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The American College of Radiology will periodically define new practice guidelines and technical standards for radiologic practice to help advance the science of radiology and to improve the quality of service to patients throughout the United States. Existing practice guidelines and technical standards will be reviewed for revision or renewal, as appropriate, on their fifth anniversary or sooner, if indicated.

Each practice guideline and technical standard, representing a policy statement by the College, has undergone a thorough consensus process in which it has been subjected to extensive review, requiring the approval of the Commission on Quality and Safety as well as the ACR Board of Chancellors, the ACR Council Steering Committee, and the ACR Council. The practice guidelines and technical standards recognize that the safe and effective use of diagnostic and therapeutic radiology requires specific training, skills, and techniques, as described in each document. Reproduction or modification of the published practice guideline and technical standard by those entities not providing these services is not authorized.

1994 (Res. 21)  
Revised 1995 (Res. 26)  
Revised 1998 (Res. 35)  
Revised 2002 (Res. 11)  
Effective 1/1/03

## **ACR TECHNICAL STANDARD FOR TELERADIOLOGY**

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### **PREAMBLE**

These guidelines are an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. They are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care. For these reasons and those set forth below, the American College of Radiology cautions against the use of these guidelines in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the physician or medical physicist in light of all the circumstances presented. Thus, an approach that differs from the guidelines, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in the guidelines when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations on available resources or advances in knowledge or technology subsequent to publication of the guidelines. However, a practitioner who employs an approach substantially different from these guidelines is advised to document in the patient record information sufficient to explain the approach taken.

The practice of medicine involves not only the science, but also the art of dealing with the prevention, diagnosis, alleviation and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict

with certainty a particular response to treatment. It should be recognized; therefore, that adherence to these guidelines will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of these guidelines is to assist practitioners in achieving this objective.

### **I. INTRODUCTION AND DEFINITION**

Teleradiology is the electronic transmission of radiologic images from one location to another for the purposes of interpretation and/or consultation. Teleradiology may allow more timely interpretation of radiologic images and give greater access to secondary consultations and to improved continuing education. Users in different locations may simultaneously view images. Appropriately utilized, teleradiology may improve access to radiologic interpretations and thus significantly improve patient care.

Teleradiology is not appropriate if the available teleradiology system does not provide images of sufficient quality to perform the indicated task. When a teleradiology system is used to render the official

interpretation,<sup>1</sup> there should not be a clinically significant loss of data from image acquisition through transmission to final image display. For transmission of images for display use only, the image quality should be sufficient to satisfy the needs of the clinical circumstance.

This standard defines goals, qualifications of personnel, equipment guidelines, licensing, credentialing, liability, communication, quality control, and quality improvement for teleradiology. While not all-inclusive, the standard should serve as a model for all physicians and health care workers who utilize teleradiology. A glossary of commonly used terminology (Appendix A) and a reference list are included.

## II. GOALS

Teleradiology is an evolving technology. New goals will continue to emerge.

The current goals of teleradiology include:

- A. Providing consultative and interpretative radiologic services.
- B. Making radiologic consultations available in medical facilities without on-site radiologic support.
- C. Providing timely availability of radiologic images and image interpretation in emergent and nonemergent clinical care areas.
- D. Facilitating radiologic interpretations in on-call situations.
- E. Providing subspecialty radiologic support as needed.
- F. Enhancing educational opportunities for practicing radiologists.
- G. Promoting efficiency and quality improvement.
- H. Providing interpreted images to referring providers.
- I. Supporting telemedicine.
- J. Providing supervision of off-site imaging studies.

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<sup>1</sup>The ACR Medical Legal Committee defines official interpretation as that written report (and any supplements or amendments thereto) that attach to the patient's permanent record. In healthcare facilities with a privilege delineation system, such a written report is prepared only by a qualified physician who has been granted specific delineated clinical privileges for that purpose by the facility's governing body upon the recommendation of the medical staff.

## III. QUALIFICATIONS OF PERSONNEL

The radiologic examination at the transmitting site must be performed by qualified personnel trained in the examination to be performed. In all cases this means a licensed and/or registered radiologic technologist, radiation therapist, nuclear medicine technologist, or sonographer. This technologist must be under the supervision of a qualified licensed physician.

