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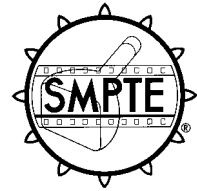
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SMPTE ENGINEERING GUIDELINE

Annotated Glossary of Essential Terms for Electronic Production



Page 1 of 45 pages

1 Scope

Program production, as a skill and an applied art, historically began when photographic cinematography followed the Greek theater, and from there, expanded to embrace television and video. Now essential further contributions and modulations are recognized from computer graphics, data processing, graphic arts, telecommunications, psychophysics, etc., and their affiliates. Each of these technologies not only contributes associated hardware and software resources, but — since each has had an independent development — brings unfamiliar terms and uniquely specific definitions to a nominally common vocabulary.

Program production, which is defined in overview in figure 1 and in detail within the text of this glossary, is increasingly reliant upon this full spectrum of resources to be effective and efficient in its subsets of origination, post-production, and distribution.

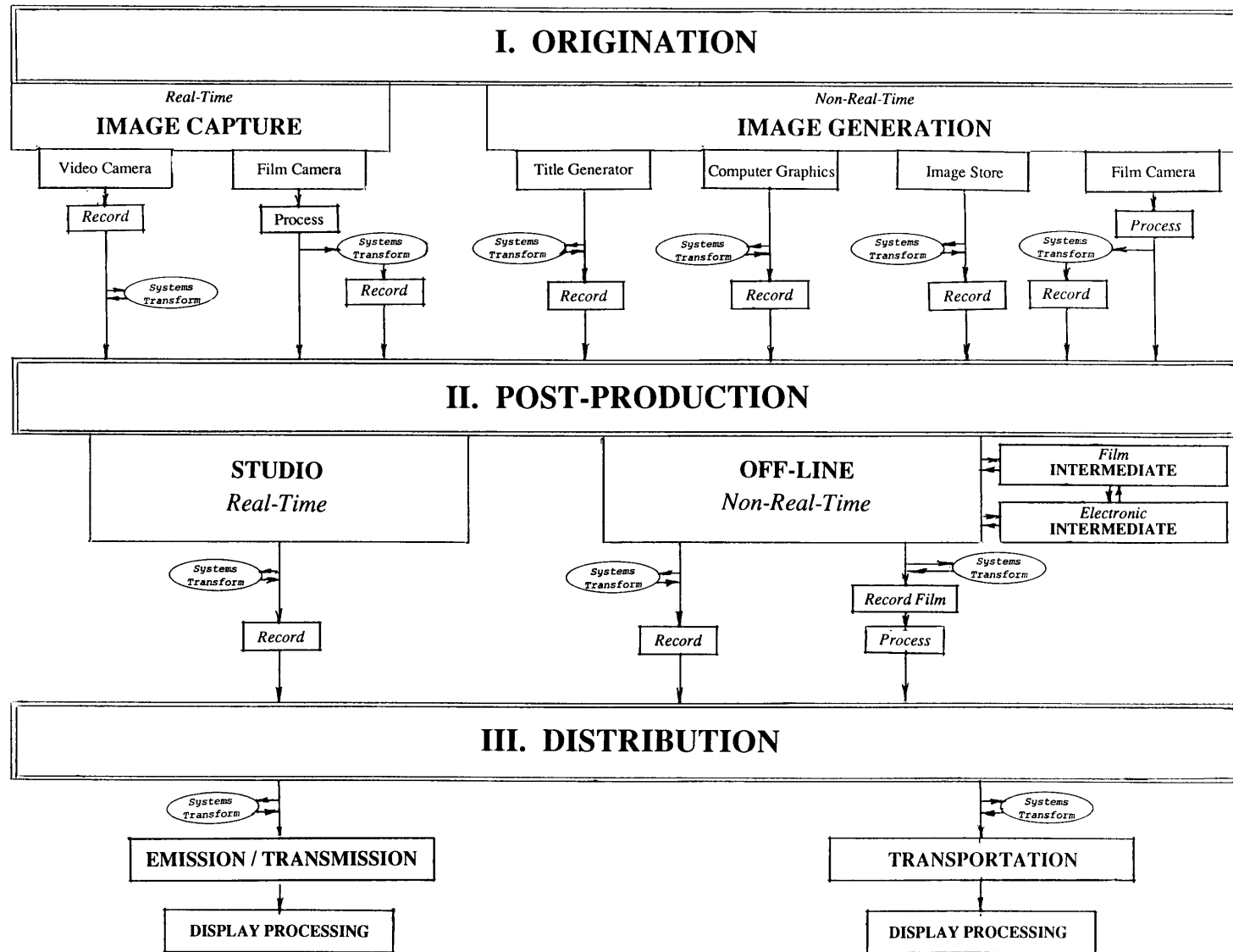
Program origination is provided with a multiplicity of potential sources for capturing, generating, and evaluating images. Post-production offers an increasingly evolving pallet of tools for merging, integrating, and evaluating source material to achieve maximum artistic impact. Distribution channels and facilities are multiplying both in number and in diversity, suggesting that programs' creative formats may need to be transformed eventually into a multiplicity of distribution formats in order to meet definitive needs.

Specific technical glossaries have developed within each technology. In the broadly electronic environment — embracing electronic imaging, computer graphics, data processing, and telecommunications

— the primary reference directing unambiguous communication is ANSI/IEEE 100, Dictionary of Electrical and Electronics Terms, with 24,793 entries in the fourth edition. Within the photographic environment there have been several more informal glossaries. ISO 4246, Cinematography — Vocabulary, is taking leadership in coordination with a multilingual vocabulary responding to international concerns for precise communication. Graphic arts is another present focus for integrating technologies. And psychophysics identifying and quantifying the transfer function to human perception is defining the validity of assumptions on what is acceptable and improving methods of evaluation. Each of these technologies meets at the interface with program production as an essential partner.

This glossary brings together many of the terms that are essential in the production process. It draws upon the existing data bases when appropriate, noting the specific definitions and interpretations that apply to program production. Its intent is to include only those terms which impact upon production's basic needs and procedures, and whose clear interpretation in this environment is therefore essential. Nevertheless, it is important to recognize prevalent alternate definitions, perhaps relating to other applications of the participating technologies and thus to caution and to identify that one specific definition which may be most appropriate to program production.

