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Law Enforcement and Corrections Standards and Testing Program

VIDEO SURVEILLANCE EQUIPMENT SELECTION AND APPLICATION GUIDE

NIJ Guide 201-99

ABOUT THE LAW ENFORCEMENT AND CORRECTIONS STANDARDS AND TESTING PROGRAM

The Law Enforcement and Corrections Standards and Testing Program is sponsored by the Office of Science and Technology of the National Institute of Justice (NIJ), U.S. Department of Justice. The program responds to the mandate of the Justice System Improvement Act of 1979, which created NIJ and directed it to encourage research and development to improve the criminal justice system and to disseminate the results to Federal, State, and local agencies.

The Law Enforcement and Corrections Standards and Testing Program is an applied research effort that determines the technological needs of justice system agencies, sets minimum performance standards for specific devices, tests commercially available equipment against those standards, and disseminates the standards and the test results to criminal justice agencies nationally and internationally.

The program operates through:

The *Law Enforcement and Corrections Technology Advisory Council* (LECTAC) consisting of nationally recognized criminal justice practitioners from Federal, State, and local agencies, which assesses technological needs and sets priorities for research programs and items to be evaluated and tested.

The *Office of Law Enforcement Standards* (OLES) at the National Institute of Standards and Technology, which develops voluntary national performance standards for compliance testing to ensure that individual items of equipment are suitable for use by criminal justice agencies. The standards are based upon laboratory testing and evaluation of representative samples of each item of equipment to determine the key attributes, develop test methods, and establish minimum performance requirements for each essential attribute. In addition to the highly technical standards, OLES also produces technical reports and user guidelines that explain in nontechnical terms the capabilities of available equipment.

The *National Law Enforcement and Corrections Technology Center (NLECTC)*, operated by a grantee, which supervises a national compliance testing program conducted by independent laboratories. The standards developed by OLES serve as performance benchmarks against which commercial equipment is measured. The facilities, personnel, and testing capabilities of the independent laboratories are evaluated by OLES prior to testing each item of equipment, and OLES helps the NLECTC staff review and analyze data. Test results are published in Equipment Performance Reports designed to help justice system procurement officials make informed purchasing decisions.

Publications are available at no charge through the National Law Enforcement and Corrections Technology Center. Some documents are also available online through the Internet/World Wide Web. To request a document or additional information, call 800-248-2742 or 301-519-5060, or write:

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Video Surveillance Equipment Selection and Application Guide

NIJ Guide 201-99

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Prepared for:
National Institute of Justice
Office of Science and Technology
U.S. Department of Justice
Washington, DC 20531

October 1999

National Institute of Justice

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Director

The technical effort to develop this Guide was conducted under Interagency Agreement No. 94-IJ-R-004, Project No. 97-029-CTT.

This Guide was prepared by the Office of Law Enforcement Standards (OLES) of the National Institute of Standards and Technology (NIST) under the direction of A. George Lieberman, Program Manager for Communications Systems, and Kathleen M. Higgins, Director of OLES. The work resulting in this Guide was sponsored by the National Institute of Justice, David G. Boyd, Director, Office of Science and Technology.

FOREWORD

The Office of Law Enforcement Standards (OLES) of the National Institute of Standards and Technology furnishes technical support to the National Institute of Justice (NIJ) program to strengthen law enforcement and criminal justice in the United States. OLES' function is to conduct research that will assist law enforcement and criminal justice agencies in the selection and procurement of quality equipment.

OLES is: (1) Subjecting existing equipment to laboratory testing and evaluation, and (2) conducting research leading to the development of several series of documents, including national voluntary equipment standards, user guides, and technical reports.

This document covers research on law enforcement equipment conducted by OLES under the sponsorship of NIJ. Additional reports, as well as other documents, are being issued under the OLES program in the areas of protective clothing and equipment, communications systems, emergency equipment, investigative aids, security systems, vehicles, weapons, and analytical techniques and standard reference materials used by the forensic community.

Technical comments and suggestions concerning this document are invited from all interested parties. They may be addressed to the Director, Office of Law Enforcement Standards, National Institute of Standards and Technology, Gaithersburg, MD 20899-8102.

David G. Boyd, Director
Office of Science and Technology
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BACKGROUND

The Office of Law Enforcement Standards (OLES) was established by the National Institute of Justice (NIJ) to provide focus on two major objectives: (1) to find existing equipment which can be purchased today, and (2) to develop new law-enforcement equipment that can be made available as soon as possible. A part of OLES' mission is to become thoroughly familiar with existing equipment, to evaluate its performance by means of objective laboratory tests, to develop and improve these test methods, to develop performance standards for selected equipment items, and to prepare guidelines for the selection and use of this equipment. All of these activities are directed toward providing law enforcement agencies with assistance in making good equipment selections and acquisitions in accordance with their own requirements.

As the OLES program has matured, there has been a gradual shift in the objectives of the OLES projects. The initial emphasis on the development of standards has decreased, and the emphasis on the development of guidelines has increased. For the significance of this shift in emphasis to be appreciated, the precise definitions of the words "standard" and "guideline" as used in this context must be clearly understood.

A "standard" for a particular item of equipment is understood to be a formal document, in a conventional format, that details the performance the equipment is required to give and describes test methods by which its actual performance can be measured. These requirements are technical and are stated in terms directly related to the equipment's use. The basic purposes of a standard are (1) to be a reference in procurement documents created by purchasing officers who wish to specify equipment of the "standard" quality, and (2) to identify objectively equipment of acceptable performance.

A standard is not intended to inform and guide the reader; that is the function of a guideline

Note that a standard is not intended to inform and guide the reader; that is the function of a guideline. Guidelines are written in non-technical language and are addressed to the potential user of the equipment. They include a general discussion of the equipment, its important performance attributes, the various models currently on the market, objective test data where available, and any other information that might help the reader make a rational selection among the various options or available alternatives.

This video surveillance equipment guide is provided to inform the reader of the principles that can be used to select video surveillance equipment that will meet the requirements of the application where it will be used.

Kathleen Higgins
National Institute of Standards and Technology
August 1999

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CONVENTIONS USED IN THIS GUIDE

To improve the readability of this document, several type-face conventions have been adopted. These are as follows:

Bold type	indicates equipment and technologies that are discussed in detail in the "Description of Video Surveillance Components and Systems" section of this guide.
Italic type	indicates terms that are defined in the glossary.
<u>Underlined type</u>	identifies brand names or specific equipment used in the development of this guide.

COMMONLY USED SYMBOLS AND ABBREVIATIONS

A	ampere	H	henry	nm	nanometer
ac	alternating current	h	hour	No.	number
AM	amplitude modulation	hf	high frequency	o.d.	outside diameter
cd	candela	Hz	hertz (c/s)		ohm
cm	centimeter	i.d.	inside diameter	p.	page
CP	chemically pure	in	inch	Pa	pascal
c/s	cycle per second	ir	infrared	pe	probable error
d	day	J	joule	pp.	pages
dB	decibel	L	lambert	ppm	part per million
dc	direct current	L	liter	qt	quart
C	degree Celsius	lb	pound	rad	radian
F	degree Fahrenheit	lbf	pound-force	rf	radio frequency
dia	diameter	lbf in	pound-force inch	rh	relative humidity
emf	electromotive force	lm	lumen	s	second
eq	equation	ln	logarithm (natural)	SD	standard deviation
F	farad	log	logarithm (common)	sec.	section
fc	footcandle	M	molar	SWR	standing wave ratio
fig.	figure	m	meter	uhf	ultrahigh frequency
FM	frequency modulation	min	minute	uv	ultraviolet
ft	foot	mm	millimeter	V	volt
ft/s	foot per second	mph	mile per hour	vhf	very high frequency
g	acceleration	m/s	meter per second	W	watt
g	gram	N	newton		wavelength
gr	grain	N m	newton meter	wt	weight

area = $unit^2$ (e.g., ft^2, in^2, etc.); volume = $unit^3$ (e.g., ft^2, m^3, etc.)

PREFIXES

d	deci (10^{-1})	da	deka (10)
c	centi (10^{-2})	h	hecto (10^{2})
m	milli (10^{-3})	k	kilo (10^{3})
µ	micro (10^{-6})	M	mega (10^{6})
n	nano (10^{-9})	G	giga (10^{9})
p	pico (10^{-12})	T	tera (10^{12})

COMMON CONVERSIONS (See ASTM E380)

0.30480 m = 1ft	4.448222 N = lbf
2.54 cm = 1 in	1.355818 J = 1 ft lbf
0.4535924 kg = 1 lb	0.1129848 N m = lbf in
0.06479891g = 1gr	14.59390 N/m = 1 lbf/ft
0.9463529 L = 1 qt	6894.757 Pa = 1 lbf/in^2
3600000 J = 1 kW hr	1.609344 km/h = mph

Temperature: $T_C = (T_F\ 32)\times5/9$

Temperature: $T_F = (T_C\times9/5)+32$

1. Introduction

In this era of rapid technical advancement, the marketplace is flooded with a tremendous variety of *video* equipment. This can be both good and bad. It is good from the standpoint that a potential purchaser of video equipment can almost certainly find a commercially available video unit or package that will meet perceived needs and desires. However, when those needs are not clear, or are changing, and the characteristics of the equipment are not understood, the number of equipment choices can lead the purchaser to a feeling of confusion or helplessness. Video equipment salespeople can confound the issue further by advocating the purchase of products which have attractive (but unnecessary) features and capabilities, or by simply recommending the more well-known manufacturers' products, which tend to be more expensive.

Personnel in the law enforcement and corrections agencies wishing to utilize video surveillance systems (for collecting evidence and promoting officer safety, for example) are challenged when required to confront these equipment choices and sales pressures while staying within an established budget. The purpose of this guide is to assist those law enforcement and procurement officials who are not technically trained in video equipment in the selection and application of video surveillance equipment that will satisfy their needs. This guide primarily addresses general-use video equipment, including separate **video cameras**, self-contained **camcorders**, **video recorders/players**, and **video display systems** (monitors). However, special-purpose video equipment is also described, such as the Patrol Car Surveillance System.[1]

The guide begins with a discussion of typical video surveillance assignments, that is, a definition of user requirements for the law enforcement and corrections communities. This requirements definition serves as a jumping-off point and reference base for all subsequent deliberations in later sections of the guide. An overview of the available video technology is presented next, along with a summary of tape formats. A delineation of the technical parameters that most influence operational performance for the various types of gear follows. Guidance is provided regarding the application of specific types of video equipment to meet functional requirements. Another important element of the guide is information on the latest advancements in video technology and the effects those advancements will have on surveillance work. With cost information, the functional requirements data will help sort out the lowest cost equipment that can effectively satisfy at least the minimally acceptable surveillance requirements established by the law enforcement and corrections community.

The appendices offer detailed experimental methods and results that are summarized in the main text. This will assist advanced users in determining what types of tests might be appropriate when evaluating new equipment for use in their application environment.

[1] Certain commercial companies, equipment, instruments, materials, and organizations are mentioned in this report to adequately explain the experiments and their results. In no case does such identification imply recommendation or endorsement by the National Institute of Justice, or any other U.S. Government department or agency, nor does it imply that those identified are necessarily the best available for the purpose.

2. Video Surveillance Requirements

2.1 Typical Video Surveillance Assignments

In order to develop a guide that would be useful to the law enforcement and corrections community, it was first necessary to determine the community's video surveillance needs. This was accomplished through the development of a survey to which state and local law enforcement agencies responded. The survey focused on uncovering the kinds of video surveillance assignments required of a typical police department. Those assignments (and the particular users' needs to accomplish the assignments) would lead naturally to the specifications for equipment. Table 1 presents a set of representative surveillance assignments based on results from the survey.

Table 1. Video Surveillance Assignments

Building or area access	Record forensic data
Building or area security	Operation/protective detail coordination
Crowd monitoring	Video mug shots
Monitor officer on routine stops	Record physical evidence
Search and rescue	Indoor surveillance
Monitor officer/suspect in dangerous situation	Record interrogations/ polygraph examinations
Monitor confinement areas	Record bomb squad work
Outdoor surveillance	Vehicular surveillance
Record crime scene	Airborne surveillance

Besides the basic functional assignments, a complete description of video surveillance applications must address performance under certain operating conditions. One of the most obvious of these conditions is the environment to which the equipment will be subjected. However, there are other operating conditions that can affect the usefulness of the equipment and the success of the surveillance assignment. They can be placed into two broad categories – usage and power requirements. Table 2 contains a list of environmental, usage and power conditions that can potentially affect the performance of a surveillance system.

Table 2. Operating Conditions Affecting Surveillance Performance

Environmental	
Temperature	Heat and/or cold
Moisture	Precipitation, humidity
Corrosive elements	Salt air, dust, sand
Shock/Vibration	Tolerance
Usage	
Light	Minimum requirements
Distance	Useful range
Clarity	Faces or figures/activities
Record time	Maximum time unattended
Physical	Size/weight
Shutter speed	Sensitivity to motion
Power	
Source	AC only/car battery/ battery pack
Battery life	Overall life/maximum number of charges
Recharge cycles	Discharge/recharge time

It is necessary to define in finer detail the scope of three of the most important usage requirements: *light*, *clarity*, and *distance*. The range of values for each usage condition will help determine the feasibility of using certain types of video equipment and the minimum equipment specifications required of them. For example, lighting levels must be classified to reflect various indoor and outdoor settings.

Clarity, as a usage condition, is meant to relate how explicit the surveyed image has to be to satisfy the intended use of the user. From a law enforcement and corrections perspective, clarity can be subdivided into two quality levels – being able to identify faces, and being able to identify figures and activities. Distance classifications are related to the clarity of images and to typical scenarios of police operations (i.e., where the police are and where the subject is). Table 3 summarizes the subclassifications of light, clarity, and distance conditions.

Table 3. Subclassification of Select Usage Conditions

Parameter	Subclassifications
Light	Daylight, indoor, night with dim light, no noticeable light
Clarity	Facial detail, figures and activities
Distance	Less than 50 yards, 50 to 200 yards, greater than 200 yards

2.2 Other Survey Results

The survey revealed that there are several areas of interest to the law enforcement and corrections agencies. The area that elicited the most interest was *still video*, a newer technology that shows much promise for the surveillance community. Agencies believe this will be particularly useful in recording information at the scene of a crime, but it will also be useful for video mug shots and forensic data collection. Also of great interest was *low-light*, *amplified-light* and *infrared* video equipment for use in night surveillance. This would be used primarily to provide a means to track the movements of suspects, and to better perform building and area surveillance. The third significant area of interest was identification of suspects at distances greater than 200 yards. Where equipment is concerned, slightly more agencies currently procure more general-purpose equipment than specialized equipment. The most common piece of equipment in use is a consumer quality (*VHS*, *S-VHS*, 8 mm, or Beta) videocassette recorder. The other two most common pieces of equipment in use are low to medium resolution color cameras and low to medium resolution camcorders. The frequency of use of these types of equipment is logical in that they are the easiest to obtain and use. However, they are not the only type of equipment in use. The only piece of equipment that the surveys did not indicate was in use was a camera concealed on a person. In light of this survey result, body cameras are not included in this guide.

The physical treatment of video equipment can vary greatly. Many pieces of equipment are subjected to vibration, moisture, and both heat and cold, while others are only used in environmentally controlled areas. The field storage conditions of the equipment also vary greatly. They range from custom mounts in vehicles to car trunks and seats. The temperatures in these surroundings can vary more than the usage (outside) conditions, especially if the car is unoccupied for more than 30 min at a time. The permanent storage space for the equipment, however, is fairly consistent: usually an office environment or air-conditioned room.

Also of interest is the agencies' video equipment operators. Survey responses indicate that most of the agencies have video specialists who are the only ones to operate video equipment. There is also, however, a significant number of responses from agencies where everyone is required to operate at least some video equipment.

One area of possible concern is the amount of training available for the video equipment operators. Only one agency reported that it had more than 2 percent of its training budget available for training on the mechanics and techniques of video equipment usage. Several reported that no budget was available for this type of training.

2.3 Summary

Video surveillance requirements for law enforcement and corrections span a number of different applications but may be cataloged into a fundamental set of six areas. These requirements areas are:

1. Identifying subjects (including persons) at varied distances and at varied light levels. Different quality levels of identification are required for different applications (e.g., positive facial identification of persons under surveillance versus identification of persons breaking into a building to prompt security forces to respond).

2. Recording/documenting data and/or evidence during or after a crime. Exact color may be very important to immediately apprehend a suspect based on what he/she was wearing, or it may be necessary to record precisely the hue of mud at a crime scene.

3. Handling scenes/locations with multiple activities and/or multiple subjects. The responsiveness of cameras or camcorders may make the difference between capturing on film only one illegal act or several.

4. Covering indoor and outdoor activities in different geographic areas. No two police departments deal with exactly the same environment.

5. Establishing multi-purpose flexibility so as to allow selected equipment to operate with other existing or new equipment. Equipment suites require physical and functional compatibility.

6. Promoting operational effectiveness. The best equipment in the world will not produce results if it cannot be used by law enforcement and corrections personnel effectively when it is required. Limitations on training budgets make it mandatory that equipment operation also be straightforward.

3. Description of Video Surveillance Components and Systems

3.1 Overview

When selecting equipment for video surveillance applications, there are a number of choices to make. This section reviews the four basic types of video surveillance equipment – cameras, camcorders (camera-recorders), recorders/players, and video displays (monitors/televisions) – that can be used (in some combination) to form a complete video system. Cameras are presented first. In the technology description, the difference between **tube** and **solid-state** (i.e., charge coupled device *[CCD]*) camera units is explained, as well as differences between analog and digital cameras and camcorders. After a summary of video camera features and an outline of lenses, two special camera types are described. **Still-video** cameras and low-light cameras are addressed in the context of continuing and emerging law enforcement applications.

Since magnetic tape is the primary storage medium used in video equipment, a description of **videotape technology** and quality has been included at the beginning of the discussion related to tape machines (i.e., camcorders and recorders/players). Where taping is concerned, there are six video tape formats (and their derivatives) that are applicable to video surveillance: D1, D5, DV, Betacam™ (analog and digital), VHS, and 8 mm. In many cases, the tape format and its inherent capabilities will strongly influence equipment selection.

