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Standard Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE)[1]

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1. Scope

1.1 This practice facilitates the interoperability of NDE imaging and data acquisition equipment by specifying the image data file format in commonly accepted terms. This practice represents a harmonization of NDE imaging systems, or modalities, with the NEMA Standards Publication titled Digital Imaging and Communications in Medicine (DICOM, see http://medical.nema.org), an international standard for image data acquisition, review, storage and archival. In addition, this practice will provide a standard set of industrial NDE specific information object definitions, which travel beyond the scope of standard DICOM modalities. The goal of this practice is to provide a standard by which NDE image/signal data may be displayed on by any system conforming to the ASTM DICONDE format, regardless of which NDE modality was used to acquire the data.

1.2 This practice has been developed to overcome the issues that arise when archiving or analyzing the data from a variety of NDE techniques, each using proprietary data acquisition systems. As data acquisition modalities evolve, data acquired in the past must remain decipherable. This practice proposes an image data file format in such a way that all the technique parameters, along with the image file, are preserved, regardless of changes in NDE technology. This practice will also permit the viewing of a variety of image types (CT, CR, Ultrasonic, Infrared and Eddy Current) on a single workstation, maintaining all of the pertinent technique parameters along with the image file. This practice addresses the exchange of digital information between NDE imaging equipment.

1.3 This practice does not specify:

1.3.1 A testing or validation procedure to assess an implementation's conformance to the standard.

1.3.2 The implementation details of any features of the standard on a device claiming conformance.

1.3.3 The overall set of features and functions to be expected from a system implemented by integrating a group of devices each claiming DICONDE or DICOM conformance.

2. Referenced Documents

2.1 *ASTM Standards:*

E 1316 Terminology for Nondestructive Examinations

2.2 *Other Documentation:*

NEMA Standards Publication PS3.1, Version 3: Digital Imaging and Communications in Medicine (DICOM)

ACR-NEMA 300–1998 Digital Imaging and Communication in Medicine

3. Terminology

3.1 *Definitions:*

3.1.1 Nondestructive evaluation terms used in this practice can be found in Terminology E 1316.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *AE*—application entity

3.2.2 *attribute*—a property of an information object. An attribute has a name and a value, which are independent of any encoding scheme.

3.2.3 *attribute tag* —a unique identifier for an *attribute* of an *information object* composed of an ordered pair (gggg, eeee) where gggg represents the group number and eeee represents the data element.

3.2.4 *conformance statement*—a formal statement associated with a specific implementation of the standard, specifying the service class, information objects, and communications protocols supported by the implementations.

3.2.5 *data dictionary*—a registry of data elements, which assigns a unique tag, a name, value characteristics, and semantics to each data element.

3.2.6 *data element*—a unit of information as defined by a single entry in the *data dictionary*. An encoded IOD attribute that is composed of, at a minimum, three fields: a *data element tag*, a *value length*, and a *value field*.

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3.2.7 *data element tag*—a unique identifier for a *data element* composed of an ordered pair of numbers (a *group number* followed by an *element number*).

3.2.8 *data element type*—used to specify whether an *attribute* of an IOD is mandatory, mandatory only under certain conditions, or optional.

3.2.9 *element number*—the second number in the ordered pair of numbers that make up a *data element tag*.

3.2.10 *group number*—the first number in the ordered pair of numbers that makes up a *data element tag*.

3.2.11 *information object definition (IOD)*—a data abstraction of a class of similar *real-world objects* which defines the nature and *attributes* relevant to the class of *real-world object* represented.

3.2.12 *module*—a set of *attributes* with an *Information Object Definition*.

3.2.13 *private data element*—additional *data element*, defined by an implementer, to communicate information that is not contained in standard *data elements*. Private *data elements* have odd *group numbers*.

3.2.14 *value*—a component of a *value field*. A *value field* may consist of one or more of these components.

3.2.15 *value field*—the field within a *data element* that contains the *value* (s) of that *data element*.

3.2.16 *value length*—the field within a *data element* that contains the length of the *value field* of the *data element*.

3.2.17 *value multiplicity (VM)*—specifies the number of *values* contained in the *value field* of a *data element*.

3.2.18 *value representation (VR)*—specifies the data type and format of the *value* (s) contained in the *value field* of a *data element*. A complete list of all the VR's can be found in 6.2 of Part 5 of the DICOM standard.

