



CCTV Installation guidelines for transit vehicles.

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1. Introduction

The transit industry has many requirements where the use of closed circuit TV (CCTV) is of benefit to vehicle crew, operations staff, and management and security agencies.

This guideline is intended to identify some of the more common areas where CCTV capabilities can be introduced and to set out some basic guidelines for operators considering the installation of such services.

In developing these guidelines it is also intended that the transit industry should adopt, where possible, common standards and quality of service criteria for CCTV operations in order to aid operators and agencies alike that need to utilise the output of these systems.

Transit vehicles have varying degrees of complexity when considering CCTV systems. It should be stated that wherever possible core systems capability will be of a standard design with additional ancillary equipment being provided for use in larger or more complex platforms.

A number of systems have been already been deployed to date for various reasons, mostly revenue security or passenger surveillance.

This guideline document will endeavour to outline the use of the system and, through dialogue with technical committee members, associate a ‘standard of resolution and functionality’ appropriate to that function / application.

2. Draft outline of guidelines

There are many uses of CCTV in transit applications and this guideline document aims to focus on the ‘on board’ applications of various transit vehicles.

Transit vehicle include Light Rail, Commuter Rail, Heavy Rail, Freight and Bus vehicles.

There are many uses for CCTV within transit vehicles and users must be clear on the type of application, and required use of the relevant imagery before embarking on a design.

Examples of this are outlined in the following broad example:

Passenger revenue protection: cameras can be used to validate the number of passengers entering and leaving a vehicle for revenue purposes. The primary use of the camera therefore is to recognise the number and type of passengers entering and leaving a vehicle in order to validate revenues and to identify corridors requiring additional inspections or policing where ‘fare dodging’ is discovered. The resolution capabilities of the cameras and recording systems for ‘passenger counting’ therefore need only to recognise ‘body types’. This will allow a ‘lower’ resolution, lower cost sensor to be used with a limited number of cameras covering access doors.

Alternatively, if the camera is required to be able to recognise details of ‘facial features’ for later identification, a much higher resolution sensor and recording system must used .

There are numerous uses of cameras systems ranging from ‘covert’ cameras designed to monitor passengers for safety and security, including anti terrorist security, to cameras aimed at aiding the on-board crew check that doors are clear. In each of these cases a differing resolution, or quality of image, can be used.

Why is this of importance? Well higher quality cameras are more expensive than lower quality cameras. The use of high quality cameras therefore requires higher quality recording systems on board to be used and thus the whole installation cost can become prohibitively expensive unless a detailed understanding of the use that the CCTV system is to be put to is clearly understood.

The following ‘system outlines’ will help operators have a clearer understanding of some of these issues and in doing so will enable system designers to design a system with the various operational features in mind rather than relying on a ‘one size fits all’ approach which may be inappropriate for the type of use required.

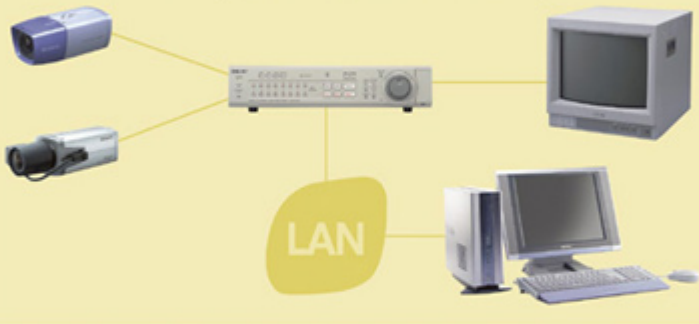
With this IP-based model, the traditional signal path of analogue CCTV:

Analogue video cameras are connected to an analogue video recorder which is connected to a video monitor.



... is replaced by a hybrid analogue - digital system:

Analogue video cameras capture video images and transmit them to a network video recorder. The video recorder is connected with a video monitor and via the network to a PC for viewing and to a server for archive and backup.



... or by an all-IP based networked system:

All equipment (video cameras, video server, PC) have network capability and inter-connect via the network.

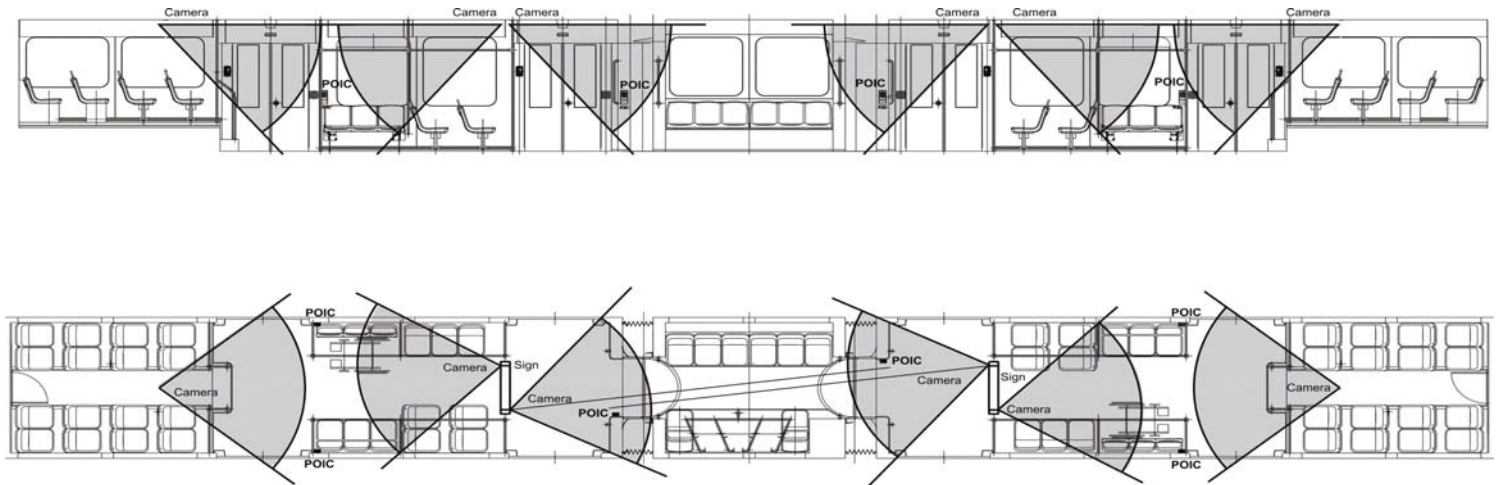


In the world of video monitoring, the shift to digital has seen an incremental evolution, beginning with the replacement of the traditional videocassette recorder with digital tape based recorders and, more recently, dedicated hard disk based systems that offer the advantages of non-linear random access recording and playback. Digital technologies are inherently more reliable than analogue video recording and playback, and picture quality remains consistent under a wide range of operating conditions, even after **hundreds of repeated viewings**. Digital video images can also be copied, edited, transmitted, stored and archived **without quality loss**.