Any discussion of video surveillance equipment becomes confusing immediately unless the equipment types (camcorders, etc.) are categorized into smaller, similar groups based on quality levels. There are two primary performance parameters that can be used to differentiate quality levels for each video equipment type – *resolution* and *color*. Resolution, expressed simply, is how clearly one can distinguish the detailed parts of an image. Color relates to the ability of equipment to record, display, or playback color or black and white images. These performance parameters, and other equipment characteristics that directly influence the quality levels of video equipment, will be explained fully in later sections of this guide.

Table 4 presents the breakdown of equipment types based on their quality levels. Equipment types with low- and medium-resolution capability have been lumped together (within a color or black and white category) because they employ essentially the same technology. The equipment with the greater (medium) resolution has taken advantage of later technological refinements to achieve a higher quality level. High-resolution video gear (also broken down by a color or black and white capability) was especially planned and designed to accommodate high-quality applications, such as commercial television production and broadcast. It is unlikely that low- and medium-resolution equipment will ever migrate to the levels of the high level gear through subsequent design refinements. As with most electronic equipment, it will be shown later that improvements in video equipment capability and quality result in differences in price; most significantly as the equipment quality jumps from a medium-resolution level to one of high-resolution.

3.2 Video Cameras

3.2.1 Technology Summary

Tube cameras have been around since the beginning of television and the electronic video industry. There have been several names associated with tube cameras, including Vidicon™, Saticon™, and

Plumbicon™. However, these names always have the same implication: *electron tube* video pickup. A relative newcomer in the video world is the CCD (Charge Coupled Device). Figure 1 contains an example of a CCD camera. A CCD camera uses light sensitive semi-conductor technology as a video pickup device. As mentioned later, CCDs have gained a significant share of the market and will eventually totally displace electron tubes as pickups. See figure 2 for an example of how a CCD pick-up is installed in a camera.

Table 4. Breakdown of Video Equipment Types

Equipment Type	Breakdown of category
Cameras	1. Low & medium resolution black & white 2. Low & medium resolution color 3. High resolution black & white 4. High resolution color
Camcorders	1. Low & medium resolution 2. High resolution
Tape Recorder/ Players	1. VHS, S-VHS, 8 mm and Beta format 2. U-Matic, Betacam™, 1" and digital formats
Displays	1. Low & medium resolution black & white 2. Low & medium resolution color 3. High resolution black & white 4. High resolution color
Specialized Equipment	1. Low-light, intensified-light, infrared 2. Still video

There are several differences that can be directly attributed to the fact that one technology is solid-state and the other is tube-based. First is sensitivity to light. It is true for both CCD and tube cameras that more light helps the camera generate better pictures. However, for low-level lighting, standard CCD devices tend to produce a higher quality picture at a given light level than their tube counterparts. Special formulations of CCDs are available to make them even more sensitive in very-low-light level situations. For very-high-level lighting situations, CCDs have the advantage, also. When photographing bright lights, tube cameras tend to leave trails when displaying the image, as the camera pans or the light source moves. This image persistence can cause damage to the tube if the light source is sufficiently bright or photographed for sufficient duration. CCD pickups, on the other hand, are virtually indestructible when it comes to photographing light sources. CCDs never have problems with image persistence and can only be

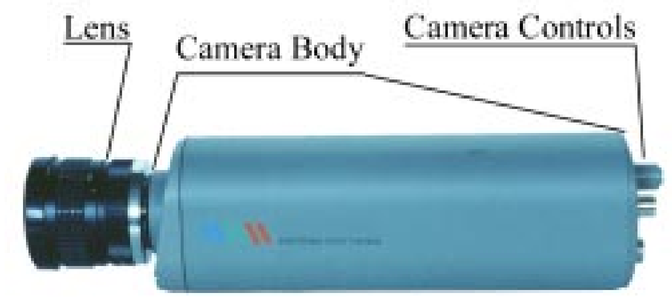

Figure 1. Example of a CCD camera

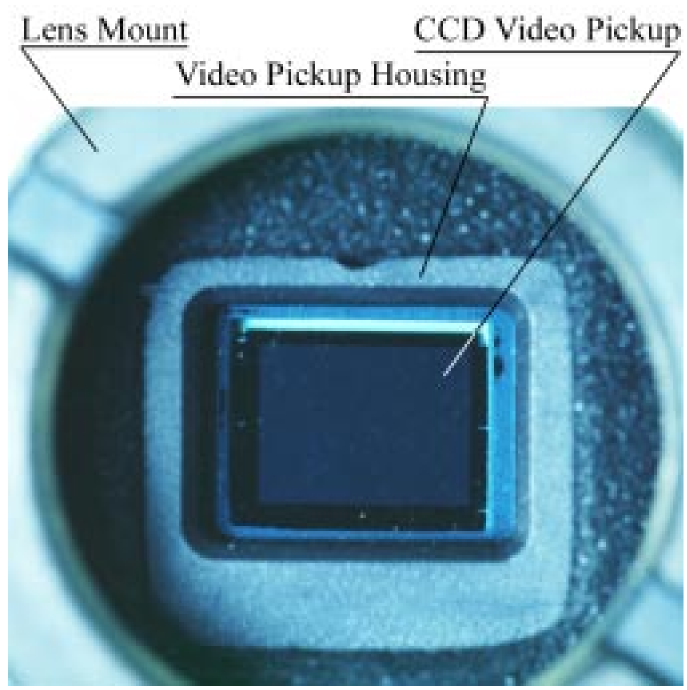

Figure 2. A CCD pickup device mounted in a camera

damaged by an intense heat source (e.g., created by focused light from direct photography the sun).

Another difference between solid-state and electron tube pickups is the solid-state device has the ability to simulate a shutter with an adjustable speed, while the electron tube device cannot. This is because of the method in which each device obtains the image data. A pick-up tube must continuously scan through a scene to provide a consistent image. For example, if the tube camera was being used to capture a color image for use by the television broadcast industry in the United States, it would follow the National Television System Committee *(NTSC)* standard and scan through the 525 lines of the image 30 times per second. A point of the image would be read, and then the scanning beam would move to the next point. This requires that the aperture between the scene and the pickup device always be open. A CCD, on the other hand, obtains information about the whole scene at the same time. Once the information from the scene has been registered onto the CCD, the information is translated to a scanning video signal by the electronics of the camera. Because a CCD registers all scene information simultaneously, a shutter can be placed between the scene and the pick-up. A high-speed shutter provides the potential for crisp, still-frame images during action scenes (like re-plays of sporting events). This is the same method that is used for stop action in conventional photography. Like conventional photography, however, use of a high-speed shutter demands more scene lighting to obtain a good quality image because the imaging pickup device (film in the conventional camera and the CCD in the video camera) is exposed to the scene for a shorter period of time.

For low (240 lines, comparable to the VHS videotape format) or medium (400 lines, comparable to Super VHS) resolution cameras, CCDs are much less expensive to produce than low-resolution tubes. Because of this, almost all cameras in this resolution range use CCDs as their pickup device.

Until very recently, tubes were the only devices that could provide the quality needed for high-resolution cameras (more than 500 lines). This, however, began changing as high-resolution CCD cameras entered production in 1998. As reliability and production of high-resolution CCDs increase, CCDs will take over this segment of the market as they did for low- and medium-resolution cameras. During the transition phase, however, one must compare the advantages and pricing of both CCD and tube cameras for high-resolution applications.

Another important innovation in video technology is the advent of the digital camera. All of the traditional cameras mentioned above provide output as an analog electrical signal that can be stored on tape or viewed on a monitor. Recently, digital cameras have been introduced that output the video as a stream of bits (binary ones and zeroes) that can be understood by digital displays or digital recorders. One advantage of digital video is the ability to make perfect copies because the bit pattern used to create the displayed image can be replicated exactly. Another advantage, specifically related to transmission, is digital video signals are less prone to degradation over distance or in the presence of a weak or noisy signal. However, once the signal crosses a certain signal-to-noise threshold, the loss is usually total, not the gradual degradation experienced in traditional analog systems.

3.2.2 Video Camera Features

The basic specifications of video equipment give the user a good, general idea of how a unit should perform. (These specified parameters are thoroughly explained in the next section of the guide, “Quality Parameters and the User – Interpreting Manufacturers' Specifications”). Along with the characteristics of a video camera that have a direct impact on its level of performance, however, other features are sometimes offered that can either give the user added flexibility and capability, or make the operation of the camera easier under different conditions. In some cases, they can also enhance the fundamental ability of the camera to perform better.

Below is a list of features that are offered in video cameras. Obviously, they will not all be offered in all makes and models of cameras because cameras are manufactured and sold to satisfy certain applications of the perceived market. The more features, the higher the cost! If the "importance" of these features is not currently understood, their merits will become obvious later in the guide. Even without knowing the specific details of individual video surveillance assignments for all readers of this guide, it seems likely that most will want to consider a number of these features. As a minimum, auto/manual white balance, auto-iris control, lens compatibility, multiple mounting holes, and environmental robustness are desirable features. As a starting point toward understanding the available features, figure 3 shows the controls for the CCD camera shown in figure 1.

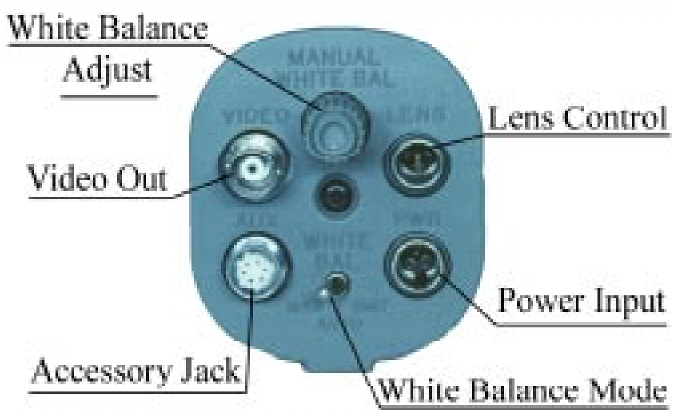

Figure 3. Controls for camera shown in Figure 1

White balance and/or black balance: Automatic, manual or remote-control – switch selectable. External white or black balance sensor possible.

RGB adjustments: Independent gain controls on red, green, blue, outputs. Remote control of red, green, blue, and master gain (i.e., overall video signal level).

Auto-iris control: For auto-iris lenses, an automatic gain control (AGC) or variable gain (e.g., 6 *dB*) – selectable on/off.

Synchronization options: Internal (crystal) or external source.

Power options: Ac or dc power options, typically 12 V dc, 24 V dc or 115 V ac.

Lens Mount: Adjustable C-mount (adapter).

Lens compatibility: Accepts all (or most) types of manual and auto-iris TV lenses.

Electronic shutter: Enables the camera to produce clear images in still or slow-motion playback even when the objects are moving at very high speeds.

Dynamic contrast control: Allows accommodation of scenes with a much wider range of light levels than normal (e.g., allows detail in both sun-lit and shadowy areas of the same scene).

Filters: Built-in optical filters can improve video results under various lighting conditions (e.g., bright, subdued, inside, outside).

Viewfinder compatibility: A jack is provided to accommodate a viewfinder, if desired.

Microphone holder: An adjustable ring or some other type of connection apparatus is provided on the camera to mount a microphone.

Multiple mounting holes: Two or more tapped holes for mounting the camera (e.g., on a tripod or wall-mounted bracket). More holes allow different size (and weight) lenses to be accommodated while keeping the assembly balanced.

Environmentally robust: Can operate in a wide temperature range (e.g., 14 °F to 122 °F) and can be stored in a wider range (e.g., -22 °F to 158 °F). Can operate at altitude (e.g., 10,000 ft) and in heavy relative humidity (e.g., 95 percent). Can tolerate shock and vibration.

Another thing to be aware of is a camera does not usually come as an all-inclusive video package. Components must be purchased along with it to permit it to function. A few of the most common items required for the camera system, but not supplied with it are listed below:

1. Ac power pack or ac/dc power supply
2. Lens
3. Coaxial cables (e.g., RG-59/U) for connections to recorder or monitor from "video out" jack, from camera to external sensor or synchronization, for remote control, etc.
4. Television monitor for focusing and other adjustments (such as white balance)

3.2.3 Camera Lenses

One important component of the video camera system is the lens. A lens for a video camera plays the same role as a lens for a 35 mm single lens reflex (film) camera. It allows the user to capture an image in the camera. Why all the different lenses? The difference in lenses is dictated by the difference in shooting environments and the kind of pictures that are needed. In a nutshell, the size of the subject, the distance to the subject, and how much light is on the subject determines the best lens. Figure 4 shows a fairly simple, manual focus, manual aperture lens.

The primary specifications of all camera lenses are their focal lengths and their f-stop ratings. Focal length is the distance from the center of the lens to the point at which parallel rays from a distant subject come to a common focal point. The f-stop number is the ratio of the focal length to the diameter of the lens. These terms are explained below.

The size of an image that a lens forms inside the camera is determined by three things – the physical size of the subject, the distance from the lens (camera) to the subject, and the focal length of the lens. Lenses with a short focal length (for example, 8 mm to 20 mm) are normally used for wide-angle pictures and are called "wide-angle" lens. Lenses with long focal

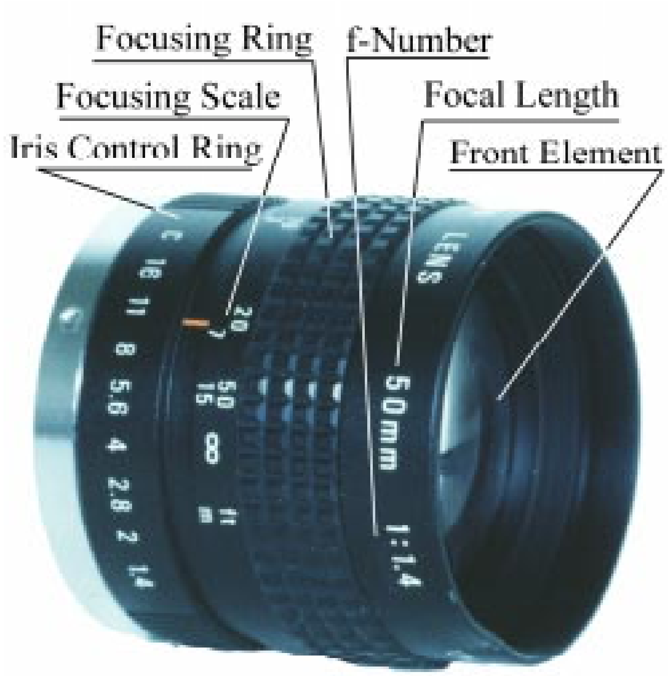

Figure 4. 50 mm, f-1:1.4 manual camera lens

lengths (80 mm to 300+ mm) are used to capture distant subjects and make them look close. These lenses are generally called "telephoto" lenses. A middle-of-the-line kind of focal length is 50 mm. Many new single reflex cameras come with a 50 mm lens because camera manufacturers feel it will give good overall performance for general recreational uses on the average. It cannot do wide angle or telephoto shots. Because lenses have different focal lengths, they also have different coverage ratios. That means that their fields of view vary. The camera/lens field of view is how much of the subject and the immediate surroundings will be filmed.

A wide-angle lens has a tremendous field of view. If observing a person on the street with a 16 mm camera system mounted on the side of a building, several feet of the street, both sidewalks, and other buildings may be in view. For a telephoto lens, just the opposite happens. A 300 mm lens camera may capture the head of a subject at 100 ft and nothing else. The light and viewing angles from the lens to the subject are very narrow. In both simple cases given here, the ability of the lens to satisfactorily capture the video image is dependent upon the light present. That fact leads to a discussion of the f-stop parameter.

The light-gathering ability of a camera is determined by the diameter of the lens. The larger the diameter of the lens, the greater the amount of light falling on the subject. Lenses are rated at maximum diameter (i.e., the largest iris opening). (The iris is either fixed at one size or is an adjustable diaphragm that varies the opening for light to enter the lens. The opening itself is called the aperture.) A lens' so-called f-rating is defined as the focal length of the lens divided by its diameter (with the iris fully open). The smaller the f-rating, the more light the lens can take in. This means that a low f-number is needed when a scene has low light. High f-numbers operate well in bright sunlight.

If a lens with a fixed iris and a 50 mm focal length had a diameter of 35.7 mm, its f-rating would be 1.4. The iris ring would probably have the rating f-1.4 written on it. This lens would work well in a fixed location with fairly low light. If a lens with an adjustable iris had a focal length of 25 mm and a diameter of 13 mm with the iris completely open, its f-rating would be 1.9. On the movable iris, calibrated marks called f-stops would indicate to the user that besides the f/1.9 setting, other settings for brighter light conditions were also available by turning the iris ring. These f-stops might be: 2.8, 4, 5.6, 8, 11, 16, and 22. The f-stop numbers increase in steps so that each higher stop allows one half the light input of the previous stop. For bright sunlight, f-22 is selected. Figure 5 shows a camera lens with the aperture wide open and also with the aperture partially closed. Auto-iris lenses control the light level automatically.

One important consideration in video camera operation that is affected by the lens opening, f-stop, is the depth of field. The depth of field is the distance between the object in focus closest to the camera and that object farthest from the camera that remains in focus. An example of this is clearly seen in a television scene when the camera is focused on a performer close to the camera and the background goes out of focus. When the f-stop is lowest (iris fully opened), the depth of field is poorest. To capture everything in focus within the field of view, the camera system must have the f-stop set as high as possible (ideally at f/16 or f/22). Once lighting is reduced, however, only lower f-stops will capture any image successfully. This correspondingly reduces the depth of field.