3.2.19 *DICONDE version identifier*—unique string placed in the DICONDE object to identify the version of DICONDE used to create the object.

4. Summary of Practice

4.1 The basic concept of using DICONDE (or DICOM) is the usage of standardized data tag identifiers. This means all participants are using database entries representing the same information and have a common understanding of communication protocols for mutual use. For standardization of data transfer, the conformance statement, a mutually agreed upon document provides the specific database tag identifiers for every part of the NDE data stream as well as the communications protocols.

4.2 The DICONDE practice will consist of descriptions of the object definitions that are specific to NDE (that is, no equivalent counterpart in medicine) and provide standard database tag identifiers for use with the DICOM database already in existence. The use of this practice is based upon and to be used in conjunction with the medical DICOM standard. This practice, in conjunction with the DICOM standard, will set forth the requirements for the transfer and display of NDE image data from any NDE image modalities equipment.

5. Significance and Use

5.1 Personnel that are responsible for the transfer of NDE data between systems will use this standard. This practice will define a set of NDE information object definitions that along with the DICOM standard will provide a standard means to organize image data. Once conformance statements have been generated, the NDE image data may be displayed on any imaging/analysis device that conforms to the standard. This process of developing conformance statements with both the NDE specific object definitions and the DICOM accepted definitions, will provide a means to automatically and transparently communicate between compliant equipment without loss of information.

NOTE 1—Knowledge and understanding of the existing DICOM standard will be required to generate conformance statements and thereby facilitate the data transfer.

6. Background: DICOM (Digital Imaging Communication for Medicine)

6.1 *History*

6.1.1 With the introduction of computed tomography (CT) and other digital diagnostic imaging modalities in the 1970's, and the increasing use of computers in clinical applications, the American College of Radiology (ACR) and the National Electrical Manufacturers Association (NEMA) recognized the emerging need for a standard method for transferring images and associated information between devices manufactured by various vendors. These devices produce a variety of digital image formats.

6.1.2 The American College of Radiology (ACR) and the National Electrical Manufacturers Association (NEMA) formed a joint committee in 1983 to develop a standard to:

6.1.2.1 promote communication of digital image information, regardless of device manufacturer;

6.1.2.2 facilitate the development and expansion of picture archiving and communication systems (PACS) that can also interface with other systems of hospital information;

6.1.2.3 allow the creation of diagnostic information data bases that can be interrogated by a wide variety of devices distributed geographically.

6.1.3 ACR-NEMA Standards Publication No. 300-1985, published in 1985 was designated version 1.0. The Standard was followed by two revisions, No. 1 dated October 1986 and No. 2 dated January 1988.

6.1.4 ACR-NEMA Standards Publication No. 300-1988, published in 1988 was designated version 2.0. It included version 1.0, the published revisions, and additional revisions. It also included new material to provide command support for display devices, to introduce a new hierarchy scheme to identify an image, and to add data elements for increased specificity when describing an image.

6.1.5 These standards publications specified a hardware interface, a minimum set of software commands, and a consistent set of data formats.

6.2 *The DICOM Standard*

6.2.1 DICOM, Digital Imaging and Communications in Medicine Version 3.0 embodies a number of major enhancements to previous versions of the standard:

6.2.1.1 It is applicable to a networked environment. The previous versions were applicable in a point-to-point environment only; for operation in a networked environment a

Network Interface Unit (NIU) was required. DICOM Version 3.0 supports operation in a networked environment using standard networking protocols such as OSI and TCP/IP.

6.2.1.2 It specifies how devices claiming conformance to the standard react to commands and data being exchanged. Previous versions were confined to the transfer of data, but DICOM Version 3.0 specifies, through the concept of service classes, the semantics of commands and associated data.

6.2.1.3 It specifies levels of conformance. Previous versions specified a minimum level of conformance. DICOM Version 3.0 explicitly describes how an implementer must structure a conformance claim to select specific options.

6.2.1.4 It is structured as a multi-part document. This facilitates evolution of the Standard in a rapidly evolving environment by simplifying the addition of new features. ISO directives which define how to structure multi-part documents have been followed in the construction of the DICOM Standard.

6.2.1.5 It introduces explicit Information Objects not only for images and graphics but also for studies, reports, and so forth.

