fps.
- Shutter speed vs Frame Rate: How are these two related?
- Bandwidth vs Frame Rate: How much does bandwidth rise with increases in frame rate?
- Average Frame Rates used: What is the industry average?

Walking Examples

As our subject walks through the FOV, we view how far he moves from one frame to the next. In 30 and 10 fps streams, he does not complete a full stride. However, in the 1fps example, he has progressed ~4' between frames, which falls in line with our measured walking speed of ~4' a second.

Note: ***Click here to view the comparison on IPVM***

Running Examples

With our subject sprinting through the FOV, the 30 fps stream still catches him mid stride, while in the 10 fps stream, he has traveled ~1' between frames. In the 1 fps example, only one frame of the subject is captured, with him clearing the rest of the FOV between frames, with only his back foot visible in the second frame.

Note: ***Click here to view the comparison on IPVM***

Capturing Faces

Trying to get a clear face shot can be difficult when people move because they naturally shift their head frequently. In this demonstration, we had the subject shake their head back and forth walking down a hallway to show the difference frame rate plays.

Take a look:

Note: ***Click here to view the comparison on IPVM***

Notice, at 1fps, only a single clear head shot is captured, but at 10fps, you get many more. Finally, at 30fps, you may get one or two more, but it is not much of an improvement.

Playing Cards

In this test, our subject dealt a series of playing cards from ace to five with the camera set to default shutter speed (1/30).

In the 30 and 10 fps examples, we can see each card as it is removed from the top of the deck and placed on the table. However, in the 1 fps example, we see only the cards appearing on the table, not the motions of the dealer, as frame rate is too low.

Note: ***Click here to view the comparison on IPVM***

Shutter Speed vs Frame Rate

Frame rate does not cause blurring. This is a misconception. The camera's automatic shutter speed control does.

Dealing cards ace through 5 again, we raised the camera's minimum shutter speed to 1/4000 of a second. The image below compares the motion blur in the dealers hand and card, with the 2 card much more easily legible in the fast shutter speed example.

Note: Click here to view the comparison on IPVM

1/4000s shutter speed completely eliminated all traces of motion blur. 1/1000 and 1/2000 of a second shutter speeds significantly reduces blur, but it was still noticeable around the dealers fingers and edges of the cards when looking at the recordings frame-by-frame.

If you have blurring, you have shutter speed configuration problem, not a frame rate one.

Slow Shutter and Frame Rate

On the other side, sometimes users want or camera manufacturers default their maximum shutter to a rate slower than the frame rate (e.g., a 1/4s shutter for a 1/30s camera). Not only does this cause blurring of moving objects, you lose frames.

Key lesson: The frame rate per second can never be higher than the number of exposures per second. If you have a 1/4s shutter, the shutter / exposure only open and closes 4 times per second (i.e., 1/4s + 1/4s + 14/s + 1/4s = 1s). Since this only happens 4 times, you can only have 4 frames in that second.

Some manufacturers fake frames with slow shutter, simply copying the same frame over and over again. For example, if you have 1/15s shutter, you can only have 15 exposures and, therefore, 15 frames. To make it seem like you have 30 frames, each frame can be sent twice in a row.

Be careful with slow shutter. Beyond blur, you can either lose frames or waste storage.

Bandwidth vs Frame Rate

Frame rate impacts bandwidth, but for modern codecs, like H.264, it is less than linear. So if you increase frame rate by 10x, the increase in bandwidth is likely to be far less, often only 3 to 5 times more bandwidth. This is something we see mistaken regularly in the industry.

The reason for this is inter-frame compression, that reduces bandwidth needs for parts of scenes that remain the same across frames (for more on inter and intra frame compression, see our CODEC tutorial).

Illustrating this point further, we took 30, 10 and 1 fps measurements to demonstrate the change in bit rate in a controlled setting in our conference room. The average bitrates were as follows:

- 1 fps was 0.179 Mb/s

- 10 fps, with 10x more frames, consumed 4x more bandwidth than 1 fps (0.693 Mb/s)
- 30 fps, with 3x more frames, consumed double the bandwidth of 10fps and, with 30x the frames, 7x the bandwidth of 1fps (1.299 Mb/s)

These measurements were done with 1 I frame per second, the most common setting in professional video surveillance (for more on this, see: Test: H.264 I vs P Frame Impact).

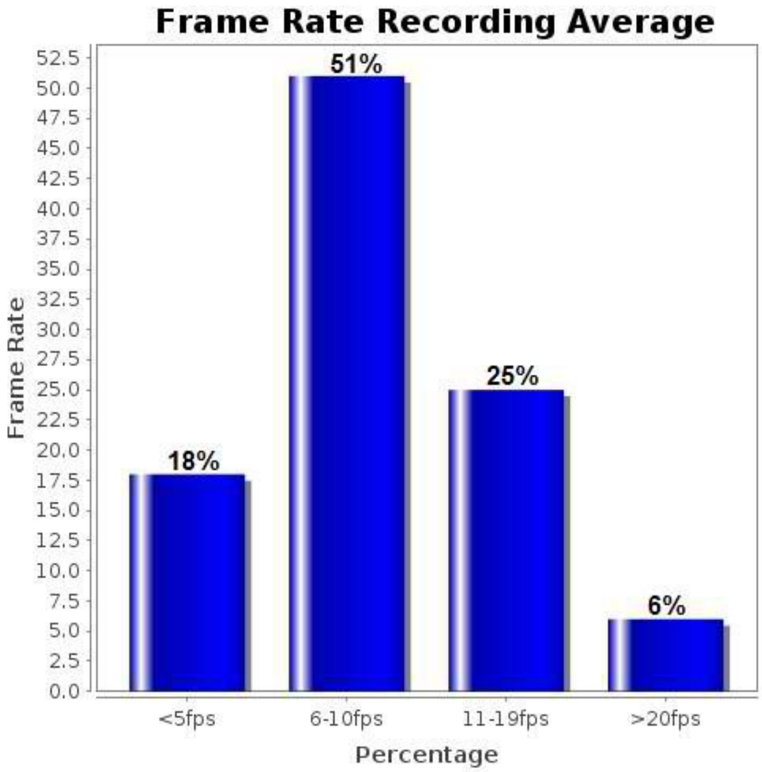
For more on this, see our reports testing bandwidth vs frame rate and 30 vs 60 fps.

Average Frame Rates Used

Average industry frame rate is ~8-10fps, reflecting that this level provides enough frames to capture most actions granularly while minimizing storage costs.

As show above, going from 10fps to 30fps can double storage costs but only marginally improve details captured.

From our Average Frame Rate Used for Recording survey results, see this table:



For more commentary on why integrators choose the frame rates hey do, see the Average Frame Rate Used for Recording report.

Methodology

For this test we used an Axis Q1604 (firmware version 5.50.3) with three streams (30/10/1) recorded by ExacqVision 6.2.7.63216.

To see for yourself, download the 6 video samples.

Bandwidth

Bandwidth is one of the most fundamental, complex and overlooked aspects of video surveillance.

Many simply assume it is a linear function of resolution and frame rate. Not only is that wrong, it misses a number of other critical elements.

The most basic commonly missed element is scene complexity.

Contrast the 'simple' indoor room to the 'complex' parking lot:

Even if everything else is equal (same camera, same settings), the 'complex' parking lot routinely requires 300%+ more bandwidth than the 'simple' indoor room because there is more activity and more details.

Making it tougher, while it is easy to contrast scenes like the 2 above, there's no simple way to gauge relative scene complexity. And, even with scene complexity factored in, many other drivers exist.

In this industry leading guide, we break down 10 total drivers including:

- Resolution: Does doubling pixels double bandwidth?
- Compression: How do compression levels impact bandwidth?
- CODEC: How does CODEC choice impact bandwidth?
- Framerate: Is 30 FPS triple the bandwidth of 10 FPS?
- Low light: How do low lux levels impact bandwidth?
- Field of view: Do wider views mean more bandwidth?
- Sharpness: How does this oft-forgotten setting impact bitrate?
- WDR: Is bitrate higher with WDR on or off?
- Color: How much does color impact bandwidth?
- Manufacturer model performance: Same manufacturer, same resolution, same FPS. Same bitrate?

Understanding bandwidth is critical because it impacts network load and storage use / cost.

Resolution

On average, a linear relationship exists between pixel count (1MP, 2MP, etc.) and bandwidth. However, variations across manufacturers and models are significant. In IPVM testing, some cameras increase at a far less than linear level (e.g., just 60% more bandwidth for 100% more pixels) while others rose at far greater than linear (e.g., over 200% more bandwidth for 100% more pixels). There were no obvious drivers / factors that distinguished why models differed in their rate of increase.

As a rule of thumb, one may use 1x ratio when estimating bandwidth difference across resolution. However, we strongly recommend measurements of actual cameras as such a rule of thumb may be off by a lot.

Compression

Compression, also known as quantization, has an inverse relationship to bandwidth: the higher the compression, the lower bandwidth will be.

