WHITE PAPER

# VIDEO SURVEILLANCE TRADE-OFFS

## A QUESTION OF BALANCE: FINDING THE RIGHT COMBINATION OF IMAGE QUALITY, FRAME RATE AND BANDWIDTH

MOTOROLA

# EXECUTIVE SUMMARY

A 911 call reports a convenience store robbery in progress. Police arrive in minutes, but the robber has fled. The officers play back video from a pole-mounted surveillance camera that shows the culprit, a medium build sandy-haired male wearing a plaid shirt and jeans. As police search the area, the video is delivered to the Video Command Center, where the man is recognized by an officer as a known offender. His address is sent to teams of officers, who find the man hiding in a nearby alley and take him into custody without incident. Months later, before his trial, the man is confronted with the surveillance video identifying him and, on the advice of his attorney, agrees to plead guilty.

As video surveillance technology becomes indispensable in public safety and law enforcement around the world, one thing is clear: image quality is paramount. The benefits of video surveillance – from monitoring and real-time protection to investigation and evidence preservation – are largely dependent on the quality of the images transmitted by digital video surveillance cameras and networks. To balance the need for high quality images with the need for affordable solutions, network designers and operators have to make certain trade-offs. In this discussion, we will introduce these trade-offs to help CIOs and other professionals understand the factors they must consider in planning and deploying efficient, cost-effective video surveillance networks.

## THE IDEAL

It would be great if every video and every image would offer an incredible amount of detail with full motion. The highest possible resolution would make faces clearly identifiable. Distinguishing features would be completely visible. License plates would be easily readable. High frame rates would provide smooth motion so you could tell exactly what was happening on the screen. Compression wouldn't be necessary so the videos would always be totally unaltered. So why can't we have this ideal? For one thing, in many cases, the technology is not yet available. For another, even if it is available or will soon become available, it will be extremely costly.

What are these ideal specifications? For super high clarity and detail, a system would need resolution that's sharper than HDTV, frame rates much higher than the movies and full color without compression. This requires many gigabits of bandwidth. What should be done? The situation must be carefully analyzed and trade-offs explored. Here's how the analysis usually works.

## QUALITY VS. AFFORDABILITY

In the best of all possible worlds, every video surveillance image would be clear, smooth, sharp and "just like being there" every time. In reality, designers of public safety video systems face a series of choices, or trade-offs, that balance video surveillance quality and effectiveness with bandwidth affordability. Based on the levels of image quality needed and available funding, video network operators must find just the right balance, making choices about bandwidth, resolution, frame rate and compression.

| OPTION | RESULT/IMPLICATION |
|---|---|
| Increase Bandwidth | Improves quality but increases cost |
| Reduce Resolution | Reduces cost but provides less detail |
| Reduce Frame Rate | Reduces cost but results in choppier motion |
| Use Digital Compression Techniques | Essential to all modern digital surveillance solutions to help balance quality and bandwidth needs |

## RESOLUTION

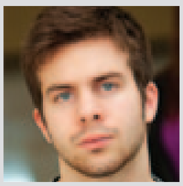
Resolution defines the size and sharpness of the picture. In many situations, high levels of detail may not be necessary. When security guards are monitoring video surveillance of a remote parking lot or the perimeter of a campus, they need to know that someone has entered an area where no one should be. They don't need to recognize who it is, they just need to know someone's there and be able to dispatch a response team. For applications like intrusion detection, traffic monitoring and crowd control, high resolution is likely to be both expensive and very often unnecessary.

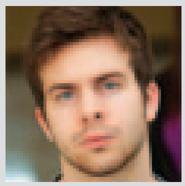
In other cases, of course, detail is of paramount importance. In particular, when video evidence is shown in court, faces should be recognizable and license plates readable. The issue is resolution, and that means a discussion of pixels.