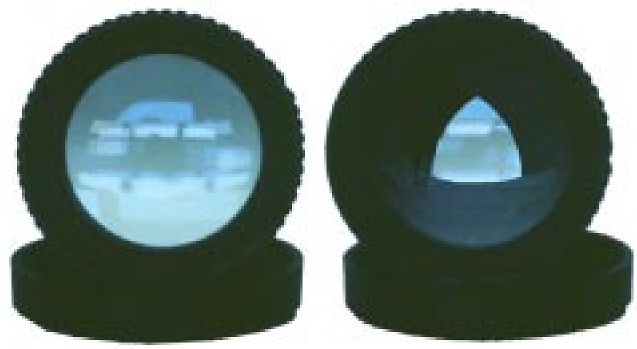

Figure 5. Camera lens with aperture wide open (left) and partially closed (right)

Zoom Lenses

Zoom lenses have continuously variable focal lengths. This reduces the need to change lenses for different applications. Wide-angle and telephoto tasks can be satisfied by the same camera with the same lens. A good zoom lens may vary from less than a 10 mm focal length to more than 140 mm with an f-stop of only 1.8. Zoom lenses are specified by the ratio of the minimum and maximum focal lengths. For a lens that can produce focal lengths from 9.5 mm to 143 mm, its zoom range is 143 divided by 9.5, or 15. Product literature would express this ratio as 15:1 or 15X.

An important consideration in zoom lenses is whether or not the aperture changes as the focal length changes. *Variable aperture zoom lenses* are lenses whose maximum aperture changes, generally increasing, as the lens is zoomed from smallest focal length to longest focal length. *Fixed aperture zooms* maintain the same maximum aperture throughout the zoom range of the lens. Fixed aperture zooms generally provide better quality than variable aperture zooms. However, variable aperture zooms are generally less expensive and smaller than their fixed aperture counterparts.

Lenses for Special Camera Systems

A number of ultra-small color and black and white camera systems, sometimes called microcameras, are available that have a separate control unit and a separate camera head connected by a cable. (fig. 6.) The control unit (box) contains the circuitry and adjustment controls (e.g., white balance, noise reduction, high-speed shutters, internal/external sync) normally found in and on the camera body, while the camera head includes the lens and sensor subsystems. The reason for having such a camera system is that it can essentially be placed virtually anywhere. It is an ideal and versatile tool for several industrial applications such as the observation of processes, material handling, quality control, and laboratory experiments. In addition, it can be used very effectively for video surveillance.

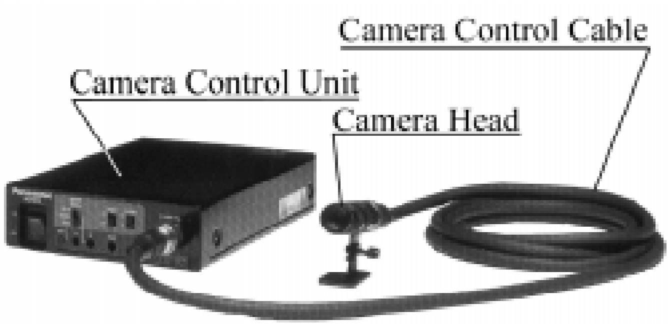

Figure 6. Typical microcamera system

The camera control unit is small and light. Typical dimensions might be: less than 4 1/2 in wide, less than 6 1/2 in deep, and about 1 1/2 in high. It may weigh less than 2 lb. The cables, which connect the head to the control unit, can be several lengths – from a few feet to almost 100 ft. The camera head comes with a standard C-mount to accommodate a virtual “catalog” of different lenses. Those lenses can be as diverse as the lenses used in a normal one-piece camera system. They range from “super wide angle” to telephoto, and many are available in a pinhole lens design.

Pinhole lenses vary in size but have one attribute in common: their front element is very small and their overall construction mirrors this. Even with lenses of focal lengths as low as 4.5 mm and as high as 200 mm, the diameter of the lens barrel (the cylinder that houses the lens) is normally only about an inch in diameter. The lens opening at the end of the lens barrel may be just a few millimeters in diameter. (The conversion of millimeters to inches is: 25.4 mm equals 1 in.) This means that a pinhole lens could look through a hole (e.g., in a picture, wall or door), that was about the size a pin would make. As an actual example, among the lenses that Knox Security Engineering Corporation sells are two very different products – the model SXZ4.5 auto-iris 4.5 mm lens and the model YX200 200 mm manual lens (fig. 7.). The wide-angle SXZ4.5 has a lens opening of 1.6 mm, about 1/16 in. The "huge" 200 mm telephoto lens needs an opening of 10 mm, a little more than 3/8 of an inch. Figure 7 shows the profiles for these lenses and their barrels, and gives their specifications.

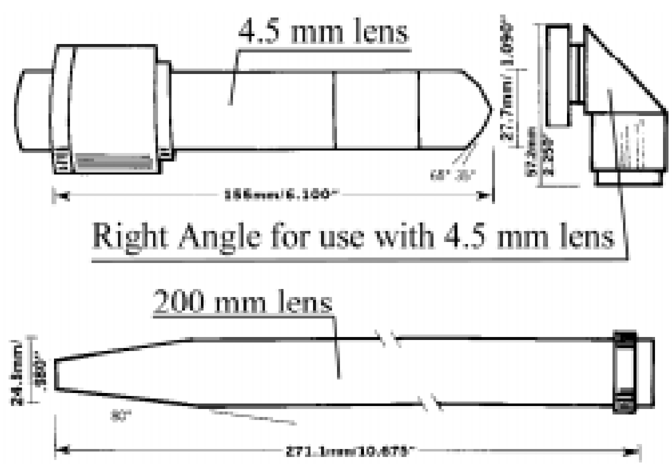

Figure 7. Wide angle (top) and telephoto pinhole lenses

Another tiny camera system is called a “board camera.” Board cameras are CCD devices with a small lens and all other required electronics mounted on an electronic circuit board. The board is typically 1.5 in square and requires that video output cables and a power input source be wired (and typically soldered) to the board. These cameras can be particularly useful in cases where a traditional camera simply will not fit. Figure 8 illustrates a board camera that is approximately 1.5 in square.

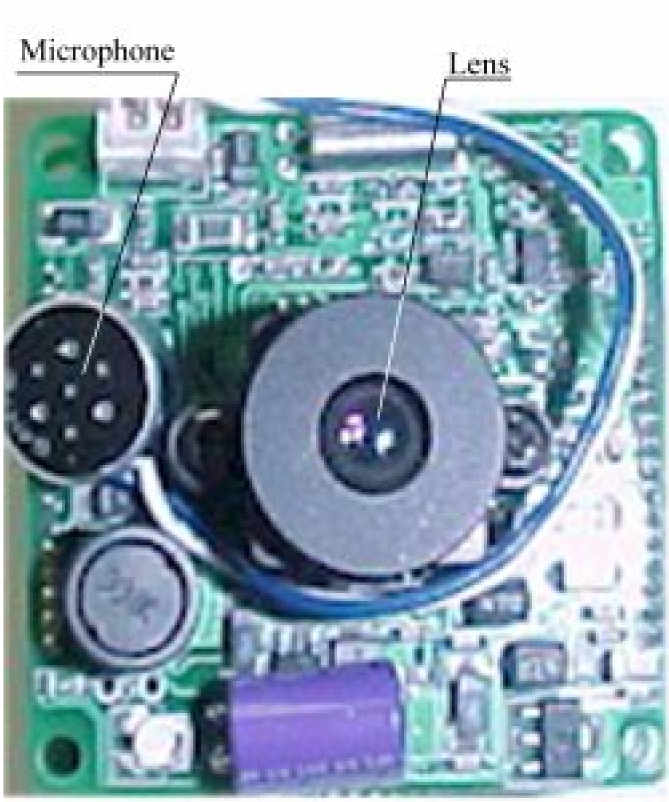

Figure 8. Example of a board camera

3.2.4 Still Video Overview

Still video, or digital still camera, technology was first demonstrated to the public in 1981. The device demonstrated at that time was revolutionary. It used a CCD to capture a video image, which was then stored on a matchbook-sized floppy disk. The disk was capable of holding 25 frames of video or 50 fields of video (a field is the equivalent of every other scan line of a frame). The images stored on the disk could be viewed on any standard television or printed on a special printer. The combined cost of the disk and the paper and printer dye was significantly less than the cost of a standard print. The problem with the device displayed in 1981 was a lack of resolution. The still video camera at that time had a horizontal resolution of about 200 lines, significantly less than a VHS recorder would have. Because of the poor resolution available, actual production of still video equipment was delayed until 1986. The equipment introduced in 1986 showed vastly improved resolution. The manufacturers had doubled the initial resolution to something that is comparable with Super VHS, i.e., 400 lines. Development has continued, and mainstream still video cameras can now be purchased that have a resolution of more than 700 lines. There are some very specialized digital cameras that have a resolution of more than 2,000 lines. This is approaching the resolution of 35 mm film, which has a resolution of about 4,000 lines to 6,000 lines, depending on the type of film.

One of the most touted features of still video is the ability to take and view pictures instantly. With still video, there is no need for messy, time consuming and costly development of slides or prints. Also, the images recorded on the disk can be sent in digital form anywhere instantly with no loss of quality. Finally, unlike film, the floppy disks that are used to store image data can be used again once unusable or unneeded pictures are deleted.

3.2.5 Low-Light Cameras

Low-light CCD cameras can be categorized into two types: low-light and low-light intensified. The simple low-light variety uses the same technology as “normal light” CCD cameras and camcorders; the difference is that their imaging chips are optimized for low-light conditions and/or have additional refinements to be more noise-free over an expanded range of incident light.

In low-light video surveillance situations, standard CCD chips have one particular advantage over their predecessors, video pickup tubes: their resistance to image burn-in caused by incident light that is too intense. If a video tube were to focus on a scene that contained an overly intense light source, an image of that light source would be permanently burned into the tube and would be seen in all subsequent use, even after the scene had changed. When devices are extra sensitive, as in the case of low-light equipment, something as simple as a flashlight shined directly into the lens can cause damage. Using a CCD camera in this type of situation helps prevent damage.

CCD cameras designed for use in extreme low-light conditions (approximately 0.05 lux and below[2]) usually have a device called an *intensifier* built in front of the CCD array that multiplies the incoming light for the CCD chips behind it. Modern intensifier technology exhibits the same propensity to burn-in as video pickup tubes, however. Note that in this case it is the intensifier and not the CCDs that exhibit this tendency.

The method of intensification enjoys widespread use because the use of CCDs keeps the cost of the low-light camera below that of a video tube type implementation, gives it ruggedness and durability, provides freedom from frequent calibrations, and allows it to be used in a wider variety of environments. If the intensifier were subjected to excessive light and had some image burned permanently into it, the replacement cost for the camera would be considerable.

Low-light intensified cameras can be found in a wide variety of price ranges. Such devices range from attachments for existing cameras to full-blown amplified-light surveillance systems, with the quality and sensitivity of the device depending on the cost. Given they can be used in rooms that would look completely dark to the human eye, a very sensitive (therefore, very expensive) camera may be a small price to pay for law enforcement or surveillance applications requiring this capability. Regardless, the more typical application would be a poorly lit room or night-time city scene, in which case a nominal sensitivity of 0.1 lux or more would be sufficient for gathering evidence or performing general, fixed, or mobile surveillance. Cameras claiming such sensitivities are generally monochromatic (black and white), and do not employ the intensification technology. They are significantly less costly than intensified light cameras, making them a very attractive choice in many applications.

[2] Section 4 will explain “lux” and present examples of different lux levels.

Some practical examples are helpful to consider when deciding between these two low-light camera technologies. A standard low-light camera would probably enable a car’s front license plate to be read at night, even though the car’s headlights were on. A low-light intensified camera probably would not. In addition, the intensifier would probably be burned and need to be replaced at a cost of around $4,000. If a very dimly lit warehouse required surveillance, a low-light intensified camera involved in that surveillance could be severely limited, if not altogether disabled, by one very bright flashlight aimed at the camera’s lens.

3.2.6 Infrared Cameras

Infrared cameras use special pickup devices that are sensitive to light with wavelengths longer than those visible to humans. Within this category, there are two types of equipment: thermal imaging systems and near-IR systems. Both systems can be used in an environment that is totally dark to human eyes but well illuminated from the camera’s perspective. This perspective changes, depending on the category of equipment.

Thermal imaging equipment is commonly used by the military for night action. The image it forms is based on heat emissions from the subject it is pointed at. The higher the temperature of the subject, the brighter the image. This requires no special illumination but does require that your subject be a different temperature from the background. Thermal imaging systems are fairly expensive, ranging from $5,000 to $40,000.

Near-IR cameras use a special light source to illuminate the subject area. While subjects may be in total darkness, the special light source makes the scene appear bright-as-day to the camera. This special light source, an infrared light, often will be provided with an infrared camera but can also be purchased separately. Near-IR cameras with an accompanying light source range in price from $700 to $1,500.

Some caution must be used in the selection of an infrared light source. As wavelengths approach the red end of the visible spectrum (700 nm), it might be possible for some humans to perceive the emitted light. Therefore, it is desirable to have an infrared source with a wavelength of more than 800 nm.

3.3 Camcorders and Recorder/Players

3.3.1 Video Tape Technology

Of the many video formats, *VHS* is the most popular in the world today. Since the format's introduction in 1975, the popularity of the VHS system has grown such that more than two-thirds of the households in this country contain at least one piece of VHS equipment. The VHS format's primary advantage is it is the lowest cost option for video. However, being the least expensive format has its trade-offs: at 240 lines, it has the lowest horizontal resolution of the available formats. (Resolution and other important perfor-mance parameters are explained in section 4 of this guide, called "Quality Parameters and the User – Interpreting Manufacturers' Specifications.") The VHS format has also produced some variants, which are on the market today. Included in these are *VHS-C*, Super-VHS (*S-VHS*), and Super-VHS-C (*S-VHS-C*).

The "-C" designation implies that the system is compact. To achieve this, the system uses a smaller cassette. The -C format is used almost exclusively in camcorders because size and weight have a significant impact on the camcorder user. Camcorders have been produced with this format that weigh less than 2 lb. The smaller cassette employed by -C systems still use the same size and type of VHS tape, but the smaller cassette only holds approximately one-sixth of the amount of tape that a "normal" VHS cassette holds. The amount of information recordable on a tape is reduced accordingly. The small cassettes are playable in a standard VHS machine with an adapter.

The "Super" designation indicates the same tape size and cassette as VHS format but uses newer recording technologies to dramatically improve picture quality. Super VHS equipment have a greater signal-to-noise ratio and a higher resolution (400 lines) than the plain (240 lines) VHS. Tapes recorded in standard VHS format are playable on Super VHS machines, but Super VHS tapes recorded in S-VHS format are not playable on standard VHS equipment. (S-VHS tapes recorded in VHS mode may be played back in either VHS or S-VHS players with the 240-line VHS resolution).

For several years after its introduction in 1974, the Beta format was thought to be superior to VHS. As far as resolution was concerned, that was true: Beta format has a resolution of about 260 lines. On other fronts, however, Beta was not superior. Sony opted not to license the format to other manufacturers, while licenses to produce VHS equip-ment were readily available. The availability of a var-iety of equipment led to a greater variety of prerecor-ded VHS material for public use. This drove the pop-ularity of VHS up while decreasing that of Beta. Eventually, market forces led to an almost total stop-page of Beta equipment production. In spite of the dearth of programming and the lack of mass market support, there is still a small market for Beta equip-ment. This, however, will continue to wane in the face of technology that is better and less expensive. Beta did manage to produce one variation – ED-Beta (1985). This format improved on the resolution of Beta, but failed to capture the interest of the market. Its availability in the United States is very limited.

One technology that is currently gaining ground in the consumer marketplace is 8 mm. This technology, introduced in 1985, uses a cassette that is about the size of an audio cassette, yet will hold a full 2 h or 4 h of video information. The resolution of this format is approximately 300 lines, somewhat better than that offered by VHS. Like VHS-C, the most common use for this format is in camcorders. Also like VHS-C, camcorders using this format have been produced weighing less than 2 lb. A possible disadvantage of 8 mm, when compared to VHS-C, is the 8 mm tape/ cassette format is incompatible with any VHS equipment. However, if the recording device, or another 8 mm camcorder or *VCR* system is available, the tape will be playable through that device onto any

NTSC television or monitor. The tradeoff between available recording time and compatibility has caused acceptance of the 8 mm format to grow slowly. However, the installed base of 8 mm equipment appears to have reached critical mass, as new home-based 8 mm equipment is becoming available at prices only slightly higher than those available for VHS. The only existing variation on this format is Hi-8, which has all the features of standard 8 mm, but the resolution increases to approximately 400 lines. Like Super VHS, tapes recorded in standard 8 mm can be viewed on Hi-8 machines, but tapes recorded in Hi-8 format cannot be viewed on standard 8 mm equipment.

A format introduced in 1982 that had sufficient quality for use in some field production work is Betacam™. Betacam™ was phased out when a vast improvement was made on this system in 1986 with the introduction of Betacam™-SP. This change increased the resolution from 320 lines to approximately 450 lines. This format is currently very popular among circles where quality is very important, such as television field production, and is used extensively in studios. Panasonic has a proprietary format that is roughly equivalent to Betacam™, called MII™.

The final analog format under discussion is C. This format is for absolute top-of-the-line NTSC analog video. It provides more than 600 lines of resolution. It is the only major format that uses a reel-to-reel tape instead of a cassette. This technology makes the equipment rather bulky, but the size would be acceptable for use in surveillance vans. The bulk also prohibits the use of the C format in camcorders and therefore requires the use of a separate camera unit. There is, however, a price to be paid for the quality of C format – the equipment is very expensive.

Recently, digital video recorders, cameras and camcorders have been introduced. Professional equipment is currently divided into two camps: Sony and Panasonic. Sony currently has five digital formats (D1, D2, Digital Betacam™, Betacam™ SX, and DVCAM™) and Panasonic has three (D3, D5, and DVCPRO™). Resolution of digital cameras is generally at least 400 lines. Figures 9 and 10 illustrate a typical digital camcorder and some of the controls one might expect to encounter.

Table 5 offers a list of video formats available for video surveillance equipment, the resolution associated with those formats, and the price ranges for equipment represented under each of the formats. The price ranges include the prices for individual pieces of video equipment, that is, for camcorders and recorder/players, unless otherwise noted. (For instance, for the VHS-C format, there are no VHS-C player/recorders on the market. VHS-C cassettes are played in normal VHS player/recorders with an adapter. The figures in the price range reflect the prices of VHS-C camcorders only).