CRITICAL: Compression and resolution are two different things. In IPVM courses, we routinely see professionals mix the two. Resolution, in our industry, is the number of pixels in an image / video. Compression is how heavily compressed those pixels are.

For example, the chart below shows the impact of compression across four different cameras (note: with H.264, quantization / compression is measured on a standard scale of 0 to 51, higher meaning more compression, lower quality).

Lowering quantization from 34 (high compression) to 28 (average) resulted in at least a 3x increase in bandwidth, while further lowering it to 22 (very low compression) resulted increases of 5-11x depending on the camera.

Approximate Compression Impact on Bandwidth			
Camera Name	Q of 34	Q of 28	Q of 22
Dahua IPC-HF3101N	1	3x	5x
Hikvision DS-2CD864FWD-E	1	3x	10x
Samsung SNB-6004	1	5x	6x
Sony SNC-VB630	1	3x	11x
*** Bandwidth measurements based off Mbps.*			
*** Findings are based from our conference room scene, and are being used as a rule of thumb. Scene complexity and camera settings will affect camera bandwidth consumption.*			

Additionally, manufacturers use different scales and terminology for their compression levels with most giving little indication of what actual quantization level is used. Some may use a numeric scale from 1-100, while others use labels such as "low, high, best", and others use the actual 0-51 quantization scale. This chart shows just some of the options in use:

Camera Compression Scales		
Manufacturer	Name of Scale	Range of Scale
ACTi	Quality	"High - Low"
Avigilon	Quality	"1 - 20"
Axis	Compression	"0 - 100"
Bosch	P-Frame Quality	"Auto - 51"
Dahua	Quality	"1 - 6"
Hikvision	Video Quality	"Lowest - Highest"
Samsung	Compression	"Best (1) - Worst (20)"
Sony	Image Quality	"1 - 10"

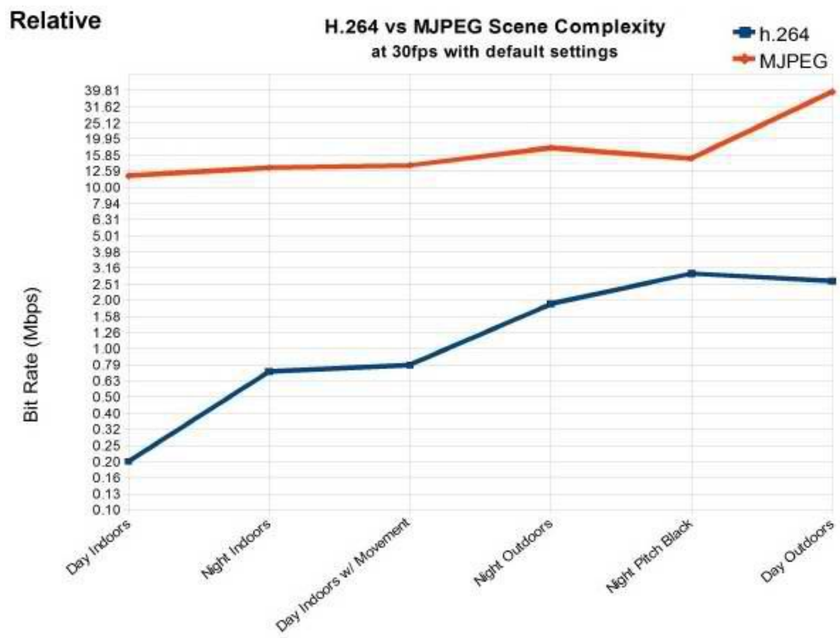
See our IP Camera Manufacturer Compression Comparison for more detail on understanding manufacturer differences and how to standardize Q levels across different lines.

CODECs

A key differentiation across CODECs is supporting inter-frames (e.g., H.264, MPEG-4) vs intra-frame only (e.g., MJPEG, JPEG2000).

- Inter-frame CODECs such as H.264 not only compress similar pixels in an image, they reference previous frames and transmit only the changes in the scene from frame to frame, potentially a large bandwidth savings. For example, if a subject moves through an empty hallway, only the pixels displaying him change between frames and are transmitted, while the static background is not.
- Intra-frame only CODECs encode each individual frame as an image, compressing similar pixels to reduce bitrate. This results in higher bandwidth as each frame must be re-encoded fully, regardless of any activity in the scene.

The vast majority of cameras in use today, and for the past several years, use H.264, due to its bandwidth advantages over MPEG-4 and Motion JPEG. In our H.264 vsMJPEG - Quality and Bandwidth Tested shootout, H.264 consumed far less bandwidth in all scenes than MJPEG, seen in the chart below:



For more on inter and intra frame compression, see our CODEC tutorial.

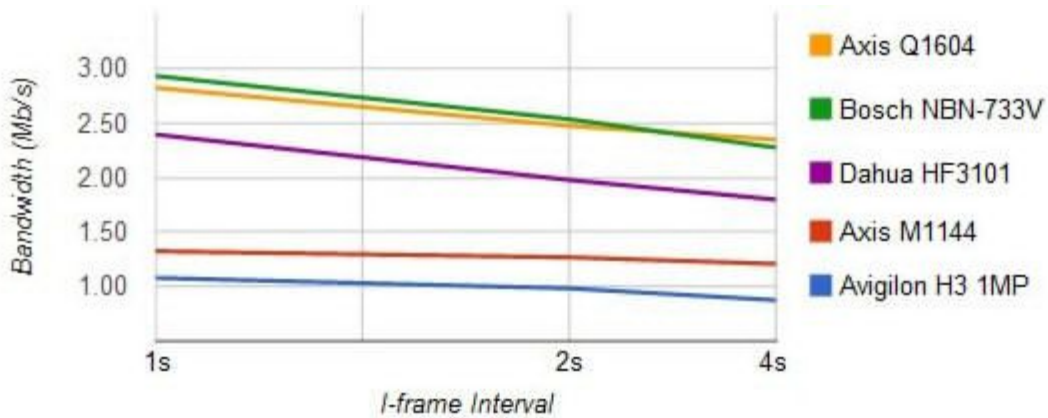
I-Frames vs. P-Frames

In inter-frame CODECs, frames which capture the full field of view are called I-frames, while those sending only changes are P-frames. Because they capture a full image, the more I-frames in a stream, the higher the bandwidth.

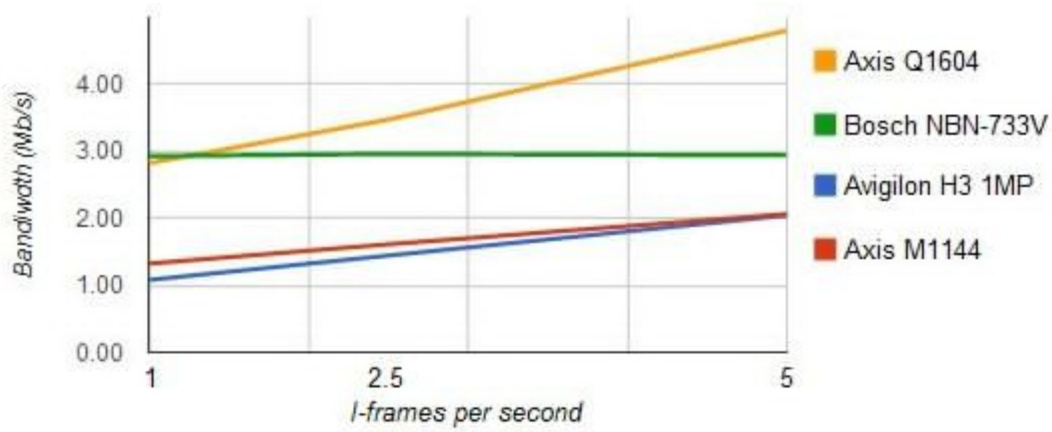
In almost all cases, one I-frame per second is the best balance between bandwidth and image quality. Too few I-frames may negatively impact imaging, with long "trails" of encoding artifacts, while more than one I-frame per second provides little to no visible benefit, seen in this video:

Note: ***Click here to watch the video on IPVM***

Reducing the number of I-frames (moving from 1 to 2 to 4 second interval) produces minimal bandwidth reductions, as seen below, despite the severe negative image quality impact.



Inversely, increasing the number of I-frames to more than one per second significantly increased bandwidth, despite the minimal incrase in image quality.



For full details on I and P frame impact on bandwidth and image quality see our H.264 I vs P Frame Test.

Frame Rate

Frame rate impacts bandwidth, but for inter-frame CODECs such as H.264, it is less than linear. So if you increase frame rate by 10x, the increase in bandwidth is likely to be far less, often only 3 to 5 times more bandwidth. Illustrating this, we took 30, 10, and 1 fps measurements to demonstrate the change in bit rate in a controlled setting in our conference room. The average bitrates were as follows:

- 1 fps: 0.179 Mb/s
- 10 fps: 0.693 Mb/s (10x the frames of 1 fps, but only 4x bandwidth)
- 30 fps: 1.299 Mb/s (3x the frames of 10 fps, but only double bandwidth. 30x frames of 1 fps, but only 7x bandwidth)

(These measurements were done at 1 I frame per second with quantization standardized ~28.)