Annotations are an essential component of this glossary since translations often must be accompanied by explanations. It is thus the objective of this limited scope glossary to help clarify and promote both communication and understanding among the formerly distinct technologies involved.



NOTE – **Production**, working with images and their associated audio, employs a multidisciplinary blending of technologies and arts. Implementation of concepts first materializes with **origination**. These source materials are then edited and composed into a **program** via **post-production**. Finally, the completed **program** is transformed into the formats required for **distribution**.

Figure 1 – Program production

2 Definitions

adaptation: “Visual process whereby approximate compensation is made for changes in the luminances and colors of stimuli, especially in the case of changes in illuminants” [Hunt].

AES: Audio Engineering Society, New York. Of potential interest in electronic production are the following: SC-2, Subcommittee on Digital Audio; SC-3, Subcommittee on the Preservation and Restoration of Audio Recording; and SC-4, Subcommittee on Acoustics.

alias: An **artifact** in the reproduced image. 1. Most commonly, **artifacts** result from sampling frequencies or bandwidth limits too low for faithful reproduction of image detail, and thereby violating the **Nyquist limit**. Video images are sampled in two or three dimensions and computer graphics are sampled in three. (*Time* = *T* related to field or frame rate; *image height* = *Y* related to scanning lines; and for pixel-type sensors, *image width* = *X*. Upon presentation in the display, the signal is customarily reformatted to appear continuous in *X*.) Sampling theory establishes that the resulting frequency spectrum consists of an infinite number of copies of the baseband signal. These copies overlap if the sampling frequency is less than $2F_{\max}$, where $F_{\max}$ is the maximum frequency expected to be recoverable from the image without **alias**. The spectrum copies are separated if the sampling frequency is greater than $2F_{\max}$. With overlapped spectra, **aliasing** has been introduced and cannot be removed. Thus the ratio of imaging bandwidth to sampling frequency is a critical design feature. With the desired sequence of separated spectra, **aliasing** can be avoided in the **display** by the choice of a bandpass reconstruction filter that passes only one copy of the spectrum. 2. Appearance of multiple copies of the baseband spectra may also result from FM modulation of an analog video spectrum with its inevitable sidebands and harmonics; if the sidebands of a harmonic overlap the baseband sidebands, visible **aliasing** is observed. A sufficiently low modulation index (the FM equivalent of the ratio of video bandwidth to sampling frequency) becomes critical for these systems. 3. In a composite (complex) spectral channel, any crosstalk of the information cannot be eliminated by filtering,

and will produce **aliasing**, for example as **cross-color** and/or **cross-luminance**. 4. Moiré from color subcarrier decoded as **luminance** produces **aliasing**. 5. In a rectilinearly sampled system, lines not parallel to a sampling axis will appear stepped unless antialiasing processing algorithms have been applied. *cf.* **artifact**; **composite color**; **cross-color**; **cross-luminance**; **Nyquist limit**.

alpha channel: (production) In **electronic production** and **post-production**, there is increasing application of 4:4:4:4 encoding — which provides full-bandwidth R' , G' , and B' plus the additional **alpha channel** to carry processing information. An adaptation from computer graphics, the **alpha channel** may contain information for **linear key**, for **luminance** and/or **chroma** transparency, for variable **edge enhancement**, and similar image-processing information. The term *alpha* derives from a processing coefficient designed to provide a degree of transparency in the foreground. The parameter *a* carries transparency information, used in the formula that computes the composite (of a foreground image and a background image) = $(1-a)(\text{foreground}) + (a)(\text{background})$. *cf.* **chroma key**; **composite image**; **linear key**; **matte channel**; **post-production**.

aperture, camera: The available maximum dimensions of the optical image on the active surface of the photo-sensor, within which good quality image information is being recorded. The **camera aperture** determines the maximum usable scene information captured and introduced into the system, and available for subsequent processing and display. These dimensions are usually defined by standards. (Note - Not to be confused with lens aperture, which defines the luminous flux transmission of the optical path.) *cf.* **aperture, clean**; **aperture, display**; **aperture, production**; **aperture, safe action**; **display**; **post-production**.

aperture, clean: (video) The concept of a clean aperture in a digital system defines an inner picture area (within the **production aperture**) within which the picture information is subjectively uncontaminated by all edge transient distortions (SMPTE 260M). Filtrations for bandwidth limitation, multiple digital blanking, cascaded spatial filtering, etc., introduce tran-

sient disturbances at the picture boundaries, both horizontally and vertically. It is not possible to impose any bounds on the number of cascaded digital processes which might be encountered in the practical **post-production** system. Hence, the **clean aperture** is defined to represent an acceptable (and practical) worst-case level of protection. *cf.* **aperture, camera; aperture, display; aperture, production; aperture, safe action; production, electronic, digital.**

aperture correction: In a scanned image system:
1. "Electrical compensation for the distortion introduced by the [limiting] size of a scanning aperture" [IEEE 100]. 2. **(video):** The properties of the camera lens, optical beam-splitting installation, and camera tube all contribute to a reduced signal at higher spatial frequencies — generally falling off as an approximate $(\sin X)/X$ function. Additionally, it is obvious in a scanning system that the frequency response falls off as the effective wavelength of the detail to be resolved in the image approaches the dimension of the scanning aperture and becomes zero when that effective wavelength equals the dimension of the scanning aperture. **Aperture correction** normally introduced in all video cameras restores the depth of modulation to the waveform at higher frequencies with the objective of flat response to 400 TV lines (in NTSC) for a subjective improvement in image quality. *cf.* **contour enhancement; edge enhancement; image enhancement; resolution, visual; sharpness.**

aperture, display: The available maximum dimensions (mapped back into the camera aperture) for the system's ability to display good quality image information. The information available for **display** is usually cropped from the total captured by the cascade of tolerances that may be incorporated in the system, and also by intentional design features that may be introduced in the **display**. *cf.* **aperture, camera; aperture, production; display; post-production.**