3.3.2 Camcorders and Video Recorder/Players Features

Camcorder and video recorder/player products offer a vast number of features. Many of these are well known, while others are not obvious, and are therefore not considered very often. Some of these "subtle" features may be just what are needed for certain kinds of surveillance applications. A number of the commonly advertised features are briefly explained below, along with some of those receiving less attention.

Auto/manual focus: Automatic focus will change the focus based on the perceived target and maintain it until something changes. Even if auto focus is available, professionals often will use manual focus in cases when there is a chance that automatic feature will have trouble differentiating the target from other activity.

Auto/manual white balance: Automatic white balance will maintain the optimum color balance in either indoor or outdoor conditions. Manual control is useful if unique conditions exist that the auto white balance feature cannot deal with (e.g., strong backlight).

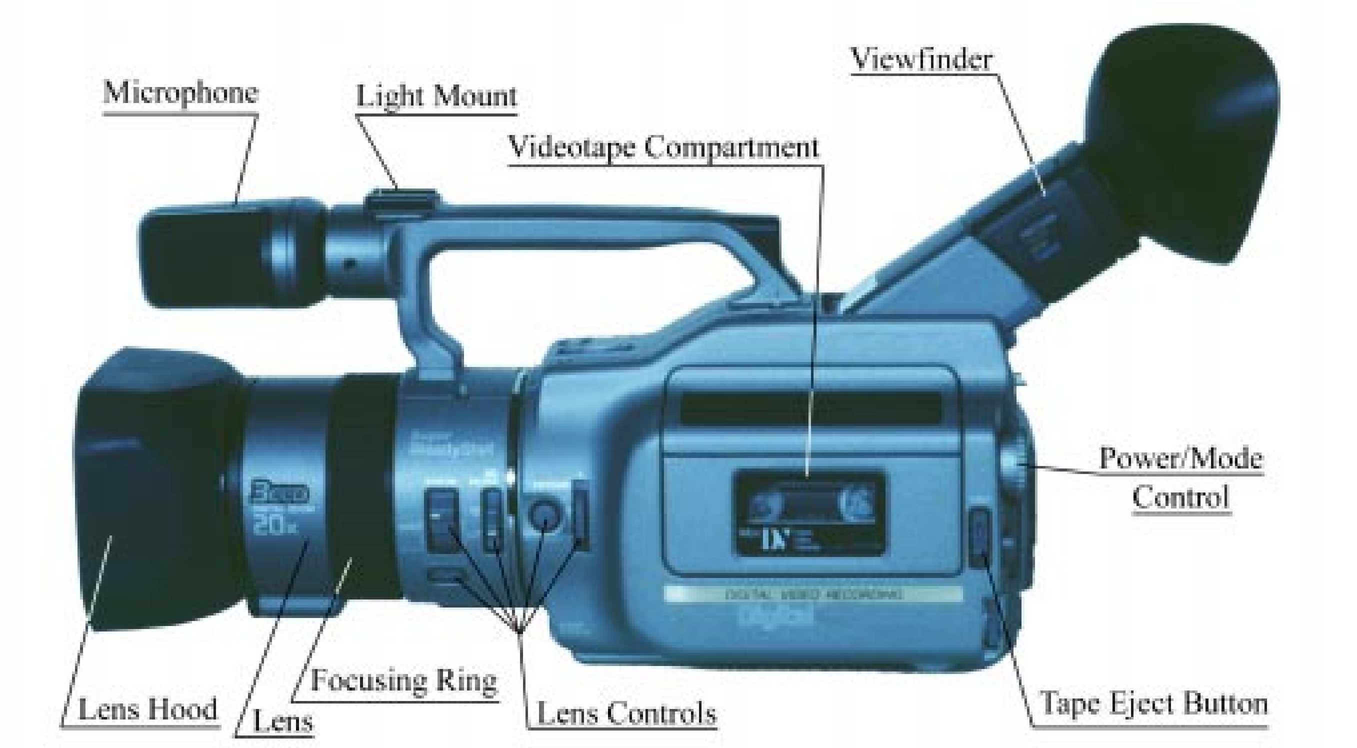

Figure 9. Left side of a typical digital video camcorder

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]

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.

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

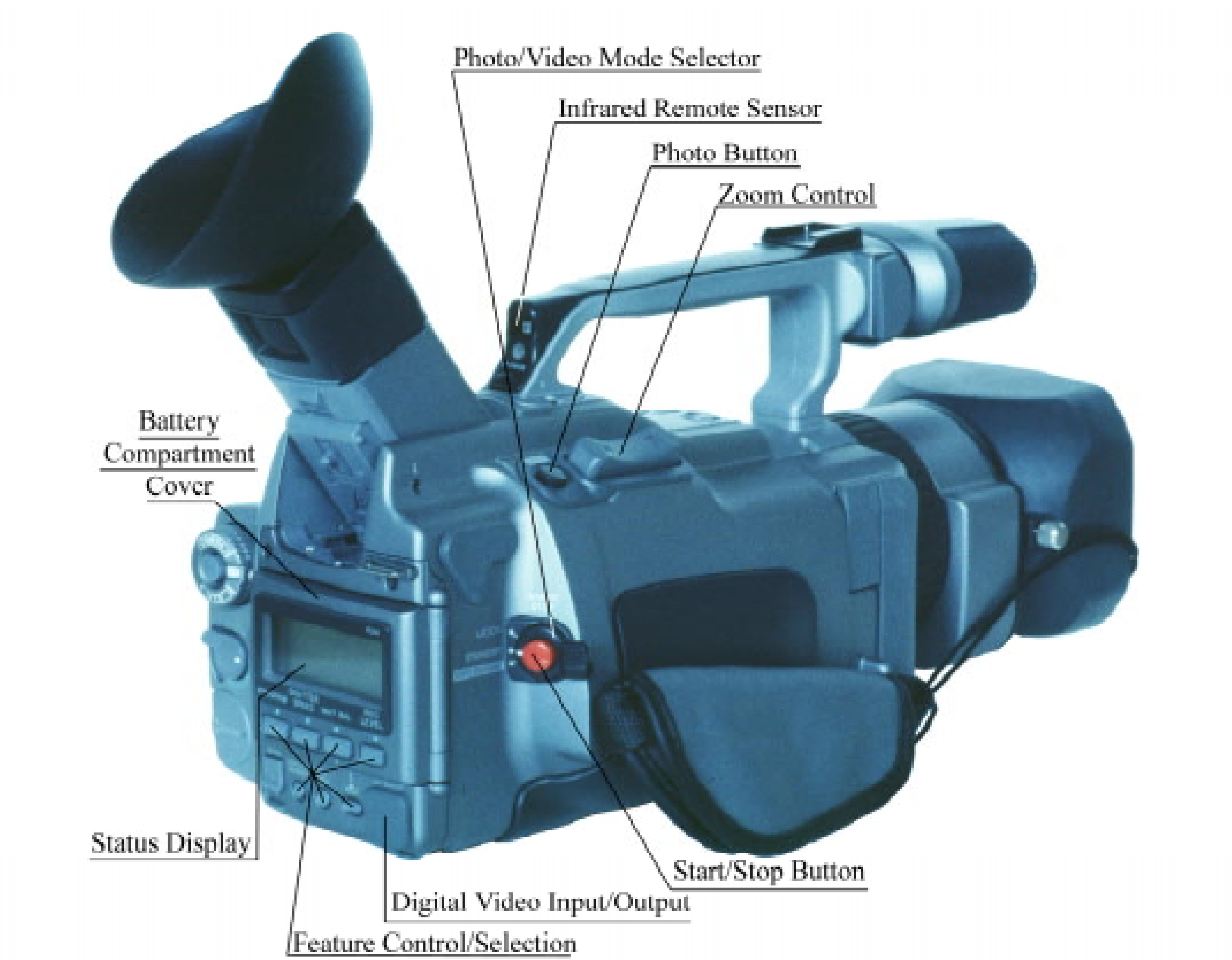

Figure 10. Right side and rear of a typical digital video camcorder

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

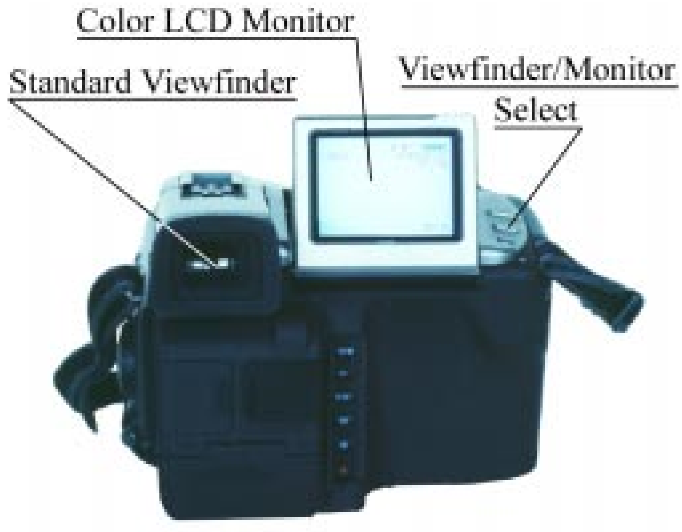

Figure 11. Example of a camcorder with both a viewfinder and an LCD monitor

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.

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 <u>at least</u> 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

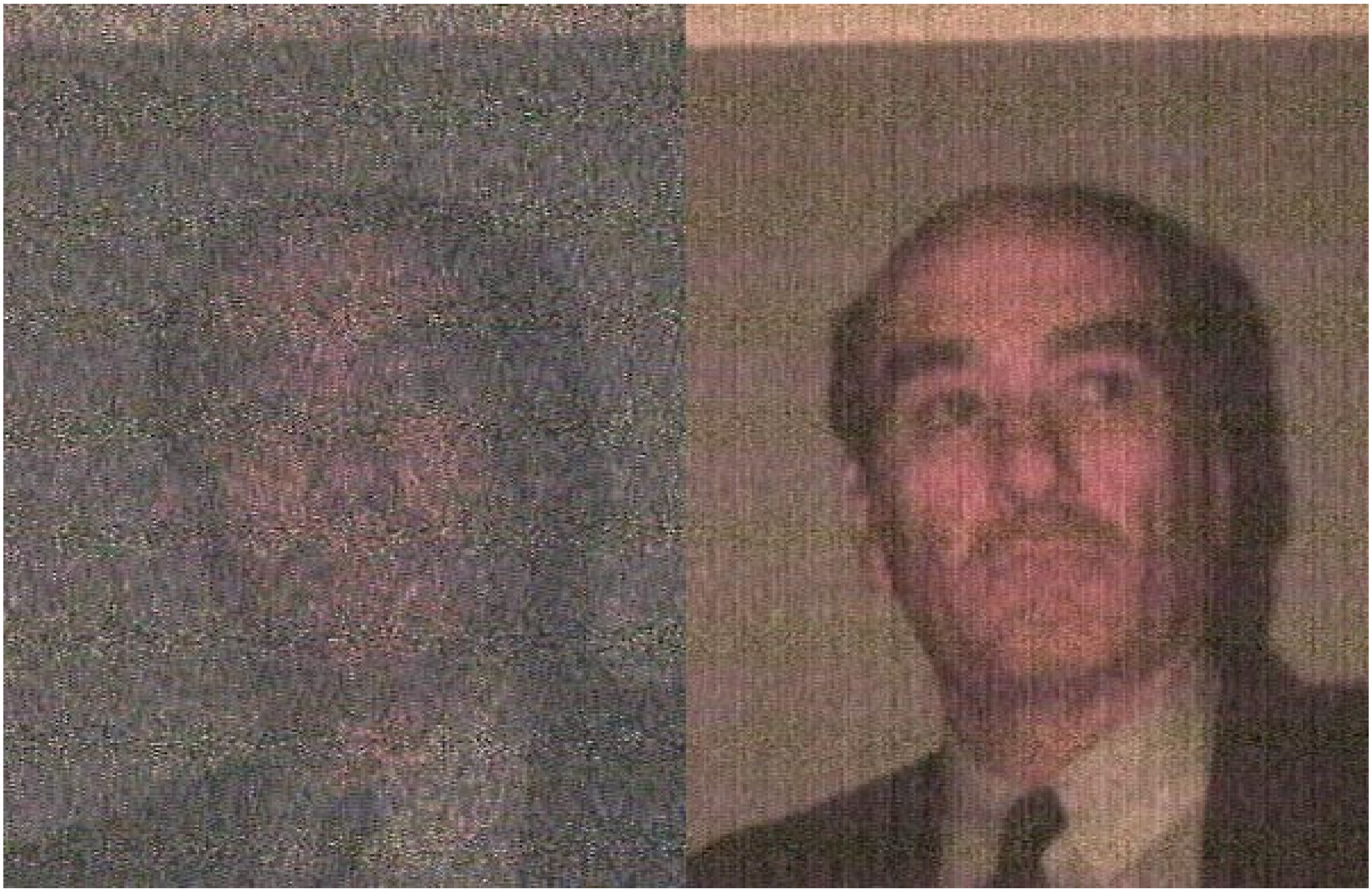

Figure 12. Extracting useful data from videotape shot in conditions below the light threshold

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.

4.2.6 Maximum Lens Aperture

This characteristic of cameras and camcorders tells something about how good the lens is. The better a lens is, the faster it gathers light for conversion into electrical signals and the easier it is for the rest of the camera or camcorder to maintain a noise-free image, since there is more light coming from the scene than there would have been with a slower lens. If most of the perceived applications involve nighttime or twilight conditions, it is important to obtain the fastest lens available (within the established budget).

Most cameras/camcorders have the maximum aperture marked on (or near) the lens as an "f-number." It may be shown, for example, as "f/1.4," "1:1.4," or simply "1.4." Speed in a lens, as determined by the aperture, provides an indicator of how long it takes to expose the video pick up (or any type of film). With an f/1.4 lens, the light can be one-eighth as bright as with an f/4 and still allow the same length exposure. For the same brightness of light on the subject, the shutter speed can be shortened by a factor of eight. For the police photographer, lens speed is of the greatest value in a covert surveillance situation where there is little natural light and supplementary illumination cannot be used. A lower f-number may be the difference between getting a picture and not getting it.

Table 10 lists standard f-numbers and compares the relative brightness requirements of each. The table uses f/1.4 as a typical "best" limit for lenses, however, some cameras offer an f/1.2 lens. An f-number of 1.0 is the theoretical lower limit for standard lenses.

Table 10. f-Numbers and Light Brightness

f-number	1.4	2.0	2.8	4.0	5.6	8.0	11	16	22
Relative Brightness Required	1	2	4	8	16	32	64	128	256

For most surveillance cameras, it is fairly easy to cover applications involving different lighting conditions by buying more than one lens. Lenses can be switched on and off the camera body, even in the field. Camcorders are not so flexible. The lens that comes with the camcorder cannot normally be removed.[7] If two camcorders are essentially the same except for the maximum aperture, it may be prudent to choose the one with the lower f-number, especially if both show the same lux specification.

4.2.7 Minimum Focusing Distance

Almost all of today's common camera and camcorder lenses focus as close as 2 1/2 feet to 3 feet. This is suitable for satisfying most needs of law enforcement and corrections, except for acquiring some forensic footage. If there is a need to record extremely close footage of an object that will serve as evidence, the 'macro' function of the lens should be engaged, if available. This effectively switches the lens into another mode that has a focusing range from about 2 1/2 feet right down to zero – which is right at the lens. In this mode, focusing is typically accomplished with the zoom controls and with more difficulty.

4.2.8 Zoom

Although such a function is considered a "special" lens on a photographic camera, it is the norm for video cameras and camcorders. Usually a lens will come with the unit and be designated, for example, an "8:1" zoom. This means that if the lens is zoomed to its wide-angle limit (that which makes the subject look the farthest away), then zoomed to the other end (as close as possible), the subject will appear eight times as close. This extreme is called "telephoto." While not true for all lenses, in most camcorders, zooming to the telephoto end of the lens also reduces the light transmission (i.e., f-rating) through the lens. In spite of this restriction, having a zoom feature means the camera or camcorder can be used in a wider range of situations than would otherwise be the case.

[7] It is true that "wide angle" and "telephoto" lenses can be mounted in front of the camcorder's permanently mounted lens, increasing the range of situations in which the device can be used. These lenses do, however, generally reduce the amount of light reaching the lens by one or two f-stops.

When zoom functionality is solely dependent on the lens, it is considered an optical zoom. Some of the new digital camcorders have a digital zoom feature in addition to the optical zoom, in which they use a subset of the elements of the CCD video pick-up device and enlarge that subset to cover the full screen. When reporting zoom ranges, manufacturers typically multiply the optical zoom and the digital zoom features. For example, a camcorder with a 12x optical zoom lens and a 5x digital zoom feature would be touted as a 60x zoom. That is, the image of an object fully zoomed in (magnified) will appear 60 times larger than if the camera were fully zoomed out. Remember, however, that much of the increase was due to sampling a subset of the CCD, thus reducing the overall resolution of the image.

4.2.9 Autofocus

A number of consumer-grade cameras and camcorders on the market offer the user the choice of either manually focusing on a subject or allowing the video device to automatically focus. In some cases, the user has no choice – the equipment comes with only a manual or auto-focus lens. Whether the auto-focus is optional or mandatory, it is important to realize what its capabilities (and limitations) are before making a selection.

Two methods are typically used in auto-focus cameras and camcorders – contrast-maximization and infra-red ranging. These methods are described below.

<u>Contrast Maximization (CM)</u>

Imagine, as in the discussion on resolution, a series of vertical lines alternating between pure black and pure white. If this scene is viewed with a lens system that is in focus, the boundaries between the two types of regions will be distinct. If the eye scans from left to right, it sees light levels alternating in sequence between a very low light level (a black region) and a very high light level (a white region). If the lens is completely out of focus, all that will be seen is a large area of uniform medium gray (a medium light level). In fact, for any given scene, the lens setting that is in focus also produces the maximum contrast in light levels. Cameras scan pictures as described above but see pictures in terms of electrical levels. A camera can find the best focus by changing the lens until the difference between the highest voltage and the lowest voltage in a scene is maximized. This principle has been exploited to allow camcorders to find the "best" focus automatically and is called "contrast maximization."