For more detail on frame rate's impact on bitrate, see our Frame Rate Guide for Video Surveillance.

Low Light

Compared to day time, low light bitrates were an average of nearly 500% higher (seen below). This is mainly caused by increased digital noise caused by high levels of gain.

Camera	Resolution	FPS	Day	Night	Increase	% Increase
Axis Q1615	1080p	10	0.42	4.28	3.86	909%
Bosch NBN-932V	1080p	10	0.64	3.12	2.48	388%
Samsung SNB-6004	1080p	10	1.89	2.58	0.70	37%
Sony SNC-VB630	1080p	10	2.49	8.24	5.75	231%
Arecont AV3116DNv1	3MP	10	1.25	3.04	1.79	144%
Avigilon H3 1MP	720p	10	0.48	2.02	1.54	322%
Bosch 733	720p	10	0.18	0.30	0.13	73%
Dahua HF3100N	720p	10	0.19	4.00	3.81	1983%
Hikvision 864	720p	10	0.56	5.28	4.72	843%
Samsung 5004	720p	10	0.68	2.54	1.86	274%
Sony VB600B	720p	10	0.16	0.60	0.44	275%
Averages			**0.81**	**3.27**	**2.46**	**498%**
					All measurements in Mb/s	

However, two key improvements are increasingly used to reduce this:

- Digital noise reduction techniques have improved in recent years, greatly reducing these spikes on many cameras.
- Increased use of integrated IR cameras results in smaller spikes at night. Compared to nearly 500% in day/night models, integrated IR cameras increased by an average of 176% due to IR illumination (seen below).

Camera	Resolution	FPS	Day	Night	Increase	% Increase
Axis M1144-L	720p	10	1.20	5.44	4.24	353%
Avigilon 3.0W-H3A-BO1	1080p	10	1.15	1.32	0.17	15%
Dahua HFW3200S	1080p	10	3.20	8.80	5.60	175%
Hikvision DS-2CD2032-I	1080p	10	2.75	7.20	4.45	162%
Averages			**2.08**	**5.69**	**3.61**	**176%**

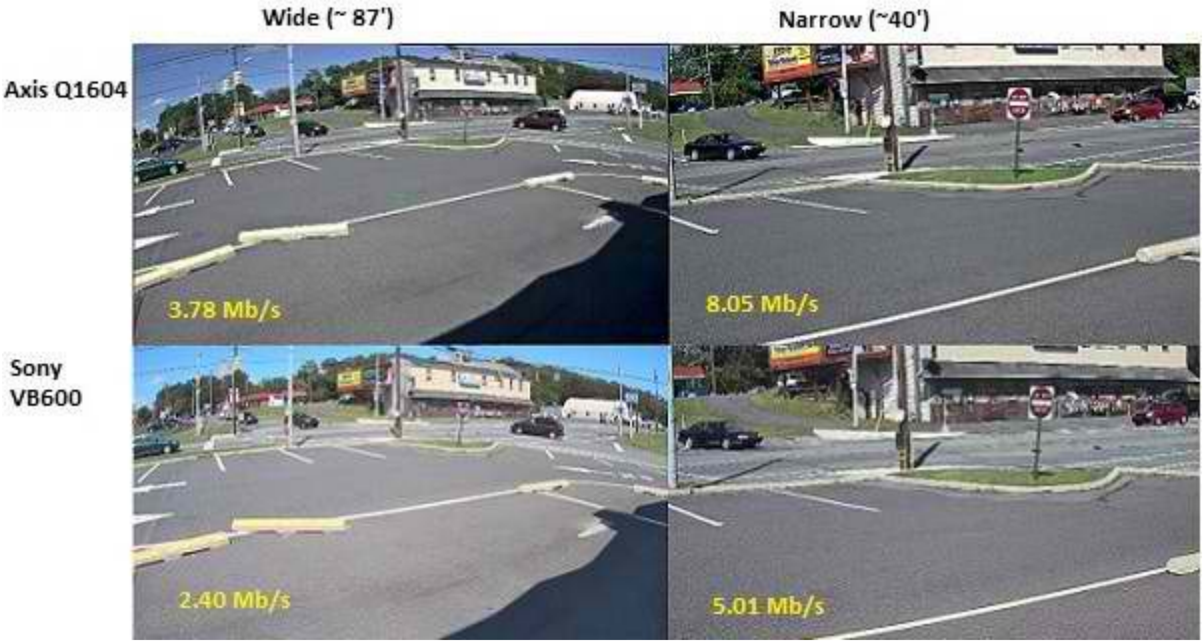
For full details of low light's impact on bandwidth, see our Bandwidth vs Low Light test report.

Camera Field of View

Field of view's impact on bandwidth varies depending on which width reveals more complex details of the scene. In scenes with large areas of moving objects, such as trees or other blowing vegetation, widening the field of view will likely increase bandwidth. In scenes with relatively low movement but repetitive backgrounds, such as parking lots, roofing, patterned carpet or walls, etc., narrowing the field of view will increase bandwidth due to more of these fine details being discernable.

For example, in the park shown below, increasing the field of view results in a ~60% increase in bandwidth due to more moving foliage and shadows in the scene compared to the narrower field of view.

However, in a busy intersection/parking lot, bandwidth decreases by over 50% in the cameras below when widening the field of view. In the narrower FOV, more details of buildings are visible, and the repetitive pattern of the asphalt parking lot may be seen as well, making the scene more difficult to encode.



For further details of field of view's impact on bandwidth, see our Advanced Camera Bandwidth Test.

Sharpness

Sharpness has a huge impact on bandwidth consumption, yet it is rarely considered during configuration, even by experienced technicians. Oversharpening reveals more fine (though rarely practically useful) details of the scene, such as carpet and fabric patterns, edges of leaves and blades of grass, etc. Because more detail is shown, bandwidth increases.

For example, in the FOV below (from our Advanced Camera Bandwidth Test), bitrate increases by nearly 600% from minimum to maximum sharpness in the Dahua camera, and almost 300% in the Axis Q1604.

Wide Dynamic Performance

WDR's impact on bitrate varies depending on the camera and the scene. Again taking examples from our Advanced Camera Bandwidth Test, when switching WDR on in an Axis WDR in an outdoor intersection scene, bandwidth increases, as more details are visible (beneath the eaves of buildings, in the treeline, etc.).

However, looking at an outdoor track and sports field, bandwidth decreases. In this case, the Q1604 increases contrast slightly on some areas of the image, such as the trees and bleachers in the center/left of the FOV. Because of this, these areas are more similarly colored and easier to compress, lowering bitrate.

Note that for other cameras, these results may vary, depending on how well they handle light and dark areas, how they handle contrast when WDR is turned on, and more.

Color

At practical levels (without desaturation or oversaturation effects), color has minimal impact on bandwidth. In the examples below, moving from default color settings to monochrome decreases bandwidth by 20 Kb/s, about an 8% decrease.

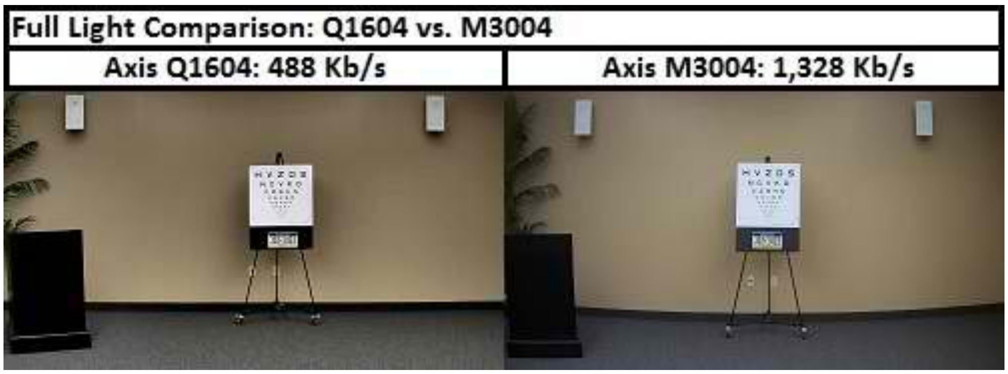
However, oversaturation may result in abnormally high bandwidth. In this example, bandwidth increases by over 200% when changing color settings from default to their highest level, which also creates oversaturation effects such as color bleeding (seen in the red chair).

One practical example of a manufacture desaturating their video to 'save' bandwidth is Arecont Bandwidth Savings Mode (which we tested here).

Manufacturer Model Differences

Across specific models in a given manufacturer's line, significant differences in bitrate may occur, despite the cameras using the same resolution and framerate. This may be due to different image sensors or processors being used, different default settings in each model, better or worse low light performance, or any number of other factors.

For example, the following image shows two cameras, an Axis Q1604 and Axis M3004, both 720p, 10 fps, set to a ~20' horizontal FOV, at compression of ~Q28. Despite these factors being standardized, in this well lit indoor scene, the Q1604's bitrate was 488 Kb/s while the M3004 consumed 1.32 Mb/s, nearly 3x the bandwidth.