6.2.1.6 It specifies an established technique for uniquely identifying any information object. This facilitates unambiguous definitions of relationships between Information Objects as they are acted upon across the network.

6.2.2 DICOM was developed in liaison with ACR (the American College of Radiology) and NEMA (the National Electrical Manufacturers Association) and other Standard Organizations including CEN TC251 in Europe and JIRA in Japan, with review also by other organizations including IEEE, HL7 and ANSI in the USA. The DICOM Standard is structured as a multi-part document.

6.2.3 The DICOM standard consists of the following parts:

6.2.3.1 Part 1—*Introduction and Overview*

6.2.3.2 Part 2—*Conformance:* The principles that implementations claiming conformance to the standard shall follow, specifically, the requirements as defined in the DICOM standard. The conformance requirement specifies the general requirements, which must be met by any implementation claiming conformance. The conformance claim defines the structure of a conformance claim and specifies the information, which must be present in a conformance claim. These are further referenced in the conformance sections of each of the NDE modality practices.

6.2.3.3 Part 3—*Information Object Definitions*

6.2.3.4 Part 4—*Service Class Specifications:* The characteristics shared by all service classes, and how a conformance claim to an individual service class is structured is defined.

6.2.3.5 Part 5—*Data Structure and Semantics:* The encoding rules necessary to construct a Data Stream to be conveyed in a message are addressed.

6.2.3.6 Part 6—*Data Dictionary:* The centralized registry, which defines the collection of all data elements available to represent information, is called the data dictionary.

6.2.3.7 Part 7—*Message Exchange:* The message exchange specifies the rules to establish and terminate associations provided by the communications support; the rules that govern the exchange of command requests and responses; and the encoding rules necessary to construct command streams and messages.

6.2.3.8 Part 8—*Network Communication Support for Message Exchange:* The communication services and the upper layer protocols necessary to support, in a networked environment, the application message exchange are specified.

6.2.3.9 Part 9—*Point-to-Point Communication Support for Message Exchange:* The service and protocols used for point-to-point communications (the physical interface and signaling protocols) are specified. The OSI-like data link and session/transport/network protocols and the services of the protocol stack to be used on this physical interface are defined.

6.2.4 The Parts are related but independent documents. Their development level and approval status may differ.

7. DICONDE Introduction

7.1 This practice provides an introduction and overview of DICONDE standard, the industrial NDE extension of the medical community DICOM standard published by NEMA.

7.1.1 *General Structure of DICONDE*

7.1.1.1 DICONDE, utilizing the existing DICOM database of object definitions, provides both replacement and additional module definitions that represent a conversion between the medical community language present in DICOM, to the terminology appropriate for NDE. An Image Information Object Definition exists for each image that is created by an NDE imaging device. For this practice, only the common NDE Image Information Object Definition Modules that differ from the medical system will be discussed. For each specific NDE modality, refer to the practice that describes that specific technique.

7.1.1.2 Table 1 is a summary of the modules that have modified or additional attributes for use with NDE data. Each of the specific NDE modalities IOD's will be covered in their own standards. This practice will describe only the common NDE specific modules that differ from the existing DICOM standard. In the case where no replacement module exists, the DICOM standard should be followed.

8. Information Object Definitions

8.1 *Information Object Definitions*

8.1.1 Details of the DICOM Information Object Definitions can be found in the DICOM Standard Part 3 Sections A.1.1 through A.1.3.

8.2 *DICOM to DICONDE Information Object Definition*

8.2.1 The DICOM standard specifies mandatory, conditional, and user option modules for each DICOM IOD. The relationship between the IODs and modules is found in the DICOM Standard Part 3 Sections A.1.3 and A.1.4. The DICONDE standard will follow that relationship except as noted in the following sections.

8.2.2 The terminology associated with certain elements of the DICOM information modules must be changed for use in an industrial context. For instance, industry deals with parts not patients. The DICONDE standard defines industrial information modules that are equivalent to those found in the DICOM standard. In the industrial modules, the equivalent medical data

elements will be reused when possible. For example, a component ID number or serial number will be assigned to the Patient ID attribute.

8.2.3 In some cases, there will exist no equivalent medical data element for a required industrial data element. There is no equivalent of Component Manufacturer in the current DICOM data model. When no equivalent DICOM data element exists, an industrial specific data element will be created as part of that module.