<u>Infrared Ranging (IR)</u>

In this radar-like system, an infrared emitter, typically located next to the camcorder's lens, transmits a pulse of light that is not in the range visible to humans. An infrared light sensor then waits for a reflection of the original pulse and notes how long it took for the reflection to return. Knowing how fast the pulse travels, the system then calculates the distance to the object that reflected the light pulse and adjusts the lens apparatus accordingly. These calculations and adjustments are done from 5 to 10 times per second.

In implementing both the CM and IR methods, engineers had to answer many questions. For example, in the case of the CM camcorder, the true focus could be anywhere in the range of the lens (or too close). While sweeping from nearest to farthest, the contrast might not simply increase until focus is attained, but instead, it may increase a little, then decrease, and then increase a lot. How should the camcorder decide whether to find an even greater contrast, or to stand pat on its current decision? If it stays where it is, it might not be in focus, and then just stay there, out of focus, forever. If it is in focus but goes hunting for a better focus, it might simply waste time, losing valuable information by recording out of focus until it comes back or stays elsewhere incorrectly.

In the case of the IR focusing camcorder, the pulse should spread as it travels outward, away from the camera and toward the subject to be videotaped. If it does not spread but stays thin as a pencil, it could focus, for example, through to the other side of library bookshelves (when there is an opening through and things and people on the other side can be seen) when the books are the intended subject. If the beam is too wide, the camera could focus on the books, when it is the people on the other side who should be monitored. In another scenario, what if the user of the camcorder is by a chain-link fence, and something else is on the other side? Should the point of focus be the chain-link fence or the object on the other side? Both cases are possible, but how does the user inform the camera what's on his/her mind? He/she does not with auto focus! Manufacturers made decisions for the user.

Regardless of how the manufacturers ultimately decided, it is imperative that the user understand what they decided to do and how that impacts the effectiveness of auto-focus for certain video applications. Some of the advantages and disadvantages of the two technologies are given below:

IR focuses on glass, whether you want to or not. This makes observation of people in houses and vehicles very difficult.

CM looks for the greatest difference between black and white. If the room is relatively dark, it takes longer to decide that a given lens setting is right or wrong. It could take up to 30 s to focus in a well-lit indoor room when the subject is of low contrast already.

IR systems can focus perfectly on a subject even if there is absolutely no visible light. This does not mean the camera can operate and/or record images in pitch black surroundings. This means the camera can be focused and ready to go, and once the light level reaches the minimum illumination the camera requires, it will operate. An IR autofocus camera, then, could be placed in a dark room and record happenings when a lamp was turned on or some sunlight shone in. From bright light to little light, the IR focusing ability is not progressively diminished as the light grows dimmer.

CM uses only the center third of the frame when calculating focus; therefore the zoom interacts with the auto-focus. CM maintains focus when moving from wide-angle to telephoto but loses it badly in the other direction.

Regardless of whether the auto-focus mechanism is CM or IR, depending on the particular camera, the auto-focus can be swift or slow. The swift ones tend to hunt indecisively once they get close to focus, whereas the slow ones take longer to get there but are very accurate and stable once they decide they are focused.

Linked in with all of this is the auto-iris, the part of the camera that adjusts for changing light levels. As the iris opens and closes, the depth of field will change, making parts of the scene that are not at the same distance as the subject go in and out of focus. While the CM types will be affected by this, the IR types do not appear to be.

4.2.10 Shutter Speed Control

The fact that most video devices in the United States produce frames at the rate of 30 per second means that if a subject moves considerably in 1/30 second, it will appear blurred under normal circumstances. One of the features available (with the proper device) that can solve this problem is shutter speed control. Just as with a photographic camera, higher shutter speeds reduce the amount of time the shutter is open and decrease the blur seen during that time. The payback is the faster the shutter speed, the more light that must be available; however, with a subject illuminated by full sunlight, shutter speeds of one 0.0001 second are possible with uncompromised quality.

5. The Ergonomic Aspects of Equipment

One of the experiences people have had with new video equipment is they could not get it to work. No, this is not another story relating to poor workmanship, missing parts, or bad information from the salesman! In the vast majority of cases, there was nothing wrong (theoretically) with the equipment. Problems arose because users did not know what to do; the equipment was not straightforward to operate; technical manuals were incomplete, misleading, or confusing; or the equipment controls could not physically be moved or positioned. These were all ergonomic problems. (Ergonomics is the science concerned with the characteristics of people that need to be considered in designing and arranging things. That is, how should something be made so that people will interact with it effectively?) A video product can have the best specifications and features in the world, but if no one can easily use it, it has no real practical value.

This section addresses a few of the "nitty-gritty" items that may be forgotten during the selection process for video surveillance equipment. If specifications, features, and cost all fall out as about equal, one of these items may be the deciding factor. Even if the video units mentioned below did not have any drawbacks in specific categories, it still would be prudent to look at those kinds of categories when actually contemplating a purchase.

5.1 Time Needed to Learn Basic and Advanced Operations

With a technical manual as a guide, it only took about 5 or 10 min for ordinary people (non-experts) to get the various video units described in this guide working. (That is, if the batteries came already fully charged with the camcorders). The Sony DXC-M7 camera took somewhat longer because it is a more complex piece of equipment (e.g., more function switches, feature controls, and connectors). An officer who had never used a camera or camcorder before would be ineffective if forced to use one "cold" in a pressure situation, but 2 h of use over a couple of days probably would allow that officer to use all of the basic features adequately and to record valuable information. To learn and use advanced features, such as toggling sensitivity gain and autofocus, adjusting white balance, connecting a 10 W lamp to the camcorder, and using the macro feature of the lens, some weeks of use would be required. In addition, there are some things an artist can do with skillful control of the camcorder that your average operator will never be able to do. This personal element is no more of a problem with certain officers than trying to photograph evidence with a standard 35 mm single lens reflex camera, however.

5.2 Controls – What Kinds are Better?

This subject is general to cameras, camcorders, televisions, monitors, and VCRs. Even in this realm, things have changed a lot since the days when TVs were powered on with a loud mechanical click. This is mostly due to solid state electronics, but also to materials science. Since silicon switches use so little energy, it is not uncommon now for a part of an electronic instrument to remain on even when it has been turned off. Turning it back on consists of moving a switch that closes an electrical contact that tells the part of the instrument that remains on to turn on the rest of the instrument. Since the switch is just a contact, it can be made quite small. Unfortunately, some manufacturers have gotten overzealous in their desire to show off just how small they can make their switches, and the result is full-size camcorders that have switches that are too small to use comfortably with just fingers, not to mention gloves.

The most common types of controls are buttons, sliders, knobs, and switches. (See figs. 3, 9, 10, and 11.) Switches are generally of the variety that can be in one of two positions and stay there. More popular than switches are buttons, knobs, and sliders. Buttons most often are just electrical contacts that electronically toggle functions: the first time you press it the auto-focus turns off; the next time it turns back on. Of course, if these toggle buttons are too large, it becomes possible to bump them when it is not desirable to do so. It could be disastrous if such a button controlled the power for the entire camcorder or for the cassette eject mechanism. These functions are usually protected by a slider, the function of which is invoked by moving a spring-loaded control to the side momentarily for electrical contact. Sliders return themselves to a home position upon release. Since pressure straight upon their surfaces does not bring them to operation, they are safe for the more important functions. Knobs are most commonly used to allow the user to select one of many options. One example of this is the power-on knob of the Sony DCR VX-1000. This knob allows selection of VCR or camcorder mode, as well as various levels of automation.

An example of a more complicated control that can be found on some devices is the power control on the Sony CCD-V99 camcorder. It has a center position and slides to one side to use the device as a camcorder or to the other side to use it as a VCR. Before moving it from its center position, however, a tiny green button in the middle of the sliding switch must be depressed to unlock it. It has proven to be a formidable task even with bare fingers.

Even simple controls like buttons can be made difficult to operate by placement. Many times frequently used controls are placed behind covers or doors. This slows access to those controls. One extreme example of poor placement are the menu controls on the Sony DCR VX-1000. These controls are behind the battery compartment door, on the side closest to the hinge. This makes the buttons awkward to reach without the added complication of having to hold the camcorder at eye level to see the menu in the viewfinder and having the battery door continually bumping into your chin.

Monitors and televisions are used almost exclusively indoors or at least not in sub-zero outdoor weather. Since they are relatively large, there does not seem to be a leaning by designers to give them unnaturally small switches. Operation is rarely an ergonomics problem.

In general, understand that modern equipment will have many controls to maximize functionality, and they may need to be somewhat small to fit them all logically onto a control panel. Beware of controls that are smaller than they need to be – especially if you may need to use the equipment with gloves or in tight places.

5.3 Camcorder Use with Gloves and Other Heavy Clothing

Most of the hand straps that come manufactured with camcorders can be adjusted to fit large hands, even ones sporting gloves that are not too thick (e.g., driving gloves or work gloves). Shoulder supported camcorders (most standard size VHS units) and cameras may not have a hand strap but an area built through the device that is intended for use as a grip. The size of this grip may not be adjustable, and this should be taken into account when considering purchase. The low end of the operating temperature range is usually specified to be above the freezing point of water (32 °F)anyway, and extremely thick and heavy gloves probably would not be needed at this temperature. The other consideration when using thick, heavy gloves is the size of the buttons and knobs on the unit. This should not be a problem either if gloves are not too thick, given the typical button and knob size.

5.4 Weight and Handling Versus Steadiness When Operating

Weight is mostly irrelevant when dealing with devices intended to sit on a shelf, such as most VCRs and monitors. Some monitors can be transported between sites, but system design options should not include having a monitor strapped to a human assistant. For cameras, portability, weight, and handling are a significant issue, because manufacturers always try to compromise between quality, manufacturing cost, and consumers' desires for something small and easy to operate. This is even more true when you try to design a tape recorder into the same small enclosure as the camera. Such a device is called a camcorder. As far as weight goes, it is desirable to keep it low, but stability will suffer if weight is insufficient to keep the camcorder steady when the operator moves. Muscles sometimes shake a little when asked to remain perfectly still. At the other end of the extreme, even aside from the obvious discomfort of carrying around a camcorder weighing 15 lb, excessive weight can make muscles shake just from the sheer effort of supporting it after awhile. Somewhere in between is the ideal weight for a particular operator.

In addition, since 8 mm videotape is so much smaller than VHS videotape, most camcorders employing it are smaller and lighter than their VHS counterparts. They are carried in front of the operator's body and face, whereas VHS models are typically carried on the shoulder, as simple video cameras are. The compact version of VHS, called VHS-C, can be carried in front of the operator like 8 mm camcorders also, since their videotapes are much smaller than standard VHS videotapes. If the camcorder is carried in front of the operator, the device is typically lighter than one carried on the shoulder, but it has only the operator's two hands to support and steady it. If the camcorder is carried on the shoulder, the device is typically heavier than the 8 mm or VHS-C varieties, but the shoulder support is both quite strong and very stable or steady.

All cameras and camcorders come with a screw mount on the bottom for attaching to a tripod. A tripod can serve to simplify surveillance, as the burden of supporting the machine is moved to the tripod, and there is no risk of a human operator wavering off target.

5.5 Equipment Compatibility

If your entire contingent of video equipment is of VHS format and you acquire one 8 mm camcorder, then when you want to view the tapes you have recorded with the 8 mm camcorder, you will have to use the camcorder for playback. In addition, within the VHS universe, if you acquire a VHS-C camcorder, you will need an adapter to play its tapes on standard VHS systems. These adapters are usually included with VHS-C systems.

5.6 Helpful and Useless Features

The ability to switch off automatic features is invaluable if an operator is skilled in the use of a particular piece of video equipment. There is always a situation where autofocus is undesirable or ill-suited or the operator must force the *iris* open to gain detail for the features of a face against a brighter background.

Since camcorders are already quite a mature product, most of the features that are required to obtain quality images are available on almost every model. Manufacturers try to distinguish their products through the addition of features that can be generally considered useless for video surveillance applications. Part of the reason for this is in most cases it costs the manufacturer so little to include features (e.g., titling, strobe effects, artful fades or dissolves from one take to another) that they are just installed as a matter of course. This is especially true as microprocessors evolve and drop in price. It is conceivable that, since the complexity of the device is increased to incorporate these features, the chance is increased that an officer not so experienced with video equipment might press the wrong button and actually lose the ability to accurately record information.

5.7 Viewfinders

Are some viewfinders bigger and better than others? Until recently, viewfinders were almost always just a small (about 1 in diagonal) monochrome *CRT* connected electrically to the body of the camera/camcorder. More recently, color LCD viewfinders are coming to dominate the camera and camcorder market. These viewfinders are typically mounted within an enclosure that can swivel up and away from the body to allow the user to get the camera lower for shots of children or to shoot under a fence, for example. The viewfinder is made comfortable to place against the user's face by including an eyecup of very flexible rubber molded to approximate the average user's facial contours. Since the user is actually placing his eye up to the eyecup within 1 in or 2 in of the CRT within the viewfinder and the eye can't focus at that distance, a lens is provided within the viewfinder between the eye and the CRT. This lens can be adjusted to match the natural focal length of the user's eye so that extended use of the viewfinder is comfortable.

In addition to viewfinders, many consumer camcorders are available with a 2-in to 4-in LCD monitor that flips out from the camera body to tilt and swivel. Many camcorders with an LCD monitor also have a viewfinder, although some models have totally replaced the viewfinder with the monitor.

It is not a straightforward choice to select between the types of viewfinders. The small viewfinder must be held to the eye but the required stance is stable, and the aiming motion is quite natural, ensuring the intended subject gets recorded on the tape. The LCD monitor allows more flexibility in holding the camera and a larger display on which to read all the information provided by the camcorder. It also allows the videographer to interact more directly with those around, making the subjects more comfortable with the presence of the camera. Sacrificed are a little bit of stability and precision. If possible, a camcorder with both would be desirable and provide the most flexibility.

5.8 Battery Life and Replacement

Rechargeable batteries[8] supplied by the camcorder manufacturer are intended to last for 2 h – the length of time available for recording on one videotape (8 mm and VHS). When one tape is completely full of recorded material, tapes and batteries can be swapped simultaneously, and then the expended battery can be connected to the recharging unit so it can be ready in 2 h. Multiple batteries are rarely supplied with the camcorder, so it will be necessary to specify extra batteries at the time of purchase of the camcorder. Even though extra batteries are not included, some units provide charging capacity for two other batteries while another is being used.

Some of the more compact camcorders carry their rechargeable batteries in a compartment under the hand strap. Thus, during camcorder operation, the user's hand wraps around the battery compartment. This can be a good attribute, because the warmth that the hand provides also keeps the battery warm and, electrically, more potent. This can also be bad, because it can be less than convenient to try to exchange batteries in a hurry when a panel has to be removed and batteries have to be removed out from under the hand strap.

5.9 Tapes – Cost versus Quality; Problems Reading Tapes

It is commonly felt (and consumer product testing firms have found) that tape is tape is tape, and all tapes record the full bandwidth of their respective formats (e.g., VHS, 8 mm, S-VHS). There does not seem to be a difference even between regular grade and "high-grade" tapes. Also, there is no good reason to pay extra for tapes designated as "hi-fi," since any tape can record high-quality sound in a VCR that records in the VHS hi-fi format.

The defect that is found on videotapes manifests itself as "dropout," where the signal is lost temporarily, so the playing machinery must resynchronize. It is the frequency of these dropouts that determines the relative quality of videotapes. It is worth noting that the average viewer does not notice most dropouts, although this is little consolation to work as critical as law enforcement and corrections. As a general rule, it may be a better approach to buy brand-name tapes on sale than to buy off-brand tapes that may not have satisfied the same types of quality manufacturing standards.

As far as reading tapes, there should not be any problems except for those associated with the environment. The heads that read the tape are actually dipoles mounted in the surface of the rotor, and the helical rotor actually does not touch the tape being

[8] For more information on batteries, consult the "New Technology Batteries Guide," NIJ Guide 200-98. This and other NIJ guides are available from NIST/OLES, 100 Bureau Dr., Stop 8102, Gaithersburg, Maryland, 20899-8102.

transported across it at an angle but forces a film of air between its own surface and the tape because of friction and high rotation speeds. Moisture particles in the atmosphere (from simple humidity or outright rain) can be larger than the gap between the rotor and the tape, causing drag and improper operation. This can be sensed and relayed to the operator, usually with a "DEW" indicator, such as an LED. When this indicator appears, remove the battery and let the camera sit (with all doors open) in a dry spot for a couple of hours (or overnight) before trying to use it again. This should give the moisture enough time to evaporate.

5.10 Maintenance for a Machine with Tape Heads?

While some newer camcorders and VCRs have self cleaning heads, head cleaning is one of the most common maintenance tasks for these devices. Here is a paragraph from one manufacturer's operating instructions:

> Cleaning the Heads: It is recommended that head cleaning be performed by a qualified service technician. Please contact your nearest Service Center. An alternate solution is to obtain a head–cleaning cassette. There are many types of cleaning cassettes, so be sure to follow the cleaning instructions carefully. Excessive use of the cleaning cassette could shorten head life. Use this cassette only when a head clogging symptom occurs.

Cleaning heads on any helical scan device, whether VCR or camcorder, is almost a judgement call. They do not need to be cleaned exceedingly often unless the work they record or reproduce is critical. When cleaning is necessary, it can best be done by disassembling or reaching in with special equipment – in other words: professionally. It can be done with head cleaning tapes, which consist of an abrasive material manufactured into a cassette just like a standard videotape. They are first wet with a head cleaning fluid and then “played” in the camcorder or VCR. Sometimes, because of their abrasiveness, they are not recommended by the manufacturer of the camcorder or VCR, and sometimes they just do not do the job very well anyway.

5.11 Documentation/Instructions

Camcorders are manufactured exclusively in foreign lands. Unfortunately, manufacturers believe, for some reason, it is not necessary to hire native speakers from target market countries to write or assist in the writing of documentation for these pieces of equipment. The result can sometimes be confusing and frustrating.

Documentation has been found to be complete. The technical writers working for the manufacturer try to make documentation complete for a unit by binding together manuals for several closely related units. This is not enough, however, since the writing is often poor in grammar and clarity. If a camcorder does NOT have a particular feature, such as the capability of turning off autofocus, it probably will not say so in the manual. The obvious intent is not to highlight a lack of something in the product, but it might be beneficial to the user to know it as soon as possible.

