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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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Director

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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: $T_C = (T_F\ 32)\times 5/9$

Temperature: $T_F = (T_C \times 9/5)+32$

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 <u>Vidicon™</u>, <u>Saticon™</u>, 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

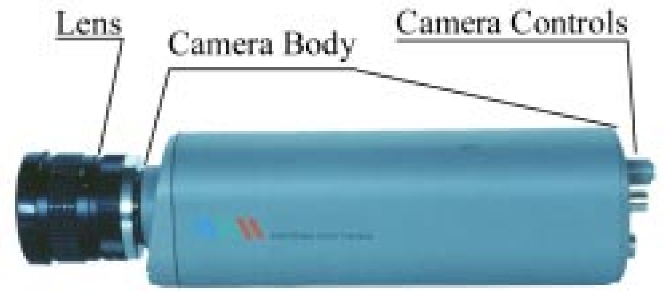

Figure 1. Example of a CCD camera

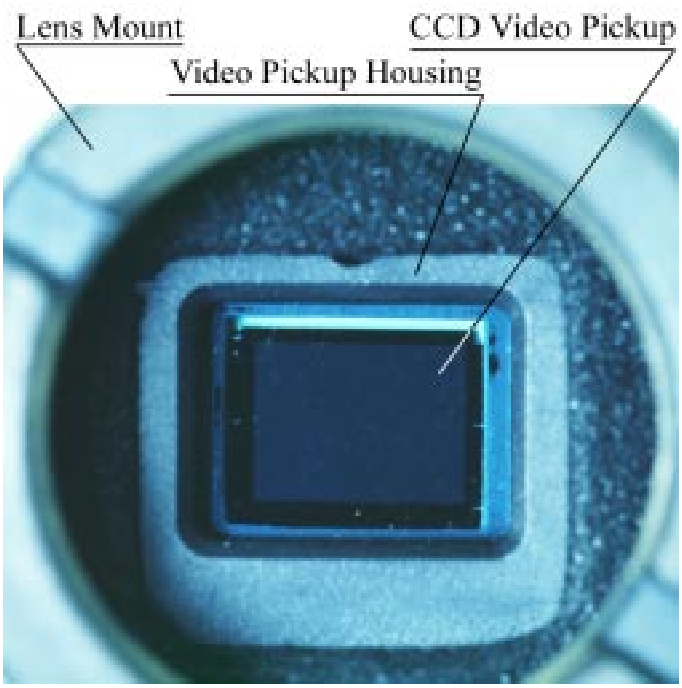

Figure 2. A CCD pickup device mounted in a camera

have problems with image persistence and can only be 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.

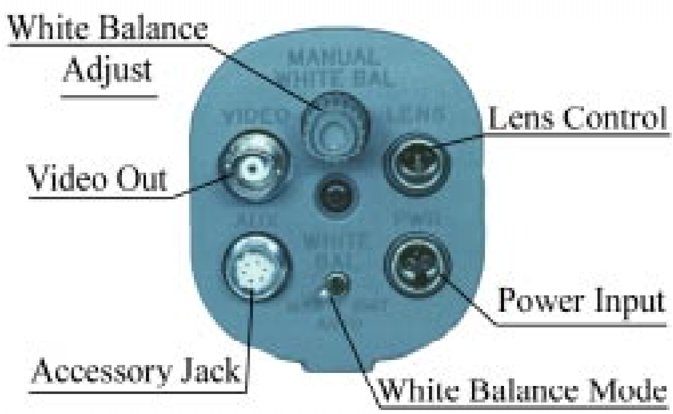

Figure 3. Controls for camera shown in Figure 1

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.

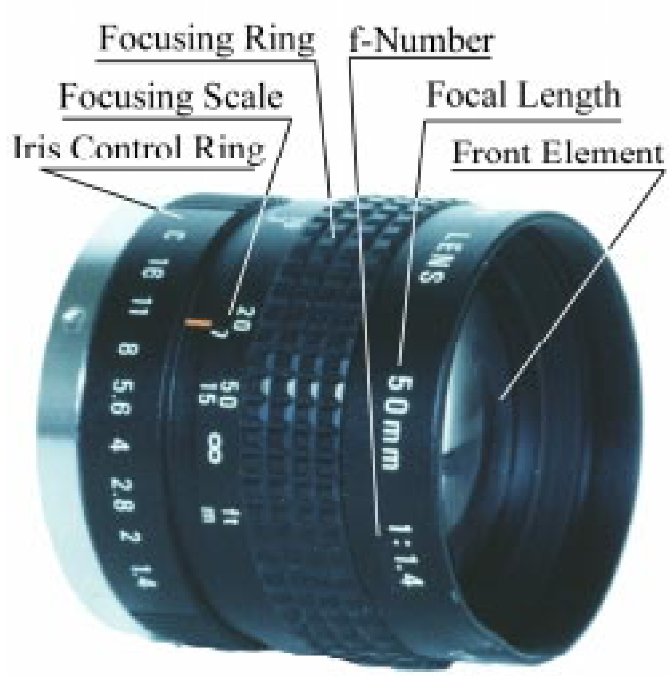

Figure 4. 50 mm, f-1:1.4 manual camera lens

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 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.

