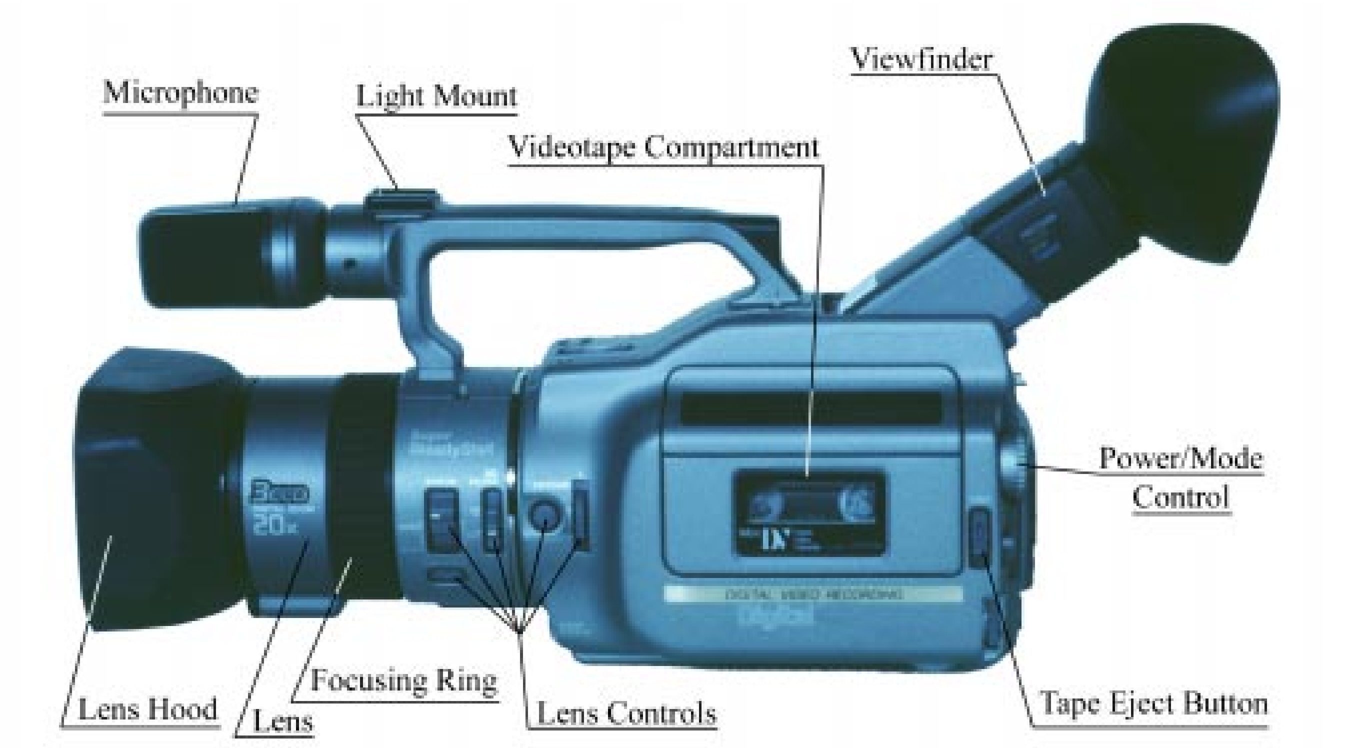

Figure 9. Left side of a typical digital video camcorder

Auxiliary microphones and jacks for special applications: Many camcorders will accommodate the use of auxiliary microphones if the built-in microphones are not adequate for special applications. A desirable characteristic of some camcorders is the existence of a separate jack for the auxiliary microphone. With the jack, it is not necessary to remove the basic microphone from the camcorder. This keeps that microphone stored on the camcorder and eliminates the chance of it being misplaced. Wireless microphone sets, like the Vivitar WMK-2 Wireless Mike Outfit, transmit over radio frequencies for hundreds of feet and are capable of transferring clear audio through typical doors and walls.

Battery type: The ability to use batteries allows portability. Equipment might use rechargeable batteries (e.g., nickel-cadmium or lithium-ion) or single-use batteries (e.g., alkaline). See NIJ Guide 200-98 for more information on batteries.[3]

[3]NIJ Guide 200-98 and other NIJ guides can be ordered from NIST/OLES , 100 Bureau Dr., Stop 8102, Gaithersburg, Maryland, 20899-8102.

Book mark search: With this feature, one may return to the point where recording had previously ended.

Day/time setting: A built-in calendar and clock allows each recording to be "stamped." A "button cell" battery keeps the date and time correct.

DV in/out jacks: Many digital camcorders have a special jack for digital video input and output. These input and output signals are most frequently based on IEEE Standard 1394, also known as "FireWire." Personal computer interface kits can be purchased from both Sony and Canon that will allow digital video to be downloaded from one of these camcorders to a PC.

Edit controller interface: *LANC* is the most widely available interface for camcorders.

Fade control: When this control is activated, the picture in the viewfinder of a camcorder and on the tape will fade out. When the control is disengaged, the picture will automatically fade back in.