Measure Your Own Cameras

As this guide shows, there are few easy, safe rules for estimating bandwidth (and therefore) storage, abstractly. Too many factors impact it, and some of them are driven by impossible to know factors within the camera.

Though it is important to understand which factors impact bandwidth, use this knowledge with your own measurements of the cameras you plan to deploy. This will ensure the most accurate estimates and planning for deployments.

Low Light

Lux ratings are one of the worst specifications to use in selecting cameras.

You need to be able to understand why lux rating (aka minimum illumination specifications) are so problematic, how they are established and what tricks / techniques are used.

In this guide, we explain:

- How lux ratings are tested / determined
- The incorporation of shutter speeds in lux ratings
- Dealing with lux ratings that include 'sens up' settings
- Color vs B/W Impact
- Understanding how IRE levels are used
- IR illumination and lux ratings
- The practical lux levels typically specified based on analyzing 2000+ camera specifications
- How to avoid getting burnt by lux levels

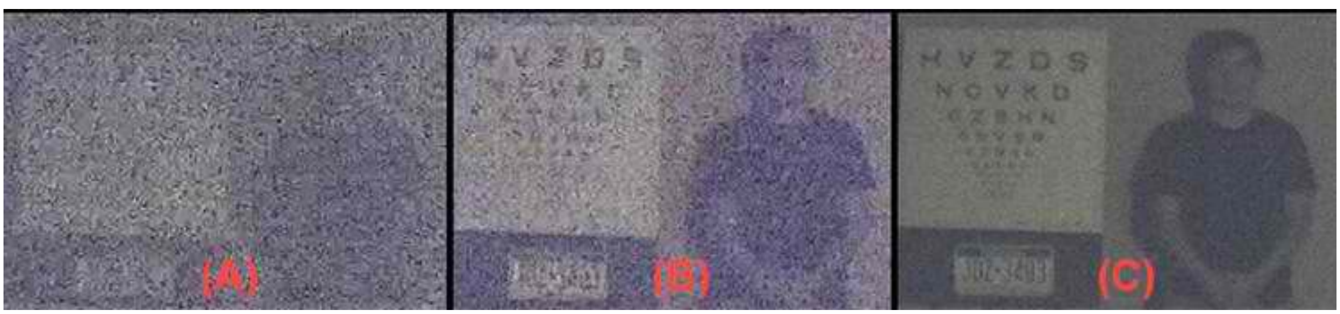
Lux Rating Tests / Determination

Most importantly, there are no standardized or verified means to assess manufacturer lux ratings. They are always self-assigned and, at the discretion of the manufacturer.

This means that each manufacturer gets to decide what light source they use, the size of the testing area, the positioning of the light, the test subject / chart employed, etc.

Most critically, each manufacturer decides when an image is or
is not usable. It is this point, solely at their discretion that becomes the self-assigned lux rating.

For example, in the image below, each lux level could easily be considered "dark", but with no standardization of levels nor minimum usability, which is "right"?



Since each manufacturer is free to make their own goal, they have an incentive to choose the darkest one possible, knowing many of their competitors will do the same thing.

Shutter Speeds and Lux Ratings

Often manufacturers will list lux ratings at different or multiple shutter speeds. Some list 1/30s, others 1/2s, some still 1 full second shutter.

Users should ignore specifications at any shutter speed other than 1/30s. While these longer shutter speeds allow more light and lower minimum illumination levels, motion blur is a significant problem with slow shutter speeds.

In the spec sheet example below, the manufacturer lists minimum illumination at 1/30s and 1/2s shutter speeds:

MIN. SUBJECT ILLUMINATION - DAY (COLOR)	0.3 lux (F1.2, shutter speed 1/30 sec., SSC off , 50IRE) 0.02 lux (F1.2, shutter speed 1/2 sec., SSC off , 50IRE)

Of course, the minimum illumination specification 'looks' better at 1/2s, but that is not technological improvement, simply trading off more light for more blur.

F Number and Lux Ratings

Every so often a manufacturer will specify their minimum illumination assuming a different F number than the lens the camera uses. For example, a manufacturer might say their camera lux rating is 0.01 lux at f/1.0 but the camera may have an integrated f/2.0 lens.

In the example below, this is the case, with minimum illumination listed at F1.2, but the camera shipping with an F1.8 lens, which captures less than half the amount of light of an F1.2 lens.

Model	DH-IPC-HFW1000S
Camera	
Min. Illumination	0. 1Lux/F1.2 (Color), 0.01Lux/F1.2(B/W);0Lux/F1.2(IR on)
Lens	
Focal Length	3.6mm (,6mm optional)
Max Aperture	F1.8(F1.8)

Even assuming the manufacturer's own rosy self assesment, correcting this basic error means the minimum illumination is at least .225 lux rather than .1 lux.

Sens Up and Lux Ratings

Sens-up is typically a marketing term for slow shutter. The higher the sens up "level", the slower shutter, with each multiplier (2x, 8x, 64x, etc.) simply multiplied times 1/30s to produce the effective shutter speed.

For example, the spec sheet below lists a separate minimum illumination at "x256 Sens-up." This essentially amounts to an astounding 8.5 second (256/30s = 8.53) exposure time, which would result in massive ghosting of moving objects.

Min. Illumination:	0.25lux color / 0.01lux B/W (50IRE, F1.2) 0.001lux color / 0.00004lux B/W (@ x256 Sens-up)

The hope is that you see the lower lux rating and are impressed. Beware.

Color vs B/W

Cameras that support integrated cut filters (aka D/N cameras) will often list 2 lux ratings, the first in color mode, the second in monochrome. This difference is due to increased performance in monchrome mode due to ambient IR light which the IR cut filter blocks in color mode. Claimed differences are often substantial, as in the examples below, which both list monochrome minimum illumination specs 1/10th of color mode (theoretically 10x better).

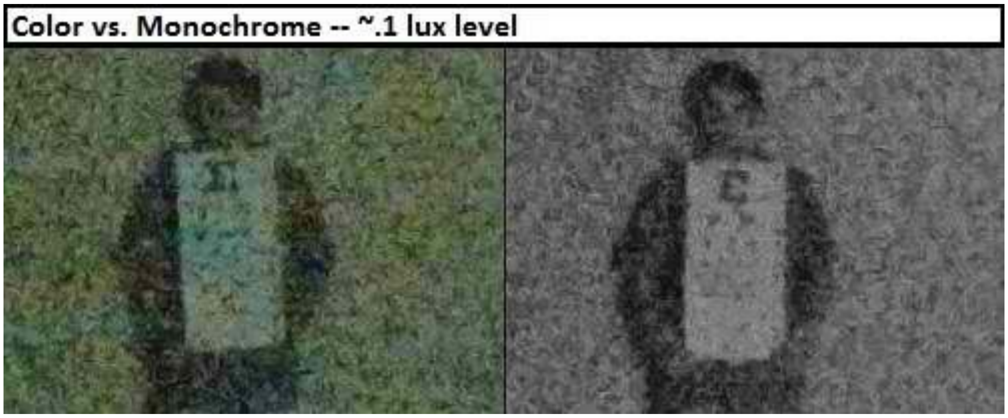
Avigilon 2.0-H3-B2:

Minimum Illumination	0.2 lux (F1.2) in color mode; 0.02 lux (F1.2) in monochrome mode

Hikvision DS-2CD864FWD-E:

DS-2CD864FWD-E		
	Image Sensor:	1/3" Progressive Scan CMOS
	Minimum Illumination:	Color: 0.01 lux@F1.2, AGC ON B/W: 0.001 lux@F1.2, AGC ON

While gains due to ambient monochome light do occure, 10x increases are typically overstated. Camera image enhancement and improved DSP has brough performance of color and monochrome imaging much closer, as seen in this comparison image from a current generation camera in the same scene.



IRE Levels

IRE levels could be helpful for analog cameras but are not applicable in IP. IRE is a measure of the contrast level in an analog video signal, tested using composite video outputs. Since IP cameras do not provide analog output of their full resolution, it is a moot metric.

A few manufacturers still list it on spec sheets, showing different minimum illumination levels for different IREs (most often 30 and 50). However, since it is unknown how manufacturers are testing this IRE, we recommend using the worse minimum illumination spec in these cases (typically 50), and ignoring lower readings.

Samsung SND-7084N:

Min. Illumination	Color : 0.1Lux (F1.2, 50IRE) 0.06Lux (F1.2, 30IRE) B/W : 0.01Lux (F1.2, 50IRE) 0.006Lux (F1.2, 30IRE)

Sony SNC-EB630:

Minimum Illumination (50 IRE)	Color: 0.1 lx (F1.2, View-DR OFF, VE OFF, AGC ON, 1/30 s, 30 fps)
	B/W: 0.07 lx (F1.2, View-DR OFF, VE OFF, AGC ON, 1/30 s, 30 fps)
Minimum Illumination (30 IRE)	Color: 0.06 lx (F1.2, View-DR OFF, VE OFF, AGC ON, 1/30 s, 30 fps)
	B/W: 0.05 lx (F1.2, View-DR OFF, VE OFF, AGC ON, 1/30 s, 30 fps)

IR illumination and Lux Levels

Today, many cameras have IR illuminators integrated. Those cameras will typically list their lux rating as 0 lux, with the implication that because the camera has its own built-in light source (the IR illuminators) that it needs no other light. This is a reasonable assumption though, integrated IR performance can vary (see Infrared IR Surveillance Tutorial).