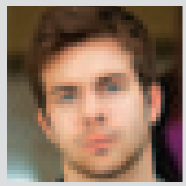
## A PIXEL PRIMER

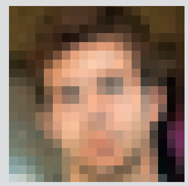
The measurement for resolution is Pixels Per Foot (PPF). A pixel, or picture element, is defined as the smallest piece of information in an image, usually in the form of a dot. As a rule of thumb, the minimum number of pixels to recognize faces is 40 PPF; the minimum number for reading license plates is 80 PPF. Distance from the camera also plays a part. If the subject is far away from the camera, it will be a smaller portion of the overall image; that means fewer pixels are available, so resolution will suffer.


ORIGINAL IMAGE

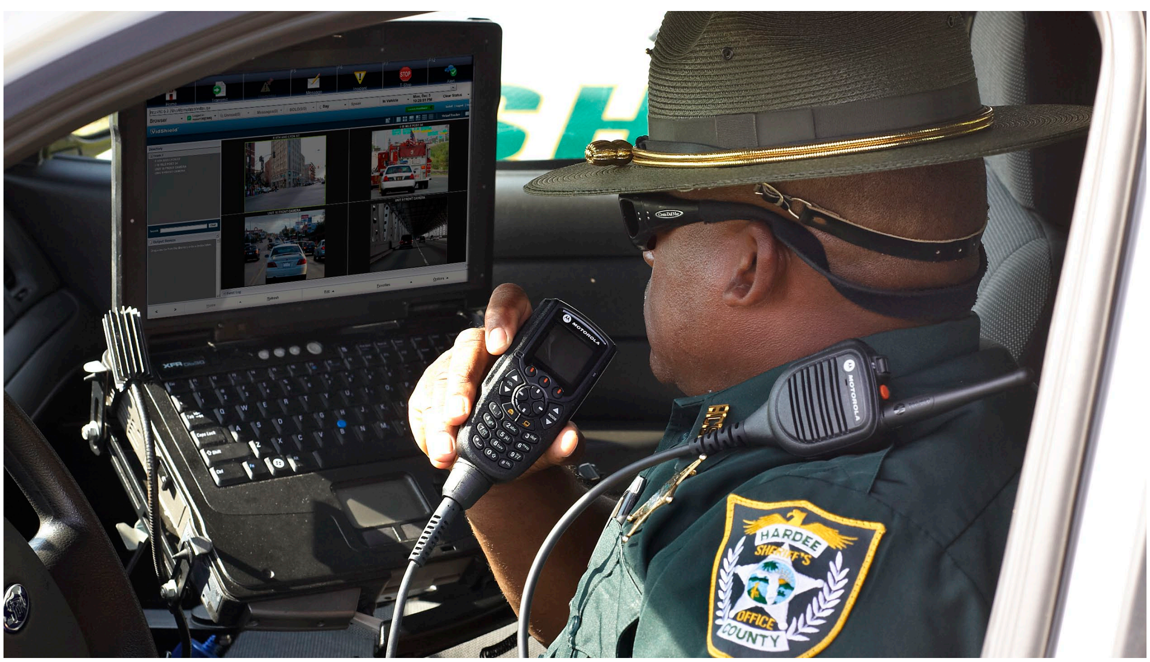

80 PPF


60 PPF


40 PPF


20 PPF

Why is higher resolution more costly? PPF is a one-dimensional measure, but pictures are two dimensional. The number of pixels in a picture is proportional to the square of the PPF. That means the 40 PPF needed to recognize a face is actually 40x40, or 1600 pixels (a face is roughly one square foot in area). To display the 80 PPF that permits license plate readability, the same picture must be 80x80, or 6400 pixels. The more pixels, the more information to be sent over the network, and that means more bandwidth.



## CAMERA RESOLUTIONS

The more area covered by a camera – whether analog or digital – the higher the pixel resolution needed. Digital cameras with Pan-Tilt-Zoom (PTZ) capabilities, although more costly, offer one way to mitigate this requirement. Zooming in on an object narrows the field of vision without affecting resolution. That means optically zooming in on an object effectively increases available PPF. (Digital zooming has no effect on resolution.) Of course, PTZ capabilities involve a trade-off too: while panning or zooming in on one area of the screen, you may be missing out on something else. For example, if you're zooming in on a breach in a fence, you may be missing a car as it leaves the scene.