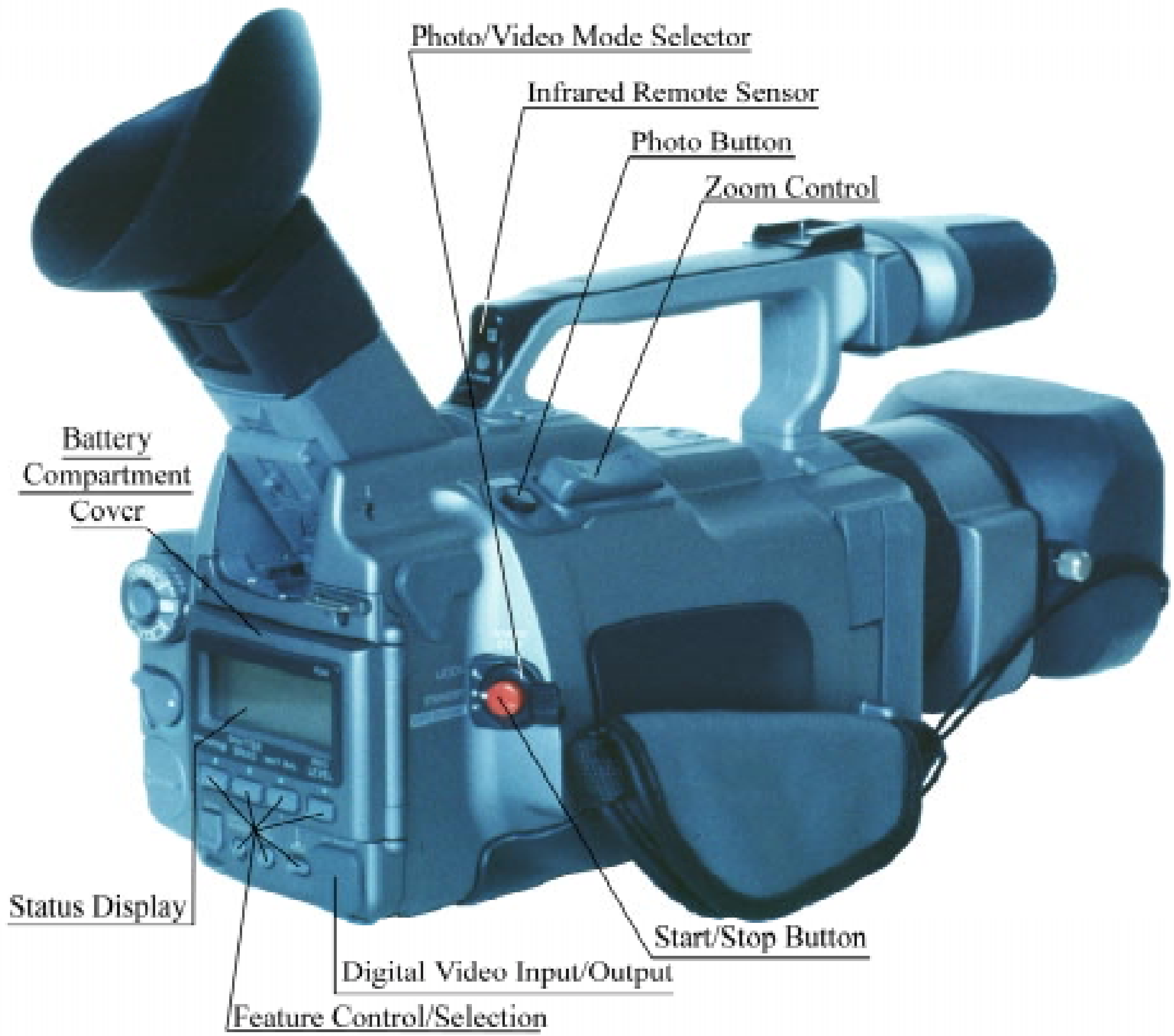

Figure 10. Right side and rear of a typical digital video camcorder

Flying erase head: Allows user to make exceptionally clean edits of the video tape. Video and audio "dubbing" (i.e., changing) is possible.

Headphone jack: Usually a 1/8 in stereo phono jack.

High speed shutter switch: Allows the camcorder to capture and record high speed activities for slow motion or still playback. Speeds might include 1/250 s, 1/500 s and 1/1000 s.

Image stabilization: Optical or electrical.

Index search: An index mark can be placed at the beginning of each recording so that automatic review and playback can be accomplished easily.

LCD monitor: Provides viewfinder information in a larger screen so camcorder does not have to be held to the eye. Typical sizes range from 2 in to 4 in, color or black and white. Figure 11 illustrates a camcorder with both LCD monitor and viewfinder.

Light source: Built- in or accessory.

Macro control: This is used to unlock the zoom lens on a camcorder so that it can be used to get in-focus close-ups of subjects normally too close to shoot.

Motion sensor: Useful for situations requiring constant surveillance but where a low activity rate does not justify constant recording. Motion sensor activates recording function. Audio sensors are also available.

Table 5. Price Ranges for Various Video Surveillance Equipment Formats

Video Format	Resolution (Lines)	Price Range	Note
VHS	240	$200-$5,000	
VHS-C	240	$700-$1,500	1
Super VHS	400	$900-$6,500	
Super VHS-C	400	$1,200-$3,500	1
Beta	260	$2,000-$3,500	2
ED-Beta	400	$2,500-$4,000	2
8 mm	300	$700-$2,000	
Hi-8	400	$1,200-$3,500	
U-matic	300	$4,000-$15,000	2
Betacam™	320	N.A.	
Betacam™-SP	450	$15,000-$40,000	
C	600	$40,000-$160,000	3
Digital Component			
D1	700	$120,000-$180,000	3
D5, MII	700	$50,000-$70,000	3
Digital Betacam™	600	$25,000-$51,000	
Betacam™ SX	600	$23,000-$48,000	
DVCPRO50	500	$9,000-$50,000	3
DVCAM	450	$4,000-$20,000	
DVCPRO	450	$5,000-$30,000	3
Digital Composite			
D2	600	$40,000-$90,000	3
D3	600	$45,000-$55,000	3
Mini-DV	400	$800-$5,000	1

Notes: 1. Includes price of camcorders only.
2. Beta and U-matic formats are not recommended for new equipment purchases because of the short projected support lifetime of these products.
3. Includes price of player/recorders only.

Multiple heads for still frames/slow motion playback: Video head design is an area where significant improvements have been made in the past 5 years. In simple systems, one video head is required to record and playback the video track. Multiple heads have been added to improve quality at different speeds, with some units automatically switching the output from head to head to maximize the amount of signal that can be recovered from a tape. As a result, noise-free still frames and slow motion effects can be produced. It is also possible to have less noise (snow) in the picture scan mode.

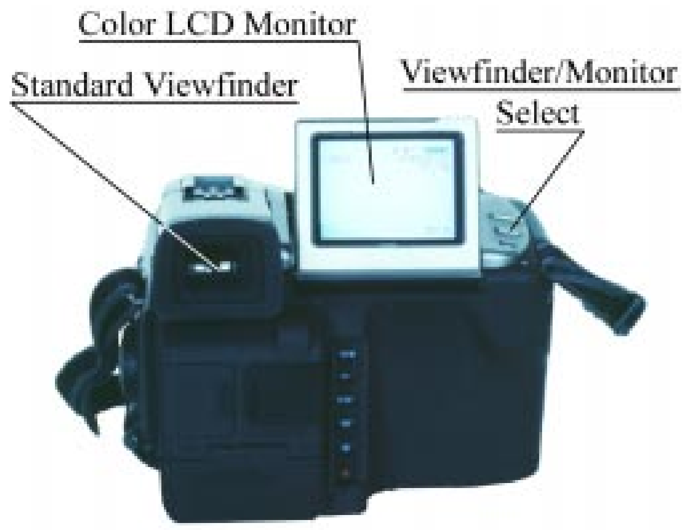

Figure 11. Example of a camcorder with both a viewfinder and an LCD monitor

Multiple start/stop buttons for diverse operating conditions: Some camcorders have more than one "start/stop record" button – the Ricoh R800 for instance. One button is found in or near the grip and the zoom switch. The other button is located on or near the lens barrel, for use when the camera is in a low position and a normal grip is impractical.

Noise reduction: Improves the picture quality in marginal lighting situations.

Optical and digital zoom: Many camcorders, especially digital camcorders, provide a combination of optical zoom and digital zoom. Optical zoom is the traditional method of providing zoom lens capability. It is achieved through rearranging the distances between some of the optical elements of the lens. As the magnification of the subject increases, generally the camcorder loses some of its light sensitivity. Digital zoom is achieved by expanding a small area of the image pickup device (specifically a CCD) to fill the whole screen. This generally results in a loss of image sharpness and/or resolution.

Photo mode: Usually available on digital camcorders, less frequently on analog models. This feature allows a single frame of video to be recorded across several seconds of tape.

Remote controls: Typically using wireless technology, remote controllers can start and stop recording and even control zoom functions.

Self timer/time-lapse recording: Self-timers are an attractive feature for surveillance that involves predictable patterns. Camcorders and recorders can be programmed to start and end at a certain time, or to record only 1 s each minute for several hours.

Sensitivity/gain-up controls for shadows: "Sensitivity/ gain-up" controls or buttons are intended to increase the brightness in scenes that need it. The better sensitivity mechanisms have made shadowed images 50 percent to 80 percent brighter with little increase in noise or distortion (graininess in the image).

Special effects (Special FX): Examples include fades, wipes, solarization and posterization. These functions produce interesting visual effects but are probably not very useful for surveillance applications.

Tape and time counter: Displays a number reading for the position on the tape or the elapsed time during a recording. Time remaining may also be displayed.

Wireless playback: Using wireless technology (e.g., infrared transmission), camcorder recordings are played back using a display that has an appropriate receiver (typically supplied) for the wireless transmission.

Titling: Annotations of various lengths and types can be added to the tape.

3.3.3 Camcorder Accessories

In addition to the features that come directly with a camcorder, other accessories can be purchased that make the tedious and difficult operational tasks of the camcorder a little more tolerable. A few are listed below. Others are available where video equipment is sold.

