The ACR-NEMA Digital Imaging and Communications Standard: A Nontechnical Description

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The purpose of this report is to present, in nontechnical terms, the purpose and history of the American College of Radiology and National Electrical Manufacturers Association (ACR-NEMA) Digital Imaging and Communications Standard (ACR-NEMA Standards Publication no. 300-1985), an explanation of what the standard is, the characteristics of the standard, possible applications of the standard, and ongoing standardization efforts. It is assumed that the reader has at least a basic understanding of the concepts and technologies described collectively as picture archiving and communication systems (PACS). For information on PACS, please refer to the NEMA PACS Primer and the list of suggested reading contained therein (for copies, write or call NEMA, 2101 L St, Suite 300, Washington, DC 20037, ATTN: Ms Cindy Fuscoe; telephone 202-457-1965).

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WHEN THE AMERICAN College of Radiology (ACR) and the National Electrical Manufacturers Association (NEMA) formed a joint committee to develop an interface standard, they had as their goal extending the capabilities of existing and future imaging equipment to better serve the medical community. (A standard is an accepted model to which participants adhere when performing a relevant activity). Alone, the array of diagnostic tools available is powerful. Connected, the impact of these systems would be greater than the sum of them taken individually. Through the use of such an extended system, an institution could more effectively and efficiently use the diagnostic skills of its professional staff than previously possible. These extended systems also have the potential to increase productivity beyond that possible with film-based imaging systems and to facilitate the management of information, personnel, and other resources. As stated in the standard, the three specific objectives are:

1. to promote communication of digital image information regardless of the image format, or the technology or manufacturer of the imaging system;
2. to facilitate the development and implementation of picture archiving and com-

munication systems (PACS), which can also be connected (interfaced) to other computer-based systems within a hospital (eg, hospital information systems [HIS], radiology information systems [RIS], and nursing systems); and

3. to make possible the creation of diagnostic information data bases (organized collections of information) to which users can gain access from various devices located in distributed geographic locations (eg, within a hospital, between two local hospitals, between two hospitals in different countries, etc).

HISTORY OF THE STANDARD

The ACR-NEMA Digital Imaging and Communications Standards Committee first met in January 1984. The committee, representing ACR, users of imaging equipment, and NEMA, developers and manufacturers of that same equipment, has met and worked for almost five years on the development of standards, and continues to examine issues regarding the integration of information from various imaging systems from different manufacturers in a cohesive and usable system.

The ACR brought to the committee a thorough understanding of the current and future clinical needs and requirements for the operation of a digital imaging department in a multiple vendor environment. NEMA contributed the collective expertise of the manufacturers, who were able to analyze those clinical requirements and suggest solutions.

A draft of the standard was made available for comment in late 1984. The first version of the standard was adopted by ACR and NEMA in late 1985. Working groups of the committee have been formed to validate the standard and investi-

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gate the need for additional standards, and when necessary, adapt or develop them. As of this writing, there exist drafts of a magnetic tape standard (for the transfer of information when a direct connection between two systems is not available), a data compression standard (for reduction of the amount of digital information that must be stored or moved), and a second revised version of the standard with some enhancements.

In developing the standard, the ACR-NEMA committee examined a number of existing standards for possible use. Among those standards considered were the Institute for Electrical and Electronic Engineers Standard Digital Interface for Programmable Instrumentation (IEEE 488), the International Standards Organization's Open Systems Interconnect Reference Model (ISO-OSI), the American National Standards Institute Codes for Information Interchange (ANSI X3.4-1977), and the Electronic Industries Association Standard for Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multipoint Systems (EIA 485). Although portions of the standards were used or were, in part, the basis of the model for the ACR-NEMA standard, the committee chose to develop an original standard that would more adequately address the requirements of medical imaging.

The standard is seen as a dynamic document, being changed and improved in response to the needs of the medical community with the support of the manufacturers. A goal of the committee is to make future versions of the standard compatible with previous versions, and where possible, develop new versions which can be "understood" by existing implementations.

WHAT IS THE STANDARD?

The standard describes the transmission of an image (or other information) across an interface between a medical imaging device and another object, such as a network or another imaging device. Figure 1 shows a set of diagrams describing possible types of connections using the standard. Specific applications of the standard will be discussed.