Beware IR Sensitive

Some manufacturers (notably Arecont) attempt to mislead specifiers by listing "0 Lux, IR sensitive" for their non-integrated IR cameras. What they are saying is "If you buy and add your own IR light source, our cameras need no light." That is trivially true for any D/N camera but misleading because it requires adding light.

Practical Lux Levels

IPVM lists the minimum illumination specifications of 2000+ cameras in its Camera Finder. From this, we found these practical levels:

- .00X Lux and Below
- .0X Lux and Below

- .X and Above

0.00X Lux And Below

Manufacturers specifying minimum illumination at these levels are often aggressively overstating their camera's low light performance. In some cases, these claims are due to manufacturer tricks such as slow shutter, while in others, it is simply overstatement.

Among the unbelievable models in this category are standouts such as Speco's IP intensifier line (which blurred moving objects massively due to slow shutter, see our test results) and Vivotek's FE8174V, a 5MP panoramic camera with a very high F2.8 lens.

In short, be careful of manufacturers making claims below 0.01 lux, as performance rarely matches these specs.

0.0X Lux

We found this range to be where most super low light cameras are typically specified. This range includes top low light performers such as Axis' Lightfinder Q1604 andQ1615, Samsung SNB-5004 and SNB-6005, and Sony's 6th Gen SNC-VB600 and SNC-VB630, making it the "safest" categorization for those seeking top low light performance.

This is not to say no manufacturers are overstating performance at these levels. For example, both the Avigilon 3.0W-H3-B2 and Axis Q1604 are specified at 0.02 lux. However, our tests show the Avigilon camera's performance is well below that of the Q1604.

0.X Lux

Cameras specified at this level are generally poor in low light. This category contains many previous generation cameras whose low light performance has been superseded by new generation models. Additionally, many lower cost fixed lens/high F-stop models which more likely belong in the 1+ lux range are specified here.

With both of these factors considered, if low light is a key concern, cameras specified at this level will likely not deliver necessary performance.

1+ Lux

Cameras with minimum illumination ratings above 1 lux will be poor in even moderate low light conditions. These ratings are most likely among lower cost fixed lens minidomes (such as the Axis M30 and Bosch microdomes) and panoramic models such as the Samsung SNF-7010 and Panasonic WV-SF438/458.

What To Do

If low light is important to you, you do not want IR, and you must specify minimum illumination, IPVM recommends the following specification language:

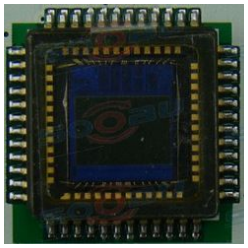
"Minimum illumination of 0.09 lux at 1/30s shutter, no sens up allowed."

The rationale for this is that cameras specified at 0.1 lux or higher are almost always fairly bad in low light, so, at least, you can reject those cameras. However, if you specify something lower than that, like .001, you significantly increase the chance of rejecting high-quality low light cameras that are conservatively specified.

Finally, make sure to include the "1/30s shutter, no sens up allowed" to prevent manufacturers including specifications that are heavily gamed and certain to introduce problematic motion blur.

Beyond that, review IPVM test results that all include low light standardized testing and test yourself to see how well it works in your scenes / light levels.

Imagers



Imagers - CCD, CMOS, 1/2", 1/4", big pixels, small pixels, etc.

In this tutorial, we explain the fundamental issues and drivers in surveillance camera imagers, including:

- Sensor vs Imager
- CCD vs CMOS
- Imager Manufacturers
- Camera Manufacturer Imager Disclosure
- Imager vs Resolution
- Imager Size
- Pixel Size
- Imager vs FoV Width
- Imager vs Low Light Performance

Plus, we provide a 7 question quiz at the end to test your knowledge.

Sensor vs Imager

Industry people alternatively call these components 'sensor' or 'imager'. When referring to surveillance cameras, they mean the same thing, though, technically, an imager is a specific type of sensor. Because of this, we more typically refer to 'imager' when speaking about surveillance cameras.

CCD vs CMOS

The two main historical types of imagers have been CCD and CMOS.

Today, in 2016, virtually all surveillance cameras use CMOS, from the very 'best' to the 'worst'. This is the opposite of a decade ago, when CCD imagers were predominant and CMOS was looked down upon as a lower cost, lower quality alternative.

Because CCD once was better, a prejudice remains against CMOS. However, this is wrong, antiquated and, as a practical matter, impossible. If you only choose CCD imagers, you would eliminate almost all modern surveillance cameras, including the 'top' brands and models.

Imager Manufacturers

There are only a few significant manufacturers of surveillance imagers, with the most frequently cited including Omnivision, Aptina and Sony. Like camera manufacturers, imager manufacturers offer a range of models with varying size, max resolution, frame rate and WDR capabilities, to name a few.

Camera Manufacturer Imager Disclosure

Camera manufacturers generally hide what imager manufacturer / models they use, so it is not easy to compare two cameras based on their imagers. Some will list the imager manufacturer but not the specific model. For example, even if you knew it was an Omnivision, Omnivision makes dozens of imagers with varying price / performance tradeoffs. Moreover, even if you knew 2 cameras were using the exact same imager (which is rare, in practice), differences in tuning, encoding and compression could still result in noticeable quality differences.

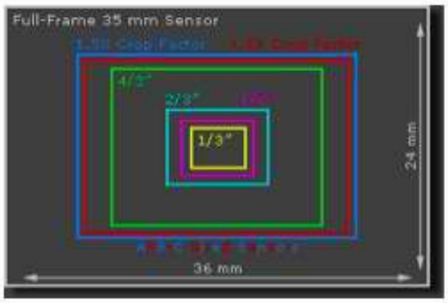
Imager vs Resolution

Imagers vary in the maximum resolution they support. This constrains the camera's overall resolution. Some imagers max out at VGA, 1.3MP, 3MP, 5MP, etc. Recently, 4K / 10MP sensors have emerged which is helping to foster 4K cameras.

Imager Size

Imagers can range from extremely large (e.g., DLSRs) to extremely small (e.g., cell phones). Surveillance camera imagers tend to fall in the middle, closer, but typically larger, than cell phone imagers.

This chart compares, on the left, photography imager, and, on the right, surveillance:



In surveillance, 95% of cameras have imagers that are between 1/2" and 1/4". The most common imager size in surveillance is 1/3", with 3MP+ cameras often having slightly larger imagers (1/2.7" or 1/2.5" are common) and lower cost SD and 720p ones having 1/4" imagers.

Increasing Imager Size

Over the past few years (e.g., 2014, 2015), the average imager size has increased moderately. As resolutions increase, 3MP, 4MP, 5MP, 4K, etc., imager sizes larger than 1/3" are definitely becoming more common.

Rise of 1/2" 1080p Imagers

The most important recent shift in imager size used is the rise of 1/2" 1080p imagers. Quite a number of manufacturers know have at least one 'special' model using a 1/2" 1080p imager, targeted for super low light.

Size Disclosure

On the plus side, imager size is almost always disclosed by camera manufacturers on specification sheets. Here's an example of the level of detail typically provided:

P3353/P3363-V: Progressive scan RGB CMOS 1/3"

Pixel Size

Imagers vary in the size of their pixels, measured in microns.

Pixel size is most strongly determined by imager size and number of pixels (i.e., resolution). The bigger the imager, everything else equal, the bigger the pixel size. However, if you add more pixels (e.g., going from SD to HD) and the imager size stays the same, the pixel size decreases.

Here's an excerpt from an imager manufacturers showing imager size, resolution and pixel size side by side:

Optical Format	1/4"	1/3"	1/3"	1/4"	1/3"	1/3"	1/2.5"
Resolution	VGA	1.2 MP	1.2 MP	1.1 MP	3.5 MP	3.1 MP	5 MP
Pixel Size	5.6 µm	3.75 µm	3.75 µm	3.0 µm	2.2 µm	2.2 µm	2.2 µm

Many prefer larger pixel sizes because, everything else equal, a larger pixel can collect more light, and therefore deliver brighter / better low light images. However, many other factors impact low light performance so it is not simple / easy to conclude one camera is better than another based on pixel size.

Also, pixel size is almost never disclosed by camera manufacturers, so the best one can do is estimate by looking at the resolution and imager size of each model.