It is desirable to have a Qualified Medical Physicist and/or image management specialist on site or as consultants.

### A. Physician

The official interpretation of images must be done by a physician who has:

1. An understanding of the basic technology of teleradiology, its strengths and weaknesses (as well as limitations), and who is knowledgeable in the use of the teleradiology equipment.
2. Demonstrated qualifications as delineated in the appropriate American College of Radiology (ACR) guidelines or standards for the particular diagnostic modality being transmitted through teleradiology.

### B. Radiologic Technologist, Radiation Therapist, Nuclear Medicine Technologist, or Sonographer

The technologist, therapist, or sonographer should be:

1. Certified by the appropriate registry and/or possess unrestricted state licensure.
2. Trained to properly operate and supervise the teleradiology system.

### C. Qualified Medical Physicist

A Qualified Medical Physicist is an individual who is competent to practice independently in one or more of the subfields in medical physics. The ACR considers that certification and continuing education in the appropriate subfield(s) demonstrate that an individual is competent to practice one or more of the subfields in medical physics and to be a Qualified Medical Physicist. The ACR recommends that the individual be certified in the appropriate subfield(s) by the American Board of Radiology (ABR).

The appropriate subfields of medical physics for this standard are Therapeutic Radiological Physics, Diagnostic Radiological Physics, Medical Nuclear Physics, and Radiological Physics.

The continuing education of a Qualified Medical Physicist should be in accordance with the [ACR Practice Guideline for Continuing Medical Education \(CME\)](#).

#### D. Image Management Specialist

1. The image management specialist is an individual who is qualified to assess and provide problem-solving input, initiate repair, and coordinate system-wide maintenance programs to assure sustainable high-image quality and system function. This individual would also be directly involved with any system expansion programs.
2. This specialist should be available in a timely manner in case of malfunction to facilitate return to optimal system functionality.

#### IV. EQUIPMENT SPECIFICATIONS

Specifications for equipment used in teleradiology will vary depending on the individual facility's needs, but in all cases it should provide image quality and availability appropriate to the clinical need.

Compliance with the ACR/NEMA (National Electrical Manufacturers Association) Digital Imaging and Communication in Medicine (DICOM) standard is strongly recommended for all new equipment acquisitions, and consideration of periodic upgrades incorporating the expanding features of that standard should be part of the continuing quality improvement program.

Equipment guidelines cover two basic categories of teleradiology when used for rendering the official interpretation: small matrix size (e.g., computed tomography [CT], magnetic resonance imaging [MRI], ultrasound, nuclear medicine, digital fluorography, and digital angiography) and large matrix size (e.g., digital radiography and digitized radiographic films).

**Small matrix:** The data set should provide a minimum of 512 x 512 matrix size at a minimum 8-bit pixel depth for processing or manipulation with no loss of matrix size or bit depth at display.

**Large matrix:** The data set should allow a minimum of 2.5 lp/mm spatial resolution at a minimum 10-bit pixel depth.

##### A. Acquisition or Digitization

Initial image acquisition should be performed in accordance with the appropriate ACR modality or examination guideline or standard.

1. **Direct image capture**  
The entire image data set produced by the digital modality in terms of both image matrix size and pixel bit depth, should be transferred to the teleradiology system. It is recommended that the DICOM standard be used.

2. **Secondary image capture**
  - a. **Small matrix images:** Each individual image should be digitized to a matrix size as large as or larger than that of the original image by the imaging modality. The images should be digitized to a minimum of 8 bits pixel depth. Film digitization or video frame grab systems conforming to the above specifications are acceptable.
  - b. **Large matrix images:** These images should be digitized to a matrix size corresponding to 2.5 lp/mm or greater, measured in the original detector plane. These images should be digitized to a minimum of 10 bits pixel depth.

##### 3. General requirements

At the time of acquisition (small or large matrix), the system must include annotation capabilities including patient name, identification number, date and time of examination, name of facility or institution of acquisition, type of examination, patient or anatomic part orientation (e.g., right, left, superior, inferior), and amount and method of data compression.

The capability to record a brief patient history is desirable.

##### B. Compression

Data compression may be used to increase transmission speed and reduce storage requirements. Several methods, including both reversible and irreversible techniques, may be used, under the direction of a qualified physician, with no reduction in clinically significant diagnostic image quality. The types and ratios of compression used for different imaging studies transmitted and stored by the system should be selected and periodically reviewed by the responsible physician to ensure appropriate clinical image quality.