As well as offering superior picture quality in comparison with analogue recording, digital techniques also offer far greater flexibility and creative possibilities for the processing, control and distribution of video signals. For example, digital images can be enhanced to resolve fine details under

‘difficult’ lighting conditions, permitting the more effective identification of a subject’s face or the accurate reading of a vehicle number plate.

Typical arrangements of a modern light rail vehicle internal surveillance and monitoring system



2.1.1. Cameras

There are two principle types of camera in use within CCTV systems. These are Analogue and Digital. Both of these camera types describe the method by which the image from the field of view (FOV) is captured, recorded and transmitted. This does not describe the method by which the FOV is achieved. Optical capabilities, through basic laws of physics, are derived via the lens or arrangement of lenses. Cameras with wide angle capabilities would therefore have a different lens configuration compared to that of a narrow FOV long range lens. Thus depending on your application, or mixture of applications, the lens that is attached to the camera sensor will vary and with it the quality of the optical image presented to the sensor. It goes without saying that a ‘pinhole’ camera as seen in some commercial security systems, without an appropriate optical lens, will provide less quality than a camera with a dedicated and appropriate lens selected for the application.

2.1.1. Analogue Systems.

Analogue Systems and cameras have been in use for many years and provide a range of capabilities allowing low, medium and high resolution capabilities described in terms of ‘lines of resolution’. Generally the higher the line count the greater the resolution, or quality, of image. Using Charged Couple Devices (CCD’s) of various types (single or three chip are typical) the analogue camera is connected to a recording or monitoring device via a coaxial cable and therefore systems using analogue cameras are usually identified by the ‘radial circuit’ arrangement of the wiring. One cable per camera arranged in a spider fashion. This can be a benefit and a disadvantage depending on the wiring capabilities within the car or vehicle. As an example vehicle’s using high voltage propulsion systems would require greater screening of cabling than those using diesel propulsion, thereby potentially increasing the cost of an installation.

Analogue cameras are frequently ‘converted’ to operate in a digital mode on a digital network and this requires conversion of the analogue signal to digital, via a codec. The digital signal can then be transmitted via a digital network to a recorder or controller via this network. There are disadvantages and advantages to this which will be better described under the digital camera overview.

Control of analogue cameras varies depending on manufacturing type, lens arrangement and whether the camera sensor is fixed or capable of being moved (swept) in terms of pan or tilt. Basic controls are usually provided via a separate control line to the sensor.

Considerations when selecting the right surveillance cameras.

It is virtually impossible to describe all types of available security cameras in this report. However the following are some of the most popular and widely used camera types instead.

CCTV security cameras produce images using CMOS or CCD (Charge Couple Device) chips. Tiny, very low price CCTV cameras usually use CMOS technology, produce poor quality images and have very poor light sensitivity. Decent quality CCTV cameras use CCD technology. The size of the CCD chip is normally 1/4", 1/3" or 1/2". As a rule of thumb, the larger the size, the higher the quality of the image produced and the higher the price. However, higher density 1/4" and 1/3" CCD chips can now produce as good an image as many 1/3" or 1/2" chips.

The number of TV lines in the security camera image is a measure of picture resolution (sharpness). The larger the number of TV lines, the better the resolution and hence, overall picture quality. Standard resolution camera may have 350-380 lines, over 400 TV Lines is generally considered good resolution while over 500 TV lines is considered high resolution.

B/W chip cameras produce greater resolution and better light sensitivity, therefore suitable for use in dark areas where light conditions are poor most of the time.

On the other hand colour cameras offer more realistic and natural picture.

CCTV cameras are usually divided into different types based on the body of the camera used.

Professional grade cameras.

Have box type body with the ability to use different types and size of lenses. Exchangeable lenses enable this camera, to monitor objects from virtually any distance.

Although for indoor use, they can be used for outdoor when combined with weatherproof housing. They are considered to be the most flexible and widely used by professionals for commercial installations.

Bullet cameras.

Bullet cameras are, as the name suggested contained inside bullet shaped housing.

Most bullet cameras are weatherproof and sealed without the ability to use different lenses. Great advantage of bullet camera is the small size and integrated design, some bullet cameras will even have infrared LED future built-in. Infrared technology is simply LED light in infrared spectrum (not visible to human eye). This light will illuminate viewing area, making possible monitoring in complete darkness. This is great future, but it only works up to certain distance (usually between 10 and 50 ft. depending on model)

Vary simple to install and estheticly designed, bullet cameras are great choice for residential and do-it-yourself installations where monitoring objects are within about 25ft from the camera location (with standard 3.6mm lens).

Board Cameras.

Board Cameras are basically fixed lens mounted on a circuit board. These cameras may be packaged in a small case (Mini Cameras) or dome (Mini Dome) or simply sold unpackaged, for mounting by the purchaser. Lenses in these cameras are either of a normal industry aperture or a "pinhole" lens of very small aperture. Pinhole lens cameras are often called "spy" cameras and may be mounted in a concealed way for covert surveillance purposes.

The most popular examples of covert board cameras are smoke detector and motion detector cameras.

Since the lenses in board cameras are pre-mounted, have a fixed iris and are usually of a short focal length (i.e. wide angle), their flexibility of usefulness is limited. However, this type of camera can provide a low cost solution in the right situation, particularly in a home environment.

Professional type cameras with C/CS mount lens attachment generally offer best performance and many important features, like lens control output, Back Light Compensation and many more...

Distance from monitoring object to the camera is not an issue, that is why ability to select different lenses, based on camera location is so important. Installation is bit complicated and professional installation strongly recommended.

We recommend this type of security cameras for commercial installations.

Most Bullet cameras in comparison, do not offer high resolution and lens selection flexibility, but are likely to be weatherproof; some will have infrared light built-in and most of all they are relatively easy to implement.

Bullet cameras usually come with 3.6mm lens which are considered to be suitable for most standard installations (good for covering small to medium size room or equivalent).

For larger rooms or longer distances, cameras with 6mm or higher lens may be required.