Devices connected using the standard can be devices that transmit images across the interface

Fig 1. Location of the ACR-NEMA interface (A) without network; (B) with network.

(source), devices that receive images that have been transmitted across the interface (sink), both, or neither. Table 1 lists devices which can be connected via the standard, categorized as image sources, sinks, both, or neither.

Table 1. Image Sources and Sinks

Device	Image Source	Image Sink	Both	Neither
Film digitizer	x			
Digital radiography unit	x			
Ultrasound system	x			
Densitometer	x			
Thermographic system	x			
Electrocardiograph	x			
Gamma camera	x			
Multiformat camera		x		
Printer		x		
Work station		x	x	
Archive			x	
Management terminal				x
CT systems	x		x	
MR systems	x		x	
PET systems	x		x	
Digital subtraction angiography systems	x		x	

NOTE. Image source, a piece of equipment that transmits an image across the ACR-NEMA interface; sink, a piece of equipment that receives an image across the ACR-NEMA interface.

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The standard is made up of a number of parts. The first describes a common image data format, which can be understood by equipment that complies with the standard. (An image data format is the arrangement of image data such that the image can be recognized and understood by a particular device or devices). Commonly, each imaging system within a hospital generates images in a slightly or vastly different format than the others, regardless of modality or manufacturer. The image format portion of the standard will allow manufacturers to understand images generated by each other's systems. Only conversion of each manufacturer's internal image format (by the respective manufacturer) to the standard format is necessary.

The next component of the standard specifies an actual physical connector ("plug") and defines what information can be found on the respective "pins" of the plug (Fig 2). (Pins are the end points of the wires that carry the digital information, and they allow the connection to other wires.) The connector provides 50 pins and will be present on any ACR-NEMA-compatible device. The 50-pin connector was selected because it is a standard connector large enough to accommodate both current requirements and future expansion of the standard.

Although the plug is not yet present on installed equipment, it should be possible to modify many existing systems to make them comply with the standard. The plug will be increasingly found as an integrated part of new imaging systems.

The standard also describes a set of commands (SEND, FIND, GET, MOVE, DIALOG, CANCEL, and ECHO) used to communicate across the interface. A description of the commands specified by the standard follows.

Commands

SEND. Used to transfer image and supporting data from one device to another device.

FIND. Used to ask a device whether certain information can be found within that device.

GET. Used by one device to request information from another device.

MOVE. Used by one device to ask another device to send information to a third device.

DIALOG. Used to send unformatted and interactive information between two devices, eg, conferencing, electronic mail.

CANCEL. Used to cancel a command currently being executed.

ECHO. Used to test and verify the communication status between two devices.

Finally, the Standard specifies various groups (also referred to as layers) of data protocols which allow digital data to be transmitted. (A protocol is a set of rules governing the exchange of information between two systems or parts of the same system). Segregating the protocols into layers allows the implementation of each layer to be independent of the other layers. This, in turn, allows for the connection of equipment to various networks using many different interfaces and facilitates expansion of the extended system over time.

Fig 2. Fifty-pin ACR-NEMA physical connector.

In summary, the commands specified in the standard can be thought of as the words, while the protocols represent the context in which the words are used.

As discussed previously, the ACR-NEMA committee elected to adopt an independent standard rather than an existing one. Among the reasons for creating a new standard were the volume and characteristics of the data involved. Files, organizational units of information associated with images, are larger than those intended for use with existing standards. The ACR-NEMA standard is tailored to the requirements of medical images, using the standard 50-pin connector and using the layer concept of the ISO-OSI Reference Model.

CHARACTERISTICS OF THE STANDARD

The ACR-NEMA standard provides performance goals. One such goal is a maximum allowable error rate of 17×10^{-9} . Another goal, the speed of information transfer across the interface between two devices, could be as much as 8 Mbytes/s; however, the standard allows for implementations resulting in much slower speeds. If "fast" and "slow" devices are connected using the standard, the interface will operate at the slower speed, so that communication is assured and no data is lost. This method of communication is called asynchronous operation. Other factors may cause the actual throughput to be less than 8 Mbytes/s. Throughput is the amount of useful information, such as computed-tomography image information, transmitted or processed in a given period of time.