##### C. Transmission

The type and specifications of the transmission devices used will be dictated by the environment of the studies to be transmitted. In all cases, for official interpretation, the digital data received at the receiving end of any transmission must have no loss of clinically significant information. The transmission system shall have adequate error-checking capability.

#### D. Display Capabilities

Display workstations used for official interpretation and employed for small-matrix and large-matrix systems should provide the following characteristics:

1. Luminance of the gray-scale monitors should be at least 50 foot-lamberts.
2. Lighting in the reading room that can be controlled to eliminate reflections in the monitor and to lower the ambient lighting level as much as is feasible.
3. Capability for selecting image sequence.
4. Capability of accurately associating the patient and study demographic characterizations with the study images.
5. Capability of window and level adjustment, if those data are available.
6. Capability of pan and zoom functions.
7. Capability of rotating or flipping the images provided correct labeling of patient orientation is preserved.
8. Capability of calculating and displaying accurate linear measurements and pixel value determinations in appropriate values for the modality (e.g., Hounsfield units for CT images), if those data are available.
9. Capability of displaying prior image compression ratio, processing, or cropping.
10. The following elements of display:
  - a. Matrix size.
  - b. Bit depth.
  - c. Total number of images acquired in the study.
  - d. Clinically relevant technical parameters.

When the display systems are not used for the official interpretation, they need not meet all the characteristics listed above.

#### E. Archiving and Retrieval

If electronic archiving is to be employed, the guidelines listed below should be followed:

1. Teleradiology systems should provide storage capacity sufficient to comply with all facility, state, and federal regulations regarding medical record retention. Images stored at either site should meet the jurisdictional requirements of the transmitting site. Images interpreted off-site need not be stored at the receiving facility, provided they are stored at the transmitting site. However, if the images are retained at the receiving site, the retention period of that jurisdiction must be met as well. The policy on record retention must be in writing.
2. Each examination data file must have an accurate corresponding patient and examination database

record that includes patient name, identification number, examination date, type of examination, and facility at which examination was performed. It is desirable that space be available for a brief clinical history.

3. Prior examinations should be retrievable from archives in a time frame appropriate to the clinical needs of the facility and medical staff.
4. Each facility should have policies and procedures for archiving and storage of digital image data equivalent to the policies for protection of hard-copy storage media to preserve imaging records.

#### F. Security

Teleradiology systems should provide network and software security protocols to protect the confidentiality of patients' identification and imaging data consistent with federal and state legal requirements. There should be measures to safeguard the data and to ensure data integrity against intentional or unintentional corruption of the data.

#### G. Reliability and Redundancy

Quality patient care may depend on timely availability of the image interpretation. Written policies and procedures should be in place to ensure continuity of teleradiology services at a level consistent with those for hard-copy imaging studies and medical records within a facility or institution. This should include internal redundancy systems, backup telecommunication links, and a disaster plan.

#### V. LICENSING, CREDENTIALING, AND LIABILITY

Physicians who provide the official interpretation of images transmitted by teleradiology should maintain licensure as may be required for provision of radiologic service at both the transmitting and receiving sites. When providing the official interpretation of images from a hospital, the physician should be credentialed and obtain appropriate privileges at that institution. These physicians should consult with their professional liability carrier to ensure coverage in both the sending and receiving sites (state or jurisdiction).

The physician performing the official interpretations is responsible for the quality of the images being reviewed.<sup>2</sup>

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<sup>2</sup>The ACR Rules of Ethics state: "it is proper for a diagnostic radiologist to provide a consultative opinion on radiographs and other images regardless of their origin. A diagnostic radiologist should regularly interpret radiographs and other images only when the radiologist reasonably participates in the quality of medical imaging, utilization review, and matters of policy which affect the quality of patient care."

Images stored at either site should meet the jurisdictional requirements of the transmitting site. Images interpreted off-site need not be stored at the receiving facility, provided they are stored at the transmitting site. However, if images are retained at the receiving site, the retention period of that jurisdiction must be met as well. The policy on record retention should be in writing.

The physicians who are involved in practicing teleradiology will conduct their practice in a manner consistent with the bylaws, rules, and regulations for patient care at the transmitting site.