Supports

Even with a small camcorder, it is a chore to hold it in front of you for any period of time. Fortunately, certain devices are available to help you carry your camcorder. One such device is called SteadyCam™, and another is called Glidecam™. These units have a harness that attaches the camera and steadying mechanism to the body and an arm that holds the camera out in front of you and swings to the side. The user has both hands free to manipulate the camera or camcorder. The price of such an equipment aid varies from about $200 to about $4,000, which may be well justified if several hours of "hand-held" video taping is needed.

Another type of support is a basic shoulder mount. This kind of item comes with a padded shoulder rest and handle and costs about $200. The tripod mount of the camcorder is attached to the product which allows the camcorder to be adjusted back and forth to suit the user's eye position. Some may find this device awkward to use and somewhat less comfortable than a harness system, especially if the camcorder is long or front-heavy. An example of a shoulder mount product is the Videosmith's MightyWonderCam™.

The conventional tripod is yet one more type of support product. Unfortunately, many of the sturdy tripods tend to be bulky and awkward to carry. A number of products on the market, however, including the Cullman Video Magic Tripod, use aluminum materials and good folding designs so that units weigh less than 3 lb and can be collapsed into a very manageable 14 in x 6 in x 1½ in shape. The Cullman product also includes a built-in monopod, a two-way pan head with handle that allows easy and fluid panning. The Cullman unit has a manufacturer's suggested retail price of about $200.

Auxiliary Monitors

Most camcorder viewfinders are quite small in size (about an inch square) but provide the user with a relatively good image of the scene in view. At the same time, they can provide much data about the current operation of the camcorder (e.g., time remaining on the tape, manual or auto settings, and battery condition). With all of those data appearing and the necessity to concentrate on the scene to be recorded, some users may prefer to deal with a larger display. Some camcorders come with larger displays in addition to or instead of the traditional viewfinder. For those camcorders that do not have a larger display built-in, auxiliary monitors, which fit on the accessory "hot shoe" found on many camcorders, offer one way to see a larger color image of the scene. They also allow the user to review camera settings and status without constantly glancing down into the viewfinder. One such monitor is the Citizen LCD Color Monitor. It weighs only 6.3 oz, has a 3 in diagonal screen, and can be powered by AA batteries (for 3½ h), battery pack, or AC.

Environmental Enclosures

To expand the utility of camcorders, many companies offer environmental enclosures for cameras and camcorders. These range from simple rain covers to underwater enclosures. Rain covers vary in price from $50 to several hundred dollars, depending on manufacturer, degree of protection, and features (some come with heaters!). Underwater housings vary in price from $600 to several thousand dollars, depending on manufacturer, depth rating, and camcorder model.

Video Capture Cards

With the advent of "multimedia computing," a large number of computer interface devices have become available that allow video to be imported into a computer for inclusion in reports, presentations, and to be printed on computer printers. The devices are varied and command a wide range of prices. At the bottom end is the Snappy Video Snapshot, a device that hooks to a computer's printer port and converts a composite analog video frame to a computer image. More elaborate systems include cards that plug into the expansion slots inside the computer. These cards might have video input/output jacks and record full motion video to the computer's hard drive (e.g., Data Translation Broadway Beginner).

For digital camcorders with a DV interface, there are special kits available from the manufacturers of the digital camcorders to allow easy download of the digital video from the camcorder to a personal computer. One example is the Canon Video DK-1 DV Capture Kit. The kit includes an IEEE 1394 interface card for the computer; a cable to connect the digital camcorder to the computer; and software to control the digital camcorder, download images, and save the images to disk.

3.3.4 Format Applicability to Surveillance Requirements

Following are several tables that provide information on what type of equipment would be applicable to specific surveillance conditions. The equipment recommendations conveyed in the tables are oriented toward the need to perform real-time information collection. Equipment not meeting these requirements are not shown in the tables. For example: while a monitor/television is required to display information on a videotape, it is not necessary to be able to view the tape in great detail at a crime scene. However, for some surveillance applications, such as where a high power or amplified light lens is being used on a camera, a monitor may be necessary to make sure the subject is being properly recorded for later presentation (e.g., in court).

Table 6 provides a list of video equipment applications along with recommendations on what equipment types would produce meaningful video data. Table 7 provides a bit more focused detail by recommending equipment based on specific surveillance performance requirements.

A note of clarification regarding table 7 is in order since standard VHS and 8 mm equipment was generally not recommended because of its lower quality (i.e., resolution). Higher-resolution Super VHS and Hi-8 equipment is now widely available at reasonable prices. If, however, cost is the most important factor in the decision of what equipment to purchase, the standard VHS and 8 mm formats should produce moderate results for any performance requirement where Super VHS and Hi-8 is specified.

Another consideration when determining what equipment will meet a performance requirement is light level. In all cases, camera resolution drops when light drops. The lowest light level in which manufacturers claim their cameras can acceptably record a scene varies from as high as 30 lux to less than 1 lux. Thirty lux corresponds to the lighting expected in an underground parking garage, and 1 lux would be equivalent to a medium sized dining room lit by two or three candles. It is the 1 lux rating of some of the camcorders available on the market that allowed them to be included as a possibility for meeting performance requirements in dim lighting conditions.

3.4 Monitors/Televisions

3.4.1 Technology Summary

Since computers and video equipment both use monitors, one might conclude that a computer monitor should work with a video camera system, right? However, this is not the case. Computer displays have a different function than the video displays used for industrial or broadcast video. The video systems used throughout the world for such purposes as recreation, news, education, and surveillance were designed and implemented to broadcast moving pictures. Motion tends to make humans focus their visual attention (and their need for sharpness) in the center of the screen, with the corners and edges of the screen treated as only a secondary concern. Video systems display objects that people recognize in real life. They also count on people to "help the images along" by using their experiences to fill in lacking details and color as required. This is often needed because video systems that people are most frequently exposed to, such as television, are medium-resolution black and white systems with a low-resolution color channel overlaid on the black and white image. Even the *"high-definition" television (HDTV)* systems proposed as the next generation of TV (that will have about twice the resolution of existing systems) will continue this approach.

Computer systems display static images of detailed information, such as words or numbers. Picture elements (*pixels*), which can be thought of as little dots of light, are grouped in patterns to form the lines, letters, words, numbers, and other symbols seen on a computer monitor. Information found in the corners and on the sides of a computer monitor is just as important as that found in the center of the screen. The graphics created by computers and their displays, although much improved from just a few years ago, still do not perfectly reflect natural things but tend to be abstract.

Table 6. Surveillance Applications and Recommended Equipment

Surveillance Application	Recommended Video Tape Formats[1]	Recommended Equipment Types[2]
Building/area access	V,S,8,H,F	C,T,M
Building/area security	V,S,8,H,F	C,T,M
Operation/protective detail coordination	S,H,B,C,D,E,F	C,T,M
Crowd monitoring	V,S,8,H,F	C,T,M
Monitor officer on routine stops	V,S,8,H,F	C,T,R,M
Monitor officer/suspect in dangerous situation	S,H,F	C,T,R,M
Monitor confinement areas	V,S,8,H,F	C,T,M
Record bomb squad	V,S,8,H,B,D,E,F	C,T,R,M
Record crime scene	V,S,8,H,B,D,E,F	R
Record forensic data	V,S,8,H,B,D,E,F	R
Record interrogations/polygraph examinations	V,S,8,H,B,D,E,F	C,T,R
Record physical evidence	V,S,8,H,B,D,E,F	R
Search and rescue	S,H,B,D,E,F	C,T,R
Airborne surveillance	S,H,B,D,E,F	C,T,R,M
Indoor surveillance	S,H,B,D,E,F	C,T,R,M
Outdoor surveillance	S,H,B,D,E,F	C,T,R,M
Vehicular surveillance	S,H,B,C,D,E,F	C,T,R,M
Video mug shots	V,S,8,H,F	C,T,R

Notes for Table 6:

1. Video Tape Format abbreviations: C = C; V = VHS and VHS-C; S = Super VHS and Super VHS-C; 8 = 8 mm; H = Hi-8; B = Betacam™, D = Digital Component, E = Digital Composite, F = Mini-DV. Beta and U-matic formats are not recommended for new equipment purchases because of the short projected support lifetime of these products.