6. Summary

With all the advances in videography today, there will come a day in the not-too-distant future when still photography will no longer be the preferred technique for recording data for most law enforcement and corrections needs. As the resolution and electronic shutter speeds of video equipment continue to improve and the costs of video units are reduced even further, the current advantages of conventional photography will diminish. Also, digital video and multimedia computing could have a significant impact on the future of video surveillance and how the data are gathered and processed. That is why the basic concepts of this guide are important to both imminent purchasing decisions and planning in anticipation of new technologies.

This guide has attempted to convey the many aspects of video in enough detail to allow a fundamental understanding of technical parameters and how they relate to law enforcement needs. It is hoped, however, that the discussions of the guide will have stimulated readers to conduct subsequent investigations into the ever-changing capabilities and applications of video gear. Only by having a clear recognition of what the potential benefits are, can those in the law enforcement and corrections communities hope to take advantage of the ongoing video revolution.

7. Glossary

amplified light – An attribute of a camera or other video device indicating use of a special module to amplify ambient light before it gets to the pick up unit.

amplitude – The voltage level of a signal. Could be relative (e.g., peak-to-peak for ac signals) or absolute (for dc signals).

aspect ratio – In facsimile or television, the ratio of the width to the height of a picture, document, or scanning field. NTSC television has standardized the aspect ratio at 4:3 (i.e., the picture is wider than it is high by a factor of 1 1/3). If an image is not reproduced at the intended aspect ratio, objects in the image are distorted.

automatic iris control – An automatic control that regulates the amount of light that reaches the video pickup unit.

auxiliary jacks – Any of a number of connectors that a piece of video equipment can have to allow it to be connected to and interwork with other equipment.

bandwidth – The difference between the limiting frequencies within which performance of a device, in respect to some characteristic, falls within specified limits. An analogy to bandwidth might be the width of a street or a highway, where each lane is a radio frequency.

battery – A device used for storing energy until it is required for use by a piece of equipment. Enables equipment to work without being plugged into a wall outlet.

battery memory – In rechargeable batteries, refers to the tendency of some batteries to "remember" the level to which they were charged or discharged, reducing the overall useful storage capacity of the battery. (See NIJ Guide 200-98, "New Technology Batteries Guide," for more information.)

black balance – See *white balance*.

blue-only control – A switch that turns off the red and green electron guns in a monitor. This allows for the monitor to be calibrated based on the signal from the blue gun only.

book mark – A feature of camcorders and recorders that allows the user to quickly find the end of previously recorded material so that additional recording can resume from that point.

brightness – A qualitative attribute of visual perception in which a source appears to emit a given amount of light. In monitors, overall brightness is dependent on the high-voltage level and the dc-grid bias.

broadcast quality – A generic descriptor indicating a piece of equipment is of sufficient quality to be used regularly by the broadcast television industry. Typically, the requirement is that resolution be greater than 450 TVL.

CCD (charge coupled device) – These tiny light-to-electric-charge transducers are placed in rectangular arrays on silicon wafers and used as video pickup devices instead of electron tubes. The signal is read out from the array sequentially from side-to-side and top-to-bottom to determine one video frame.

chrominance – In color television, that signal or portion of the composite signal that bears the color information.

clarity – A qualitative term generally referring to the combination of resolution, contrast, and color accuracy.

CM (contrast maximization) – a technique for autofocusing cameras and camcorders based on maximizing the contrast of the video signal.

color – Having a non-white spectral characteristic.

comb filter – a filter which helps to minimize the loss of resolution and reduce streaking and wavy edges on fine patterns. Common in middle range to high-end television displays and monitors.

contrast – In display systems, the relation between (a) the intensity of color, brightness, or shading of an area occupied by display elements, a display group, or a display image on the display surface of a display device and (b) the intensity of an area not occupied by a display element, a display group, or a display image. For a monitor, contrast is determined by the peak-to-peak amplitude of the video signal.

counter – In cameras and recorders, counters are used to keep track of tape position between start and finish. Counters can be in arbitrary units, time counting up, or time counting down.

CRT (cathode ray tube) – the vacuum (electron) tube that generates an image in a television monitor using cathode-ray electrons.

dB (deciBels) – 1) one tenth of the common logarithm of the ratio of relative powers (P), equal to 0.1 bel. The formula is given by $dB = 10 \log_{10} (P_1/P_2)$. 2) One-twentieth of the common logarithm of the ratio of relative voltages (V) or currents (I), equal to 0.1 bel. The formula is given by $dB = 20 \log_{10} (V_1/V_2)$ for voltage and $dB = 20 \log_{10} (I_1/I_2)$ for current.

dichroic lens – A lens in a camera which splits the incoming light into the three primary colors (red, green, and blue) so they can be picked up by separate CCDs or different areas on one CCD.

digital zoom – A relatively new feature of digital cameras whereby they use only a portion of the pickup device and magnify the image to fill the full frame.

distance – The position of the subject relative to the camera.

DSO (digital storage oscilloscope) – an electronic test instrument used primarily for making visible the instantaneous value of one or more rapidly varying electrical quantities as a function of time or of another electrical or mechanical quantity. Its storage function allows several values to be recorded (and displayed together).

DV in/out – IEEE 1394 (also known as “FireWire”) interface available on digital camcorders.

dynamic contrast control – An automatic control to maximize the contrast of a scene. Generally, use of dynamic contrast control produces an improvement in overall picture quality.

electron beam spot size – The diameter of the focused electron beam that causes the phosphor on a monitor screen to fluoresce.

edit controller – A jack on a piece of equipment that allows it to be precisely controlled by another device for the purpose of editing tapes.

electron tube – A vacuum tube designed to focus and direct beams of electrons. A common type of electron tube is a television picture tube (i.e., a CRT).

electronic shutter – Use of electronics to simulate placing a shutter in front of a video pick-up device.

environmentally robust – A manufacturer’s subjective claim that their equipment can operate in a variety of temperature, humidity, lighting and physically abusive conditions.

fade – A non-abrupt interruption of the signal. In video, generally refers to a graceful transition from one video signal to another.

filters – In electronics, a device that transmits only part of the incident energy and may thereby change the spectral distribution of energy.

flying erase head – In camcorders and recorders, a recording technique that allows for a single frame to be erased from a video tape and then immediately replaced with a frame from another source. This allows for smooth transitions between scenes.

focus – The mechanism used to ensure that the scene produces a sharp image on the video pickup device.

gain-up – A control to increase the gain on the output of the video pickup device in low-light situations.

headphone jack – On video equipment, this is usually a 1/8 in stereo phono jack.

high definition television (HDTV) – Television that has approximately twice the horizontal and twice the vertical emitted resolution specified by the NTSC standard.

high-speed shutter – A physical or electronic shutter that operates at faster than 1/60 s.

hue – The visible spectral content of an image or part of an image, which depends on the phase angle of the chrominance signal. The phase is varied with respect to a color synchronizing signal by a "tint" or "hue" control. This control is subjectively set for the correct hue of any known color on the screen (e.g., green grass or blue sky), then all other hues are automatically corrected, since the color synchronization holds all hues in the proper phase with respect to each other.

image stabilization – A camcorder or camera feature to reduce the visible effects of shake and wobble introduced by hand-holding the camera. Two techniques are currently used to accomplish this. The first is through the use of a deformable prism. As the camera/lens detects shake and vibration, the prism is reshaped to provide stability to the image. The second is to electronically remove the effects of shake and distortion by modifying the output signal from the pick-up device.

index – A feature that "marks" the videotape each time recording is started, enabling the user to easily find a particular recorded section of tape.

infrared light – The region of the electromagnetic spectrum bounded by the long-wavelength extreme of the visible spectrum (approximately 0.7 µm) and the shortest microwaves (approximately 0.1 mm).

infrared playback – See wireless playback.

inputs – The types of signals that a device can receive, and the connectors through which those signals are received.

intensifier – A device placed in front of a camera or camcorder's pickup device that amplifies available light from a scene.

IR ranging – An autofocus technique that uses an infrared signal to determine the optimum focusing distance.

iris – The adjustable physical opening that light passes through en route to the video pickup unit.

intermediate frequency (if) – A frequency to which a carrier frequency is shifted as an intermediate step in transmission or reception.

LANC – Sony's edit control interface for high-end consumer equipment.

LCD monitor – A viewing device for a camera or camcorder that is based on liquid crystal display technology and is 2 in to 4 in in size.

lens compatibility – Indicates a camera has many interchangeable lenses, including interchangeability with those of other manufacturers.

lens mount – The physical connection between the lens and the camera. The most common lens mount for video cameras is the “C” mount.

light (1) – In a strict sense, the region of the electromagnetic spectrum that can be perceived by human vision, i.e. , the visible spectrum, which is approximately the wavelength range of 0.4 μm to 0.7 μm.

light (2) – An attachment for a camera or camcorder to help illuminate scenes where available light is too low to allow recording of a satisfactory image.

low light – Low-light cameras typically have published minimum acceptable light levels between 0.1 lux and 2 lux.

luminance – In color television, that signal or portion of the composite signal that bears the brightness information.

lumen – A well-defined measure of light power emitted by a source.

lux – The light level incident on a 1 square meter area when a lumen of light is distributed across it.

macro mode – A special mode for some lenses that allows focusing at closer distances than normal to provide greater magnification of a small object or detail on a larger object.

microphone holder – A bracket on a camera or camcorder that allows attachment of an external microphone.

minimum illumination – The minimum ambient light level (usually given in lux) required to give the camera a sufficient signal to make an “acceptable” picture. Each manufacturer has a different definition of acceptable.

monitor bridging – a mode in which a monitor can receive and display a video signal and then pass it on to another device without modification.

motion sensor – An automatic sensor in a camera or camcorder that allows the system to be activated when motion is detected and deactivated at a specified interval after motion ceases.

multiple heads – In video playback units, multiple heads improve the image quality during high-speed and slow-motion playback.

multiple mounting holes – For cameras, multiple tripod mounting holes enable the camera to be balanced atop the tripod to provide more stable images.

noise – A disturbance that affects a signal and may distort the information carried by the signal, or, loosely, any disturbance tending to interfere with the normal operation of a device or system.

noise reduction – Using filtering or digital signal processing techniques to reduce the amount of noise in an image. Noise reduction figures of 6 dB are common.

NTSC (National Television System Committee) – denotes the body that set the original standards for American television and is also used as a reference to the television standard they published.

NTSC video – The North American standard (525-line interlaced raster-scanned video) for the generation, transmission, and reception of television signals. Note: In addition to North America, the NTSC standard is used in Central America, a number of South American countries, and some Asian countries, including Japan.

optical zoom – The zoom achieved by a lens.

phase – Of a periodic, varying phenomenon (e.g., an electrical signal or electromagnetic wave), any distinguishable instantaneous state of the phenomenon, referred to a fixed reference or another periodic varying phenomenon. Note: The phase of a periodic phenomenon can also be expressed or specified by angular measure, with one period usually encompassing 360° (2 π radians).

photo mode – a camcorder/videotape recorder "captures" a single frame of video and records that one frame for 6 s to 10 s on the videotape, essentially making a still photo on the videotape.

pixel – In a raster-scanned imaging system, the smallest discrete scanning line sample that can contain gray scale information. An abbreviation for picture element.

playthrough – The condition of taking a known input, passing it through a device, and comparing the output of the device with that known input.

radio frequency (rf) tuner – The part of a circuit that can be adjusted to resonate at a particular frequency. Allows "channels" to be received from broadcast or cable systems.

remote control – a device that is detached from the main chassis of a piece of equipment, yet provides a mechanism for the user to control that piece of equipment. The two most common types of remote control are wired and wireless. Wired remotes require a physical connection (via wire) from the remote control to the main chassis. Wireless remotes typically use an infrared signal to communicate between the remote control and the main chassis.

resolution – A measurement of the smallest detail that can be distinguished by a video system or device under specific conditions.

rf (radio frequency) – any frequency within the electromagnetic spectrum normally associated with radio wave propagation. Normally, information signals are modulated to be transmitted at a radio frequency.

RGB (red-green-blue) – pertaining to the use of three separate signals to carry the red, green, and blue components, respectively, of a color video image.

RS-170A (EIA-170) – An Electronic Industries Alliance (EIA) standard describing a black and white television system containing 525 lines in two interlaced fields at a field rate of 59.94 Hz. This is the basis of the modern, North American NTSC television system.

saturation – In video systems, the level of color relative to the maximum handling capacity for that color. The level of saturation is dependent on the level of the chrominance component of the video signal.

scan rate – The frequency at which the electron beam scans a single line of an image. This is 15.7 kHz for an NTSC system and can be as high as 100 kHz for computer monitors.

screen size – the diagonal dimension of a display screen (measured in inches or centimeters). Sometimes part of a display screen may be hidden behind a plastic housing (i.e., the case of the display), thus causing a mismatch between the published screen size and the viewable screen size.

self timer – A feature of a camcorder or video recorder that allows it to turn itself on and/or off at a particular time or time interval.

sensitivity – In an electronic device (e.g., a communications system receiver such as a television), the minimum input signal required to produce a specified output signal having a specified signal-to-noise ratio or other specified criteria.

shutter – A device that opens and closes, allowing or disallowing light to reach the video pickup device.

signal – Detectable transmitted energy that can be used to carry information.

SNR – signal-to-noise ratio – the ratio of the amplitude of the desired signal to the amplitude of noise signals at a given point in time. Note 1: SNR is expressed as 20 times the logarithm of the amplitude ratio or 10 times the logarithm of the power ratio. Note 2: SNR is usually expressed in dB and in terms of peak values for impulse noise and root-mean-square values for random noise. In defining or specifying the SNR, both the signal and noise should be characterized (e.g., peak-signal-to-peak-noise ratio), to avoid ambiguity.

speaker – An electrical signal to audio sound pressure transducer.

special effects (special FX) – Any number of features added by camera manufacturers that affect the video in special ways. Includes fades, wipes, and solarization.

still video – Recording a single frame of video to several seconds of videotape, essentially creating a still image that can be annotated with audio (i.e., use the audio recording tracks to record information about the picture).

S-VHS (Super VHS) – the same as standard VHS except that the luminance carrier is shifted to a higher frequency, allowing for greater carrier bandwidth and, hence, greater resolution (about 400 TVL).

S-VHS -C– A piece of equipment using S-VHS videotape in a smaller cassette.

synchronization signal – a signal used to synchronize pieces of video equipment to a common clock. In medium- and large-sized video facilities, it is necessary to synchronize all pieces of equipment to avoid problems when recording or playing video.

TIFF (Tagged Image File Format) – a standardized file format used to store images.

time-lapse – The technique of recording one frame at a time at specified intervals. When played back at normal speed, time appears compressed, allowing viewing of a whole day's worth of video in just a few minutes.

tint – See hue.

titling – Referring to the ability to overlay text or symbols onto a video signal. An example of titling is credits at the beginning or end of a movie.

TVL (television lines) – a unit of horizontal resolution for video devices.

VCR (video cassette recorder) – denotes all formats of video tape recorder except reel-to-reel.

VHS (video home system) – a piece of equipment using ½ in video tape and a cassette approximately 4 in by 7 1/2 in.

VHS -C – A piece of equipment using standard VHS video tape in a smaller cassette.

video – An electrical signal containing timing (synchronization), luminance (intensity), and often chrominance (color) information that, when displayed on an appropriate device, gives a visual image or representation of the original image sequences.

viewfinder compatibility – Implies that a camera or camcorder has a jack to which an LCD monitor can be attached.

white balance – A camera control that controls the overall intensity of a video signal. Most cameras come with an automatic white balance adjustment that can be overridden in situations where the content of the scene is not "average" (i.e., the subject is either lighter or darker than average).

wind screen – a device (typically sponge rubber) that is used to cover a microphone and prevent wind from striking the diaphragm and causing extraneous (usually annoying) noise while still allowing sound waves to pass through, creating an audio signal.

wireless playback – A feature on some camcorders and recorders that allows playback on a television or monitor without physically connecting wires.

This is accomplished through the use of an infrared transmitter in the camcorder/recorder and an infrared receiver that needs to be attached to the television/monitor. The receiver is usually included as a part of the package.

YIQ – Luminance, In-phase, Quadrature (the letter Y is commonly used in video work as a symbol for luminance).

Appendix A. Information Resources on the Web

Below is a list of web addresses for companies selling video equipment that might be useful in video surveillance applications. This is not a comprehensive list. Inclusion or exclusion neither implies that the products of one company are better than the products of another for a given application, nor does it imply that all claims made by these companies are accurate. Before purchasing any product, check as many options as possible.

http://www.advancedalarms.com

http://www.advdig.com

http://www.canon.com

http://www.cohu.com

http://www.concealedcameras.com

http://www.dxsystems.com

http://www.eagletcs.com

http://www.electrophysics.com

http://www.eyeqsys.com

http://www.jeffhall.com

http://www.jvc.com

http://www.midniteyes.com

http://www.midwestcommunications.com

http://www.p2comm.com

http://www.panasonic.com

http://www.rock2000.com

http://www.rparker.com

http://www.sharpcom.com

http://www.sharpelectronics.com

http://www.sony.com

http://www.spiderweb1.com/pi-supply

http://www.spyman.com

http://www.spyshops.com

http://www.spysite.com

http://www.spyworld.com

http://www.spyzone.com

http://www.supercircuits.com

http://www.visualmethods.com

http://www.wireless-experts.com

http://www.wirelesstech.com

http://www.xybion.com

Appendix B: Effect of Low Light Situations on Cameras

To provide more detailed information on the effects of shooting in low-light situations, testing on actual video gear was conducted in a major Federal video-quality laboratory. This appendix illustrates how image quality changes as light levels change. In addition, one image enhancement technique, useful for extracting a useable image from footage taken in too little light, is demonstrated. This technique can be employed by someone with moderate computer skills working with commercial software on a standard personal computer.

B.1 Working in Less-Than-Ideal Light

To illustrate the effects of using cameras in low-light situations, experiments were conducted to show how the ability to distinguish human faces changes as light decreases. Furthermore, the experimental results illustrate the impact of both optical and digital zoom and differences in manufacturers' claims of a certain light level rating.