aperture, production: (video) A **production aperture** for a studio digital signal defines an active picture area produced by signal sources such as cameras, telecines, digital video tape recorders, and computer-generated pictures. It is recommended that all of this video information be care-

fully produced, stored, and properly processed by subsequent digital equipment. In particular, digital blanking in all studio equipment should rigorously conform to this specified **production aperture** [SMPTE 260M]. The width of the analog **active horizontal line** is measured at the 50% points of the analog video signal. However, the analog blanking may differ from equipment to equipment, and the digital blanking may not always coincide with the analog blanking. *cf.* **aperture, camera; aperture, clean; aperture, safe action; lines, active horizontal; lines, active vertical; post-production, electronic.**

aperture, safe action: As defined by a test pattern, a **safe action aperture** indicates the safe action image area within which all significant action must take place, and the safe title image area, within which the most important information must be confined, to ensure visibility of the information on the majority of home television receivers. SMPTE RP 27.3 defines these areas for 35-mm and 16-mm film and for 2x2-inch slides. *cf.* **aperture, camera; aperture, clean; aperture, production.**

artifact: A defect or distortion of the image, introduced along the sequence from **origination** and **image capture** to final **display**. **Artifacts** may arise from the overload of channel capacity by excess signal bandwidth. Artifacts may also result from (1) sampling effects in temporal, spatial, or frequency domains, (2) processing by the **transfer functions**, (3) compromises and inadequacies in the system employed, (4) cascading of minor defects, and (5) basically any other departure of the total system from "complete transparency." *cf.* **alias; image enhancement; judder; mixing, digital; motion artifacts; rounding; transform, systems.**

bandwidth limiting: A reduction in the effective bandwidth of a signal, usually to facilitate recording, transmission, broadcast, display, etc. The reduction is usually accomplished through the action of an algorithm, which may involve simple lowpass filtering, more complex processing such as interleaving or quadrature modulation, or complete **resampling**. The term **bandwidth limiting** is normally applied in analog systems, although it also has a comparable meaning in digital systems. *cf.* **bit-rate reduction; compression, lossless; compression, lossy; data**

compression; data resampling; image compression; IRE units; transfer function.

bit: 1. "A contraction of the term binary digit; a unit of information represented by either a zero or a one" [IEEE 100]. 2. One digit in a binary (base 2) mathematical system. 3. "A unit of information content equal to the information content of a message the a priori probability of which is one-half" [IEEE 100]. *cf.* **byte.**

bit error rate (BER): The average probability of a digital recording system reproducing a bit in error. Note - IEEE 100 defines error rate: "Ratio of the number of characters of a message incorrectly received to the number of characters of the message received." **Bit error rates** typical of current digital tape recording are: digital video tape, about 10⁻⁶; digital instrumentation tape, about 10⁻⁹; digital computer tape, about 10⁻¹². *cf.* **bit-rate; error concealment; error correction.**

bit-rate: "The speed at which bits are transmitted, usually expressed in bits per second" [IEEE 100]. Video information, in a **digitized image** for example, is transferred, recorded, and reproduced through the **production** process at some rate (bits/s) appropriate to the nature and capabilities of the origination, the channel, and the receptor.

bit-rate, real-time: When the information is obtained from a continuously varying source, and the information is being transmitted continuously without buffering, it is exchanged at the **real-time bit-rate**. Within the **production** sequence, it is actually only the image capture (i.e., camera and its recording system) that is required to be in real-time. The balance of **production**, including **post-production** operations, can be at a fraction of real-time if a more desirable result is achieved. (Subsequent to **production**, the final **display** must of course also be in real-time). *cf.* **bit-rate, recording; display; origination; post-production, off-line; production.**

bit-rate, recording: The **bit-rate** required of a recorder mated to a video camera or functioning in the **origination, post-production, or distribution** is generally greater than the concurrent **bit-rate, real-time** because of the **error correction** designed into the recording format. This

"overhead" may increase the **bit-rate**, sometimes by as much as one-third, and frequently sets a practical limit in systems design. Examples in table 1 are intended only to clarify the definition. They indicate the range of some systems currently considered and a first estimate of their challenges. *cf.* **error concealment; error correction; post-production; origination.**

Table 1 – Probable recording rate, Mbits/s ^{1), 2)}

Bits per pixel	Maximum levels defined	CCIR Rec 601-2 ³⁾		CCIR Rec 709 ³⁾	
		4:2:2	4:4:4	4:2:2	4:4:4
8 ³⁾	256	227 ⁴⁾	340	1290	1940
10	1024	284	426	1610	2420
12	4096	340	510	1940	2910

¹⁾ All systems postulated employ field rates of 60 or 59.94 Mbits/s, with component encoding and 2:1 interlace. Progressive scan systems at the same frame rates would have double these **bit-rates**.
²⁾ Estimates for gross data recording rates assume the same ratio of overhead to data bits in **component format** recording as that in the D-1 standard.
³⁾ CCIR Recommendations 601-2 and 709 document 8-bit and 10-bit sampling, based upon sampling frequencies that are integral multiples of 2.25 MHz (i.e., 13.5 MHz for Rec 601-2).
⁴⁾ The D-1 standard recording format is defined by SMPTE 224M and its related SMPTE Recommended Practices and Engineering Guidelines.