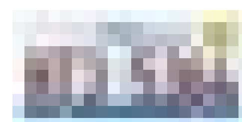
Bandwidth requirements grow with resolution so the higher the resolution, the higher the bandwidth and storage capacity needed.


ORIGINAL IMAGE


80 PPF


60 PPF

40 PPF



20 PPF


## FRAME RATE

The term "frame rate" comes from the film industry. Film is composed of a series of frames, each containing an image. These images are displayed in rapid succession, putting the "motion" into motion pictures. In the 1930's, Hollywood decided on a standard frame rate of 24 frames per second (fps), which was determined to be the lowest acceptable speed for viewing a movie. Lower speed means less film used, therefore it's less expensive. Trade-offs – the necessity of balancing quality and cost – were around back then, too.

What happens when frame rates are reduced? At speeds down to about 15 fps, the motion becomes jerky but the eye can understand what's happening (silent movies were often projected at 16-18 fps). At speeds under 10 fps, the eye perceives only a series of still photographs with no motion.

## FRAME RATE TRADE-OFFS

Because video surveillance is not being used for entertainment, the optimum frame rate should be determined by the specific task at hand. Sometimes an application demands full-motion video of 30 fps or more. These high rates are normally used to capture high-speed events of short duration. For example, casino security generally uses high-speed cameras to detect suspicious activity at the gaming tables.

Other applications, such as live viewing, work well at lower frame rates. In most cases, video being viewed live should be shown at 24-30 fps. At lower speeds, the jerky motion can cause fatigue and eyestrain, while higher speeds are unnecessary because the increase in quality will not generally be perceivable to the human eye. Similarly, high resolution in terms of more pixels is also unnecessary for live viewing, since the eye will normally not notice the small details lower resolution may hide. In this situation, it is inefficient to trade lower frame rates for higher resolution.

For video being recorded for later review, it's best to choose higher resolution over higher frame rate. Even at 5 fps, there are 5 images for every second of action, allowing plenty of time to capture events. The higher resolution allows viewers to see a suspect's face clearly, read a license plate, note the make and model of a vehicle and look for identifying marks.

On some video systems, it is possible to increase or decrease frame rate and resolution on the fly, in response to need. This new equipment allows operators to transmit video to a monitor at 24-30 fps at lower resolution and then switch to 5 fps with higher resolution for storage and retrieval.

Certain video intelligence systems can adjust video in real time in response to available bandwidth and client capabilities, ensuring that video gets through even in challenging conditions.

## THE COMPRESSION SOLUTION

In general, the higher the resolution and frame rate, the more bandwidth is needed and the costlier the system becomes. The use of compression, however, helps retain higher image quality while reducing bandwidth and cost. Compression is performed by a computer program that, through a series of algorithms, exploits redundancies and eliminates "unimportant" or redundant data to reduce bandwidth requirements without viewers being aware of any changes.

As effective as compression is, however, there are still trade-offs for network designers to consider. Compression works by permitting the encoder to throw away data it deems to be unimportant. Most compression is based on the idea that a person will be watching the video like a movie, not examining details for evidence. The more aggressively compression programs work to reduce bandwidth requirements, the more information is thrown away. Once again, it's a trade-off.

## TODAY'S COMPRESSION FORMATS

Compression is based on similarities between neighboring pixels in the image or the differences between frames, as well as on the limitations of human perception. There are a number of compression methods, each operating slightly differently and offering competing strengths and weaknesses. Today's most common compression include:

### MJPEG

Like film, the MJPEG format is a series of pictures, each of which is individually compressed. MJPEG selects image blocks of pixels of similar color and assigns them the identical color. MJPEG then breaks the frame into smaller blocks, and mathematically reduces the data required to describe each block, taking advantage of the limits of the human eye.

In the MJPEG format, although details are reduced, images are generally free from unexpected visual anomalies like missing parts of objects that can occur under certain conditions in compression schemes that use inter-frame compression, such as MPEG-2 and MPEG-4.

One MJPEG factor limits its use in video surveillance applications: it nearly always requires more bandwidth than newer formats. By using MJPEG compression, organizations lose the important cost savings opportunities inherent in the use of lower bandwidth to monitor non-changing environments like parking lots or remote locations.