4K Pixel Size

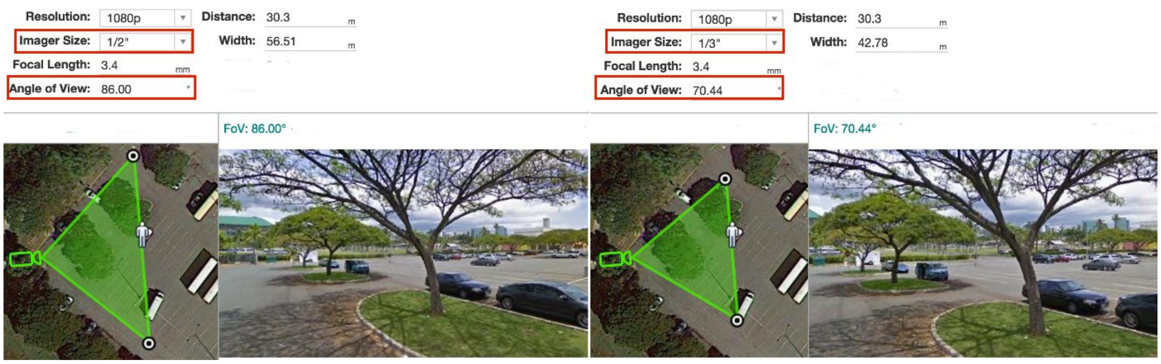
4K cameras are increasingly common. Although they have ~4x the pixels of 1080p cameras and 4K camera imagers are generally larger than 1080p, generally the pixel size for 4K cameras is smaller. This can hurt low light performance. Also, as we explain further, limits in image processing also hurt 4K cameras.

Imager Size vs FoV Width

Imager size has a modest impact on FoV width. The primary determinant of FoV is lens length (e.g., 3mm, 10mm, 30mm, etc.).

However, the larger the imager, everything else equal, the larger the FoV.

On the other hand, imager sizes in surveillance do not vary that much, so even with notably different imager sizes, the FoV only changes moderately. For example:



As such, it generally is not a major concern, but is worth being aware of.

Imager vs CODECs

Imagers have nothing to do with compressing video (i.e., H.264, MJPEG, etc.). The imager sends the video uncompressed to the an encoder / System on a Chip (SoC) to perform this.

Imager vs Low Light Performance

Besides CCD vs CMOS, the strongest, and most flawed, belief in imagers is that larger imagers deliver better low light performance. Though larger imagers help, there are other key drivers that typically are more important, namely low light image processing that is done by the encoder / CPU on the camera. IPVM has shown this in our imager size vs low light performance study.

Related, the newer 1/2" 1080p cameras specialized for low light are generally better than the top 1/3" 1080p cameras (see test results of 1/2" imagers). Imager size can help, however, to get maximum low light performance, both strong low light image processing and larger imagers are key. There are a number of 1/2" imager cameras out there, lacking image processing that are quite poor in low light. Also, a number of 4K cameras have 1/2" imagers or larger, but are still bad in low light because the pixel size is fairly small and the cameras tend to lack the processing power to enhance such large resolutions.

Quiz Yourself

Take the 7 question quiz and see how well you know imagers.

Updated 2016

This post was originally released in 2014 but was updated in 2016 to reflect developments in 1/2" imagers and 4K cameras.

WDR

WDR is one of the most important and highly differentiating capabilities of surveillance cameras, critical to ensuring strong image quality in many real world applications. However, any manufacturer can claim WDR, and many do even if actual performance is weak. In this tutorial, we break down WDR:

- What is WDR?
- How Do You Measure WDR?
- Camera WDR Challenges
- WDR vs Resolution
- WDR Implementations

Our Tests

This tutorial summarizes and explains key points on WDR. For those that want to see the testing and analysis in depth, see our WDR Shootout and Megapixel WDR Shootout.

What is WDR?

WDR is the ability to produce high quality image across a range of light levels. The term stands for 'wide dynamic range' with the wide referring to the range of light levels. Alternatively, but less common in surveillance, HDR or 'high dynamic range' is used. Both terms, in surveillance, essentially refer to the same ability.

WDR can make a big difference. Here's an exmple of a person walking in a doorway:

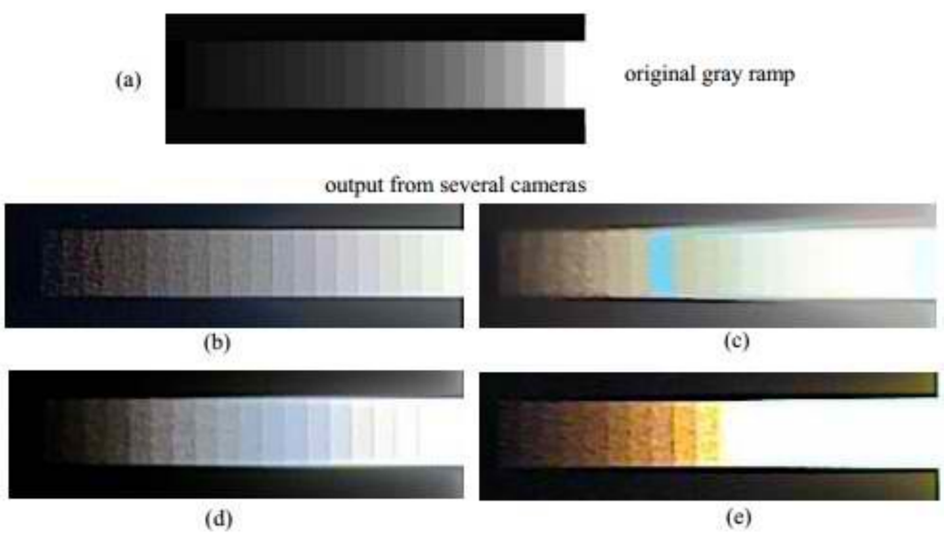
Now, the image below demonstrates what we mean by light levels:

The single scene has a very bright middle and far less bright sides.

Measuring WDR

It is critical to know how wide the range of light levels a scene has. The generally accepted term in surveillance to measure this is the decibel (e.g., 58dB, 113dB, etc.) with higher levels indicating stronger WDR performance. Unfortunately, these measurements are not standardized, at the discretion of each manufacturer and should not be trusted upon.

While dB measurements alone are fairly cryptic (i.e., what does it mean physically?), they are grounded on a specific test scenario. A grayscale chart is used with numerous shades from white to black. The more levels a camera can display/capture, the higher its dB rating and the better its WDR performance should be. Below is an example image from Pixim's WDR measurement whitepaper:



Unfortunately, this does not translate well to real world scenes (i.e., what can I expect for my front door camera?) nor is this approach guaranteed to be used or measured fairly by all manufacturers.

Manufacturer WDR Specifications

You can never trust manufacturer dB specifications as they are self-assigned and not validated independently. However, there are some patterns to consider:

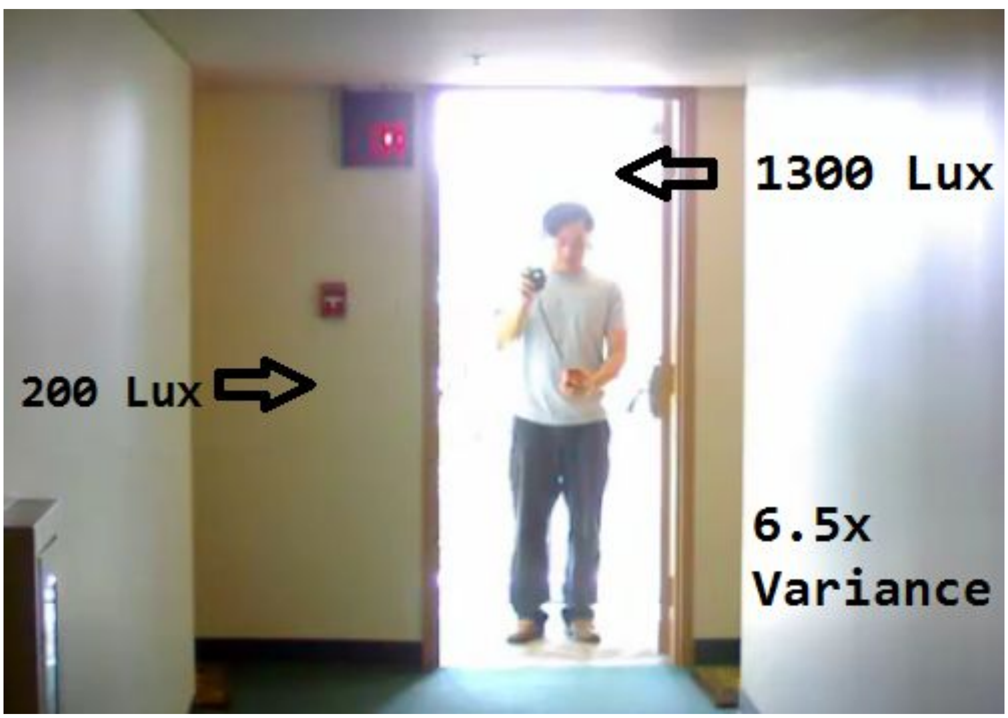
- A WDR dB rating of 70dB or less almost always means that the camera does not support true WDR as manufacturers know that rating their cameras this low will ensure that the camera is low on the WDR 'scale'. 'Regular', non WDR cameras frequently are specified in the range of 55 - 70dB.
- A WDR dB rating of 100+ usually, but not always, means that the camera supports true multi-exposure WDR. Again, though, since manufacturers are free to choose any value they want, it is not guaranteed. Make sure to verify. See our WDR Manufacturer Cheat Sheet and Camera Tracking
- Related, Sony is (relatively) conservative in their WDR / dB ratings and lists many of their true WDR cameras as 'only' 90dB. This does not mean they are worse than a more liberal manufacturer self-assigning 120dB or 130dB. Actual testing is required to verify.
- In the past few years, we have seen manufacturers accelerate the dB race with specifications of 130dB or even 140dB. However, in our testing, cameras with lower dB specifications (even 90dB) out perform them in real-world testing.