2. Equipment Type abbreviations: C = Cameras; R = Camcorders; T = Video Tape Recorders; M = Monitors and Televisions.

Table 7. Equipment Recommendation for Various Surveillance Resolution Requirements

Surveillance Resolution Requirement	Recommended Video Tape Formats[1]	Recommended Equipment Types[2]
Facial ID at more than 200 m		
Daylight	B,C,D,E	C,T,M
Dim light	B,C,D,E	Special[3]
Darkness	B,C,D,E	Special
Facial ID at 50 m to 200 m		
Daylight	B,C,D,E	C,T,M
Dim light	B,C,D,E	Special
Darkness	B,C,D,E	Special
Facial ID at less than 50 m		
Daylight	S,H,B,C,D,E,F	C,T,R,M
Dim light	S,H,B,C,D,E,F	R,Special
Darkness	S,H,B,C,D,E,F	Special
Figure ID at more than 200 m		
Daylight	B,C,D,E	C,T,R,M
Dim light	B,C,D,E	Special
Darkness	B,C,D,E	Special
Figure ID at 50 m to 200 m		
Daylight	S,H,B,C,D,E,F	C,T,R,M
Dim light	S,H,B,C,D,E,F	R,Special
Darkness	B,C,D,E	Special
Figure ID at less than 50 m		
Daylight	S,H,B,C,D,E,F	C,T,R,M
Dim light	S,H,B,C,D,E,F	R,Special
Darkness	S,H,B,C,D,E,F	Special

Notes for Table 7:

1. Video Tape Format abbreviations: C = C; V = VHS and VHS-C; S = Super VHS and Super VHS-C; 8 = 8 mm; H = Hi-8; B = Betacam™, D = Digital Component, E = Digital Composite, F = Mini-DV. Beta and U-matic formats are not recommended for new equipment purchases because of the short projected support lifetime of these products.
2. Equipment Type abbreviations: C = Cameras; R = Camcorders; T = Video Tape Recorders; M = Monitors and Televisions.
3. Special implies that the equipment required to perform this function is highly specialized, such as low-light and low-light intensified cameras.

The difference in applications between computer monitors and video monitors will help explain the rationale behind the basic technical design of video monitors/TVs and why computer monitors would not work very well for video applications (even if the interfaces were compatible). Note that video monitors and televisions are considered to be essentially the same in this discussion, since the way video is formed, transferred, and received is fundamentally the same for both. To be more explicit, the monitor is like a TV receiver, with the picture tube and associated circuits but without the *rf (radio frequency) tuner* and *if (intermediate frequency)* section. A true monitor does not have antenna input connections to receive radio broadcasts but receives video from other sources via video input jacks. Several products are on the market that are combination monitor/televisions. Dual sets of connectors allow either TV or monitor applications.

The ability of a video monitor/TV to resolve an image, that is, to show the detail of the image, is limited by two *bandwidth* restrictions – approximately 4.7 MHz for the *luminance* (black and white) and 1.5 MHz for the *chrominance* (color) portions of the picture. These bandwidth figures apply to the *RS-170A* video standard used in the United States to define *NTSC video* (color television). The speci-fications were chosen to conserve radio frequency spectrum for the broadcast services, and because of the limitations of television technology at that time. These bandwidth limitations still apply regardless of how well the equipment is designed and built.

(Computer monitors, by the way, have a much wider bandwidth, typically from 20 MHz to 100 MHz. No real standards restrict the design of computer monitors; only technological and economic factors apply. With virtually an unlimited amount of bandwidth available, computer displays can show a tremendous amount of detail.)

For monitors, usually color is fed through 3 separate signals - red, green, and blue - with identical bandwidths. (The red, green, blue signals are where the acronym "*RGB*" comes from in video literature.) Picture tubes used in computer displays have a much smaller, highly-focused *electron beam spot size* and finer pitch screen surface than most video monitors/televisions.

Besides video bandwidth, another technical parameter that affects the “\definition, or the quality of detail on a display screen, is *scan rate*. The video picture is scanned in a sequential series of horizontal lines, one under the other, to permit one video signal to include all the elements for the entire picture. In effect, video pictures are reassembled line after line and frame after frame. For NTSC video, a total of 525 lines are required for the development of one picture (frame). All 525 lines are scanned in 1/30 of a second.

The higher the horizontal scan rate and video bandwidth, the higher the resolution. In addition, for a given horizontal scan rate, as the vertical scan rate decreases the level of detail increases because there are more horizontal lines used to make a complete image. Like the bandwidth, scan rates for NTSC video are specified in much detail in the RS-170A standard. The broadcast standard mandates a horizontal scan frequency (rate) of 15,734.263 Hz. This number is commonly referred to as 15.75 kHz. The vertical scan rate is fixed at 59.94 Hz and is normally called 60 Hz. For comparison purposes, computer monitors have horizontal scan rates between 15 kHz and 100 kHz. (Once again, no standards restrict the rate.) At 75 kHz, the computer monitor is almost five times faster than the video monitor.

Vertical scan rates for computer monitors run from about 40 Hz to 120 Hz, but many of the video cards available for computers today start with a default vertical scan rate at or around 60 Hz. This is a compromise between having the lowest possible vertical scan rate and having problems with people viewing the screen. Vertical scan rates below 60 Hz are somewhat of a problem for humans. If the scan rate is not fast enough to prevent the light emission from the phosphors in the display from decaying too far, the resulting variations in the brightness of the image can be seen. The varying *brightness* is perceived as a definite flicker.

With all of the constraints placed on video, it is no wonder that some people have compared the best resolution possible for a video monitor and a computer monitor to the difference in picture quality between a newspaper and a magazine, respectively. Nevertheless, beyond its image detail (*resolution*), a few more picture quality measures can be used to describe a good monitor's performance. Assuming it is synchronized to stay still, a color or monochrome (black and white) monitor's reproduced picture should also have high brightness, strong *contrast*, and the correct proportions of height and width (*aspect ratio*). Also, color sets should have strong color, or "*saturation*," with the correct *tints* or *hues*.

3.4.2 Monitor/Television Features

As mentioned above, many of the characteristics of video monitors and televisions are fixed by a recognized NTSC standard so that video broadcasts may be received equally well by all. Even so, monitors will be offered with various ratings for quality parameters as basic as resolution. Resolution for monitors/televisions will range from 200 lines to 300 lines[4] for inexpensive models found in the home to units with 400 lines or 500 lines for those with discriminating (and expensive) taste. Units with 800 lines to 1,000 lines are used in television broadcast studios. One way to gauge the resolution needed for a particular application is to be aware that the best resolution one can expect from over-the-air broadcast or cable TV service is 330 lines. If a "good" TV picture will suffice for a certain task using a monitor, it is not necessary to select one with more than 330 lines.