They are great choice for any do-it-yourself installation.

Board cameras in contrast are widely used in covert camera installations sometimes called Spy Cameras. Many wireless cameras are basically board cameras with built-in transmitter.

These are not discussed in detail in this report due to the quality of imagery and wireless link being very poor when considered for transit applications. General descriptions of these cameras appear later in this report for reference and comparison.

Board cameras are sold as plain circuit board, for integrating into hidden camera devices. They are also available in dome housing, as very popular Dome Camera or integrated with Smoke Detector, Motion Detector, Exit Sign and so on.

Most board cameras also come with 3.6mm lens although some will allow lens to be replaced.

Over the time, most practical design has been Dome Camera with its aesthetic appearance it blends into surroundings, especially with drop down sealing, great for use in stores, lobbies, gas stations and other public places.

Practical solution for covert installation are also, Motion and Smoke Detector cameras, they are absolutely not substitute for your security alarm or fire protection.

Cameras should always be selected based on the location of the camera (inside/outside), distance from the monitoring object, light condition and budget.

2.1.2. Digital Systems.

Digital Systems and cameras are those using CMOS based technology and therefore are usually cheaper in cost to produce due to mass production techniques of the CMOS devices. There is also advantage in the size of the sensor which leads to significantly smaller devices being able to be used in applications such as ‘pinhole’ cameras. However, CMOS devices currently have a limited quality or resolution, measured in pixel count rather than lines of resolution. An everyday example of this is the limited quality of a web camera when compared to that of a professional surveillance camera.

Currently CMOS cameras are limited to VGA quality and the use of these cameras, whilst cost effective is also limited depending on resolution requirements of the application.

Advantages that digital cameras do bring, however, are those of being able to be used in covert applications and within systems that contain digital wiring networks. The ability to use ‘network’ cameras addressable via a conventional IP address means that the wiring of a car or vehicle can be simplified. Restrictions do however exist when considering installations requiring large numbers of cameras which have to compete for ‘digital’ space on the network. This severely reduces the quality and resolution of the digital camera when working on a network. That said, if your application is for occasional surveillance of a car, or to act as a deterrent for vandalism, then this may well be acceptable. In all cases, whether using analogue cameras converted to digital or digital cameras alone, or a mixture of both a detailed understanding of the overall digital network traffic must be obtained for a system to work effectively. A badly designed system, in terms of digital traffic, can result in large ‘gaps’ in the timing of imagery causing images to be missed in terms of time as well as of a reduced resolution therefore compounding the problem.

It is important to remember that a digital video monitoring solution has the same 4 main components as a traditional analogue security solution.

- **The Camera**
- **The Cable**
- **The Recorder**
- **The Monitor**

The following is an explanation of what the technology is all about using simple terminology. It shows you just how easy it is to put a video monitoring solution together.

The Camera

While an analogue camera’s sole function is to capture images and send them down a cable to multiplexer or DVR, an IP/Network Camera is a truly intelligent digital camera. It has a computer, CMOS chip, that carries out the same process in the camera as a DVR does in the recorder unit i.e. digitises, filters and compresses the image.

In IP-surveillance most of the functionality resides in the camera including intelligent functions like motion detection.



It must be remembered that CCTV did not spawn IP technology – CCTV is simply another application using existing IP technology. A basic difference

between an Analogue and Network camera is that the Network camera has to translate the image and put it on the network as well as capturing the image.

From analogue to digital

There is a huge analogue camera legacy market out there and organisations are not simply going to throw away their existing cameras unless they absolutely have to. To address this issue a number of manufacturers have produced IP Servers and Codec's. These devices digitise and compress an analogue image allowing it to be sent onto an IP Network.

Networking terminology

including TCP/IP, compression, transmission, bandwidth, latency etc.

Unlike traditional CCTV IP Networks are shared networks. They use an organisation's IT network which is also used to carry data for other purposes. These LANs, Local Area Networks are digital networks used within organisations to link together computers and devices like printers, servers etc. A key factor in the growth in popularity of these computer networks is the ease with which a new device can be added when needed. Just simply connect it to the LAN and immediately link it with all the other devices on the network.

Nearly 90% of LANs use the Ethernet networking standard. Just as Ethernet is the dominant standard for networks so TCP/IP is the dominant protocol for communicating on networks. TCP/IP are two protocols that work together. TCP, Transmission Control Protocol verifies the data and checks that what was sent has been received. If not then it will request the data to be sent again. The IP, Internet Protocol, does the actual transport, location and addressing of the data.

IP Addressing

A fundamental concept of IP is "addressing" of hardware devices such as cameras, servers etc on a network. The IP address is a way of uniquely identifying each piece of equipment on the network just like a telephone number identifies a particular address. They are expressed in four part dotted decimal notation e.g. 101.98.126.8 and are assigned by the network administrator.

Compression

Why do we need to compress the images? The purpose of compression is simply to reduce the amount of data (data rate) of the digital video signal down to a level that is compatible with the transmission capabilities of a particular network. There are several compression methods-the best known and most commonly used are JPEG, MJPEG 2, MPEG 4, Wavelet and H323.

The cable/network - bandwidth

In Network Communication terms it stands for the amount of data that can be sent across the cable/wire at any moment in time. Each communication that passes along the wire decreases the amount of available bandwidth. It is fairly common practice to refer to the network as a pipe and this is quite a good analogy as for example the diameter of a pipe determines how much water would flow through it at any moment in time.

Research shows that 70% of buildings already have a network infrastructure in place. Nearly 90% of these are CAT5 Ethernet based. There are currently two types of Ethernet i.e. Standard Ethernet (10 BaseT) and Fast Ethernet (100 BaseT). It only really makes sense to transmit video images over Fast Ethernet – 100 Mbit/Second because video images are bandwidth hungry. Restricted Bandwidth can result in reduced frame rate and resolution as well as latency issues.

Latency

Latency issues affect the control of PTZ (Pan-Tilt-Zoom) cameras over a heavily utilised or slow network particularly if those cameras are being controlled through an IP server or Codec. If the operator is doing live tracking of an individual from camera to camera there can be a response delay to the pan tilt and zoom commands. However the pace of development of this technology is quite phenomenal and these issues are currently being resolved.

The Recorder

In IP the recorder is a PC similar to the one in most homes but because of the nature of the application will have as fast a chip as possible with the maximum amount of memory and as much disk storage as possible e.g. minimum of 512K RAM and 160 Gigabyte Hard Disk.