## VI. DOCUMENTATION

Communication is a critical component of teleradiology. Physicians interpreting teleradiology examinations should render reports in accordance with the [ACR Practice Guideline for Communication: Diagnostic Radiology](#).

## VII. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION CONCERNS

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control and Improvement, Safety, Infection Control, and Patient Education Concerns appearing elsewhere in the ACR Practice Guidelines and Technical Standards book.

Any facility using a teleradiology system must have documented policies and procedures for monitoring and evaluating the effective management, safety, and proper performance of acquisition, digitization, compression, transmission, archiving, and retrieval functions of the system. The quality control program should be designed to maximize the quality and accessibility of diagnostic information.

A test image, such as the SMPTE test pattern,<sup>3</sup> should be captured, transmitted, archived, retrieved, and displayed at appropriate intervals, but at least monthly, to test the overall operation of the system under conditions that simulate the normal operation of the system. As a spatial resolution test, at least 512 x 512 resolution should be confirmed for small-matrix official interpretation, and 2.5 lp/mm resolutions for large-matrix official interpretation.

As a test of the display, SMPTE pattern data files sized to occupy the full area used to display images on the monitor should be displayed. The overall SMPTE image appearance should be inspected to assure the absence of gross artifacts (e.g., blurring or bleeding of bright display

<sup>3</sup>SMPTE test pattern RP 133-1991. Grey JF, Lisk KG, Haddick DH, et al. Test pattern for video displays and hard copy cameras. *Radiology* 1985; 154:519-527.

areas into dark areas or aliasing of spatial resolution patterns). Display monitors used for primary interpretation should be tested at least monthly. As a dynamic range test, both the 5% and the 95% areas should be seen as distinct from the respective adjacent 0% and 100% areas.

The use of teleradiology does not reduce the responsibilities for the management and supervision of radiologic medicine.

## ACKNOWLEDGEMENTS

This standard was revised according to the process described in the ACR Practice Guidelines and Technical Standards book by the Guidelines and Standards Committee of the General and Pediatric Radiology Commission.

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## APPENDIX A

### Glossary

Analog signal - a form of information transmission in which the signal varies in a continuous manner and is not limited to discrete steps.

Archive - a repository for digital medical images in a picture archiving and communications system (PACS), typically with a specific purpose of providing either short-term or long-term (permanent) storage of images. Erasable or nonerasable media may be utilized in an archive.

Baud - the number of events processed in 1 second, usually expressed in bits per second (bps) or kilobits per second (kbps). Typical rates are 14.4 kbps, 28.8 kbps, and 56 kbps.

Bit (binary digit) - the smallest unit of digital information.

Bit depth - the number of bits used to encode the signal intensity of each pixel of the image.

Bits per second - see throughput, baud.

Byte - a grouping of 8 bits used to represent a character or value.

Carrier - see data carrier.

CCD (charge-coupled device) - a photoelectric device that converts light into electronic information. CCDs are commonly used in television cameras and image scanners and consist of an array of sensors that collect and store light as a buildup of electrical charge. The resulting electrical signal can be converted into digital values and processed digitally in a computer to form an image.

CCD scanner - a device that uses a CCD sensor to convert film images into electronic data.

Clock - a component in a computer's processor that supplies an oscillating signal used for timing command execution and information handling.

Clock speed - the rate at which the clock oscillates or cycles. Clock speed is expressed in MHz, equal to 1 million clock ticks per second.

Compression ratio - the ratio of the number of bits in an original image to that in a compressed version of that image. For example, a compression ratio of 2:1 would correspond to a compressed image with one-half the number of bits of the original.

Consultation system - a teleradiology system used to determine the completeness of examinations, to discuss findings with other physicians, or for other applications, with the knowledge that the original images will serve as the basis for the final official interpretation rendered at some later time by the physician responsible for that report.

Co-processor - a device in a computer to which specialized processing operations are delegated, such as mathematical computation or video display. The advantage of a co-processor is that it significantly increases processing speed.

CPU (central processing unit) - the device in a computer that performs the calculations. It executes instructions (the program) and performs operations on data.

CR (computed radiography) - a system that uses a storage phosphor plate contained in a cassette instead of a film-screen cassette. A laser beam scans the exposed plate to produce the digital data that is then converted into an image.