bit-rate reduction: (video) A reduction in the real-time data transmission rate in digital format, usually to facilitate recording, transmission, broadcast, display, etc., or even to comply with fixed limitations. Various algorithms appropriate for **video** signals may be employed from arbitrary resampling to more complex processing with the objective of reducing the transmission of redundant information in the image and possibly eliminating image content that will be inobvious in the final specified **display**. **Bit-rate reduction** is also appropriate and employed in audio records, either associated with video or standing alone. *cf.* **bandwidth limiting; compression, lossless; compression, lossy; data compression; image compression; resampling.**

black, absolute: 1. Optical black is no light. An absolute black can only be produced in a scene via a light-trap, "a black hole." 2. **(video)** A capped lens on the camera is the equivalent of an absolute scene black and should produce **reference black** level video signal from a properly adjusted studio camera. *cf.* **black level; black level, reference; setup.**

black compression: (video) "The reduction in gain applied to a picture signal at those levels corresponding to dark areas in a picture with respect to the gain at that level corresponding to the midrange light value in the picture. Notes – 1. The gain referred to in the definition is for a signal amplitude small in comparison with the total peak-to-peak signal involved. A quantitative evaluation of this effect can be obtained by a measurement of **differential gain**. 2. The overall effect of **black compression** beyond bandwidth limiting is to reduce contrast in the low lights of the picture as seen on a monitor" [IEEE 100]. *cf.* **differential gain; shoulder; toe; transfer function.**

black level: (video) "The level of the picture signal corresponding to the maximum limit of black peaks" [IEEE 100]. *cf.* **black level, reference; blanking level; setup.**

black level, monitor: The **luminance** produced on the monitor display by a signal at **reference black** level. Since the monitor brightness control should be adjusted to align CRT beam cut-off with reference black level signal, this provides zero excitation light from the CRT (only room ambient light reflected from the CRT faceplate). **Monitor black level** is normally set by use of a **PLUGE signal** to adjust CRT beam cutoff subjectively. *cf.* **black level, reference; IRE units; monitor, reference; monitor standardization; PLUGE signal; setup.**

black level, reference: The video signal level which is intended to produce **monitor black level** in the reproduced image. In systems with a setup level, i.e., the 7.5 IRE setup in a 525/59.94/2:1/NTSC composite video documented by ANSI/EIA TIA 250-C and SMPTE 170M, **reference black** is at the **setup level**. In systems with no setup level, **reference black** is at **blanking level**. *cf.* **black, absolute; black level; black level, monitor;**

blanking level; IRE units; PLUGE signal; setup; SMPTE 170M.

black, projection: The **luminance** level in a projected image that is correlated with **subjective scene black** has two sources: In photographic and other light-modulating systems, 1. there will be **luminance** from whatever transmitted light passes through the maximum modulating density representing scene black, 2. additional **luminance** may be produced by nonimage-forming light (flare, room illumination, stray light, etc.). *cf.* **black, absolute; black, subjective, monitor; black, subjective, scene; luminance range.**

black, subjective, monitor: The **luminance** level which produces the perception of black on the monitor display. This subject has not been explored extensively, but Bartleson and Novick present evidence that it is relative to the high-light or white level, such that the **luminance ratio** to produce **subjective black** on a monitor is higher than that in a televised scene. They propose a **luminance ratio** of 100:1 for subjective white to black on TV monitors in a control room "dimly lighted." This **luminance ratio** specification has been formalized in SMPTE RP 166. *cf.* **black level, monitor; black, subjective, scene; luminance range, monitor; monitor, reference; monitor standardization; SMPTE RP 166.**

black, subjective, scene: That fraction of the high-light **luminance** required in a scene reproduced on a television **display** to convey the perception of black. The **luminance** of **subjective black** on a CRT has been studied by Lowry and Jarvis, who measured **luminances** in the original scenes, and compared the subjective appearance on a CRT display, as evaluated by viewing audiences. They found that the perception of black depends on a great many factors both in the reproduced scene and in the viewing conditions — such as average scene reflection, **luminance** of areas adjacent to the **display**, etc. In most situations, **luminance** levels of $\frac{1}{40}$ to $\frac{1}{60}$ of the highlight **luminance** produce the perception of black even though the **scene luminance range** may reach 200:1 or more. It follows then that a scene element that is perceived as black may not necessarily be at **reference black level** in a video signal. *cf.* **black level, monitor; black, subjective, monitor; image quality, perceived; luminance range, display CRT.**

blanking level: (video) “That level of a composite picture signal which separates the range containing picture information from the range containing synchronizing information. Note – This term should be used for controls performing this function” [IEEE 100]. *cf.* **black level; black level, reference.**

brightness: “Attribute of a visual sensation according to which an area appears to emit more or less light” [CIE 845-02-28]. The subjective counterpart of objective **luminance**.

byte: “A group of adjacent binary digits operated upon as a unit, capable of holding one character in the local character set, and usually shorter than a computer word (frequently connotes a group of eight bits)” [IEEE 100]. Current usage within the context of electronic production concerns is tending to define a **byte** as eight bits to have a consistent data unit for measuring memory capacities, etc. At the same time, **image files** are being created with samples of 8, 10, or more bits — and image files are being processed in 8-, 16-, and 32-bit channels. *cf.* **bit.**

camera analysis: The measurement and evaluation of the spectral sensitivities of the three color channels of a television camera. The camera **primaries** and **matrixing** are identified and measured. *cf.* **camera analysis, ideal; color-matching functions; colors, primary; matrixing; transfer function, opto-electronic.**

camera analysis, ideal: For optimum **image quality**, both **objective** and **perceived**, the spectral sensitivities of the three color channels of a television camera should be matched to the **primary colors** of the **R,G,B color space**. Note – Some practice still exists matching the color channels of the camera to the **display** phosphors. This reduces the **color gamut** and carries unnecessary noise penalties. The practice is deprecated. *cf.* **camera analysis; colors, primary; display; RGB color space; transfer function, opto-electronic.**

CCIR: Comité Consultatif International des Radiocommunications (International Radio Consultative Committee), Geneva, Switzerland. A permanent organ of the International Telecommunications Union with the duty to study technical and operating questions relating specifically to radio communications and to

make recommendations on them. The CCIR does not prepare regulations; it draws up recommendations and reports, produced by experts from both public and private entities, which provide guidance on the best operational methods and techniques. The CCIR is expected to base its recommendations upon ISO and IEC international standards, but when no relevant one exists, the CCIR has been known to initiate standardization. These recommendations and reports provide a basis for international standardization of telecommunications. CCIR decisions are affirmed by international treaties. The U.S. is represented on the CCIR by the State Department, which is assisted by several Technical Advisory Committees composed of selected experts. The CCIR recognizes eight systems for 525/625-line images in current worldwide use [CCIR Report 624-4]. System M has 525/59.94 scanning and **NTSC** color encoding is commonly employed, hence M/NTSC, the dominant format in North America. The other seven systems have 625/50 scanning. All systems employ interlace scanning. **PAL** color encoding is commonly employed in systems B, G, H, and I, but may also be used in systems D, M, and N. **SECAM** color encoding is commonly employed in system D, but may also be used in systems B, G, H, K, K1, and L. The CCIR is currently monitoring the developments in **HDTV**. *cf.* **NTSC; PAL; SECAM; television, HDTV; television, ETV (EDTV).**