The IP Software

The software is probably the most important element of any IP security and surveillance solution. The most widely used packages have been designed to be extremely easy to install and to operate.

Software on the PC enables the images to be viewed, stored, time and date stamped and retrieved for reviewing of incidents. The software will sometimes have VMD (video motion detection) built in so if the camera does not have VMD functionality then it can reside in the PC IP software.

The software is either the simple browser type for viewing a camera over the Internet or packages designed for comprehensive security & surveillance applications. They even provide familiar multiplexed type screens with the ability to monitor live video streams from 4, 9, 16 and 25 cameras and any combination in between.

An all-IP based infrastructure affords manufacturers, system installers and end-users alike a number of benefits – most notably **reducing the capital and operational cost** of Network Video Monitoring.

IP based systems present an extremely attractive business case as an alternative to traditional CCTV solutions. While the cost of IP cameras currently represents a slight premium over traditional analogue cameras – reflecting their greater complexity and ‘embedded intelligence’ – this cost is offset by:

- systems being scaled to support more storage
- structured network cabling reducing installation costs compared with expensive, dedicated analogue co-axial systems
- camera control signals being routed over the same network cabling reducing installation costs further

Overall, by aggregating the total cost of cameras plus installation, network cabling, monitoring and storage components, IP based Network Video Monitoring can be significantly less expensive than proprietary hardware solutions.

Re-using existing office networks reduces the cost of new cabling and minimizes physical disruption within the workspace during installation.

Using ‘open’ IT industry standards rather than proprietary camera, recording, monitoring and storage technologies **reduces hardware costs** as well as providing access to a greater range of other imaging,

networking and storage products from other third party manufacturers.

IP networks are essentially unlimited by their physical size, scale and extension. Any networked PC can be used to view pictures as well as performing system management and camera control functions ‘off-site’ as well as ‘on-site’.

It is simple and cost effective to scale IP-based networks by adding extra cameras or server-based storage at any time to meet growing needs. Storage can be scaled to meet any requirement by adding sufficient capacity to store and archive images from as many cameras as required, and for any desired length of time. Similarly, there is **no restriction** on the number of sites that can be used for simultaneous monitoring. For example, desktop PCs could display pictures from a camera mounted at the front door of an office building for every authorized employee.

IP cameras can be smarter than their analogue counterparts, allowing remote control of camera functions including:

- on/off
- focus
- shutter/exposure mode
- pan/tilt/zoom movement

All accessible from an operator’s PC as well as sending alarm and event triggers from the camera.

IP based Network Video Monitoring solutions are inherently future-proofed in comparison with traditional solutions built around proprietary hardware and coaxial cabling.

Since functionality of cameras and control systems is defined in software rather than hardware, features can be upgraded to reflect new developments at incremental cost rather than requiring replacement hardware.

2.1 Recorders

When selecting security cameras, users are faced with the fact that they will need to select one or another recording device.

The days of well-known CCTV time-lapse VCR recorder are almost over.

Although some customers still prefer this old fashioned recording solution, it is essential to specify a good quality digital video recorder (DVR). Digital recorder transfers analogue camera video feed into digital format, via a Codec as mentioned earlier and stores it on hard drive. The manipulation of the Codec at the recorder can also provide significant flexibility in managing the imagery to be recorded and at what resolution or quality. This additional Codec control will almost certainly require ‘bespoke’ or ‘custom’ NRE to provide the software suitable for the application. IN terms of recorders there are two major types of digital recorders on the market right now.

PC Based CCTV Systems.

A special board and software installed on the computer will allow camera inputs and store video on the hard drive.

Many people are under the misconception that personal computer with additional hardware installed, will do the job. This explains the hundreds of companies that have hung up a sign, taken out some ads and begun working out of basements and garages, holding themselves out to be DVR manufacturers and security specialists. The main problem with this type of CCTV recorders lies in the main component of it... Yes, it is a computer, designed to do unlimited tasks, but non well. The truth is that any computer based digital video recorder is, and will always be vulnerable to software crashes, hang-ups, system instability, virus related problems etc...

Stand Alone Systems.

Very similar in appearance and control functions to standard VCR recorders, are truly remarkable devices. Most video processing is done by hardware, therefore eliminating system crashes; video is also stored on hard drive in digital format. The basic operating system, usually Linux, is permanently stored on special processor, witch is impossible to overwrite or corrupt. Designed and manufactured with single application in mind, it is by far better in performance and reliability to its PC based rival.

Some DVR systems will even have remote monitoring capability, useful when monitoring is required in different locations thru Internet or network.

Most important futures to look for when selecting the right DVR recorder are motion detection and frame speed. The higher the frame speed the more fluent video recording. Motion detection will allow recording video from each camera only when motion is detected this is great for extending video recording time.

Security Monitors.

Video from Security recorders can be displayed on regular TV monitor. It is OK to do it this way, for baby monitoring or residential application, when quality of the picture is not that important. However for professional installations where quality and reliability are a concern the you must consider that security monitors are as much important as cameras. They offer extended life of picture tube (necessary with any static picture that can cause picture burnout) or TFT/Flat screen and much grater resolution.

Cables and wiring.

Finally any camera installation will require proper wiring. Good quality cable will prevent video degradation over long distance runs as frequently seen in rail cars and buses. It is recommended to use RG59 or RG6 coaxial cables as it is fully shielded and will prevent video loss up to 400 ft. Coaxial cables (for analogue cameras) will require BNC connectors and proper installation possibly done by experienced technicians. In short runs plug and play non-coaxial cables with factory installed BNC connectors may be used (up to 150 ft.). The plug and play cables are easy enough to install by not experienced users.

Cables for CCTV cameras consist of two cables bundled in one jacket. One cable for video and one for power delivery. Installations requiring to be run from car to car in long consists may well require 2 or more control points due to losses in cables that make long runs difficult. Further considerations must be made in terms of synchronising this control or recording points via a digital network. The size or data

rate of this network is a major consideration as typical 10Mbit networks can only carry a handful of camera feeds. 100Mbit networks, now being introduced to multi car consists have the advantage of being able to carry additional camera feeds (typically up-to 16 simultaneously). Consideration must however be made for the link across multi car consists. Advanced 100Mbit 'pin' connectors are now available to replace some of the more unreliable 10Mbit wireless systems which have proved vulnerable to interference or attack.