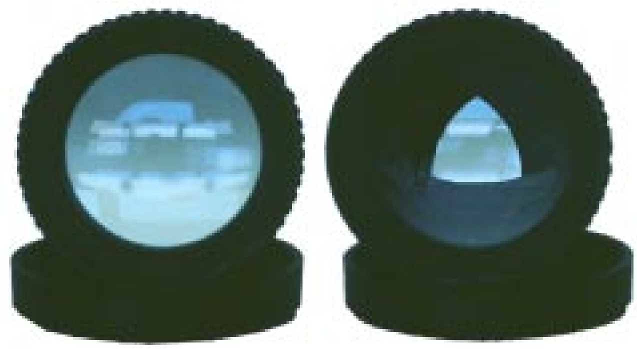

Figure 5. Camera lens with aperture wide open (left) and partially closed (right)

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.

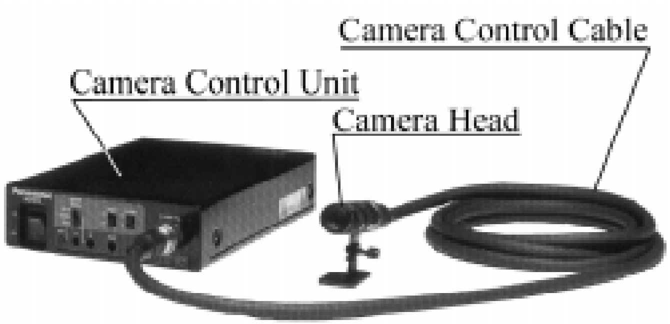

Figure 6. Typical microcamera system

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.

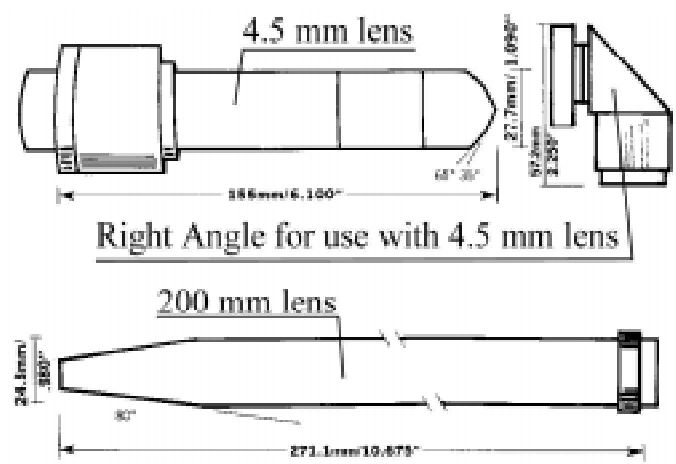

Figure 7. Wide angle (top) and telephoto pinhole lenses

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.

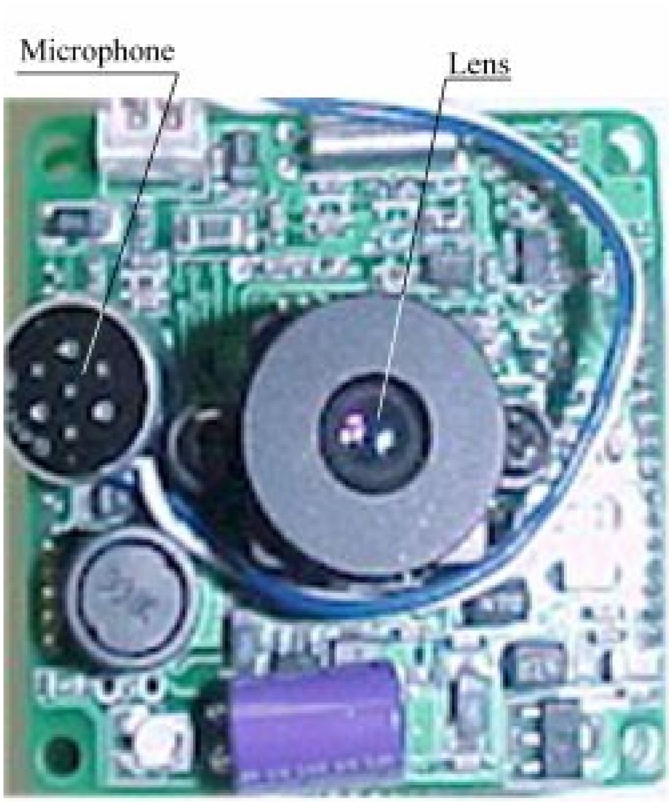

Figure 8. Example of a board camera

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).