Federal Working Group on Industrial Digital Radiography

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Guide for the Standardization and Management of Digital NDT Data

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Federal Working Group on Industrial Digital Radiography (FWG-IDR) - The FWG-IDR is a self chartered organization consisting of federal employees and government contract employees and is endorsed by the Defense Working Group on Nondestructive Testing (DWG-NDT). This working group provides a platform for identifying common concerns and critical issues facing the federal industrial radiographic community as it transitions from film to digital radiography (DR). The FWG-IDR, utilizing expertise from within the community, organizes and coordinates technical committees that formulate postions, guideance, and/or solutions for the community's common concerns and issues.

Background - With tremendous advances being made in digital radiography (DR), fueled largely by significant research investments by the medical community, and the acceptance by the general public of digital photography, it became apparent that digital radiography will have an ever increasing role in industrial radiography. Recognizing the value of DR, a good number of Federal Radiographic Facilities embraced the new technology in its earliest developmental stages and implemented DR technology. Spurred by this expanding use of DR and the recognition that a number of technological and process shortcomings existed, several meetings, attended by Department of Energy (DOE), Department of Defense (DOD), and other government and contractor NDT employees, were held to discuss the future vision for industrial digital radiography in the Federal community. Those meetings became the foundation for the Federal Working Group on Industrial Digital Radiography.

The attendees emerged from those first meetings with a consensus that, indeed, DR would be the future of industrial radiography and there were many areas of common concern. They further recognized that a concerted and organized effort needed to be mounted to ensure that all issues concerning transitioning from old to new technology be addressed. An extensive list of issues were discussed among these nondestruction evaluation (NDE) professionals and several topics were determined to be common amongst the attendees. These common issues were prioritized and task teams established to develop recommendations and guidance for the industrial radiographic community.

1. Scope

1.1. This paper is intended as a guide to aid in the standardization and management of nondestructive testing (NDT) data acquired in digital form, whether by direct digital data acquisition or subsequent secondary capture methods.

1.2. *Applicability*—This paper addresses the need for standardization and long term data management of NDT digital data. It reviews the driving motivational issues, the related activities of industrial societies (e.g., ASTM), the medical community and the Federal Working Group on Industrial Digital Radiography (FWG-IDR), conformance issues related to an existing standard (DICONDE), issues related to media storage and migration, procurement specifications and benefits of ready access to digital data (e.g., data analysis).

1.3. This guide does not purport to address all of the safety, quality or contractual concerns, if any, associated with its use. It is the responsibility of the user of this guide to establish appropriate safety, health and quality practices and determine the applicability of regulatory or contractual limitations prior to use.

2. Terminology

2.1. *Definitions* – Definitions relating to radiographic examination, which appear in ASTM E 1316, shall apply to the terms used in this guide.

2.2. *Definitions of Terms Specific to This Guide:*

2.2.1. *Representative Quality Indicator (RQI)* – a real part, or a fabrication of similar geometry in radiographically similar material to a real part, that has features of known characteristics that represent all of the features for which the parts to be inspected are being examined. Described in ASTM E1817.

2.2.2. *Verification* – The process by which the radiographers ensure that a technique is capable of meeting the inspection requirements in a simulated inspection using all procedures, equipment and personnel.

2.2.3. *Customer or Customer's Authorized Representative* – the company, government agency, or other authority responsible for the end use of the system or component for which radiographic examination is required.

2.2.4. *Level III Radiographer* – In this document, when the term level III radiographer is used, it is referring to a radiographer employed by the inspecting activity who is responsible for overseeing radiographic operations including but not limited to technique approval and system qualification.

3. Significance and Use

3.1. The guidance provided by this document addresses the adoption of data interoperability standards and the development of strategies for long-term NDT data management. The use of ASTM standards is encouraged.

3.2. The detailed guidance presented in this guide is applicable to all NDT data acquired in digital form. Future efforts of the FWG-IDR may address computed tomography and film digitizers if there is a clearly identified need and interest from members of the working group.

3.3. This guide is a starting point for development of a user's adoption of digital inspection systems that conform to the ASTM DICONDE standard and verification of compliance to the standard through the use of conformance statements and test procedures that validate adherence to the applicable ASTM standards. It does not present specified image quality levels as would be used to address the acceptance or rejection criteria established between two contracting parties, for example, NDT facility or consumer of NDT services, or both. It is not a detailed how-to procedure to be used by the NDT facility or consumer of NDT services.

3.4. *Motivation* – Critical national and commercial infrastructure requires data management solutions for long-term usage.