3.0. Further background information on lenses, standards and glossary of terms:

LINES OF RESOLUTION

"Lines of resolution" is a rather confusing term in the video and television world. This type of measurement is a carry over from the early days of analogue television. It is poorly understood, and it is inconsistently measured and reported by manufacturers. But we're stuck with it until all video is digital, at which time we might just possibly change the convention and start reporting resolution in terms of straight pixel counts perhaps.

There are some common misconceptions. "Lines of resolution" is not the same as the numbers of pixels (either horizontal or vertical) found on a camera's CCD, or on a digital monitor or other display like a video projector, and so forth. And it is also not the same as the number of scanning lines used in an analogue camera or television system such as PAL or NTSC or SECAM etc. It is easy to get a confused or incomplete idea about the real meaning of the term "lines of resolution".

"Lines of resolution" is a technical parameter that has been in use since the introduction of television to the world (so long before digital and pixels, and so forth). The measurement of "lines of resolution" attempts to give a comparative value to enable you to evaluate one television or video system against another, in terms of overall resolution. Note the reference here to "system" and "overall". So this measurement refers to a complete video or television system, which includes everything to record and display an image. It includes the lens, the camera, the video tape, and all the electronics that makes it the entire system work. This number (and it can be a horizontal or vertical value) tells us something about the overall resolution a complete television or video system is capable of. There are two types of measurement, (1) "lines of horizontal resolution," also known as LoHR, and (2) "lines of vertical resolution," or LoVR. However, it is much more common to see the term "TVL" (=TV Lines).

In precise technical terms, "lines of resolution" refers to the limit of visually resolvable lines per picture height (i.e. TVL/ph = TV Lines per Picture Height). In other words, it is measured by counting the number of horizontal or vertical black and white lines that can be distinguished on an area that is as wide as the picture is high. The idea is to make this measurement independent of the aspect ratio. So imagine a lot of horizontal lines drawn on a piece of white paper and all bunched up together pretty closely. If the system has a vertical resolution of say 500 lines, then the whole system (lens + camera + tape + electronics) can distinguish 250 black lines and 250 white spaces in between those black lines (250 + 250 = 500 lines). Now imagine a lot of vertical lines drawn on a piece of white paper and all bunched up together. If the system has a horizontal resolution of say 750 lines, then the whole system (lens + camera + tape + electronics) can distinguish 375 black lines and 375 white spaces in between (375 + 375 = 750 lines). In either case, if you add any more lines per picture height, then you can't tell

where a black line stops, and the adjacent white space in between, starts. In other words it can't resolve the lines and spaces in a distinguishable way, and the system has reached its limit of resolving detail.

Lines of horizontal resolution applies to not only cameras, but also to television displays, to signal formats such as those produced by a DVD player and so forth. Most TV's, for example, list ludicrously high numbers for their horizontal resolution. That is because manufacturers can bend and twist these measurements to make their products look good in the eyes of consumers. Same with cameras, by simply changing the lens to a much higher quality one, or even using a much higher grade of tape, you can change these numbers considerably (even if the camera is not normally used in this configuration in the field, or they only sell it with a much cheaper lens, or whatever). Different manufacturers use different measuring techniques, so direct comparisons of brand "X" camera against brand "Y" camera can be misleading. So take these TVL numbers with a grain of salt. However, they are certainly a guide nonetheless when you want to compare one camera with another, or one monitor with another, or one video projector with another, and so on.

So when people talk about "lines of resolution", but don't specify if they are horizontal or vertical lines..... then you already need to be cautious. If a manufacturer doesn't make the reference clear, then you can assume they are horizontal numbers, because they are always bigger numbers, and therefore they sound more impressive.

Perhaps another anomaly when talking about lines of horizontal resolution is to remember that vertical lines are being measured on the test chart (which is the opposite of the way it might seem, intuitively speaking). Horizontal resolution is the ability to resolve vertical lines, and visa versa. If the basic idea of this measurement is not clear, then one might think horizontal resolution is referring to horizontal lines, which is not the case.

You can't get any more than 480 vertical pixels with mini-DV because that is strictly defined by the format itself. If it has more, it simply wouldn't be DV any more, but some other format (and therefore incompatible). But you can shoot the DV format with a camera with say 500 TV lines of resolution or 750 TV lines of resolution and so on (it can be any number in theory, but ultimately governed by the quality of the technology). But you definitely aren't getting 500 or 750 pixels across your image. So remember the 500 and the 750 refer to the overall resolving power of the whole system, and doesn't tell you about how many pixels the format has.

True Pixel Count

"Lines of resolution" may ultimately be replaced by a true pixel count when referring to resolution in the future (especially in all-digital systems). In the future, as digital technology becomes much more uniform across manufacturers, the main difference in overall resolution of future video system will be more or less directly related to true pixel count. So this provides a simpler, more definite point of comparison, and therefore might make more sense that using the older "lines of resolution" method. However, "lines of resolution" will remain a technically more accurate measurement, as it takes the whole system into account.

For example, since the current DVD format has 720 horizontal pixels (on both NTSC and PAL discs), the true horizontal resolution can be calculated by dividing 720 by 1.33 (for a 4:3 aspect ratio) to get 540 lines. (On a 1.78 [16:9] display, you get 405 lines) In practice, most DVD players provide about 500 lines instead of 540 because of filtering and low-quality digital-to-analogue converters.

TV lines

TV lines of resolution are one of the trickier numbers. It measures limiting horizontal resolution of the system, but it's odd in two ways. First, a "TV line" consists of a single distinguishable detail. In our hypothetical case of alternating black-and-white vertical lines, each black line and each white line is a TV line, in contrast with the more normal measurement of line pairs or cycles used in film, lens measurement, and the audio worlds. Thus a resolution figure of 500 TV lines means that 250 black and 250 white lines could be resolved, or 250 line pairs, or 500 TV lines in total.

Second, resolution is always normalized to a square screen resolution is always specified in TV lines per picture height (TVL/ph). The normalized measurement lets you compare the horizontal resolution of a TV system (the figure normally quoted) with the vertical resolution, which is fixed by the number of scan lines used and the kind of scanning performed (interlaced or progressive), and eliminates any dependency on aspect ratio (4:3 or 16:9). A camera resolving 600 TV lines resolves those lines across a width of the image equal to the picture height. If the camera shoots 4:3 images, the camera can actually resolve 800 TV lines across the entire picture ($4/3 \times 600$); if the camera shoots true 16:9 images, it resolves 1067 TV lines across its entire picture width ($16/9 \times 600 = 1067$).