In order for a device to be "ACR-NEMA compatible," a minimum number of functions must be supported. The minimum set of functions is listed below.

1. The device must be able to recognize all of the commands discussed previously and respond to them appropriately. An acceptable response is to "refuse" the request, indicating that the device is not equipped to act on the request or that it is unable to respond, eg, because of a current malfunction or because it is currently processing another request.
2. The physical connection must be made via the 50-pin connector.
3. A message is the command and the data

set, ie, the data to be acted upon as a result of the command. Messages must include all of the required information as defined in Section IV of the standard. For example, in an image data set, an image must have details associated with it about how it was acquired and on what system, information about the patient, information that allows it to be uniquely identified, information stating anatomical location of the image and the relationship to other images, information about proper presentation or display of the image, and image pixel data.

Other image data contained in the message are optional and can be specified by a manufacturer or user. The optional information can include (but may not be limited to) descriptive text, overlay (graphics, annotation) data, and other vendor- or user-specified data. Additional information not covered by the standard can be placed in the message in optional groups called "shadow groups." A group is a set of related pieces of information.

APPLICATIONS OF THE ACR-NEMA STANDARD

Two intended uses considered during development of the standard were the interconnection of two devices that have a practical purpose for being connected and the connection of multiple devices using a network. It should be noted that "ACR-NEMA compatibility" does not imply that two devices were designed to be connected. An example of an ACR-NEMA connection without a practical purpose would be the connection of two ACR-NEMA-compatible hard-copy devices (image sinks).

There are a number of possible applications for which an ACR-NEMA standard interface could be used to connect devices or systems that meet the minimum requirements of the standard. One such application is the direct connection of two devices, such as two imaging systems or an imaging system and a hard-copy device.

Another use for the standard would be the connection of an imaging system to a PACS network. The connection would require that both the imaging system and the appropriate network interface unit comply with the standard. Because the standard does not include a network communications protocol, a network interface unit is

required for image communication between a network and the attached components.

In addition to imaging equipment, the ACR-NEMA standard could be used to connect other devices to a network. Hard-copy devices, film digitizers, and stimuable phosphor plate imaging systems are some examples of components which could be connected via the standard.

ONGOING EFFORTS OF THE ACR-NEMA COMMITTEE

The medical PACS (MedPACS) section of NEMA was formed in 1986 to address industry issues pertaining to PACS. The section has three committees: the Technical and Regulatory Committee, the Statistical Committee, and the ACR-NEMA committee. The ACR-NEMA committee is continuing its standardization efforts as described previously. Various working groups are addressing the following issues.

Working Group 4 has been developing a standard for data compression, which is being prepared for voting. The current version of the ACR-NEMA standard does not support compression; this revision would offer compression as an option, identify three compression schemes to be used as standard techniques, and allow the optional use of additional proprietary compression techniques.

Working Group 5 has developed a draft standard for the exchange of ACR-NEMA formatted data using magnetic tape (for transfer of information when a direct connection between two systems is not possible). This draft will be voted on shortly for final acceptance.

Working Group 6, the Validation Working Group, has been active in keeping track of errors found in the standard and correcting them, addressing questions about implementation of the standard, and developing updates and extensions to the standard. (Version 2 of the Standard, which accommodates additional information and enhancements for connection of digital hardcopy devices, has been accepted by NEMA.)

Working Group 7 has begun to develop an extension to the standard for multidimensional images.

Finally, Working Group 8, the most recently formed group, is actively developing a standard for the connection of RIS and HIS to PACS. As part of its efforts, Working Group 8 has contacted both users and suppliers of various computer-based health care systems (eg, clinical laboratory systems, pharmacy systems, etc) and the standards groups associated with those industries. Working Group 8 has collected considerable data in an effort to better understand the requirements of interfacing systems.

Other activities of the ACR-NEMA committee include monitoring the development of standards outside of the medical community and the standardization efforts outside of the United States, eg, Japan and Europe.

CONCLUSION

The ACR-NEMA Digital Imaging and Communication Standard is a tool that manufacturers and equipment users can expect to play a significant role in the future of imaging. It must be remembered that because the standard is not mandatory, its implementation by equipment suppliers is optional. Support for the standard will grow, with a migration from the "black box" to an integrated interface. Supplier and user experience with the standard will continue to make its implementation easier.

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