Note:

An Alternative Approach

In our testing, we have developed an alternative real world approach to measuring how tough a WDR scene is. Using a lux meter, we record the brightest and the darkest spots of each scene. The ratio of the two provides a strong indicator of how challenging the scene is.

In a doorway opening outdoors, with a small opening to an enclosed areas, the range is typically quite high, as shown below:



The WDR ratio is ~6.5x, with the open doorway at 1300 lux and the adjacent indoor sides at ~200 lux.

The closer one gets to a WDR ratio of 1, the less likely that WDR capability is needed. Moreover, the lower ratio the less powerful WDR functionality one needs.

Of course, even with our approach you will need to measure but this can be done by a field tech with a $100-$150 lux meter. However, do make sure to do this when the sun is strongest as the WDR ratio will vary throughout the day as the sun moves.

Camera WDR Challenges

Normal cameras typically struggle with wide ranges of lighting because of their dependency on a single exposure. Cameras need light to generate an image. However, too much light and the image is washed out yet too little light and the image is too dark.

If you have a scene with even lighting, it is no problem. The camera will simply adjust its iris opening size or its shutter speed to get the right amount of light. This is why manufacturers typically demo their cameras in even lighting scenes.

However, if the scene has a wide range of lighting, the camera has a tough challenge. If it restricts the amount of light it takes in to optimize for the bright areas, the lower light areas will be too dark. However, if it chooses the opposite approach, optimizing for low light areas, the bright side will be washed out. The image below shows this tough tradeoff:

Something, therefore, needs to be done to overcome this.

WDR vs Resolution

Interestingly, it turns out that higher resolution improves WDR. This is NOT the best nor the most sophisticated approach (see more below). However, increasing the number of pixels helps capture finer details even in the darker / brighter areas. See an example from our tests:

The worst is the SD, even though it is a true WDR. The 5MP non WDR beats it simply because it captures more details. Finally, the HD camera with true WDR performs the best.

While more pixels can hurt night time imaging, it helps WDR. It is an important element in understanding today's top performing WDR cameras. However, he biggest one for 'true' WDR cameras is multiple exposure functionality.

WDR Implementations - True vs Fake

Since the main challenge for WDR scenes is setting the exposure appropriately to capture both dark and bright areas, the most common viable solution is to use multiple exposures and then combine them to produce a better quality image. The short exposure captures the bright areas, while the long exposure captures the dark areas. See representation below:

In our testing, this is the core strength of all top performing WDR cameras.

While we recommend looking for WDR cameras using multiple exposures, this is not sufficient. The number of exposures used and the other image processing techniques implemented can also make a difference. However, none of these are typically revealed.

Multiple Exposure Issues in Low Light

A common downside of multi-exposure WDR implementations is worse performance in low light. Using multiple exposures typically restricts how slow a shutter can be set. However, when it is dark, slower shutters bring in more light, producing a brighter image (though go too far and you have bad motion blur).

When using WDR cameras, make sure that WDR is disabled at night for maximum low light performance. Some cameras do this automatically, others allow for manual configuration and a few have no option. This is an important element to check if low light is a priority for the location deployed.

Pixim

Perhaps the best known classical WDR cameras use Pixim chips. Pixim says they set the exposure individually for each pixel, rather than just using 2 or 3 exposures for the whole scene. While this many deliver better image quality in an SD only world, Piximhas no MP offerings. In our testing, true MP WDR cameras have surpassed Pixim. [Note: In 2012, Sony acquired Pixim and there may be new Pixim HD offerings in the future but nothing is announced.]

Pseudo-WDR Techniques

Two other pseudo-WDR techniques are often claimed by manufacturers as being alternatives. However, they are weak ones at best:

- BLC, or back light compensation, simply adjusts the (single) exposure of a camera. This is useful only when you want to capture just the bright or dark areas of the scene but not both. By using BLC, you will make one portion of the scene better at the expense of the other being worse.
- eWDR, or electronic WDR, (sometimes called dWDR for digital) represents image processing attempts that do not come close to true WDR capabilities. Be careful if you see claims of 'eWDR' or 'dWDR'.

Same Manufacturer - WDR vs Non WDR

When a manufacturers offers 'true' WDR, that version typically offers substantially better performance in harsh lighting conditions than the non WDR version. On the other hand, it is often costs a few hundred dollars more than the non WDR version.

Here is a comparison of Axis WDR vs non WDR:

And here is a comparison for Sony:

Note: Do not compare the Axis and Sony as these shots are from different tests/times. For head to head comparison, see the Axis 1604 vs Sony WDR results.

Even within a manufacturer line, be careful of how manufacturer's use the term 'WDR' to market their cameras. See this example of Axis WDR vs WDR.

Test your knowledge

Take this 8 question quiz now

Update: WDR Manufacturer Cheat Sheet and Camera Tracking

Because manufacturers can be cryptic about WDR support, we have put together a list of 14 manufacturers detailing whether they support 'true' (multi-exposure) WDR, 'fake' (digital/electronic WDR), or both. We also provide notes to marketing specifics, naming conventions, etc.

All 14 manufacturers have cameras that support 'true' WDR, while half of them also have cameras that support digital WDR.

Manuf.	True WDR	Digital WDR	Notes
ACTi	Superior WDR Extreme WDR	Basic WDR	All cameras marketed vaguely as "WDR"
Arecont	WDR	N/A	2 and 3MP models ending in 6
Avigilon	WDR	N/A	Only in 3MP models (3.0W-H3-*)
Axis	Dynamic Capture Forensic Capture	Dynamic Contrast	True WDR in select Q and P series only
Bosch	HDR	N/A	True WDR in 932 models only
Dahua	WDR Advanced WDR Ultra WDR	DWDR	See notes below.
Geovision	WDR Pro	WDR	All cameras marketed vaguely as "WDR"
Hikvision	WDR	DWDR	True WDR model numbers contain "FWD", e.g., DS-2CD864**FWD**
IQinVision	WDR	N/A	Model numbers containing "W", e.g., IQ862**WE**
Panasonic	Super Dynamic SDII SDIII SD5 Mega SD Enhanced SD	N/A	Variants differ by number of exposures and other processing.
Pelco	SureVision SureVision 2.0	N/A	VGA-1.3MP SureVision models, SVGA-3MP SureVision 2.0 models
Samsung	WDR Advanced WDR	SSDR	Current Wisenet III models simply called WDR. Previous true WDR models marketed as "Advanced WDR."
Sony	View-DR Dynaview	N/A	View-DR included in all 6th generation cameras regardless of series (V, E, or X)
Vivotek	WDR Pro WDR Pro II	WDR Enhanced	See notes below.

Note, we have also verified and compiled which cameras are true WDR and have added them to our Camera Finder (under imaging, select WDR = Yes).

Here are lists from our Camera Finder:

- 300+ cameras with true multi-exposure WDR
- 200+ dome cameras with true multi-exposure WDR
- 30+ cameras, under $400, with true multi-exposure WDR

For further details regarding this list and additional manufacturer specifics, please read our WDR Manufacturer Cheat Sheet and Camera Tracking update.

HD Analog vs IP Guide

In the past, the only way to get megapixel / HD was to use IP. Now, a crop of alternatives are emerging including SDI, CVI, TVI, 960H, to name just a few.

Here is a high level overview of how they compare:

	Digital		Analog HD			Analog SD
	IP	SDI	AHD	CVI	TVI	960H
Encoding	Camera	Recorder	Recorder	Recorder	Recorder	Recorder
Transmission	Digital/IP	Digital	Analog	Analog	Analog	Analog
Resolution	30MP+	1080p	1080p	1080p	1080p	"SD+"
Advanced Features	Most	Least	Least	Moderate	Moderate	Least
Recorder Compatibility	Add software	New Hardware	New Hardware	New Hardware	New Hardware	New Hardware
Coax Compatibility	Low	Moderate	High	High	High	High
Vendor Support	High	Very Limited	Moderate	Moderate	Moderate	Moderate
Cost	Moderate	High	Low	Low	Low	Low

Inside, we break down each of these 8 key factors, explaining how the 5 main options compare and contrast for each.

HD Analog Variants

For those unfamiliar, we review the basics of each type of HD analog type here. All have slightly different feature sets, and previous differences were greater, but AHD, CVI, and TVI all now claim to provide 1080p30 video over 1,500'+ of RG-59 cable, the typical cable used in analog camera installs.