Other featured items to be aware of when contemplating monitors include:

Screen size: Measured diagonally, this can vary dramatically. Typical sizes run from about 8½ in through 20 in, but super-small and huge monitors are available, also.

Color or black and white presentation: Both are available at many resolution ratings.

Built-in speaker, jack for external speaker, headphone jack: Allows audio monitoring publicly or privately.

Selectable inputs: BNC-type coaxial cable and/or 8-pin video jacks for composite and RGB video are available. Switchable line, camera, and VCR input jacks may also be offered.

Monitor bridging: Selectors and connectors allow bridging to display video on multiple monitors simultaneously.

Synchronization signal: External input and output synchronization interfaces for when synchronization with a separate video device is required.

Front panel controls: Include brightness, contrast, vertical hold, horizontal hold, tint, and color.

Blue-only control: This displays only the blue electron beam for simplified adjustment of chrominance and hue using a color bar signal.

Comb filter: Integral to a monitor's design, a comb filter minimizes loss of resolution and reduces streaking and wavy edges on fine patterns.

Remote control: Wireless.

Input power: 120 VAC and DC versions are available.

Mounting options: Rack mountable.

Carrying handle: Folds down when not required.

Enclosure: Metal cabinet and magnetic shield ring reduces interference from other electronic equipment.

[4]The resolution of NTSC video equipment is measured by the number of vertical lines that can be distinguished (horizontally) across a frame of video. This is because (1) vertical resolution is fixed and (2) one gets an indication of how much information the frame contains, regardless of the size of the input or viewing device.

3.5 Special Surveillance Systems

3.5.1 Specialized Camera Systems

In recent years, the electronics industry has revolutionized the video camera industry. Use of CCDs and integrated circuits have allowed a considerable reduction in the size and cost of video cameras. One product that is available is called a “board camera.” This camera consists of the CCD and other electronics on a 1.5 in square (or smaller) printed circuit board with a lens mounted over the CCD. Because of their small size, they are easily concealed. Some examples of places these cameras can be concealed include ties, hats, jacket lapels, brooches, books, cigarette packs, smoke detectors and briefcases. Power is supplied by an external device such as a transformer or battery pack. The video signal is usually fed to a monitor, video recorder, or video transmitter.

3.5.2 Patrol Car Surveillance Systems

Patrol car surveillance systems are special video (and audio) equipment ensembles that were designed specially for police applications. Originally conceived to be that silent partner for individual officers on patrol, the applications for these systems have expanded beyond officer safety. Not only do these systems provide a clear record of faces, vehicles, license numbers, weapons, and the conversations that transpired before and during dangerous situations (so that back-up can be called in), but videotape documentation of routine occasions has also been found to be valuable. Videotapes have been critical evidence in allegations and liability suits against police and have been used extensively in contested arrests, particularly drunk driving cases. In addition, video and audio tapes from patrol car surveillance systems can be used as training tools for new officers (or experienced officers) to insure proper procedure and caution are exercised under various circumstances.

A typical patrol car surveillance system consists of a camera, control and status panel, recorder (either 8 mm or VHS tape format), protective case for the recorder, and wireless microphone. The camera is mounted on the inside of the police car's front windshield. It is a digital CCD black and white or color camera that normally can operate across a wide illumination range (from low light provided by headlights to bright sunlight). An auto iris lens adjusts the light level from day to night viewing, while a polarizing filter is used to reduce reflected glare. Since the camera has been designed for the police application, it is small, lightweight, and resistant to vibration and shock. A wide-angle lens (e.g., 8.5 mm to 15 mm) allows the camera to view an extended area.

The control and status panel is located near the officer in the car. It may be installed next to the radio, for instance. This unit allows the officer to turn the system on manually or to have the system come on automatically when the overhead flashing lights are turned on. The recorder stops when the officer selects the off control. The unit also indicates the status of the recorder and the microphone. A display light or other type of warning is given when the recording time is nearing or at its end. A VHS tape records up to 6 h of video and sound; a 8 mm tape can record 2 h.

The recorder, in an environmentally controlled, fireproof, bullet-resistant case, is usually located in the trunk of the vehicle. Heat or cooling is provided into the case when thermal switches detect a need. Limited access to the trunk and into the recorder case (it can be padlocked) helps protect the tape from tampering and preserves its integrity as evidence in court. The recorder itself cannot be removed (even for playing back tapes).

A tiny wireless microphone, used in conjunction with a pocket-sized transmitter and antenna, allows the surveillance system to hear sounds around the officer, especially when he/she leaves the patrol car. The microphone can be attached to a lapel or tie and may be provided with a *wind-screen* to greatly reduce background noise caused by the wind. The transmitter and built-in antenna can be clipped to a belt or be kept in a pocket. The wireless microphone has a range of about 1,000 ft (officer to car) under normal conditions. Because its range is limited, a radio license is not required for this transmitting system.

Another component of the police car surveillance system that may be offered is a video/audio monitor in the car that can be used for continuous viewing and for focusing and adjusting the camera. If it is not practical, or too expensive, to install a monitor in each patrol car, one monitor may be used to focus and adjust the cameras of several (or all) surveillance systems in a department.

An example of a patrol car surveillance system is the Eyewitness™ system sold by Kustom Signals, Inc. of Lenexa, Kansas. A complete system is priced between $3,900 and $5,500, depending on the type of video tape format required (VHS or 8 mm). The Eyewitness™ system includes either a color camera that has a minimum illumination of 5 lux and 300 lines of horizontal resolution, or a black and white camera that can operate at 0.5 lux and 420 lines of resolution. Both cameras can operate from 14 °F to 122 °F. The selected camera is connected to either an 8 mm or VHS video recorder that resides in a patented "vault" in the trunk.

3.5.3 Retractable Surveillance Systems

Designed to replace conventional overhead closed circuit television systems, these specialized video surveillance systems take many shapes and sizes. Some, such as the Knox Forward Intelligence Gathering System (FIGS), are in-ground/above-ground products designed for both industrial and government applications. The FIGS camera head assembly can be buried in the ground, hung from a pole or traffic light, or fitted into the recesses of a building. When activated, the camera head emerges beyond the edge of its case to a desired height at or below 8 in. In its basic configuration, FIGS will connect to most pan-tilt control drivers for full control over its main functions (including vertical and horizontal viewing, focusing, zoom, iris adjustment, and other auxiliary needs). Various cameras can be used with FIGS – a standard black and white CCD; optional high resolution B&W CCD or color CCD camera, or optional intensified day/night camera.

The control unit for FIGS is available in a waterproof, air-tight carrying case, and can control the camera assembly unit via wire, or optional UHF radio control link. Video information may be transported by wire or an optional microwave radio video link. For law enforcement and military applications, FIGS can be obtained with a host of special electronics. For inner city surveillance, both data and video can be transmitted over dedicated phone lines using special line drivers. FIGS can also operate over satellite.

Another Knox product that is similar to the FIGS, but fits well into another environment, is the Covert Car Antenna Video System. Details on this system, and others, may be acquired through the manufacturer in Greenwich, Connecticut, or other makers of video surveillance gear.

3.5.4 Portable Systems

If it is not possible to monitor an area from afar or if subjects frequently move from one location to another, it may be necessary to go to where the information is. For just those occasions, undercover attaché cases are available. One such case is made by ESC. The internal components, which consolidate the image and audio capturing and transmission functions, are cleverly hidden in a false top compartment of the case leaving no visual clue as to their existence. The tiny hole in the case, through which the camera operates cannot be seen even from as close as a foot away.