3.4.1. *Licensing of nuclear power plants* – In the United States, nuclear power plants are typically licensed for forty years, but can obtain an operating extension for an additional twenty years.

3.4.2. *Military and commercial aircraft*– Military and commercial aircraft lifespan is established based on takeoff and landing cycles and can last over twenty years; many military aircraft are more than thirty years old. The age of the B-52 bomber and the KC-135 tanker that both the U.S. Air Force and U.S. Navy rely on for refueling operations average over forty-five years old.

3.4.3. *Submarine fleets* – Submarines are designed for thirty years of use but may be retired earlier to avoid substantial retrofitting after fifteen or twenty years.

3.4.4. *Bridges* – Bridges are expected to last between fifty to seventy-five years, and some, such as the San Francisco-Oakland Bay Bridge East Span, are designed to last over one hundred years.

3.5. *Changing business environments* – Over long time periods, inspection equipment is replaced and vendors may go out of business while the need to access the data acquired with the equipment remains.

3.6. *The need for interoperability* – There is a need to promote interoperability as inspection equipment is modernized and data are transferred to the newer systems.

3.7. *Parallels in the medical community* – In the 1980's, the medical field faced a similar problem as manufacturers of medical imaging devices supported proprietary communication and data exchange mechanisms similar to those found in the NDT inspection equipment industry today(6).

3.8. *DICOM* – The DICOM (Digital Imaging and Communication in Medicine) Committee started in 1983 as a joint effort between manufacturers and users of radiological imaging equipment to produce the ACR-NEMA 300-1985 publication. This publication was revised and called the DICOM standard version 3.0 in 1993.

3.8.1. *The NDT community* – In the late 1990's, a group of experts in non-destructive evaluation examined the similarities between medical and industrial non-destructive testing (NDT) inspection systems.

3.8.2. *ASTM* – ASTM International, formerly the American Standards for Testing and Materials (ASTM), developed the Digital Imaging and Communications in Non-destructive Evaluation (DICONDE) standard based on the DICOM standard.

3.8.3. *FWG-IDR* – The Federal Working Group on Industrial Digital Radiography (FWG-IDR) attempts to address NDT data standardization and management issues. A team has been formed to develop recommendations for long-term retention of digital radiographic inspection data.

3.8.4. *Maturation of ASTM standards*– The FWG-IDR supports the continued maturation of ASTM DICONDE standards and promotes the adoption of DICONDE by DoD through the Joint Standardization Board, as well as adoption by other government agencies and government contractors. It is developing a white paper that describes the need for retaining inspection data for extended periods of time and defines the need for standardized data exchange mechanisms to preserve legacy data.

3.8.5. *Government Industry Data Exchange Program (GIDEP)*– The members of this organization share data, documentation and comments via the FWG-IDR Forum hosted by the Government-Industry Data Exchange Program (GIDEP), a cooperative activity between government and industry participants seeking to reduce or eliminate expenditures of resources by sharing technical information essential during all phases of the life cycle of systems, facilities and equipment

3.8.6. *The need for new Information Object Definitions* – As DICONDE has evolved, there has been an obvious need to include more NDE inspection metadata into the standard. The additional metadata identified is often specific to only one NDE modality requiring new Information Object Definitions (IODs).

3.8.7. *ASTM Participation by FWG-IDR members* – FWG-IDR is promoting the active involvement of its members in ASTM subcommittees to extend existing ASTM standards related to both new NDT imaging modalities and NDT data management

4. ASTM Standards for Data Management

4.1. *ASTM E07.11 subcommittee* – The Data Standardization and Management Task Group of the Federal Working Group for Industrial Digital Radiography (FWG-IDR) promotes the adoption of American Society of Testing & Materials (ASTM International) Standards.

4.2. *FWG-IDR* – The FWG-IDR provides guidelines and recommendations for data management and the adoption of ASTM standards by government agencies and government contractors.

4.3. *Data Retention Requirements* – Federal agencies or their contractors are required to maintain NDT data for twenty to fifty years. The Department of Defense, Department of Energy and the National Aeronautics and Space Administration (NASA).

4.4. *Adoption of International Standards* – The FWG-IDR proposes the adoption of internationally recognized standards to reduce the costs associated with legacy data usage and conversion while exploiting the ease of storage, retrieval and dissemination of digital data.

4.5. *ACR NEMA DICOM standard* – The medical community has developed the DICOM standard and utilizes Picture Archiving and Communication Systems (PACS) for storage and retrieval of medical imagery and metadata. Similarly, the industrial radiography community can take full advantage of the capabilities of digital radiography by adopting the ASTM DICONDE standard that addresses the storage, retrieval and dissemination of digital NDT data, including radiographic inspection data.