AHD

Analog High Definition (AHD) was developed by Korean chip manufacturer NextChip, originally specified with a max resolution of 720p, but increased to 1080p in its second version. Historically, AHD has had very little manufacturer support, with the majority of product coming from cheap, no name, import brands.

Because of these limited options, tech support and availability were limited in North America. However, well known brands such as Digital Watchdog and Samsung have now released AHD product, making it a more viable option. We plan to test both manufacturers' AHD gear in the near future.

AHD performed similarly to CVI, TVI, and IP in our tests in terms of image quality and cable compatibility, though was limited to 720p at the time.

CVI

HD-CVI (Composite Video Interface) was developed by Dahua and was originally exclusive to them. However, it has since been licensed to others via HDcctv 2.0 specifications, with some non-Dahua CVI product slowly becoming available.

The major sources for CVI product in North America (where Dahua branded product is unavailable) are FLIR, Honeywell, and Q-See, which all OEM various camera and recorder models, as well as a handful of lesser known brands.

In our tests, CVI provided image quality similar to other HD (IP, TVI) cameras, with the few issues using long or poorly terminated coax cables as well as UTP.

TVI

Chip manufacturer Techpoint developed HD-TVI (Transport Video Interface), which has been adopted by several manufacturers, the largest of which is main Dahua competitor Hikvision. Others, such as KT&C, CNB, Speco, and smaller manufacturers have adopted it, as well.

In its initial release, HD-TVI had major issues using UTP or long coax cables. However, this was remedied in second generation chips, with performance similar to HD-CVI and AHD.

Encoding/Transmission

All surveillance is encoded and compressed (typically today into H.264). The key difference amongst these offerings is where the compression is done.

In IP cameras, compression (e.g., H.264) is performed inside the camera. In others, compression is performed on the server side (e.g., recorder, encoder, video server, etc.).

This is a major driver in performance differences.

Advantages of Encoding In the Camera

- Bandwidth is essentially 'unlimited'. Because the video is compressed (typically using H.264) in the camera, the output can be 3MP, 5MP, 10MP, 20MP or more and can easily 'fit' inside standard networking infrastructure (e.g., 100Mb Ethernet).

- Advanced features can easily be added as the same computer that compresses the video, can compress audio, dewarp fisheye panoramics, support multiple imagers, perform video analytics, etc.
- No specialized hardware is needed on the receiving side. Since the video is compressed typically in standards-based H.264, all the VMS / client / recorder needs is open source software to decode / display. Connecting to the camera is driven by the IP camera manufacturer's API or, increasingly, ONVIF. By contrast, when encoding on the server side, specialized hardware always needs to be provided, which limits backwards compatibility and recorder support.

Main Disadvantage of Encoding In the Camera

Every camera needs to have the processing power / hardware to encode instead of just adding it to a single or a few recorders / encoders which then handle encoding for multiple cameras. This increases the cost of the camera.

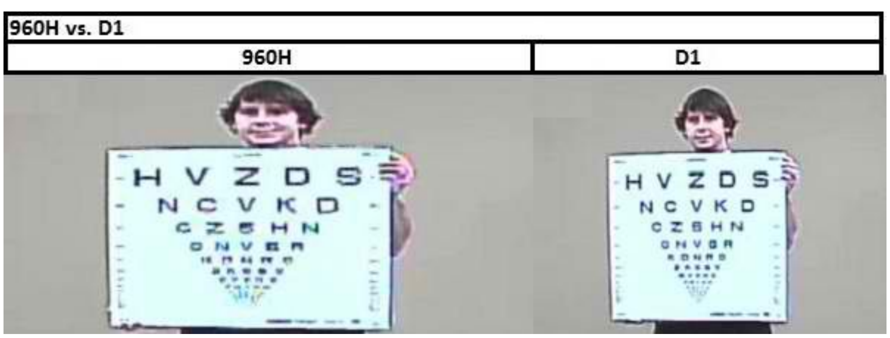
Along with this increase in cost, every camera is now a computer. With the benefits of cameras being a computer come the downsides of computers - increased complexity, potential for software incompatibilities, need for integration, etc. These issues are simply not present in analog (HD or SD) cameras.

Resolution

IP has a large lead in maximum resolution / pixel count capability. While IP cameras are now commonly available at 4K (8.3MP) resolution, 12MP, 30MP, and higher, HD analog's highest resolution is 1080p on all variants. However, HD analog manufacturers are now talking about 3MP, 5MP and even 4K resolution support in 2016, though none of this is official nor released as of September 2015.

On the other hand, while these higher resolutions increase flexibility, many would argue that practically speaking, 1080p is high enough resolution for most applications.

Note that despite manufacturer claims of using megapixel sensors and super high res images, 960H (and other SD variants) is worst, as it is not truly megapixel and, in our tests, is really just NTSC / PAL video stretched out.



Advanced Features

IP has a large lead in advanced features, given that IP cameras are basically computers with cameras attached and can therefore include all sorts of advanced processing (audio, fisheye dewarping, support multiple imagers, on board video analytics, etc.).

CVI and TVI offer some features of IP such as I/O and two-way audio, as well as PTZ control and configuration up the coax. AHD and SDI do not.

Recorder Compatibility

IP cameras can be made compatible with any recorder or client by adding software, whether it is proprietary integration or the use of "standards" like ONVIF.

All other camera types require specialized receiver / encoding hardware. None of them can be added to older analog DVRs. New recorders (or encoders) must be purchased along with cameras. Increasingly, new AHD, CVI, and TVI recorders are able to mix and match inputs of NTSC / PAL analog with their own HD analog type.

However, HD analog types are not compatible with each other. For example, if you connect a TVI camera to an AHD or CVI recorder, you will get no usable video (likewise, with the other way around). We demonstrate this in this video:

Note: ***Click here to watch the video on IPVM***

Coax Compatibility

IP cameras require Ethernet over Coax (EoC) Shootout to run over legacy coax. These typically add $100 to $400 per camera.

All other camera types are designed to run over legacy installed coaxial cable, though the distance limitations claimed vary. CVI and TVI both claim "over 1,500'" using RG-59 (and with our tests validating that up to 1000'). In our tests, early TVI releases had some issues using long cable runs, but these have since been remedied in HD-TVI 2.0 chip releases.

Vendor Support

IP has massive vendor support, both in terms of number of manufacturers and range of form factors available.

SDI, despite being available for 5 years commercially, has poor support.

960H, though only launched in the past 2-3 years, has fairly decent support among traditional analog providers.

HD analog variants have varying support, having just been developed in the last 2 years.

- AHD has historically had the least vendor support, with only low cost or no name brands utilizing it. However, manufacturers such as Samsung and Digital Watchdog have now begun offering AHD product, as well.
- CVI has broad support amongst Dahua (the founder of CVI) and their OEMs (in North America, most notably FLIR, Honeywell and Q-See).
- TVI is supported by a number of companies, but by far the largest is Hikvision (and their OEMs).

Model Availability

In 2015, a key limitation for HD analog, despite their very low price, is the lack of higher end models. Most of the CVI and TVI cameras and recorders are low-end units. Cameras including advanced functions such as true WDR, super low light, etc., are rare, though increasing in number as Dahua and Hikvision release their second and third CVI/TVI generations (and so on).

We expect advanced product options to be much more common in the next few years, but for those who want premium camera or video management features, these are key limitations compared to IP.

Cost

IP camera costs are now moderately high, failing from extreme high prices in the 2000s and helped by lower cost Asian vendor expansion in the past few years.

SDI is fairly expensive, generally similar to IP, generally because of its low adoption.

AHD, CVI, TVI and 960H cameras and recorders are extremely inexpensive, even compared to similar entry level IP cameras, with prices starting at ~$40 USD for even 1080p cameras and recorders in the few hundred dollar range.

Install Simplicity

Connecting cameras to recorders is more difficult with IP than any of the non analog versions. With IP, each camera needs an IP address, the network needs to be set up directly, the tech needs to know IP to connect the cameras, and the VMS/recorder must support them, either via direct driver or ONVIF.

Experienced IT surveillance professionals will not find this a major problem. However, many non IT and traditional low voltage techs will find HD analog's "plug and play" installation much easier.

IP Leading, CVI and TVI Strengthening in The Low End

Unsurprisingly, because IP has had such a huge head start, it has a wide lead in resolution, features, vendor support and model support.

Both CVI and TVI have established themselves as real forces, especially in the low end / entry level part of the market, where their basic but real HD quality offering at much lower prices and reduced installation complexity make them quite attractive.

AHD's future remains to be seen. Previously, with only cheap vendors supporting it, CVI and TVI were more attractive options. However, with the added support of Samsung and Digital Watchdog, it may compete respectably with CVI/TVI, though their headstart in marketing and product may outweigh these vendors' backing.

HD-SDI is essentially dead, with no notable new releases or marketing efforts. 960H/SD analog appears to have a limited life, especially with incoming true HD analog rivals.

Thank You!

Thank you for reading this book.

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