A 9 mm f/3.5 pinhole wide-angle lens is interconnected to a CCD camera that has a minimum illumination rating of 3 lux, resolution of 280 lines, and a signal to noise ratio of 46 dB. A number of video link options are offered that include UHF and microwave radio transmitters and matching receivers. The 1.3 GHz system also comes with a mini-dish antenna. All systems are powered by batteries that fit in the case.

4. Quality Parameters and the User — Interpreting Manufacturers' Specifications

The most relevant technical parameters used to measure the quality of cameras, camcorders, video recorders/players, and video monitors are described in this section. There are very specific relationships between these parameters that engineers use to assess the quality of video gear and what the typical user notices when using the equipment. The explanations of the performance parameters, therefore, contain "real world" information related to the human perception process along with the basic definitions of the engineering terms. Once a user understands how a particular technical parameter will affect him during video surveillance work, he can relate data from the manufacturers' brochures and specification sheets to his needs. Equipment selection and purchase then becomes easy.

4.1 Technical Parameters' Relationship to Law Enforcement and Corrections Needs

In the earlier section on video surveillance requirements, it was suggested that a large number of specific video needs for law enforcement and corrections could be summarized into a short set of general requirements (e.g., identifying subjects, recording data) Table 8 shows how the numerous technical parameters that are used to describe the functional and physical characteristics of equipment, and to measure its quality of performance, correlate to this fundamental set of police needs. That is, the table indicates what parameters might be especially important to consider for certain applications. In several cases, one parameter (e.g., resolution) can be seen as being relevant to more than one community need. (In fact, it can be argued it should be listed under all need categories.) The table is not intended to include all possible combinations under all conditions. Rather, it is intended to be a "jumping off point" for users to contemplate when they start to review what technical parameters are important to them.

Table 8. Test Parameters' Relationship to Law Enforcement and Corrections Needs

Parameters	Needs
Resolution Signal-to-noise ratio Minimum illumination Lens, max aperture Tape speed/"record mode" Color accuracy Focusing accuracy Audio input level Audio frequency response Self timer Wireless remote control	Identifying subjects
Color accuracy Focusing accuracy Minimum focal range Special features Audio input level Audio frequency response Self timer Wireless remote control	Recording forensic data
Zoom speed Focusing accuracy Focusing speed Time response-features Shutter speeds Resolution Signal-to-noise ratio Minimum illumination	Multiple activities
Operating temperature range Operating humidity range Power requirements Power consumption	Indoor/outdoor work

Table 8. Test Parameters' Relationship to Law Enforcement and Corrections Needs (cont'd)

Parameters	Needs
Electrical connectors Physical mounts Audio output levels	Flexibility
Dimensions Weight Physical mounts Other human engr. aspects Utility/accuracy of manuals Tape length Fast forward time Fast rewind time Power requirements Battery charging time Transportability Screen size Power consumption	Operational effectiveness

The following section introduces the technical parameters and explains their basic concepts. This background material should be helpful in tying parameters to user applications and requirements.

4.2 Parameter Definitions

4.2.1 Resolution

The parameter most often quoted as being a reliable measure of quality is resolution, which is the capability of a piece of video gear to distinguish, record, and/or reproduce the details in a scene. The higher the number of "lines," or "*TVL*" (Television Lines), the greater the horizontal resolution of an image. A look at the method used to determine the number of lines is helpful in better understanding resolution.

The number representing the measured resolution is arrived at by first focusing a camera at a test pattern, which typically has alternating black and white vertical lines of equal width. (A number of test patterns may be present on a single chart.) By situating the camera a certain distance from the chart, a pattern can be made to fill the entire view of the camera. If the camera is connected to a monitor or TV, this is easy to do by simply observing the monitor or TV. If the camera is close to the chart, it is not too difficult to find the number of lines filling the view of the camera simply by counting them on the monitor.

The number of lines seen by the camera can be increased by moving the camera back away from the chart or by zooming back with the lens. If this process is continued, there will come a point where the vertical lines are too close together for the camera to "resolve" them, that is, to see two neighboring white lines as being separated by a black one or two neighboring black lines as being separated by a white one. Instead of alternating black and white lines, the camera will begin to see a uniform, medium gray. Before this happens, the number of vertical lines across the screen is counted, and this number is noted as being the "resolution" of the camera. Note that "240 lines of resolution" means that a device can distinguish, record, and/or reproduce at least 240 lines of resolution.

For the above test to work as described, the monitor must be of higher quality than the camera. If a monitor is being tested, the camera providing its input must be of higher quality than the monitor. For a more precise measurement of resolution, a high-quality digital oscilloscope with a television synchronization option is used to view and measure the electrical output of a camera. Lines can be counted automatically between two cursors marking the edges of the test pattern's waveform.

Now that it is known that more resolution is better than less, how many lines of resolution are really necessary in a piece of video equipment? The answer depends upon the application. Some examples may provide a rule of thumb. Three hundred thirty (330) lines of resolution is considered to be the quality limit of what can be received by broadcast or cable television in the home. Two hundred forty (240) lines is the nominal figure for VHS or 8 mm video tape formats. People notice that VHS and 8 mm tape playbacks do not resolve individual hairs on a person's head when the person fills the screen to the extent that a newscaster does at a normal distance (head and shoulders – referred to in the industry as a "talking head"). If the newscaster is viewed from a broadcast ("over the air"), much more detail may be visible, and individual hairs probably will be noticeable. Super-VHS and Hi8, with common resolution figures of 400 lines to 420 lines, definitely are able to resolve hair detail at this distance. Higher quality studio-type equipment, such as Betacam™-SP, and proposed HDTV broadcast, cable, and tape standards may reveal even the pores on a person's face at a "talking head" distance.

The bottom line for resolution is this: the higher the resolution rating, the easier it is to positively identify a suspect who is across a parking lot or street. Better resolution also means the videotape played back in court will show more detail. What really is necessary though, since more resolution means more money? The answer can follow this rule of thumb. If the live image or recording has to be as good as the best broadcast or cable TV picture you have ever seen, at least 330 lines of resolution are necessary. (That means Super VHS, Hi8, digital, or broadcast quality in a camcorder.) If you can live with less detail in most cases, select a VHS or 8 mm camcorder, or a camera, player/recorder, or monitor with fewer lines of resolution.

4.2.2 Signal-to-Noise Ratio

Electrical and electromagnetic *signals* are all around us constantly. They originate at both natural and man-made sources. Many of the signals provide information for us and are desirable at a particular point in time (e.g., we tune our receivers to find signals broadcast from commercial television and radio stations). On the other hand, some signal emanations interfere with, or detract from, the information in the desired signals that we are trying to receive. These signals are called *noise*.[5] With any type of telecommunications transfer involving audio (including voice), video, data, or multimedia (i.e., combinations of audio, video, and/or data), it is important to maximize the desired signal (or signals) and minimize the noise to accurately receive the information. The *signal-to-noise ratio*, *SNR*, is a measure of how well this has been achieved. The SNR is the power of the desired signal divided by the power of the noise signal.

During video surveillance work, a number of information signals are transferred. For example, a camcorder takes video and audio information collected by its camera and microphone and records it onto a magnetic tape in its recorder. Similarly, a stand-alone video camera passes visual information to the tape of a separate video recorder or to a monitor for viewing. If noise is present during any of the transfers, the quality level of the video and audio information will be degraded. The tape will record both the desired and undesired signals, and the monitor will display the noise along with the video. Evidence of noise in video transmissions is the appearance of "snow" on the screen, which essentially dilutes the video signal. Audio noise is commonly heard as popping or hissing sounds. When noise levels become too high (as compared to the desired signals), the video image will be completely lost in a "whiteout" or in a wash of distorted colors. The audio information will be indiscernible. In many operational settings, the level of noise will not change very much over a certain time span. Therefore, if the surveillance equipment on hand is not adequate to properly capture and record the desired information under the conditions present, there is little the operator can do.[6] It is critical, then, that equipment be procured with a signal-to-noise ratio that is sufficient for prospective operational scenarios.