8.2.4 Currently four modules are defined for NDE: These common NDE specific modules are defined in this practice. In cases where there is no equivalent industrial module defined, the existing medical module should be used.

8.2.5 Table 1 summarizes the current list of industrial modules and the medical modules that they replace.

9. DICONDE Information Modules

9.1 All data elements in the industrial information modules must be described by an *attribute* name, a *data element tag*, a *value representation (VR)*, a *value multiplicity (VM)*, and a *data element type*.

9.2 The DICONDE practice represents the common modules that are needed for every technique. Tables 2-6 identify the data elements associated with the attributes in the DICONDE information modules. Any technique specific modules for NDE will have information modules, attributes and data elements identified in a technique specific practice.

9.3 When a logical correspondence exists, an existing DICOM data element, with an NDE meaning associated with them, will be used for industrial data. For example, the Patient Name data element (0010, 0010) is used to store Component Name for NDE applications.

9.4 Some industrial data element tags are unique and do not duplicate any existing medical tags. These NDE data elements are stored as DICOM Private Data Element Tags. Private *data elements tags* are defined in Part 5 Section 7.8 of the DICOM standard.

9.5 The version identifier of the DICONDE file will be stored in the Software Versions data element (0018, 1020) in the NDE Equipment Module. The Software Versions data element is mult-valued. If additional software versions are stored in this data element the DICONDE version must be the first value stored in the data element. The current DICONDE version identifier is “DICONDE06”. No changes in capitalization or spacing is allowed in the DICONDE version identifier.

10. Conformance

10.1 *Introduction*

10.1.1 The key to utilization of the DICOM/DICONDE standardization format is the conformance statement. This statement is the document that defines the current data configuration, the necessary configuration to which the NDE data format must be supplied, and the communications protocols to achieve an actual transfer of data over some transfer medium. The documentation of the current data configuration consists of using the information object definitions and the associated database element identifiers (tags) to specify the order in which the data is generated. The conformance statement also includes information on the transfer of data and what types of media are to be used.

TABLE 1 DICONDE Modules with Medical Equivalents

DICOM Module	DICONDE Module
Patient	Component
Patient Summary	Component Summary
General Study	Component Study
General Series	Component Series
General Equipment	NDE Equipment

10.2 *Conformance Statement*

10.2.1 From the DICOM standard a conformance statement consists of the following major parts:

10.2.1.1 an implementation model which describes the application entities in the implementation and how they relate to both local and remote real-world activities;

10.2.1.2 a more detailed specification of each application entity, listing the SOP classes supported and outlining the policies with which it initiates or accepts associations;

10.2.1.3 for each application entity and real-world activity combination, a description of proposed (for association initiation) and acceptable (for association acceptance) presentation contexts;

NOTE 2—A presentation context consists of an abstract syntax plus a list of acceptable transfer syntaxes. The abstract syntax identifies one SOP class or Meta SOP class (a collection of related SOP classes identified by a single abstract syntax UID). By listing the application entities with their proposed and accepted presentation contexts, the conformance statement is identifying the set of information objects and service classes, which are recognized by this implementation.

10.2.1.4 for each SOP class related to an abstract syntax, a list of any SOP options supported;

10.2.1.5 a set of communications protocols which this implementation supports;

10.2.1.6 a description of any extensions, specializations, and publicly disclosed Privatizations in this implementation;

10.2.1.7 a section describing DICOM/DICONDE related configuration details;

10.2.1.8 a description of any implementation details that may be related to DICOM/DICONDE conformance or interoperability.

10.2.2 A sample conformance statement is provided in Annex A1. This is an example of a conformance statement generated for computed radiology using only the DICOM database.

10.3 *Conformance Statement Construction*

10.3.1 The conformance statement for a data file to be transferred must include several aspects. First, each conformance statement is written with a specific data file type to be converted to DICOM/DICONDE compatibility. By type is meant each data acquisition device of the same version will use the same conformance statement to archive. This will permit the data file to be archived intact, with no loss or change in data, and accessible at a later date.

10.3.2 The conformance statement provided in Annex A1 provides an example of the level of detail required to fully document the data files and the transfer and communications protocols. This is only a sample of a specific conformance