### MPEG-2 and MPEG-4

MPEG-4 is today's most commonly used compression scheme. MPEG-2 is an older version still in use in some applications. MPEG compression takes advantage of similarities between frames. It works by periodically sending full picture frames, compressed similarly to MJPEG, at a low frame rate. In between these full pictures it sends small messages noting changes to the frame. MPEG compression is used in most of today's consumer video technologies such as DVDs and HDTV.

MPEG formats have a lot to offer. First of all, they are highly customizable. MPEG-4 offers features to handle transmission interruptions. But most important, MPEG formats almost always use less bandwidth than MJPEG compression. It is, however, still vital to provide adequate bandwidth for MPEG formats. Why?

If bandwidth is grossly inadequate, data may be lost in transmission and visual anomalies can occur. Although they may not be noticeable in casual viewing, tiny inconsistencies like figures in the background showing up in two places at once and detached arms or legs briefly appearing, create impossible-looking images that damage credibility and can lead to reasonable doubt in the minds of juries.

### H.264

The compression technique used in Blu-ray discs and other high definition video applications is H.264. Technically part of the MPEG-4 standard, H.264 applies the same compression principles but uses far more advanced algorithms. Much like all MPEG formats, it requires adequate bandwidth, although it needs less bandwidth than MPEG-2 or -4. The results are the high-quality images and smoother video of MPEG-4, but using approximately 25 percent less bandwidth. H.264, however, does require substantially more processing power to encode and decode the data, which adds to cost.

## HOW MUCH QUALITY DO YOU NEED?

How much protection do you need? How important is it to recognize faces or read license plates? Are you more interested in the fact of an intrusion than who is doing the intruding? In other words, what level of video quality is necessary to get your specific job done? Video trade-offs are predicated on the level of quality needed for success. Then and only then can you build exactly the right amount of balance into your video surveillance network and applications.

## TRADE-OFFS: RESPONSE ALTERNATIVES TO INADEQUATE VIDEO BANDWIDTH

| RESPONSE | ADVANTAGES | DISADVANTAGES |
|---|---|---|
| Reduce image resolution | Although noticeable, there is a nearly proportional drop in required bandwidth. | Loss of picture detail. Increased likelihood that some details will not be resolved. Face recognition or license plate reading may become impossible. |
| Reduce frame rate | Reduces bandwidth requirement without loss of picture detail. | Makes video more difficult to watch live, increasing fatigue. Modern compression means that payoff in bandwidth will probably be low. Increased likelihood of missing something. |
| Use more aggressive compression | Reduces required bandwidth, possibly by quite a bit. | Reduces picture detail, particularly when action/motion is taking place. Transmission gaps can result in anomalies that look strange and damage the video's credibility in court. |
| Use more advanced compression (i.e. MPEG4, H.264) | Reduces required bandwidth without sacrificing picture detail or video quality. | Requires newer hardware and software that cost more money. |
| Add more bandwidth | Allows higher-quality video to be transmitted, permitting a higher frame rate, higher resolution, less aggressive compression, or a combination of all three. | Costs more money, may require regulatory approval and could be difficult in some areas. |
| Store video in the same location as the camera, in addition to transmitting the data elsewhere. (Digital Video Recorder at the edge) | Allows high-quality video to be retained, without deploying more bandwidth. Video can be retrieved if needed, e.g. for a court case. | Video has to be downloaded or physically retrieved before it's deleted or overwritten, or the equipment is damaged. This is costly and can create personnel safety concerns. Costs grow in proportion to the number of cameras. |

There's no getting around it. Surveillance and other video applications are bandwidth-intensive. You will need to evaluate the strategies for minimizing video bandwidth requirements and costs, as well as consider a number of other challenges associated with deploying and operating a real-time video system.

Motorola understands the unique public safety environment and has the expertise and experience to help you design a system hat meets your needs. To learn how Motorola helps government and public safety agencies create robust video surveillance solutions that maximize quality while minimizing cost, visit **motorola.com/videosurveillance**.

Motorola Solutions, Inc. 1301 E. Algonquin Road, Schaumburg, Illinois 60196 U.S.A. **motorolasolutions.com**



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