CCIR Recommendation 500: “Method for the Subjective Assessment of the Quality of Television Pictures” [CCIR Rec 500-4]. A detailed review of the recommendations for conducting subjective analysis of image quality. The problems of defining **perceived image quality** are reviewed, and the evaluation procedures for **interval scaling**, **ordinal scaling**, and **ratio scaling** are described — along with the applications for which each is best employed. *cf.* **image quality evaluation, interval-scaled; image quality evaluation, ordinal-scaled; image quality evaluation, ratio-scaled; image quality, perceived.**

CCIR Recommendation 601: “Encoding Parameters of Digital Television for Studios” [CCIR Rec 601-2]. “Considering that there are clear advantages for television broadcasters and programme producers in digital studio standards which have the greatest number of significant parameter values common to 525-line and 625-line

systems: ... unanimously recommends that the following be used as a basis for digital coding standards for television studios in countries using the 525-line system as well as those using the 625-line system." Defines specifications and parameters for applications of signals Y , C_R , and C_B in a 4:2:2 system. In an annex provides tentative specifications for applications of Y , C_R , and C_B or of R, G, B in a 4:4:4 system of at least 8 bits per sample. *cf.* **SMPTE 125M**.

CCIR Recommendation 709: "Basic Parameter Values for the HDTV Standard for the Studio and for International Programme Exchange" [CCIR Rec 709]. The recommendation considers "that the HDTV studio standard must be harmonized with those of current and developing television systems and with those of existing motion-picture film." In a review of current systems, a consensus was identified in specifications for opto/electronic conversion, picture characteristics, picture scanning characteristics, and signal format (both analog and digital representations). Work is underway in the editing of national and CCIR related documents to determine whether these consensus values may be affirmed in the next review of the individual documents. The values in Rec 709 are considered interim, and CCIR notes that continuing work is expected to define target parameters for future improved image rendition. *cf.* **CCIR Rep 801; SMPTE 240M; television, broadcast; television, high-definition**.

CCIR Report 801: "The Present State of High-Definition Television" [Report 801-4, 1990]. 1. "At present, the first results on studies related to Study Programme 18U/11 have been collected [CCIR, 1986-90b]. It must be recognized that these studies must be intensified in close cooperation with such organizations as the IEC and ISO to take fully into account the requirements for implementation of HDTV for media other than broadcasting, i.e., cinema, printing, medical applications, scientific work, and video conferencing." 2. "In addition, the transmission of HDTV signals via new digital transmission channels or networks has to be considered and taken into account, for instance, as defined in CCITT Recommendation I.121, Broadband Aspects of ISDN, adopted by the IXth CCITT plenary assembly at the end of 1988. For such new networks, the definition of new services, including those related to HDTV, have to be

defined as expressed in a liaison statement (CCIR, 1986-90c) from CCITT Study Group 1 to CCIR Study Group 11." *cf.* **CCIR Rec 709, SMPTE 240M; SMPTE 260M**.

chroma: 1. To avoid the interdisciplinary confusion resulting from the two distinct definitions of **luminance**, it has been proposed that the video documents use **luma** for **luminance (video)** (i.e., the **luminance signal**) and **chroma** for **chrominance (video)** (i.e., the **chrominance signal**). Unfortunately, **chroma** is also a term with multiple distinct definitions. 2. "Chroma: The colorfulness of an area judged in proportion to the brightness of a similarly illuminated area that appears to be white or highly transmitting" [Hunt]. *cf.* **chrominance; chrominance signal; luma; luminance (video); Munsell chroma**.

chroma key: (production) A process for controlling the overlay of one video image over another, the areas of overlay being defined by a specific color or **chrominance** in one of the images. More versatility is available when working in the digital mode than in the analog since the color to define the effective mask can be more precisely specified. Effective use of **chroma key** frequently requires high definition in the color image and, therefore, full bandwidth R', G', B' is preferred. **Linear key** provides an alternate method for control of the overlay. *cf.* **alpha channel; digital image processing; linear key; mixing, digital**.

chrominance: "The colorimetric difference between any color and a reference color of an equal **luminance**, the reference color having a specified **chromaticity**. Notes: (1) In three-dimensional color space, **chrominance** is a vector that lies in a plane of uniform **luminance**. In that plane it may be resolved into components called chrominance components. (2) In color television, the **chromaticity** of the reference color may be that of a specified white" [IEEE 100]. For example, in some systems two chrominance vectors are chosen to be the difference between **reference white** and two **primary colors**; i.e., $R-Y$ and $B-Y$. *cf.* **chroma; color-difference signal; luminance; R,G,B color space; signal, chrominance**.

CIE: Commission Internationale de l'Eclairage (International Commission on Illumination),

Vienna, Austria. The CIE is concerned with methods of measurement plus recommended practices and standards concerning the properties and applications of light. "(1) The formal decisions or agreements of the CIE on technical matters, prepared by technical committees on which all the national committees having a special interest therein are represented, express as nearly as possible an international consensus of opinion on the subject dealt with. (2) They have the form of recommendations for international use and they are accepted by the national committees in that sense. (3) In order to promote international unification, the IEC expresses the wish that all national committees should adopt the text of the IEC recommendation for their national rules insofar as national conditions will permit" [CIE Publication 17.4].

CIE 1931 Standard Colorimetric System (XYZ):

"A system for determining the tristimulus values of any spectral power distribution using the set of reference color stimuli [X],[Y],[Z], and the three CIE color matching functions $x(\lambda)$, $y(\lambda)$, $z(\lambda)$, adopted by the CIE in 1931" [CIE Publication 15.2].

