1. Field Of View (FOV):
The area of the object that will be viewed on the monitor.

2. Resolution:
The smallest resolvable feature of the object.

3. Minimum and Maximum Working Distances:
Measurement from objective lens to the object.

4. Depth Of Field Requirement:
Maximum object depth needed in focus.

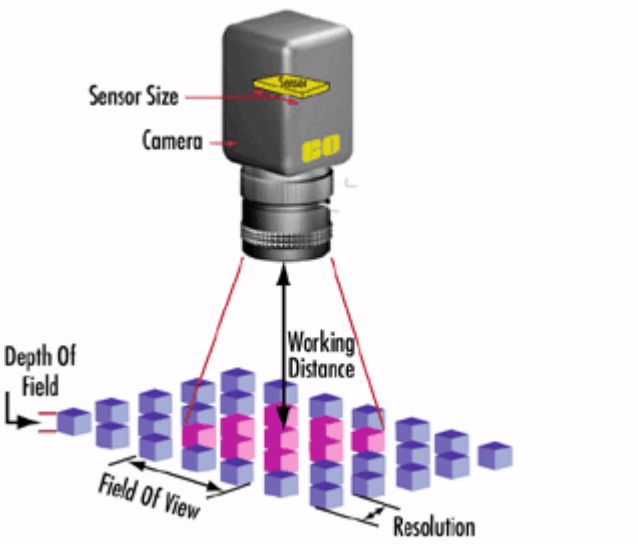

Figure 1: Fundamental Parameters of an Imaging System

FEATURES OF IMAGE QUALITY PARAMETERS	COMPONENTS AFFECTING THE PARAMETERS
Resolution: Resolution is a measurement of the imaging system's ability to reproduce object detail	◆ **Lens** ◆ **Monitor** ◆ **Camera** ◆ **Capture Board**
Contrast: Comparison of the shades of gray in the image that define an object and its background.	◆ **Camera** ◆ **Capture Board** ◆ **Illumination**
Depth of Field (DOF): The difference between the closest and farthest distances an object may be shifted before an unacceptable blur is observed. Sometimes called Depth of Focus, DOF should not be confused with working distance. This is also applicable to objects with depth.	◆ **Aperture of Lens (f/#)**
Distortion: Distortion is an optical error (aberration) in the lens that causes a difference in magnification at different points within the image.	◆ **Lens**
Perspective Errors: Also called parallax, this is	

a phenomenon in conventional lenses which causes a change in magnification as it moves in and out from best focus. Closer objects appear larger than objects further away. Telecentric lenses optically correct for this occurrence.

◆ **Lens**

Terminology Used in Electronic Imaging

Sensor Size: The size of a camera sensor's active area, typically specified in the horizontal dimension. This parameter is important in determining the primary magnification (PMAG) required to obtain a desired field of view. Note: Most analog cameras have a 4:3 (H:V) dimensional aspect ratio.

Primary Magnification: Defined as the ratio between the sensor size and the FOV, PMAG is the "work" done by the lens.

System Magnification: The total magnification from the object to the image on the monitor, this is the "work" done by the whole system. It is the product of the PMAG and the camera-to-monitor magnification (the ratio between the monitor size and the sensor size).

Resolution: Resolution is a measurement of the imaging system's ability to reproduce object detail. Figure 2 illustrates a simplified view of two squares imaged onto pixels of a CCD camera. In order for two objects to be resolvable, a certain amount of space between the objects is needed.

Linepairs per millimeter (lp/mm): In Figure 2, a linepair represents one red square and one white space. Resolution can be expressed in terms of a number of linepairs per millimeter (lp/mm), which is why resolution is often referred to as a frequency. The inverse of this frequency yields the spacing between two resolved objects (i.e. the red squares) in terms of millimeters. This specification can be used for both lenses and cameras.

Pixel Count: The resolution of digital cameras can also be specified in terms of pixel count. As shown in Figure 2, a line-pair actually corresponds to two pixels. In other words, for two red squares to be resolved, one pixel needs to be dedicated to each red square and one to the blank white space between them.

TV Lines: In analog CCD cameras, this is a unit of resolution based on a bar target with equally spaced lines. If the target was extended so that it covered the field of view, the TV line number is calculated by summing all of the lines and spaces. This value is unitless and should not be compared to the linepairs/mm specification.

F-Number (f/#): A measure of the light gathering ability of a

lens. f/# increases as the lens aperture is closed, see Figure 3. Closing the aperture can also increase the system's depth of field (see definition below) but illumination should be increased to compensate for this.

C/CS-Mount: These are both threaded mounts (1-32 TPI) found on most industrial CCD cameras and lenses. The flange (back focal) distance to the sensor is 17.52mm for C-Mount. CS-Mount has a flange distance of 12.52mm. C-Mount lenses and CS-Mount cameras are compatible using a 5mm spacer (#03-618).

Depth Of Field: The maximum object depth that can be maintained entirely in focus. DOF is also the amount of object movement (in and out from best focus) allowable while maintaining a desired amount of focus. As the object is placed closer or farther than the working distance, it goes out of focus and both the resolution and contrast suffer. For this reason, DOF only makes sense if it is defined with an associated resolution and contrast. In general, DOF can be increased by closing the lens aperture (i.e. increasing the f/#), however, the illumination must be increased accordingly.

Commonly Used Equations

CAMERA RESOLUTION

$$\text{Camera Res. } (\mu m) = \frac{1000}{\text{Camera Res. } (lp/mm)}$$

ANALOG

$$\text{Horiz. Camera Res. } (lp/mm) = \frac{\text{Horiz. TV line} \times 1.333}{2 \times \text{Sensor Size (Horiz.)}}$$

$$\text{Vertical Camera Res. } (lp/mm) = \frac{\text{Vertical TV line}}{2 \times \text{Sensor Size (Vert.)}}$$

DIGITAL

$$\text{Camera Res. } (lp/mm) = \frac{\#\text{ Pixels}}{2 \times \text{Sensor Size}}$$

$$\text{Camera Res. } (\mu m) = 2 \times \text{Pixel Size } (\mu m)$$

MAGNIFICATION

$$\text{PMAG} = \frac{\text{Sensor Size (Horiz.)}}{\text{Field of View (Horiz.)}}$$

$$\text{System Mag.} = \text{PMAG} \times \frac{\text{Monitor Size (diag.)}}{\text{Sensor Size (diag.)}}$$

SYSTEM RESOLUTION

$$\text{System Res. } (\mu m) = \frac{\text{Camera Res. } (\mu m)}{\text{PMAG}}$$

$$\text{System Res. } (lp/mm) = \text{PMAG} \times \text{Camera } (lp/mm)$$

Abbreviations Used:

Res. = Resolution	Vert. = Vertical
Mag. = Magnification	Horiz. = Horizontal
Diag. = Diagonal	FOV = Field of View

PMAG = Primary Magnification