This explains why true 16:9 switch-able cameras list the same resolution in both 4:3 and 16:9 modes the figures are normalized to picture height, even though more pixels per line are used in 16:9 than in 4:3. You'll sometimes see 16:9 camera specs that say things like "700 TVL in 16:9 mode, the equivalent of 930 TVL in 4:3 mode." What these guys are saying is, "Look, if you took all the pixels available on the 16:9 chip and squeezed them in to make a 4:3 picture that picture would have a resolution of 960 TVL, and it therefore sounds more impressive this way.

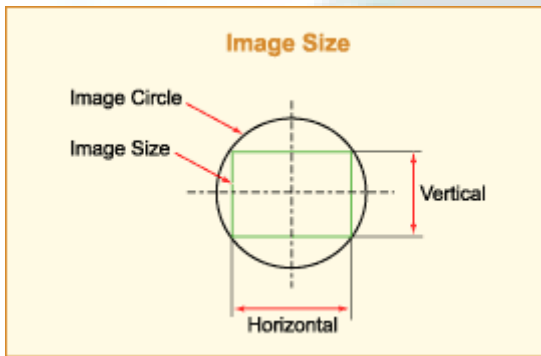
If that isn't bad enough, there's also the question of what sort of picture you'll get as you approach the specified resolution figure. What happens as you reach the absolute limits of resolution? In all video systems, aperture response tends to decrease as frequency increases. In other words, resolving power starts falling apart as the limit is approached, as the detail being captured actually becomes smaller than the individual pixels on the CCD (or smaller than the diameter of the scanning beam in analogue systems). At least one manufacturer specifies resolution at the point where the response is only 5 percent, which is a more reasonable spec. But others may measure the point where the curve actually intersects the noise floor and no detail can be seen at all. Limiting resolution can be precisely that limit, and not necessarily the usable limit from a more practical point of view.

Optical Characteristics of Video Lenses

Image Size

A lens produces images in the form of a circle, called the image circle. In a CCTV camera, the imaging element has a rectangular sensor area (the image size) that detects the image produced within the image circle. The ratio of the length of the horizontal to vertical sides of a video image is called the aspect ratio, which is normally 4:3 (H:V) for a standard CCTV camera.

Image Sensor	Image Circle	Horizontal	Vertical
1/4"	Ø4.0mm	3.2mm	2.4mm
1/3"	Ø6.0mm	4.8mm	3.6mm
1/2"	Ø8.0mm	6.4mm	4.8mm
2/3"	Ø11.0mm	8.8mm	6.6mm
1"	Ø16.0mm	12.8mm	9.6mm



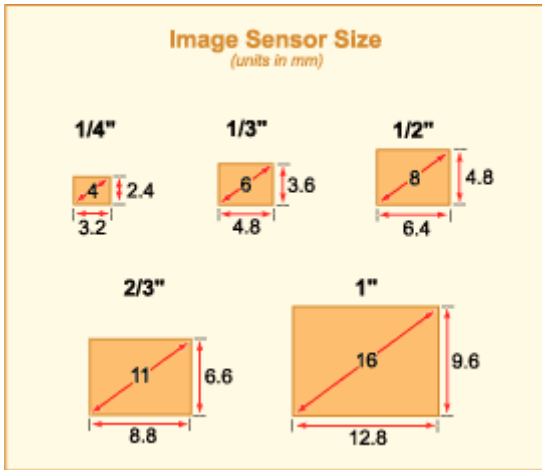
Relationship Between Angle of View and Image Sensor Size . . .

An important factor to remember is that cameras with different image sensor chip sizes (such as 1/4", 1/3", 1/2", 2/3" and 1"), using the same focal length lens, will each yield a different field of view.

Lenses designed for a larger image sensor device will work on a new, smaller size camera. However, if a lens designed for a smaller format image sensor device (i.e. 1/3") is placed on a larger one (i.e. 2/3"), the image on the monitor will have dark corners.

Image sensor sizes are in a ratio of 1:0.69:0.5:0.38:0.25. This means that a 1/2" format is 50% of a 1" format, a 1/2" format is 75% of a 2/3" format and a 1/3" format is 75% of a 1/2" format.

Image Sensor Size (units in mm)



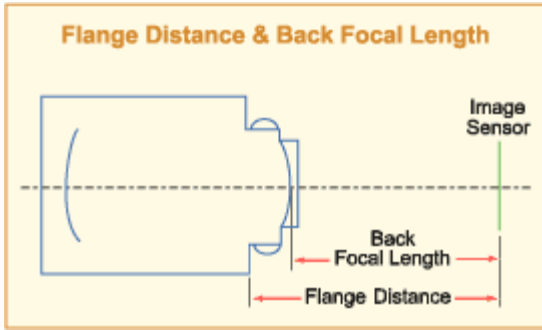
Camera to Monitor Magnification

Camera Format	Monitor Sizes (diagonal) in inches					
	9"	14"	15"	18"	20"	27"
1/4"	57.2X	88.9X	95.3X	114.3X	127X	171.5X
1/3"	38.1X	59.2X	63.5X	76.2X	84.6X	114.1X
1/2"	28.6X	44.5X	47.6X	57.2X	63.5X	87.5X
2/3"	20.8X	32.3X	34.6X	41.6X	46.2X	62.3X
1"	14.3X	22.2X	23.8X	28.6X	31.8X	42.9X

Minimum Object Distance

Minimum object distance (M.O.D.) indicates how close the lens can be placed to the object for shooting. It is measured from the vertex of the front glass of the lens.

Flange Distance and Back Focal Length



Flange Distance

Distance between mechanical mount surface and the image sensor (in air).

C-Mount=17.526 mm / .690"

CS-Mount=12.526 mm / .493"

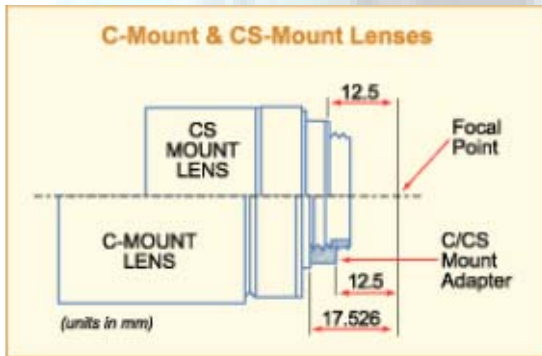
Back Focal Length

Distance between vertex of the rear element lens and image sensor.