CIELab color space: "Three-dimensional, approximately uniform color space produced by plotting in rectangular coordinates L^* , a^* , b^* quantities defined by the equations:

$$\left. \begin{aligned} L^* &= 116(Y/Y_n)^{1/3} - 16 \\ a^* &= 500[(X/X_n)^{1/3} - (Y/Y_n)^{1/3}] \\ b^* &= 200[(Y/Y_n)^{1/3} - (Z/Z_n)^{1/3}] \end{aligned} \right\} \begin{matrix} Y/Y_n \\ X/X_n \\ Z/Z_n \end{matrix} > 0.008\,856$$

X,Y,Z describe the color stimulus considered, and X_n , Y_n , Z_n describe a specified white achromatic stimulus [i.e., **white reference**] [CIE 845-03-56]. "Equal distances in the **color space** represent approximately equal color differences" [Hunt]. *cf.* **color space, reference; image file architecture; video index.**

CIELuv color space: "Three-dimensional, approximately uniform color space produced by plotting in rectangular coordinated L^* , u^* , v^* quantities defined by the equations:

$$\begin{aligned} L^* &= 116(Y/Y_n)^{1/3} - 16 & Y/Y_n &> 0.008\,856 \\ u^* &= 13\,L^* (u' - u'_n) \\ b^* &= 13\,L^* (v' - v'_n) \end{aligned}$$

Y, u', v' describe the color stimulus considered, and Y_n, u'_n, v'_n describe a specified white achromatic stimulus [**white reference**] [CIE 845-03-54]. "The

coordinates of the associated chromaticity diagram are u' and v' . L^* is the approximate correlation of lightness, u^* and v^* are used to calculate an approximate correlate of chroma" [Ref. CIE Pub 15.2]. "Equal distances in the color space represent approximately equal color differences" [Hunt]. *cf.* **color space, reference; image file architecture; video index.**

CMYK color space: "A subtractive color space with cyan, magenta, and yellow as primary color set with an optional addition of black (K). For such a color set subtractive color mixture applies. The CMYK values used represent the amount of colorant placed onto the background medium. They include the effects of dot gain" [CIE; also ISO 8613]. *cf.* **color space, reference; image file architecture; video index.**

code: "A plan for representing each of a finite number of values or symbols as a particular arrangement or sequence of discrete conditions or events. To **encode** (*cf.*) is to express given information by means of a code" [IEEE 100]. "A system of rules defining a one-to-one correspondence between information and its representation by characters, symbols, or signal elements" [CCIR].

color, additive: 1. "Over a wide range of conditions of observation, many colors can be matched completely by additive mixtures in suitable amounts of three fixed primary colors.... The choice of three primary colors, though very wide, is not entirely arbitrary. Any set which is such that none of the primaries can be matched by a mixture of the other two can be used" [Wyszecki and Stiles]. 2. It follows that the **primary color** vectors so defined are linearly independent. Therefore, transformations of a **metameric match** from one **color space** to another can be predicted via a matrix calculation. The limitations of **color gamut** apply to each space. 3. The **additive color** generalization forms the basis of most **image capture**, and of most self-luminous displays (i.e., CRTs, etc.). *cf.* **CIELab color space; CIELuv color space; color space, reference; color, subtractive; display; image capture; metameric match; R,G,B color space; spectrophotometric match.**

color coordinate transformation: "Computation of the **tristimulus values** of colors in terms of

one set of **primaries** from the **tristimulus values** of the same colors in another set of **primaries**. Note: This computation may be performed electrically in a color television system" [IEEE 100]. *cf.* **tristimulus values**.

color correction: "The adjustment of a color reproduction process to improve the perceived-color conformity of the reproduction to the original" [IEEE 100].

color-difference signal: The **chrominance** vectors carrying the color information in a **composite format**. The **color-difference signals** have been defined by the CCIR for existing television systems [Report 624-4] as follows:

$$\begin{aligned} \text{NTSC} \quad E'_I &= -(0.27)(E'_B - E'_Y) + (0.74)(E'_R - E'_Y) \\ E'_Q &= +(0.42)(E'_B - E'_Y) + (0.48)(E'_R - E'_Y) \end{aligned}$$

$$\begin{aligned} \text{PAL} \quad E'_U &= (0.493)(E'_B - E'_Y) \\ E'_V &= (0.877)(E'_R - E'_Y) \end{aligned}$$

$$\begin{aligned} \text{SECAM} \quad D'_R &= -(1.902)(E'_R - E'_Y) \\ D'_B &= +(1.505)(E'_B - E'_Y) \end{aligned}$$

The subscripts Y, R, and B refer to luminance and to color-difference points on the chromaticity plane, derived from the relationship of the primary colors red and blue to the luminance. All of the primed values are gamma pre-corrected signals. Conventionally, all color-difference vectors are bandwidth limited. *cf.* **CCIR; chrominance; Y', C'R, C'B, or Y', P'R, P'B; R', G', B' color space**.

color gamut: 1. In a system employing three color **primaries** to encode image color, each **primary** can be located on a CIE chromaticity diagram and these points connected as a plane figure. If the apexes are then connected with an appropriate value on the **white point** axis, a solid figure is produced enclosing the **color gamut** for that system. (On the CIE chromaticity diagrams, the points in x,y,z space approximate an inverted tetrahedron. In u,v,w space, they become a somewhat irregular four-cornered solid.) 2. Colors within the **color gamut** solid volume can be reproduced by the system as **metameric matches**. Colors outside the **color gamut** solid volume cannot be matched. Note that the area of the cross-section from the **color gamut** solid is a function of the **luminance**. 3. Although it is advantageous to have the widest possible **color gamut** for the ability

to provide **metameric matches** for the largest number of colors, the required transformations from **origination** colorimetry to colorimetry matched to available **display** primaries, for example, may require large matrix coefficients and, therefore, a signal-to-noise penalty. The choice of **color gamut** is a compromise between color rendition and signal-to-noise. *cf.* **color-difference signal; color match, corresponding; color match, metameric; colors, primary; color space, reference; luminance; luminance range; white point**.

colorimetry: 1. "Measurement of colors based on a set of conventions" [CIE 845-05-10]. 2. "The techniques for the measurement of color and for the interpretation of the results of such computations. Note: The measurement of color is made possible by the properties of the eye, and is based upon a set of conventions" [IEEE 100].