4.6. *Adoption of the ASTM DICONDE standard* – This team is developing a set of recommendations for adopting the ASTM DICONDE standard as it is applied to NDT imaging modalities such as computed radiography, digital radiography and computed tomography.

4.7. *Adoption of other ASTM standards* – FWG-IDR is also leading efforts to review and revise existing ASTM standards for media archival and retention to incorporate storage media such as CDs and DVDs.

4.8. *Participation in ASTM activities* – Many NDT professionals working for the Federal government or Federal contractors participate in the ASTM standards development process. FWG-IDR has encouraged increased involvement in the development of new Information Object Definitions for DICONDE. Many of the Information Modules and Attributes defined within the DICOM standard can be adapted to DICONDE usage either directly or by close analogy.

4.9. *DICONDE Information Modules* – For example, the Image Pixel Information Module or the Device Serial Number Attribute are the same for medical or industrial usage and used directly by DICONDE. Although there is no concept of a patient in industrial inspection application, the component being inspected is analogous to the patient in medical imaging applications. In DICONDE the Patient Information Module is transformed into the Component Information Module and the Patient ID Attribute is reused as Component ID.

4.10. *Modules and attributes specific to NDT* – Some DICOM Information Modules or Attributes, however, have no correlation to non-destructive evaluation. In those cases, they are typically ignored by DICONDE. Some concepts, such as geometrical information and X-ray energy levels, are used in the NDE arena but cannot be represented by existing DICOM constructs. In these cases, DICONDE introduces new Information Modules or Attributes as needed describe the required metadata.

4.11. *NDE Geometry Module* – The ASTM DICONDE standard E2339 has recently introduced a new NDE Geometry Module to contain data about the part and scanner coordinate systems required by some inspection techniques. It also specifies any transformation matrices needed to define scaling, translation or rotational operations.

4.12. *NDE Indication Module* – In similar fashion, a new NDE Indication module has been adopted to allow the specification of indications found by a reviewer of the image. The indication types may be a void, crack, porosity or inclusions. Disposition of the indication include acceptance, rejection or hold for further inspection. Another major difference between the two standards is the increased use of code sequences within the medical industry.

4.13. *Industrial Usage* – DICOM is promoting an increased use of pre-defined code sequences developed for the medical industry. In NDE, wider ranges of objects are inspected and sets of predefined codes typically are not used. Both raw and calibration data are typically not stored for medical applications where they are required for industrial imaging, but this data is required by ASTM standards relating to inspection test methods. High-energy sources are not well represented in DICOM as NDE exposures cannot be expressed solely in Rads.

4.14. *Methodology* – A methodology has been proposed to generate new ASTM draft standards that contain information specific to individual inspection modalities. The ASTM standard for ultrasonic test methods was published in 2008 and other standards are being developed for X-ray computed tomography and digital radiography using this methodology.

5. Determining Conformance to the ASTM DICONDE Standard

5.1. *The Use of Conformance Statements* – Conformance statements are documents created by vendors to demonstrate their product's DICONDE compliance and permit comparison between vendor products.

5.1.1. *The Parts of a Conformance Statement* – A typical conformance statement identifies the storage classes that can be transmitted and indicates any vendor extensions, specializations or privatizations to modules (e.g., the use of any private tags).

5.1.2. *Simultaneous Associations* – An association is an active DICONDE connection between two application entities. A conformance statement specifies the number of simultaneous associations a device can service, which can have a tremendous impact on performance and the level of resources required to serve associations.

5.1.3. *Communication Profiles*– A conformance statement describes any unique communication profiles. The communication profile describes any special networking protocol used by the device.

5.2. *Media Storage for Data Exchange* – Several parts of the DICOM standard address data exchange and these exchange mechanisms have been adopted by DICONDE.

5.3. *Support for Service-Object Pair (SOP) Classes*– A conformance statement documents all of the Service-Object Pair (SOP) classes that are supported by the NDT imaging device. Two imaging devices can share data only when they both support the same SOP class.

5.4. *Future Conformance Testing* – Future ASTM activities may support the development of DICONDE interoperability CDs or test suites as companions to the conformance statements. This would greatly accelerate the adoption of DICONDE-compliant solutions as federal NDT and government procurement personnel could perform an objective evaluation of each vendor's product.