This test was designed and conducted in this way. A one-eighth scale photograph of a recognizable person was mounted in front of the camera in a controlled lighting environment. Each of the two camcorders in the test were aimed at the picture and positioned such that the head and shoulders of the individual in the picture filled the frame at each of three distances: minimum, full optical zoom, and full digital zoom. Lighting levels started at a level high enough to generate a good quality picture and were then decreased to approximately 2.4 lux. At that point, a 0.9 neutral density filter (which blocks 90 percent of the light passing through) was added to the camera lens, allowing the room lights to be 10 times brighter than what the camera actually was seeing. Using this technique allowed the experiment to proceed to the camcorders seeing an effective light level of 0.1 lux.

Light readings were taken with a Tektronix J18 Photometer and J1811 Illuminance Head with the sensor positioned over the face in the photograph. Once the reading was taken, the sensor was moved aside, and video of the photograph was recorded.

Table B-1 lists the camcorders used in this experiment and the relevant specifications of those devices. One might notice the maximum aperture varies for Camera B but not for Camera A. This is because Camera B uses a variable aperture zoom. Variable aperture zooms generally have a smaller maximum aperture as the lenses are zoomed to their highest magnification. This is a disadvantage in low-light surveillance situations, but there are tradeoffs. Variable aperture lenses are smaller and less expensive to design and manufacture than fixed aperture zooms, such as the one used in Camera A.

Table B-1. Cameras used in the low-light experiment and their specifications

	Camera A	**Camera B**
Tape format	Mini-DV	Mini-DV
Optical zoom	10x(5.9–59 mm)	14x(5.2–72.8 mm)
Maximum aperture	f 1.6	f 1.8 – 3.2
Digital zoom	2x	2.5x
Total zoom range	20x	35x
Minimum light rating	4 lux	2.5 lux

Figures B-1 and B-2 show the facial identification ability of Camera A and Camera B (respectively) at 14 different light levels. There are many things to note in these two figures. For Camera A, the minimum light level to achieve facial identification is about 0.8 lux. For Camera B, it is about 1.5 lux. This is especially interesting given that Camera B has a lower minimum

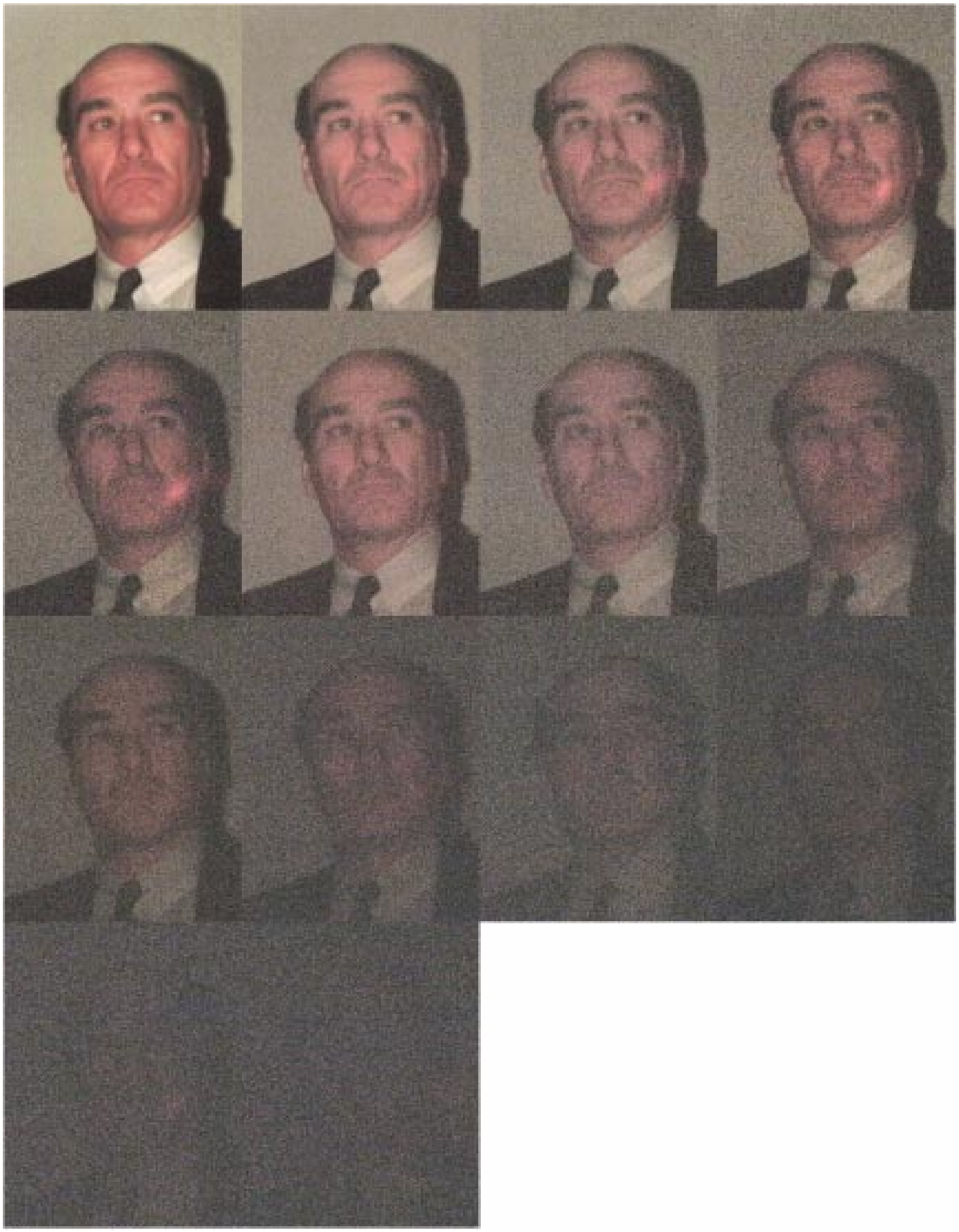

Figure B-1. Effect of diminishing light level on image integrity. Camera = Camera A. Distance = minimum distance. Light levels (in lux, from top left): Row 1 - 19.0, 7.6, 4.3, 3.4. Row 2 - 2.2, 2.2*, 1.5*, 1.0*. Row 3 - 0.8*, 0.5*, 0.35*, 0.24*. Row 4 - 0.17*, 0.10* (* indicates effective light level while using 0.9 neutral density filter.)

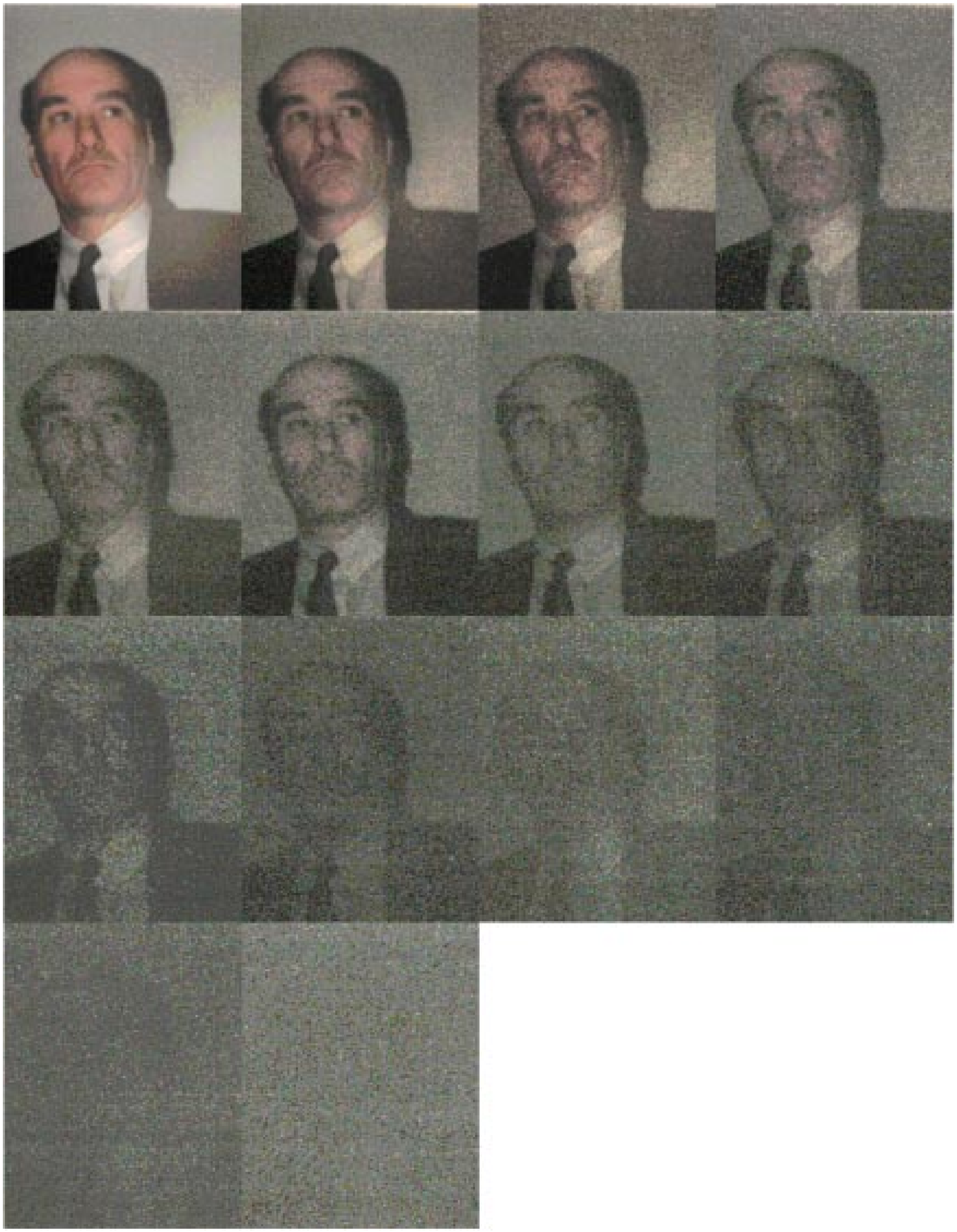

Figure B-2. Effect of diminishing light level on image integrity. Camera = Camera B. Distance = minimum distance. Light levels (in lux, from top left): Row 1 - 19.4, 7.6, 4.4, 3.3. Row 2 - 2.4, 2.5*, 1.5*, 1.0*. Row 3 - 0.8*, 0.5*, 0.36*, 0.24*. Row 4 - 0.17*, 0.11* (* indicates effective light level while using 0.9 neutral density filter.)

light rating. In fact, it is useful to compare image quality of the two camcorders at their respective minimum light rating. Camera A provides a much more colorful and identifiable face at approximately 4 lux than Camera B does near its rated 2.5 lux. This is just visual evidence of the lack of measurement standards for camera and camcorder specifications. In both sets of images, one can notice “hot spots” or spots that are brighter than they should be. This is due to reflections off the image. Because the camera lenses had such a wide field of view for generating these data, it was possible for them to pick up the brightness of the lighting source reflecting off the glossy image paper. Finally, for this part of the experiment, the lens of Camera A was about 9.5 in from the image, while the lens of Camera B was about 8.5 in distant. The required difference in placement is consistent with the difference in the shortest focal length for the lens: 5.9 mm for Camera A and 5.2 mm for the Camera B.

Figures B-3 and B-4 are similar to B-1 and B-2 except they were taken at the maximum optical zoom levels of Camera A and Camera B, respectively. Again, note the minimum useable light level for Camera A is about 0.8 lux. Camera B, however, does not produce an identifiable image below 3.4 lux, a significant shift from closest zoom range. This is due to the variable aperture zoom employed. The shift of minimum acceptable light from 1.5 lux to 3.4 lux mirrors the change in maximum aperture from f 1.8 to f 3.2. For this part of the experiment, Camera A was positioned at 54.5 in from the subject while Camera B was positioned at 69.5 in. Again, the difference is consistent with the focal length of their lenses (59 mm for Camera A and 72.8 for Camera B).

Figures B-5 and B-6 reveal the effects of using digital zoom in addition to the optical zoom. Immediately noticeable is the increased speckling or grain. This is because the cameras only use a portion of the CCD array to pick up the image: 50 percent for Camera A, 40 percent for Camera B. Camera B shows significantly more degradation from using the digital zoom than Camera A does. It also requires significantly more light for a useable picture. The lowest acceptable light level for identification is 31 lux. For Camera A, it is still possible to identify the subject at 4.3 lux. For this experiment, Camera A was 131 in from the subject and Camera B was 175 in.

B.1.1 Enhancing the Images

There may come an occasion when it is absolutely necessary to record video in light levels below what is known to be acceptable for the purposes of the surveillance. In these situations, it is best to take the highest quality video possible (i.e., stable camera, as little motion in the scene as possible). Afterwards, it may be possible to extract some useful information from the tape using image processing techniques.

One of the simplest techniques involves “capturing” or recording a sequence of video frames to a computer’s hard disk and then averaging the images to improve the signal-to-noise ratio. Figure B-7 shows the effects of averaging 30 frames of video for Camera A at maximum optical zoom. Note it is possible to identify the subject at a light level of 0.23 lux.[9] This is a significant improvement over the 0.8-lux light level that was required without averaging (fig. B-3). The procedure to accomplish this follows.

To begin, the video was taken using Camera A, a digital camcorder. The camcorder was connected to an IBM-compatible personal computer (133 MHz Pentium™ running Microsoft Windows 95®) with the Canon Video DK-1 DV Capture Kit installed using the cable supplied with the capture kit. (This capture kit is compatible with all digital camcorders that have an IEEE 1394 “Fire Wire” interface, and has no relationship to the manufacturer of Camera A or Camera B.) Using the supplied software (DV Commander®), 30 consecutive frames were saved on the PC’s hard drive. The frames had 640 x 480 pixel resolution and were saved as *TIFF* (Tagged Image File Format) images. The files were then individually

[9] At a light level of 0.23 lux, the image in the viewfinder of the camcorder was almost totally noise. Only the vaguest outline of the person in the image was discernable.

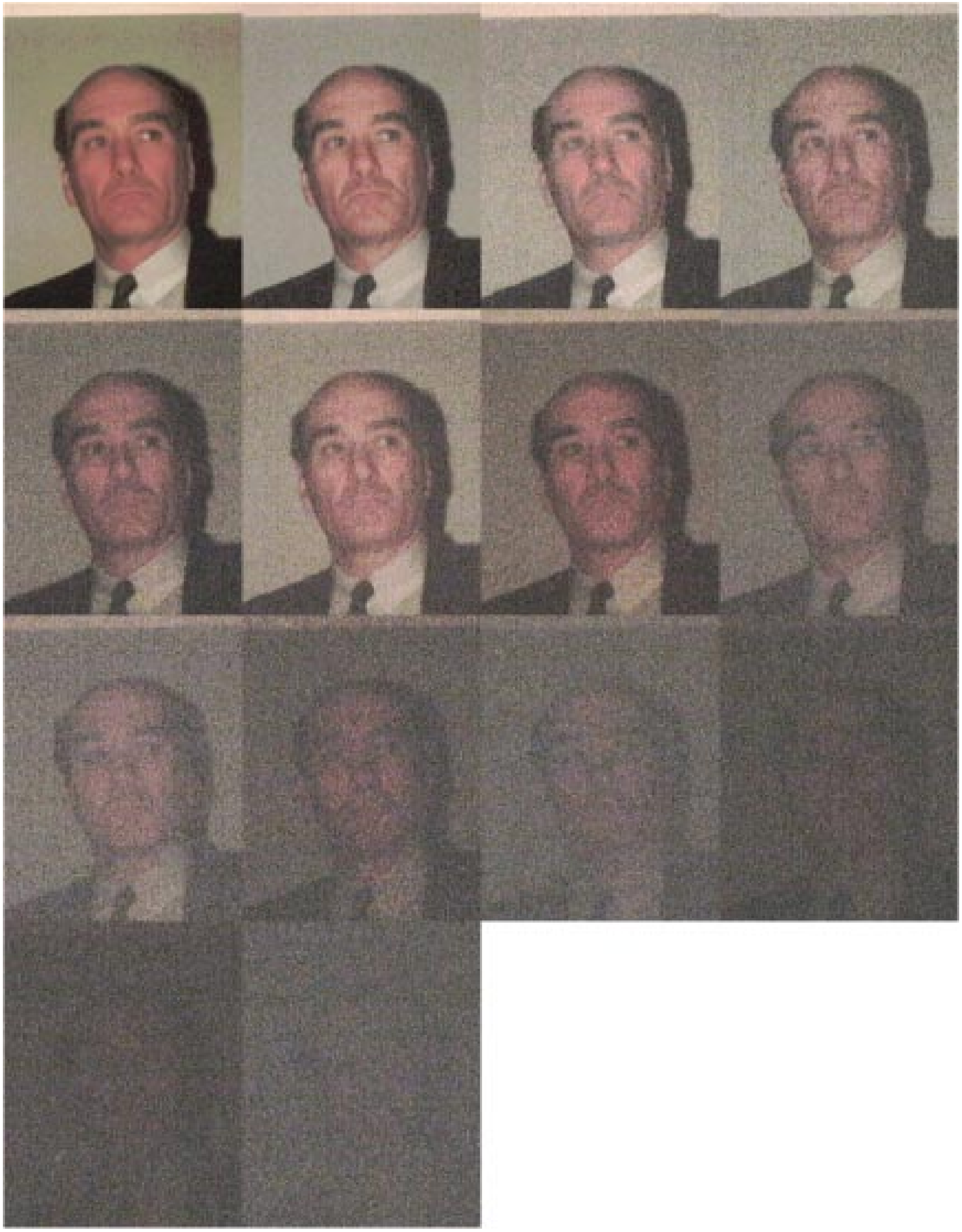

Figure B-3. Effect of diminishing light level on image integrity. Camera = Camera A. Distance = maximum optical zoom. Light levels (in lux, from top left): Row 1 - 19.0, 7.5, 4.6, 3.3. Row 2 - 2.4, 2.4*, 1.5*, 1.0*. Row 3 - 0.8*, 0.5*, 0.35*, 0.23*. Row 4 - 0.17*, 0.10* (* indicates effective light level while using 0.9 neutral density filter.)