color-matching functions: 1. "The tristimulus values of monochromatic stimuli of equal radiant power. Notes: (a) The three values of a set of color-matching functions at a given wavelength are called color-matching coefficients. (b) The color-matching functions may be used to calculate the tristimulus values of a color stimulus from the color stimulus function" [CIE 845-03-23]. 2. The **tristimulus value** per unit wavelength interval and unit spectral radiant flux. 3. "A set of three simultaneous equations used to transform a color specification from one set of matching stimuli to another" [Hunt]. "Note: **Color-matching functions** adopted by the CIE are tabulated as functions of wavelength throughout the spectrum and are given in section 13.5 of ANSI/IES RP16-1986" [IEEE 100].

color match, corresponding: "A corresponding color is defined as the stimulus that, under some different condition of adaptation, evokes the same color appearance as another stimulus when it was seen under the original state of adaptation" [Bartleson and Grum]. **Color match, corresponding** is a subjective judgment. *cf.* **color gamut; color match, metameric; colors, primary; color space, reference; spectrophotometric match; white point**.

color match, metameric: 1. Color images are **metameric matches** when their spectrally different color stimuli have identical **tristimulus values**.

The requirements for such a **metameric match** can be calculated for a specified viewing condition (and for viewing conditions other than those specified, the chromaticity will not be judged to correspond). 2. The corresponding color chosen for the **metameric match** will not provide a **spectrophotometric match**. In practical applications, **spectrophotometric matches** are of only academic interest, and **metameric matches** are sought. 3. **Color match, metameric**, resulting from calculations based upon **colorimetry**, produces a visual match as evaluated by the CIE description of human observers. *cf.* **color gamut; color match, corresponding; colors, primary; color space, reference; spectrophotometric match; white point.**

colors, primary: 1. "The colors of three reference lights by whose additive mixture nearly all other colors may be produced" [Wyszecki et al]. 2. **(video)** The primaries are chosen to be narrow-band areas or monochromatic points directed toward green, red, and blue within the Cartesian coordinates of three-dimensional **color space** — such as the CIE x,y,z color space. These **primary color** points together with the **white point** define the colorimetry of the standardized system. 3. Suitable matrix transformations provide **metameric** conversions — constrained by the practical filters, sensors, phosphors, etc, employed in order to achieve conformance to the defined **primary colors** of the specified system. Similar matrix transformations compensate for the viewing conditions such as a **white point** of the **display** different from the **white point** of the original scene. 4. Choosing and defining **primary colors** requires a balance between a wide **color gamut** reproducing the largest number of observable surface colors and the signal-to-noise penalties of colorimetric transformations requiring larger matrix coefficients as the **color gamut** is extended. 5. There is no technical requirement that **primary colors** should be chosen identical with filter or phosphor dominant wavelengths. The matrix coefficients, however, increase in magnitude as the available **display** primaries occupy a smaller and smaller portion of the **color gamut**. (Thus, spectral color primaries, desirable for improved colorimetry, become impractical for CRT **displays**.) 6. **(video)** Although a number of primary color sets are theoretically interesting, CCIR with international

consensus has established that current technology and practice internationally are based (within measurement tolerances) upon the following:

Red	$x = 0.640$	$y = 0.330$
Green	$x = 0.300$	$y = 0.600$
Blue	$x = 0.150$	$y = 0.060$

"Note: These values are related to contemporary CRT technology and may be used for current implementation. Further studies are in progress for improved color rendition. It is recognized that the availability of a wider color gamut is highly desirable in an originating system. Furthermore, it is useful for purposes of picture processing to have available video signals proportional to light levels. In particular, the encoding of linear signals commonly identified as a 'constant luminance' system is believed to be desirable" [CCIR Rec 709]. 7. (video) SMPTE, in appendix A.1 to SMPTE 240M, offers guidance for further studies in improving color rendition by extending the color gamut: "With regard to color gamut, it is felt that the system should embrace a gamut at least as large as that represented by the following primaries:

Red	$x = 0.670$	$y = 0.330$
Green	$x = 0.210$	$y = 0.710$
Blue	$x = 0.150$	$y = 0.060$."

cf. **CIELab color space; CIEluv color space; CMYK color space; color, additive; color space, reference; color, subtractive; metameric match; R,G,B color space; ISO 8613.**

color space, reference: "Geometric representation of colors in space, usually of three dimensions" [CIE 845-03-25]. There are three **reference spaces** recognized by ISO 8613: **CMYK color space; CIEluv color space; and R,G,B color space.**

color, subtractive: 1. Subtractive colorimetry achieves **metameric matching** by removing portions of the spectrum from white light. The subtractive counterparts to the **additive color primaries** are those which when removed from white leave the red, green, and blue — accordingly cyan, magenta, and yellow. Combinations of these **subtractive colors** in various admixtures provide **metameric matches** to many colors. 2. **Subtractive color** principles are employed in all hard-copy color images and in light-valve systems such as color transparencies, LCD panel displays, motion-picture films, etc..

cf. **CMYK color space; color, additive; color space, reference; display; metamerism match.**

common data rate (CDR): In the search for a single worldwide standard for HDTV, one proposal is to establish a **common data rate**, to be independent of line structure, frame rate, and sync/blanking. *cf.* **bit-rate, real-time; bit-rate, recording; common image format.**

common image format (CIF): In the search for a single worldwide standard for HDTV, one proposal is to establish a **common image format** to be independent of data rate, frame rate, and sync/blanking. *cf.* **bit-rate, real-time; bit-rate, recording; common data rate.**

component color: Structure of a video signal wherein the R' , G' , and B' signals are kept separate from one another or wherein **luminance** and two band-limited **color-difference signals** are kept separate from one another. The separation may be achieved by separate channels, or by time-division multiplexing, or by a combination of both. *cf.* **chrominance; color-difference signal; composite color; luminance; R', G', B' color space; signal, chrominance; signal, luminance.**