The developers of video equipment realize the detrimental effects that noise can have on video

[5] It is possible to have situations where desired signals for some people become the noise source for other people and their systems.

[6] If the operator of video surveillance equipment has some control over the environment where the surveillance will take place, some improvement in SNR may be possible. That is, an increase in illumination (light level) will increase SNR (as explained in the next section).

quality. Therefore, designs are employed that inherently reduce the system's sensitivity to unwanted electrical noise. At the time of manufacture, noise shielding may also be installed in areas of the product that are still susceptible to noise degradations. Overall, different manufacturers use many techniques and attain various levels of success as they attempt to protect their equipment from noise. Unfortunately, it is not clear to the casual observer examining equipment which products have the greater natural immunity to noise. The SNR specification, if provided, can be looked upon as an immunity indicator, however.

The lower the noise sensitivity (the higher the SNR), the greater the ability to get a quality image out of a device at low light levels. But how is SNR quantified? The SNR is measured by putting a known high-quality signal into a piece of video gear, recording what comes out, and comparing the output to the input. Since some noise always gets into the signal by the time it is output, measuring exactly how much noise was output can provide an SNR.

For cameras and camcorders, most specification sheets will show SNR in "*dB*" at a recommended illumination (light level). The abbreviation "dB" means *decibels*. Decibels in this case do not have anything to do with the magnitude of sounds or loudness. Decibels simply express the logarithmic ratio of two voltages, for the signal and the noise. A ratio of 6 dB (technically 6.02 dB) means the signal is twice the noise. For each additional 6 dB, the voltage ratio doubles (e.g., 12 dB = signal 4 times larger, 18 dB = signal 8 times larger). For 60 dB, the signal is 1,024 times larger than the noise.

4.2.3 Minimum Illumination

Noise sensitivity is impossible to eliminate completely, so as the signal level drops (i.e., as the light level of a scene drops) and the noise level remains the same, the signal to noise ratio drops, and noise will begin to appear in the picture. As the light level continues to drop, the scene looks progressively worse. Although there is no point at which a picture suddenly becomes completely unusable, there does come a point where at least half of the people trying to view it would consider it too annoying to watch or would be unable to discern facial or even other large features easily. Somewhere before this point, equipment manufacturers are said to measure the light level of the scene and claim that the video equipment has that certain minimum illumination requirement, a *lux* level. In general, the color carriers and color receptors require more light to function properly, thus yielding significantly higher lux ratings than the average black and white camera. For example, a color camcorder's sales ad may refer to a "3-lux" camcorder, while a black and white camera's sales ad may claim it is a 0.5 lux camera.

Unfortunately, these statements of minimum illumination leave plenty of room for confusion. First, the lux is not a common term among Americans; what does lux mean? Once lux is defined, it is not straightforward to judge lux levels. Although a user can recognize that one camcorder presumably needs less light than another to function properly, he cannot tell what the relative difference is between light levels (e.g., between 3 lux and 20 lux). Finally, the user does not know what quality can be expected at a specified lux level.

Since lux is at the center of this discussion, it is important to get some feeling for what a lux is. Lux is a measure of illumination that is used within the International System of Units (i.e., the Metric System). A lux is defined as one lumen per square meter, where the "lumen" is a well-defined measure of light power. In other words, when a lumen worth of light is uniformly distributed across an area of one square meter, the light level of that area is one lux. The foot-candle is analogous to the lux but uses dimensions that are more familiar to Americans. The foot-candle is equal to one lumen per square foot. Since the light source is the same for both measures, the only difference between the values of lux and foot-candles has to do with the areas of the illuminations (square meters and square feet). With one meter equal to approximately 3.281 ft, one square meter equals 10.76 ft^2. This means the illumination of a foot-candle is more than 10 times brighter than the lux since the same amount of light is concentrated over a much smaller area. One foot-candle equals 10.76 lux.

But how does a user determine what his typical lux levels will be? Like resolution, the answer comes after thinking about the conditions in which video equipment is likely to be used. Table 9 gives some average reference numbers for various outdoor and indoor conditions. These "rough" numbers can be used as rules of thumb from which to gauge typical illumination requirements. In general, it appears that outdoor daytime applications and indoor applications that have a normal amount of artificial lighting can be accommodated by most off-the-shelf cameras/ camcorders. Surveillance situations that occur at night or in very dimly lit locations indoors will require special, low-light cameras. True low-light camcorders are not available; however, some can be supplemented with light amplifiers to achieve low-light capability. One example of this is the Astroscope series of products from Electrophysics Corporation. In addition, some camcorder manufacturers (e.g., Sony, Panasonic) provide a feature in some of their models that disable the color channel in low-light situations, therefore reducing noise and extending the light range of their camera. While this does not approach the capabilities of light-amplified video equipment, it is much less expensive, and may improve image clarity enough to yield success from a bad surveillance situation.

Unfortunately, while manufacturers are willing to tout their light rating, they are reluctant to provide information on the quality of the video images at those light levels. Minimum levels of illumination are rarely given in the context of a resolution figure or SNR. Each manufacturer uses its own subjective method for determining the least amount of light required for producing an acceptable image. What then can the prospective purchaser use to predict performance at minimum light specifications?

Table 9. Typical Light Levels Based on Outdoor and Indoor Conditions

Condition	Typical Light Level in Lux
Overcast night sky*	0.0007
Clear night sky*	0.002
Quarter moon*	0.01
Full moon*	0.1
Twilight*	4.0
Sunrise/sunset*	500.0
Heavily overcast*	7,000.0
Unobscured sunlight*	100,000.0
Office (florescent lights & no windows)	320.0
Office (florescent lights & windows)	430.0
Office building hallway (well lit)	54.0
Narrow hallway (dimly lit)	10.8
180 square foot room with one 150 Watt lamp on	16.1

*Reference for Outdoor levels: Light Intensity Conversion Chart, XYBION Electronic Systems, not dated.

Presently, the measurement of signal-to-noise ratio or resolution at the lighting threshold is really the only way that a user can judge the potential quality of a video picture at that level. Another valid method, recently standardized, is based on the way humans see. This method is to record video from a device under test, digitize the images, and use computers to extract the same type of information the human eye and brain do, such as edge information, noise content, frequency content (another measure of resolution), and many other parameters. These parameters, when used in conjunction with data accumulated from many similar tests on many human subjects, allow the computer to judge the quality of an image produced by a video device in the same way a human viewer would. These techniques were developed in the laboratories of the Institute for Telecommunication

Sciences and are published in American National Standard T1.801.03-1996, "Digital Transport of One-Way Video Signals – Parameters for Objective Performance Assessment."

Furthermore, standardized measures for specifying minimum illumination will soon be available. These will help users ascertain quickly whether there is enough light present in some cases to even bother videotaping. Since many settings requiring surveillance by law enforcement and corrections officers will be dimly lit, these new measures will be particularly helpful.

4.2.4 Shooting Below the Light Threshold

At some point, a situation might arise for which the proper equipment is not available. Most likely, this will be a situation where surveillance must be conducted in a lower light environment than was originally anticipated. It may be that the available equipment does not provide a satisfactory image under the required lighting situation. If such a situation arises, continue to tape because useful information may be extracted using digital imaging techniques. An example of these techniques is shown in Figure 12.