C-Mount and CS-Mount Lens Compatibility

When using a C-mount lens for a CS-mount camera, a C/CS-mount adapter (5 mm thick) is required between the lens and the camera.

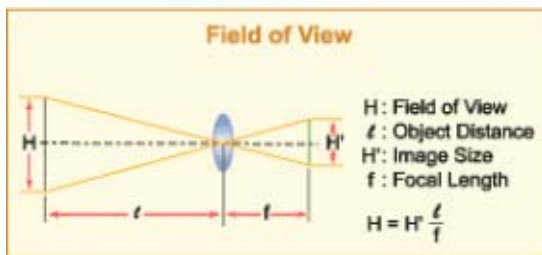
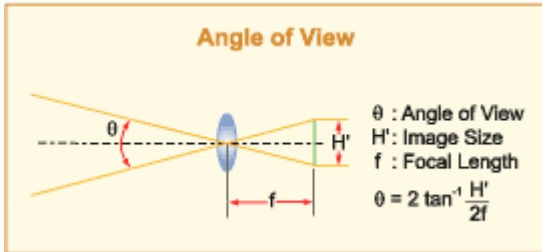
Compatibility	C-Mount Camera	CS-Mount Camera
C-Mount Lens	OK	OK
CS-Mount Lens	NO	OK



Angle of View and Field of View

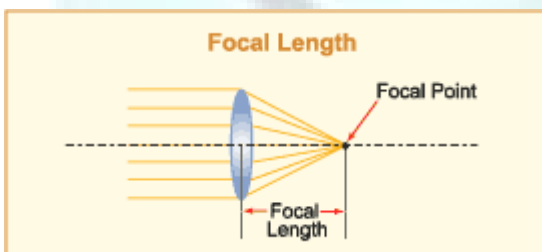
The angle of view is the shooting range that can be viewed by the lens given a specified image size. It is

usually expressed in degrees. Normally the angle of view is measured assuming a lens is focused at infinity. The angle of view can be calculated if the focal length and image size are known. If the distance of the object is finite, the angle is not used. Instead, the dimension of the range that can actually be shot, or the field of view, is used.



Focal Length

Parallel incident light transmitted into a convex lens converges to a point on the optical axis. This point is the focal point of the lens. The distance between the principle point in the optical system and the focal point is referred to as the focal length. For a single thin lens, the focal length is equal to the distance between the centre of the lens and the focal point.



It is important to use the right lens for the light conditions and desired field of view; otherwise the images seen and recorded will not be satisfactory. CCTV security cameras with an integral lens are less expensive but do not offer lens choices and are therefore limited in their usefulness. The important factors that govern the choice of lens are:

Focal Length

Lenses either have a fixed or variable focal length. Manually variable focal length lenses are called **Vari-Focal Camera Lenses**. Electrically powered variable focal length lenses are called **Zoom Camera Lenses** and while they are often used in high-end video surveillance systems, they are generally too expensive for use in most systems. The focal length of a lens is usually given in Millimetres (mm). Focal lengths of most CCTV camera lenses vary from 3.6mm to 16mm for fixed focal length lenses, to well over 70mm for zoom lenses. So what does that mean? In general, short focal length lenses (e.g. 4mm) have wide fields of view. This is good for close-ups or for seeing a large area. Objects appear smaller, rapidly, as distance from the camera increases. As lens focal length increases, the field of view narrows and more distant objects are easier to define. Take a look at the table below:

Field of View (in feet)													
Lens Focal Length (mm)	Viewable Angle (Degrees)		5 feet away		10 feet away	15 feet away		25 feet away		50 feet away		100 feet away	
	Horiz.	Vert.	Horiz.	Vert.	Horiz. Vert.	Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
3.6	74	55	7.5	5.2	15.1 10.4	22.6	15.6	37.7	26.1	75.4	52.1	151	104
6.0	42	32	3.8	2.9	7.7 5.7	11.5	8.6	19.2	14.4	38.4	28.7	77	57
8.0	32	24	2.9	2.1	5.7 4.3	8.6	6.4	14.4	10.7	28.7	21.3	57	43
12.0	22	17	1.9	1.5	3.9 3.0	5.8	4.5	9.7	7.5	19.4	14.9	39	30
16.0	15	11	1.3	1.0	2.6 1.9	3.9	2.9	6.6	4.8	13.2	9.6	26	19

If, for instance, you wanted to be able to positively identify people, 25' away from a camera, a short focal length lens (e.g. 3.6mm) would give such a large field of view (37'x 26') that recognition would be uncertain. An 8mm or even 12mm lens would be far better.

The Lens Iris

CCTV security cameras that are used in good and constant light conditions (e.g. indoors with electric lighting) will perform satisfactorily with a "**Fixed Iris Lens**". Fixed Iris lenses with fixed focal length are the least expensive and the most widely used.

In varying light conditions (e.g. outside or inside facing a window) the iris on the camera will need to open and close to accommodate changes in light intensity, otherwise the camera images will be too bright or too dark. Lenses with electrically powered irises which automatically adjust as light conditions change are called "**Auto Iris Lenses**". They are more expensive but do a much better job in varying light conditions.

In constant light conditions that are either dim or very bright, a "**Manual Iris Lens**" may be the answer. As its name implies, this type of lens can have the Iris aperture adjusted by hand to give the optimum camera image quality. Pricing for "Manual Iris" lenses is higher than Fixed Iris and lower than Auto Iris lenses.

The "F Stop" value of the lens

While "F Stop" is actually a ratio between focal length and lens aperture, in practice, when comparing lenses of the same focal length, it is an indication of the lens aperture. The smaller the "F Stop" the wider the lens aperture and the more light that lens will let into the camera. This is of particular importance in lenses with adjustable irises (both manual and auto). Our vari-focal, manual and auto-iris lenses have an "F Stop" value of 1.0, giving a far better aperture than most and consequently a better image, particularly in lower light conditions.

Conclusion.

Every CCTV system is as good and reliable as its weakest component. With this in mind, investing in the highest quality and performance cameras, while purchasing low performance recorders, from economical and practical standpoint just does not make sense. Whether your system is analogue or digitally based.

For example, why use cameras with 500 TV lines of resolution with monitors or recorders that offer only 380 or less. All the benefit of the high-resolution camera is affectively sacrificed by limited capability of the monitor or recorder. The same holds true for using a high data rate digital IP cameras and reducing the recording capability of the hard disk that you use for recording.