CRT (cathode ray tube) - the monitor or display device in the teleradiology system.

Data carrier - the signal used to transmit the data. If this signal is not present, there can be no data communication between modems.

Data communication - all forms of computer information exchange. Data communication may take place between two computers in the same building via a local area network (LAN) or elsewhere by a wide-area network (WAN).

Data compression - methods to reduce the data volume by encoding it in a more efficient manner, thus reducing the image processing and transmission times and storage space required. These methods may be reversible or irreversible.

Data transfer rate - the speed at which information is transferred between devices, such as a scanner and a computer; between components within a device, such as between storage and memory in a computer; or between teleradiology stations.

Dedicated lines - a telephone line that is reserved for the exclusive use of one customer. It can be used 24 hours a day and usually offers better quality than a standard dial-up telephone line but may not significantly increase the performance of data communication.

DICOM (digital imaging and communication in medicine) - a standard for interconnection of medical digital imaging devices, developed by the ACR-NEMA committee sponsored by the American College of Radiology and the National Electrical Manufacturers

Association, consisting of a standard image format and a standard communication protocol.

Digital signal - a form of information transmission in which the signal is made up of a series of ones and zeros, which taken together represent discrete values.

Digitize - the process by which analog (continuous value) information is converted into digital (discrete value) information. This process is a necessary function for computer imaging applications because visual information is inherently in analog format and most computers use only digital information.

Direct image capture - the capture or acquisition of digital image data that have been acquired in digital format by an imaging modality. The image produced from the data, regardless of the modality that produced it (CT, MRI, CR, ultrasound), should include the full spatial resolution and bit depth of the original.

Diskette drive - the device on a computer that can read and write to diskettes. It is used to import and export data.

dpi (dots per inch) - while in conventional radiography, resolution is commonly expressed in line pairs per millimeter (lp/mm), film digitizer resolution is commonly expressed as dots (pixels) per inch.

Dynamic range - the difference in signal intensity, or frequency, between the largest and smallest signals a system can process or display. The optical density is the difference between the lightest and darkest useful regions of the image. Increasing the number of bits per pixel in a digital image increases the dynamic range of the image.

File - a set of digital data that have a common purpose, such as an image, a program, or a database.

Floppy diskette - a data storage device made of metal-coated plastic that can store computer information and can be physically transported from one place to another.

G (giga) - stands for the number 1 billion. It is used primarily when referring to computer storage capacities; for example, 1 GB = about 1 billion bytes or 1,024 megabytes.

Gray scale - the number of different shades of levels of gray that can be stored and displayed by a computer system. The number of gray levels is directly related to the number of bits used in each pixel: 6 bits = 64 gray levels, 7 bits = 128 gray levels, 8 bits = 256 gray levels, 10 bits = 1,024 gray levels, and 12 bits = 4,096 gray levels.

Gray-scale monitor - a black-and-white display with varying shades of gray, ranging from several shades to thousands, thus being suitable for use in imaging. This type of monitor also may be referred to as a monochrome display (see also monochrome monitors).

Hard disk drive - an internal computer device used for storage of data.

Hardware - a collective term used to describe the physical components that form a computer.

HIS (hospital information system) - an integrated computer-based system used to store and retrieve patient information, including laboratory and radiology reports.

IDE (integrated device electronics) - a type of interface used for hard disk drives that integrates the control electronics for the interface on the drive itself. Its purpose is to increase the speed at which information can be transferred between the hard disk and the rest of the computer.

IMACS - image management and communication system.

Image compression - reduction of the amount of data required to represent an image. This is accomplished by encoding the spatial and contrast information more efficiently, somehow discarding some information.

Interface - the connection between two computers or parts of computers.

Irreversible compression - some permanent alteration of digital image data. This is sometimes referred to as lossy.

ISDN (integrated services digital network) - a switched network with end-to-end digital connection enabling copper wiring to perform functions such as high-speed transmission which frequently require higher capacity fiberoptic cable.

k (kilo) - stands for the number one thousand. It is used primarily when referring to computer storage and memory capacities: for example, 1 kbps = 1,024 bytes.

LAN (local area network) - computers in a limited area linked by cables that allow the exchange of data.