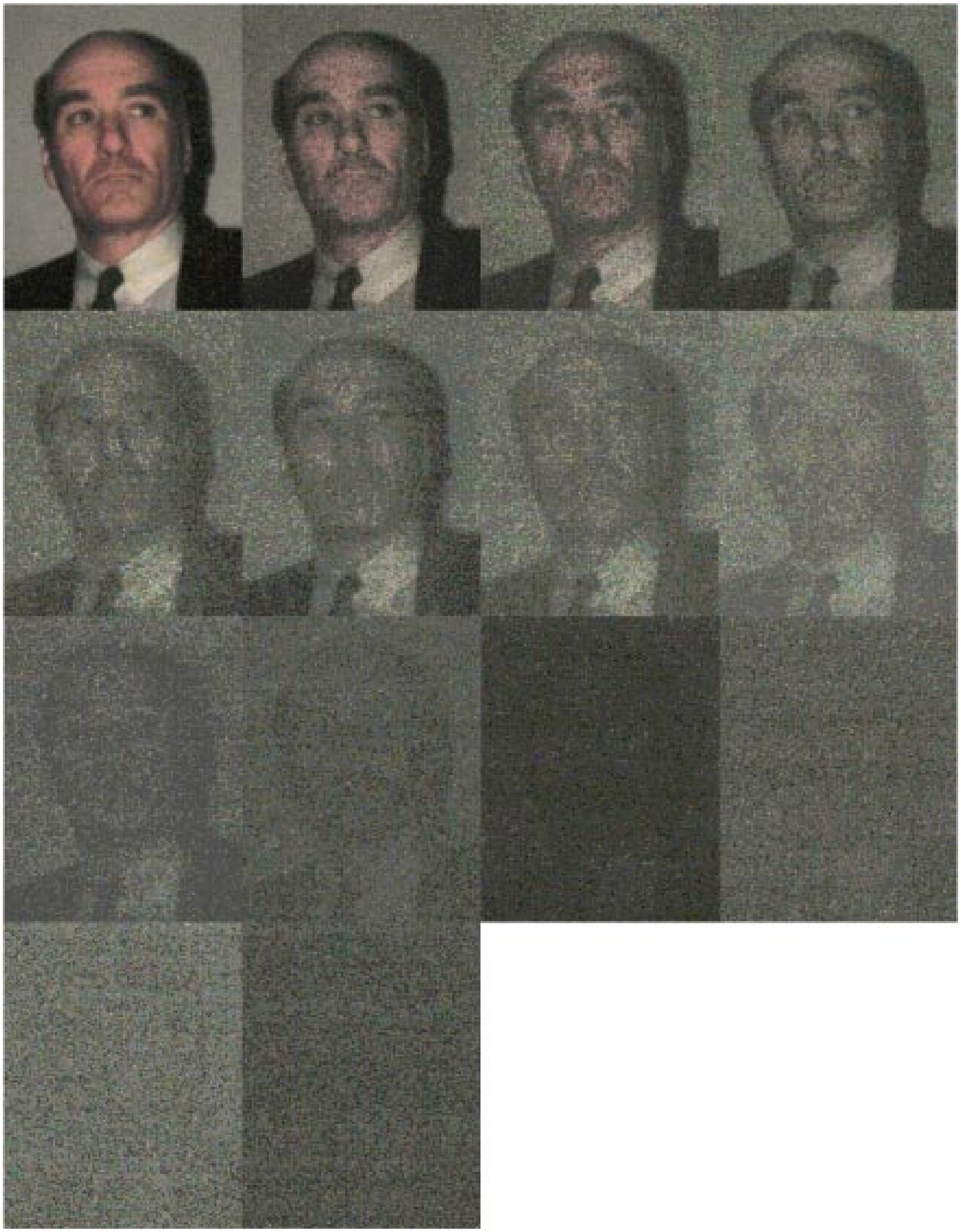

Figure B-4. Effect of diminishing light level on image integrity. Camera = Camera B. Distance = maximum optical zoom. Light levels (in lux, from top left): Row 1 - 19.4, 7.6, 4.4, 3.4. Row 2 - 2.3, 2.3*, 1.5*, 1.0*. Row 3 - 0.8*, 0.5*, 0.37*, 0.23*. Row 4 - 0.16*, 0.10* (* indicates effective light level while using 0.9 neutral density filter.)

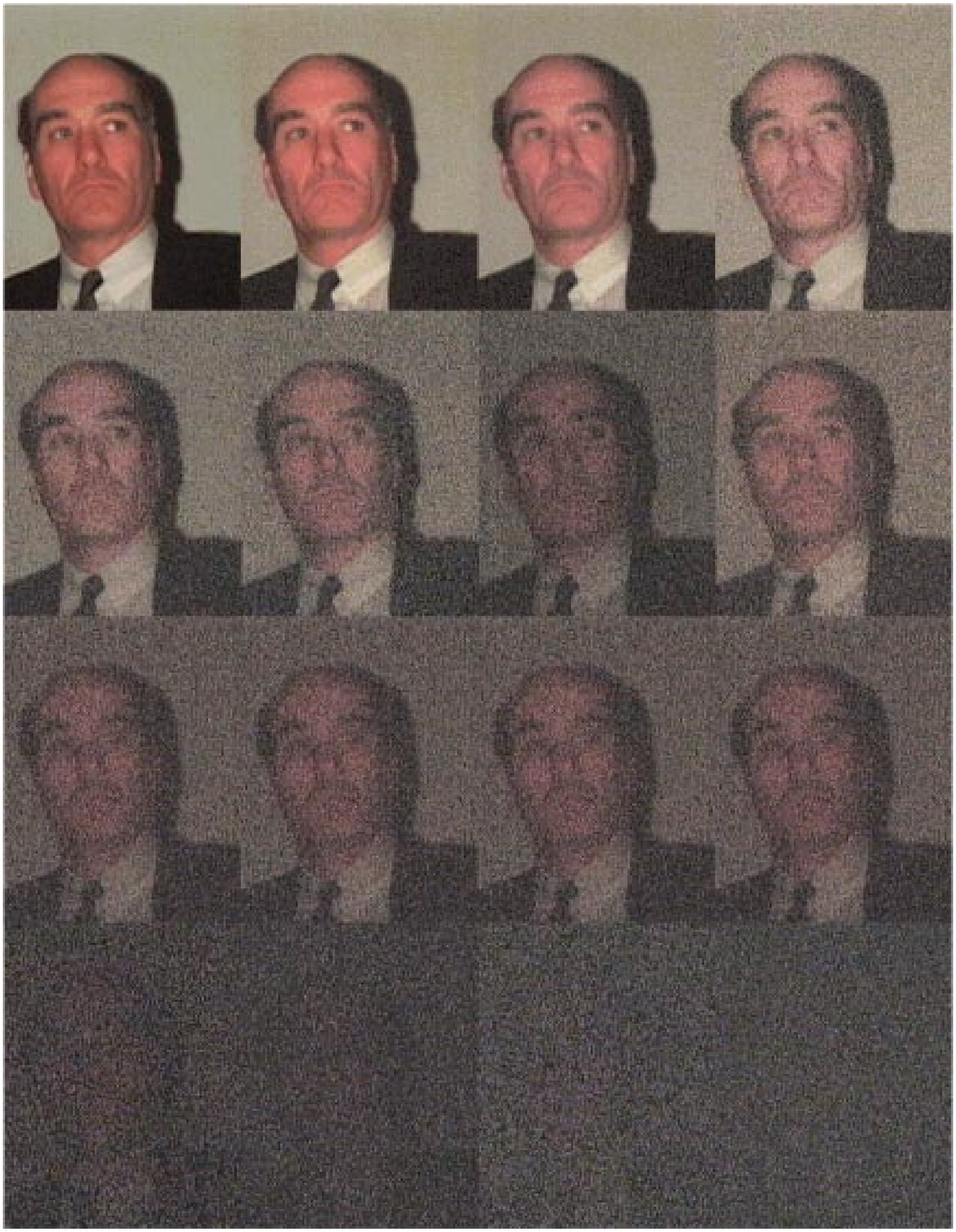

Figure B-5. Effect of diminishing light level on image integrity. Camera = Camera A. Distance = maximum digital zoom. Light levels (in lux, from top left): Row 1 - 51, 31, 19.4, 7.7. Row 2 - 4.3, 3.4, 2.3, 2.3*. Row 3 - 1.5*, 1.0*, 0.8*, 0.5*. Row 4 - 0.35, 0.24, 0.16*, 0.10* (* indicates effective light level while using 0.9 neutral density filter.)

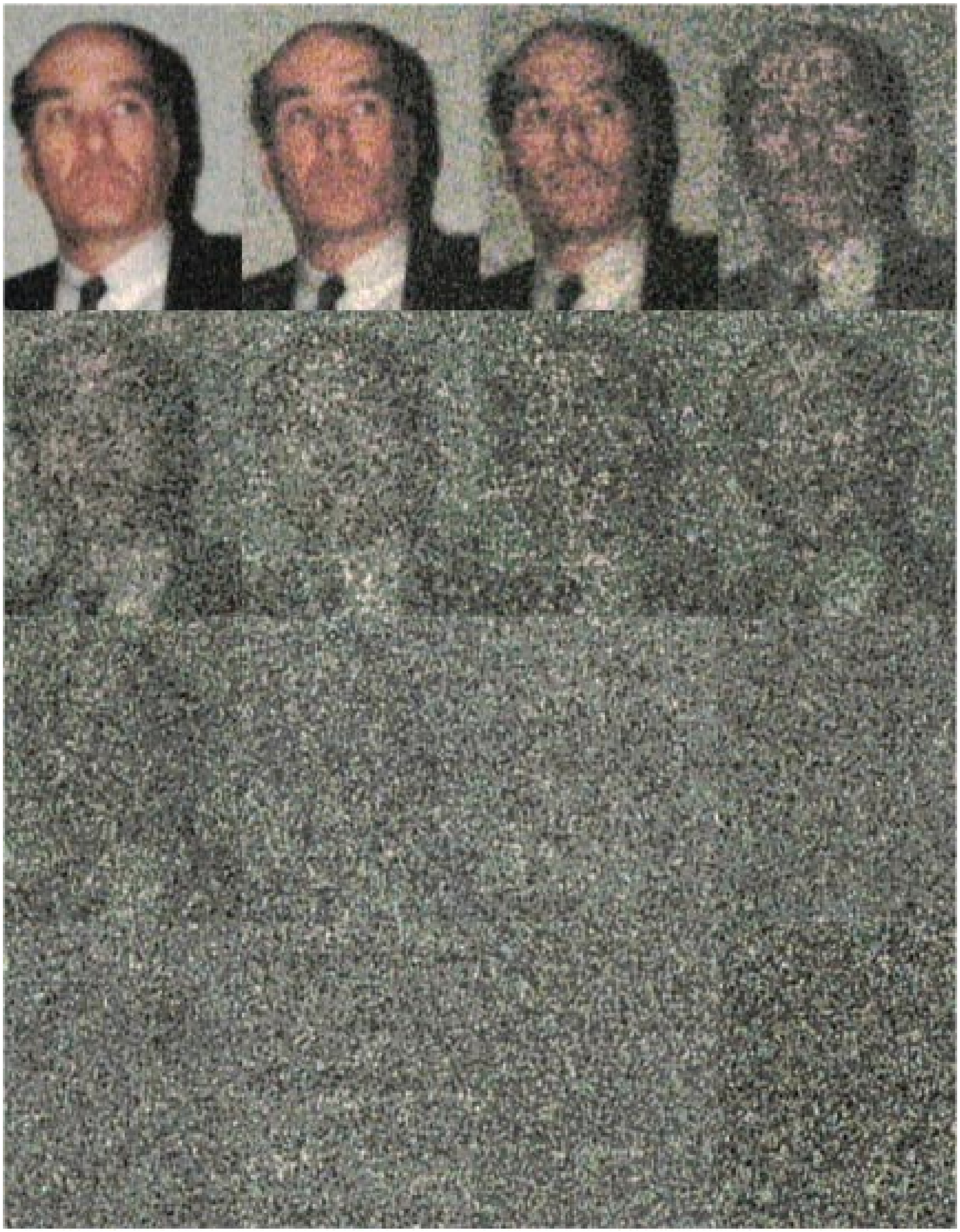

Figure B-6. Effect of diminishing light level on image integrity. Camera = Camera B. Distance = maximum digital zoom. Light levels (in lux, from top left): Row 1 - 51, 31, 19.0, 7.6. Row 2 - 4.4, 3.5, 2.4, 2.4*. Row 3 - 1.5*, 1.0*, 0.8*, 0.5*. Row 4 - 0.36*, 0.23*, 0.16*, 0.11* (* indicates effective light level while using 0.9 neutral density filter.)

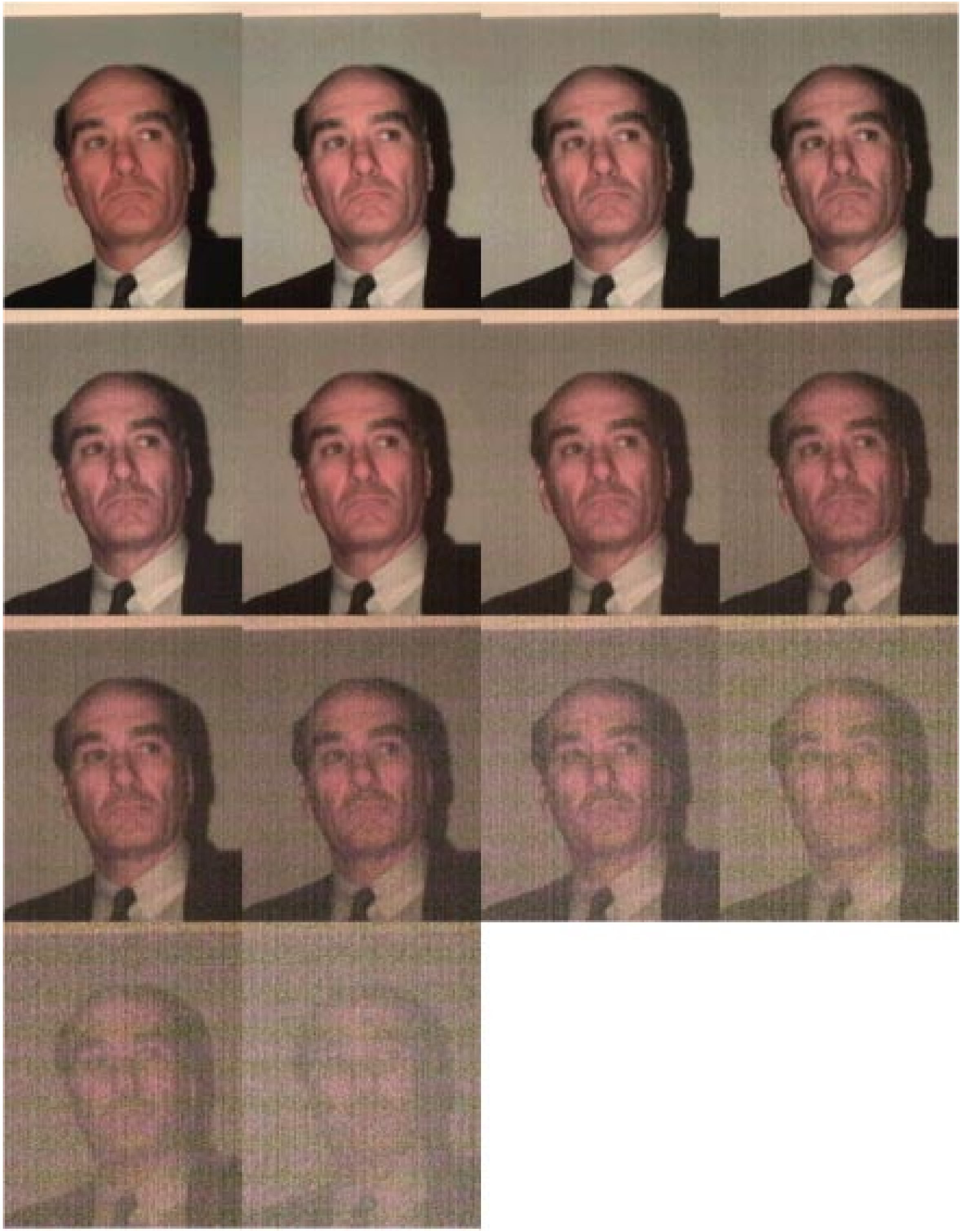

Figure B-7. Effect of diminishing light level on ability of signal processing techniques to improve image integrity. Camera = Camera A. Distance = maximum optical zoom. Light Levels (in lux, from top left): Row 1 - 19.0, 7.5, 4.6, 3.3. Row 2 - 2.4, 2.4*, 1.5*, 1.0*. Row 3 - 0.8*, 0.5*, 0.35*, 0.23*. Row 4 - 0.17*, 0.10* (* indicates effective light level while using 0.9 neutral density filter.)

loaded into a scientific computing package (IDL®), where they were individually scaled to maximize contrast. All the images were summed on a pixel-by-pixel basis, and then that result was divided (also pixel-by-pixel) by the number of frames (30). The resulting image was once again scaled to maximize contrast and then saved to a separate file. Each image in figure B-7 is cropped[10] from one of these averaged files.

While image processing using IDL® might be beyond the average computer user, there are PC-based graphics-design software packages that can be used to achieve the same goal. One such package is Adobe® Photoshop®. Using Photoshop®, one can read the TIFF images as separate files. For each image, the content can be copied and pasted into a layer of a master image. Once in a master image, each layer should be adjusted using the "Auto Levels" feature (pressing Control+Shift+L simultaneously), and the opacity should be adjusted to 100/*number of frames* percent. (For this reason it is best to try to have a number of frames that will evenly divide into 100.) Once all layers have been adjusted, the layers can be combined (i.e., flattening the image) and the image can be saved.

B.2 Summary

This appendix has provided an overview of how diminishing light can effect the images produced by video equipment. In doing this, it showed how the low-light threshold of a camera or camcorder could be visually assessed. Finally, a brief introduction into image enhancement was given showing useful information can be extracted from videotape footage even when direct viewing does not reveal anything useful.

[10]The cropping was done only to provide a more compact display in the figure.

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