Developing a systems requirement is therefore an important exercise before embarking on purchasing a video security system. It is essential to understand if your system is an 'anti-vandal' system or a system designed for use in Homeland Security facial recognition applications. The quality, performance and reliability of each are very different and this needs to be recognised in the specification that is developed.

Glossary of CCTV Terms

A

ABERRATION - Any inherent deficiency of a lens or optical system. Aberrations are responsible for imperfections in shape or sharpness of the image.

AGC - Automatic Gain Control, an electronic circuit that amplifies the video signal when the strength of the signal falls below a given value.

ALC - Photometric control, measures light intensity. Determines the iris reaction sensitivity. Sensitivity is increased when the potentiometer is turned towards PEAK, and decreased when turned towards AVERAGE.

ANGLE OF VIEW - May be expressed in Diagonal, Horizontal, or Vertical. Smaller focal lengths give a wider angle of view.

APERTURE - The opening of the lens that controls the amount of light reaching the surface of the pickup device. The size of the aperture is controlled by the iris adjustment.

APERTURE SCALE - The aperture scale is referred to as an F-number. The international aperture scale is: F1, F1.4, F2, F2.8, F4, F4.6, F8, F11, F16, etc.

ASPHERICAL LENS - A lens one or more of whose elements has a non-spherical surface. Aspherical surfaces are shaped to reduce the spherical and other aberrations.

AUTO-IRIS LENS - A lens with an electronically controlled iris. This allows the lens to maintain one light level throughout varying light conditions.

B

BACK FOCUS - A term used to describe the relationship of the distance of the lens to the image device. This distance is critical to maintaining the proper depth of field through changing focal lengths and varying light conditions. The correct back focus is normally achieved by adjusting the image pick-up device on the camera itself.

BLC - Back light compensation. A function of the camera that compensates for excessive light directed at the camera, which causes the video to bloom or the images in front of the light to be unusable.

C

CAMERA FORMAT - The approximate size of a camera image pickup device. This measurement is derived from the diagonal line of a chip or the diameter of the tube. Currently there are five format sizes in the CCTV industry: 1", 2/3", 1/4", 1/3" and, 1/2"

C-MOUNT - An industry standard for mounting a lens to a camera where a 1" x 32 thread is employed and the distance from the image plane is 17.52mm from the shoulder of the lens. A C-mount lens may be used CS-mount camera with the use of a 5mm-adapter ring.

CS-MOUNT - A relatively new industry standard for mounting a lens to a camera where a 1" X 32 thread is employed and the distance from the image plane from the shoulder of the lens is 12.52mm. A CS-mount lens may NOT be used on a C-mount camera.

D

DC TYPE AUTO-IRIS - Auto-iris lenses where the iris is controlled by the circuitry of the camera.

DEPTH OF FIELD - The regions in front of and behind the focused distance where the image remains in focus. With a greater the depth of field, more of the scene near to far is in focus. Lens aperture and scene lighting will greatly influence

the D.O.F.

E

EXTENSION TUBES - Various size spacers used between the camera and lens to reduce the Minimum Object Distance. Not recommended for use with zoom lenses due to the loss of tracking ability.

F

F-NUMBER - Indicates the brightness of the image formed by the lens, controlled by the iris. The smaller the F-number the brighter the image.

F-STOP - A term used to indicate the speed of a lens. The smaller the F-number the greater amount of light passes through the lens.

FIELD OF VIEW - The horizontal or vertical scene size at a given length from the camera to the subject.

FOCAL LENGTH - The distance from the centre of the lens to a plane at which point a sharp image of an object viewed at an infinite position. The focal length determines the size of the image and angle of FOV seen by the camera through the lens. This is the centre of the lens to the image pickup device.

H

HUNTING - An industry term used to describe an auto-iris lenses inability to stabilize under certain light conditions.

I

IRIS - A mechanical diaphragm which can be controlled manually or automatically to adjust the lens aperture.

L

LENS FORMAT - The approximate size of a lens projected image. In most cases the lens will project an image slightly greater than the designated image size to insure the pickup device is completely covered. It is recommended that camera and lenses are the same format size. A lens a larger format size can be used on a smaller format camera; however a smaller format lens should never be used with a larger format camera.

LENS SPEED - Refers to the lens aperture or its ability to transmit light. This is measured in F-stops.

LEVEL CONTROL - Used to set the auto-iris circuit to a video level desired by the user. Turning the level potentiometer towards the HIGH position will open the iris allowing more light to pass through the lens, towards the LOW will close the iris allowing less light to pass through the lens.

M

MANUAL IRIS LENS - A lens with a manual adjustment to set the iris opening (aperture) to a fixed position. This type lens is generally used in fixed lighting conditions.

MINIMUM OBJECT DISTANCE (M.O.D.) - The closest distance a given lens will be able to focus upon an object. Generally the smaller the focal length the shorter the M.O.D. This distance can be altered with use of extension tubes.

P

PINHOLE LENS - Lenses used primarily in covert applications where the camera/lens must remain out of sight.

PRE-POSITION LENSES - Pre-position lenses are specially designed lenses with extra mechanical/electrical components to allow for computer interfacing. This function allows the lens (when used with the appropriate controller) to feedback to

the controller information relevant to zoom and focus positioning allowing the controller to quickly scan to a pre-selected scene, arriving in focus at the proper zoom point without operator intervention.

S

SPOT FILTER - A neutral density filter placed at the centre of one of the elements (or on an iris blade) to increase the high end of the F-stop range of the lens.

T

TELEPHOTO - Telephoto is a term used to describe lenses that have a high focal number causing the reproduced image to appear larger than human eye reproduction.

TRACKING - A zoom lenses ability to remain in focus throughout the entire zoom range.

V

VARI-FOCAL - A low cost version of a zoom lens designed to meet installer's needs for versatility. This lens does not have the ability to track from wide to telephoto.

VIDEO TYPE LENS - An auto-iris lens with internal circuitry for processing of the video signal which controls the iris movements.

Z

ZOOM LENS - A lens with the ability to change its focal length manually or through the use of a controller to cover a variety of needs.

ZOOM RATIO - The ratio of the starting focal length (wide) to the ending focal length (telephoto) of a zoom lens. A 10X zoom will magnify the image at the wide end by 10 times. Examples of a 10X zoom lenses; 8mm~80mm, 12mm~120mm.