Laser film scanner - a device that uses a laser beam to convert an image on X-ray film into digital image data.

Leased line - same as a dedicated line.

Lossless - see reversible compression.

Lossy - see irreversible compression.

M (mega) - stands for the number 1 million. It is used primarily when referring to computer storage and memory capacities; for example, 1 MB = 1 million bytes. 1 MB = 1,024 thousand bytes or 1,000 kbytes.

Matrix size:

Small - defined as images from CT, MRI, ultrasound, nuclear medicine, and digital fluorography.

Large - defined as images from computed radiography, digital radiography, and digitized radiographic films.

Memory - electronic circuitry within a computer that stores information.

Modem - a device that converts digital signals from a computer to pulse tone signals for transmission over telephone lines.

Monochrome monitor - a computer display in which an image is presented as different shades of gray from black to white. (See also gray-scale monitor.)

Mouse - an input device that allows the computer user to point to objects on the screen and execute commands.

Operating system - software that allocates and manages the resources available within a computer system. UNIX, MS-DOS, Macintosh, and Windows are examples of operating systems.

Optical disk - a computer data storage disk used primarily for large amounts (GB) of data.

PACS - picture archiving and communication system.

Pan and zoom - the ability to select and magnify a region in the display.

Peripheral - a device that is connected to a computer and performs a function. Scanners, mouse pointers, printers, keyboards, and monitors are examples of peripherals.

Phosphor - the coating on the inside of a CRT or monitor that produces light when it is struck by an electron beam.

Pixel (picture element) - the smallest piece of information that can be displayed on a CRT. It is represented by a numerical code within the computer and displayed on the monitor as a dot of a specific color or intensity. An image is composed of a large array of pixels of differing intensities or colors.

Protocol - a set of guidelines by which two different computer devices communicate with each other.

RAM (random access memory) - a type of temporary memory in a computer in which programs are run, images are processed, and information is stored. The amount of RAM that a computer requires varies widely depending on the specific application. Information stored in RAM is lost when the power is shut off.

Resolution - spatial resolution is the ability to distinguish small objects at high contrast. It is related to and in some cases limited by the pixel size. Contrast (gray scale) resolution is the ability of a system to distinguish between objects of the same size having different signal intensity. It is related to and in some cases limited by the bit depth.

Reversible compression - no alteration of original image information upon reconstruction. This is sometimes referred to as lossless.

RIS - radiology information system.

ROM (read-only memory) - a permanent memory that is an integral part of the computer. Programs and information stored in ROM are not lost when the power is removed.

SCSI (small computer systems interface) - SCSI is an interface protocol that is used to link dissimilar computer devices so that they can exchange data. SCSI interfaces are most common in image scanners and mass storage devices. This type of interface is well suited for imaging applications.

Secondary image capture - the capture in digital format of image data that originally existed in another primary format (e.g., a digital image data file on a CT scanner, or a screen-film radiographic film) through the process of video capture or film digitization.

SMPTE - the Society of Motion Picture and Television Engineers.

Software - a name given to the programs or sets of programs that are executed on a computer.

Tera (T) - stands for approximately 1 trillion ( $10^{12}$ ). It is used primarily when referring to archive storage capabilities; for example, 1 TB = one trillion bytes or 1 million MB or 1,000 GB.

Throughput - a measure of the amount of data that is actually being communicated, expressed in bits per second. It is related to the baud rate but is usually somewhat less in value due to nonideal circumstances. Typically, modems with higher baud rates can attain a higher throughput.

Video capture - the process by which images are digitized directly from the video display console of a modality, such as CT, MRI, or ultrasound. The video signal is converted to a digital signal. This process is more efficient and produces better quality images than scanning films that are produced by the same equipment.

Voxel (volume element, derived from pixel) - a voxel is, as the name would imply, a three-dimensional version of a pixel. Voxels are generated by computer-based imaging systems, such as CT and MRI. Using voxels, three-dimensional simulations of objects can be reconstructed by imaging systems.

WAN (wide-area network) - a communication system that extends over large distances (covering more than a metropolitan area), often employing multiple communication link technologies such as copper wire, coaxial cable, and fiberoptic links. The cost of these wide-area networks is presently dominated by transmission costs.

WORM (write once read many times) - a peripheral memory device that stores information permanently.