Figure 12 contains two images. The image on the left was obtained directly from videotape. The tape was recorded in a low-light situation in the laboratory, with the camera pointing at a head–and–shoulders type picture. The ambient light level was 0.5 lux, and the manufacturer rated the camera at 4.0 lux. Thus the experiment was carried out at one-eighth of the minimum light level for the camera. It is obvious that no useful identification can be made directly from the image. The image on the right, however, is useful for identification. How do you get from one to the other?

The image on the right is composed of individual images that have been averaged together to reduce noise and increase the signal level. Thirty consecutive frames (1 second worth) of video were used to compute the averaged image. Since the noise is random, it tended to cancel itself out over the 30 frames, leaving a reasonable image. There are two conditions that must be met for this technique to work. The first has already been mentioned: the noise must be random, as is typically the case when light levels drop. Second, there must some signal there to recover (i.e., a recording in total darkness just will not work). Finally, there must be some mechanism for compensating for any motion that the subject had within the frame during the interval being averaged. This ensures that the image of the subject lines up perfectly when the frames are averaged, making for a clearer picture.

The averaging can be accomplished in several ways. First, it is important to get the images into a computer to be processed. In this case a Sony digital camcorder (model DCR VX-1000) was used with a Canon Video DK-1 Video Capture Kit. Once imported, the averaging can be done with a number of software packages, including high-powered computational packages like Matlab® and IDL®, or graphics art packages like Adobe® Photoshop®. More detail on the process is given in Appendix B.

4.2.5 Color Accuracy

Color is another way to judge quality. Even when illumination is sufficient to allow a camera to operate, there may still be built-in errors in the camera's color generation circuits that sometimes make its colors appear less than true. Specifically, problems arise with the *phase* and *amplitude* of the color part of the video signal. The phase of the color signal represents the hue of a color, and the amplitude carries the *saturation* information. Hue is defined as the particular shade or tint of a given color, but also has color as a synonym.

Examples of hues that may be used in everyday conversation are red, greenish, and blue-green. Saturation refers to the amount of pure white mixed in with a given hue. A hue that has no white mixed in is said to be 100 percent saturated, while a hue that is half white is 50 percent saturated. For example, red and pink are the same hue, but red is 100 percent saturated and pink is more like 50 percent to 75 percent saturated; pink is just red with some white mixed in. Along with brightness, hue and saturation

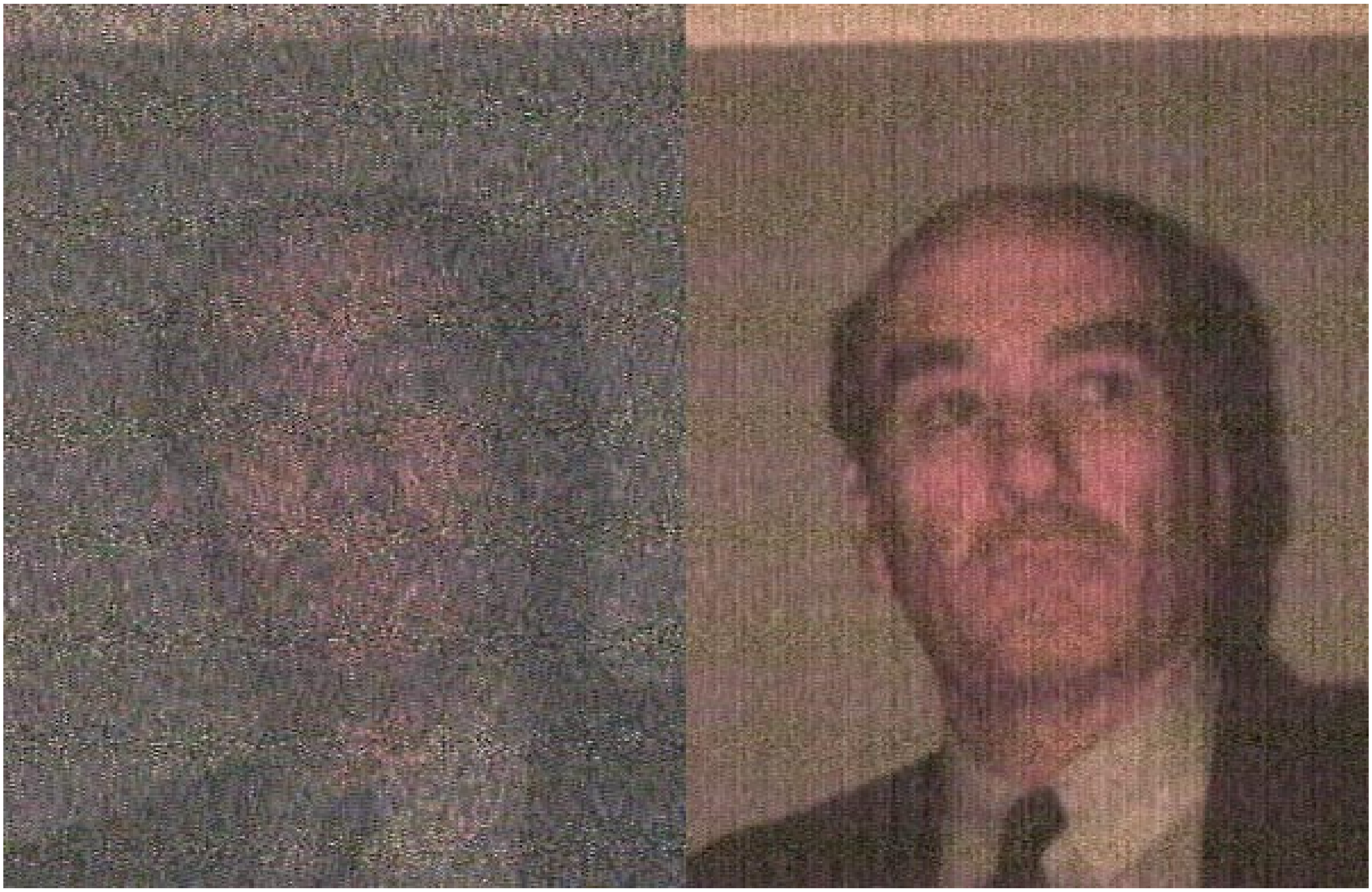

Figure 12. Extracting useful data from videotape shot in conditions below the light threshold

completely define all colors available within the constraints of the video system. To test the color accuracy of a piece of video equipment, its output is plugged into a device (vectorscope) that can isolate the color information (hue and saturation) from the brightness (luminance) information. The hue and saturation are then displayed and inspected separately. Color accuracy readings are given in degrees and reflect the deviation of the observed color from the "standard" color. The lower the deviation figure, the better. Cameras with excellent color accuracy may have accuracy numbers for colors within 5°.

It would be an impossible and unnecessary task to check all possible colors and combinations of colors; fortunately, it is sufficient just to check red, green, blue, cyan (blue+green), magenta (red+blue), and yellow (green+red). Because of this, a standard chart is available that contains just these colors – called the "color bars" chart. Sometimes color bars are broadcast by a TV station after they go "off the air" for the night. If a camera is aimed at a color bar chart (under appropriate illumination), then its output signal will be ideal for testing with a vectorscope, and it can be determined whether the camera's reproduction of blue, for example, is accurate enough for its intended application.

The reason for investigating the color accuracy of a camera or camcorder is to ensure that colors accurately divulge the race, hair and eye color, clothing, and other distinguishing characteristics of a suspect or other interviewee. It is also essential to maintain color information about pieces of evidence such as paint chips or blood and to identify quickly and accurately health problem symptoms, such as cyanosis, in a victim.