composite color: Structure of a video signal wherein the **luminance** and two band-limited **color-difference signals** are simultaneously present in the channel. The format may be achieved by frequency-division multiplexing, quadrature modulation, etc. It is common to strive for integrity by suitable separation of the frequencies, or since scanned video signals are highly periodic, by choosing frequencies such that the **chrominance** information is interleaved within spectral regions of the **luminance** signal wherein a minimum of luminance information resides. *cf.* **chrominance; color-difference signal; component color; luminance; R', G', B' color space; signal, chrominance; signal, luminance; Y', C'_R, C'_B , or Y', P'_R, P'_B .**

composite image: An image that contains elements selected from two or more separately originated images. *cf.* **alpha channel; chroma key; image processing, digital; linear key; mixing, digital; post-production.**

compression (amplitude): “1. **(data transmission)** A process in which the effective gain applied to a signal is varied as a function of the signal magnitude, the effective gain being greater for small rather than for large signals” [IEEE 100]. “2. **(video)** The reduction in amplitude gain at one level of a picture signal with respect to the gain at another level of the same signal. Note: The gain referred to in the definition is for a signal amplitude small in comparison with the total peak-to-peak picture signal involved. A quantitative evaluation of this effect can be obtained by a measurement of differential gain” [IEEE 100]. 3. **(production)** A **transfer function** [as in **gamma correction**] or other nonlinear adjustment imposed upon signal amplitude values. *cf.* **black compression; differential gain; image compression; transfer function; white compression.**

compression (bit-rate): 1. **(multimedia)** Increasingly, compression is used in the digital environment to describe (a) initial digital **quantization** employing transforms and algorithms encoding data into a representation that requires fewer bits or lower data rates; or 2. processing of an existing digital bit stream to convey the intended information in fewer bits or lower data rates. **Compression** (bit rate) may be reversible **compression, lossless** or it may be irreversible **compression, lossy**. *cf.* **bit-rate reduction; black compression; compression, lossless; compression, lossy; differential gain; image compression; white compression.**

compression, lossless: 1. **Lossless compression** requires that the reproduced reconstituted bit stream be an exact replica of the original bit stream. The useful algorithms recognize redundancy and inefficiencies in the encoding and are most effective when designed for the statistical properties of the bit stream. 2. **(video) Lossless compression** of image signals requires that the decoded images match the source images exactly. Because of differences in the statistical distributions in the bit streams, different techniques have thus been found effective for **lossless compression** of either arbitrary computer data, pictures, or sound. *cf.* **bit-rate reduction; compression; compression, lossy; compression, quasi-lossless; image compression.**

compression, lossy: 1. **(video and multimedia)** **Bit-rate reduction** of an image signal by powerful algorithms that compress beyond what is achievable in **lossless compression**, or **quasi-lossless compression**. It accepts loss of information and introduction of **artifacts** which can be ignored as unimportant when viewed in direct comparison with the original. Advantage is taken of the subtended viewing angle for the intended display, the perceptual characteristics of human vision, the statistics of image populations, and the objectives of the **display**. 2. The lost information cannot be regenerated from the compressed bit-stream. *cf.* **bit-rate reduction; compression; compression, lossless; compression, quasi-lossless; image compression**.

compression, quasi-lossless: (video and multimedia) 1. Bit-rate reduction of an image signal, by an algorithm recognizing the high degree of correlation ascertainable in specific images. The reproduced image does not replicate the original when viewed in direct comparison, but the losses are inobvious or unrecognizable under the intended **display** conditions. The algorithm may apply transform coding, predictive techniques, and other modeling of the image signal, plus some form of entropy encoding. 2. While the image appears unaltered to normal human vision, it may show losses and artifacts when analyzed in other systems (i.e., **chroma key**, computerized image analysis, etc.) 3. The lost information cannot be regenerated from the compressed bit-stream. *cf.* **bit-rate reduction; compression; compression, lossless; compression, lossy; image compression**.

contour enhancement: A general term usually intended to include both **aperture correction** and **edge enhancement**. *cf.* **aperture correction; edge enhancement; image enhancement**.

contrast: "1. In the perceptual sense: Assessment of the difference in appearance of two or more parts of a field seen simultaneously or successively (hence brightness contrast, lightness contrast, color contrast, simultaneous contrast, successive contrast, etc.). 2. In the physical sense: quantity intended to correlate with the perceived brightness contrast, usually defined by one of a number of formulae which involve the luminances of the stimuli considered,

for example: $\Delta L/L$ near the luminance threshold, or $L1/L2$ for much higher luminances" [CIE 845-02-47]. *cf.* **aperture correction; edge enhancement; sharpness**.

conversion, frame-rate: Standardized image systems now exist in the following frame rates per second: 24, 25, 29.97, 30, and 60. In transcoding from one system to another, **frame-rate conversion** algorithms perform this conversion. The algorithm may be as simple as to drop or add frames or fields, or it may process the information to generate predictive frames employing information from the original sequence. In interlace systems, the algorithm may be applied independently to each field. *cf.* **artifact; line-rate conversion; motion artifacts; Nyquist limit; post-production; resampling; transform, systems**.

conversion, systems: See **resampling; transform, systems**.

cross-color: An **artifact** observed in **composite** systems employing quadrature modulation and frequency interleaving. **Cross-color** results from the multiplicities of line-scan harmonics in the baseband signal, which provide families of frequencies surrounding each of the main harmonic peaks. These families become even more complex if there is movement in the scene **luminance** signals between scans. Since the interstices are, therefore, not completely empty, some of the information on the **luminance signal** is subsequently decoded as color information. A typical visible effect is a moiré pattern. *cf.* **artifact; composite color; cross-luminance**.

cross-luminance: An **artifact** observed in **composite** systems employing quadrature modulation and frequency interleaving. As the analog of **cross-color**, **cross-luminance** results in some of the information carried by the **chrominance signal** (on color subcarrier) being subsequently interpreted as fine detail luminance information. A typical visible effect is chroma crawl and visible subcarrier. *cf.* **artifact; composite color; cross-color**.

data: "Any representation of a digital or analog quantity to which meaning has been assigned" [IEEE 100]. *cf.* **data compression; resampling**.