The need for test suites – FWG-IDR is developing recommendations for creating a suite of DICONDE interoperability tests to validate metadata, Part 10 CDs and DICONDE messaging between workstations and NDT imaging devices. This suite of tests would complement the vendor's conformance statement by exercising the features of a vendor's products to verify compliance with the DICONDE standard.

6. Media Management

6.1. *Media Loss or Obsolescence*– The impermanence of digital media has been recognized for several years, and researchers have suggested the use of standards and emulation to solve problems associated with obsolete storage media and proprietary formats.

6.2. *Part 10 of DICOM standard, CDs and DVDs*– Part 10 of the DICOM standard discusses the use of CDs and DVDs to store data.

6.3. *Blue-Ray Storage Media* – With the advent of Blue-Ray storage media, portable storage has increased dramatically. While not explicitly mentioned in DICOM or ASTM standards, this storage media can follow the same guidelines for CDs and DVDs.

6.4. *Caveats*– While this increase in capacity permits multiple studies or emerging multiframe studies to be stored on a single Blueray disk, care must be taken to ensure that this media is duplicated so that media failure will not result in the loss of data.

6.5. *Tests for Storage Degradation*– ISO/IEC 10995 discusses a set of tests performed to assess the degradation of CD and DVD media under various environmental conditions.

7. Technology Migration

7.1. *Importance of Technology Migration*– Several case studies show the importance of technology migration.

7.1.1. *Case studies on data migration and loss* - From 1976 through 1979, the National Archives worked on certain 1960 Census data from magnetic tapes designed to run on obsolete computers. While no data was actually lost, significant effort and expense was expended to retain this data in computerized form.

7.1.2. *Case studies on data migration and loss (Part II)* - By the mid-1980's, computerized land use maps of the state of New York from the 1960s were lost, leaving them only available in print.

7.1.3. *Case studies on data migration and loss (Part III)* - In another instance, satellite observations of Brazil in the 1970's were lost irretrievably.

7.2. *Identification and prioritization of critical data* - The most important task in technology migration is the identification of the most valuable data and the establishment of a schedule to migrate this data to newer media on a schedule. Most of the failures have involved the loss of data or a large expense in recovering data from media that had been ignored for long periods of time. The goal of FWG-IDR is to raise awareness of the issues involved in technology migration.

7.3. *Centrally-managed digital archives*– Centrally-managed digital archives would follow backup schedules with disaster recovery procedures.

7.4. *Migration schedules*– DICONDE-compliant software systems can store studies on RAID systems and migrate data to newer media on a prescribed schedule. This approach, however, requires adequate funding to procure new media and support data migration.

8. Procurement Specifications

8.1. *Procurement Specifications* - Consistent procurement specifications should be developed that call for the acquisition of systems that conform to the ASTM 2339 DICONDE standard.

8.2. *Generic Purchase Requisition*–A generic purchase requisition with standard contractual language would facilitate the procurement of hardware and software that complies with the ASTM DICONDE standard.

8.3. *Terms of Compliance*– Contractual language must demand conformance statements from vendors who have responded to a request for proposal (RFP) call.

9. Data Analysis

9.1. *Data mining* – Data mining of metadata could provide NDT technicians with valuable insight into possible performance degradation of NDT imaging equipment over time.

9.1.1. *Usage Statistics* – Through usage statistics, performance degradation of NDT equipment could be identified. For example, in a computed radiography application, the number of plate exposures might be correlated to decreased image quality to identify subtle, yet meaningful, changes in the inspection process.

9.1.2. *Calibration data* – Similarly, the analysis of calibration data on a DDA might identify increasing numbers of bad pixels, indicating panel degradation which could yield decreased defect detectability.

9.2. *Component ageing studies* – Component aging studies could be supported by metadata analysis.

9.3. *Study of legacy data management* – Quantitative studies of legacy data management costs may demonstrate the efficacy of data standardization and management techniques to minimize these costs. Significant cost savings by the Federal government and its contractors is a motivating factor in devising a unified approach to standardization and management of NDT data.

10. Reference Documents

10.1. The following documents are referenced in this guide or may be useful to activities qualifying, approving and/or auditing DR systems.

10.2. DICOM Standard

Digital Imaging and Communications in Medicine (DICOM), PS3-2008, National Electrical Manufacturers Association, Rosslyn, VA, 2008.

10.3. ASTM Standards:

- CP 189 Standard for Qualification and Certification of Nondestructive Testing Personnel
- E 94 Standard Guide for Radiographic Examination
- E 543 Standard Specification for Agencies Performing Nondestructive Testing
- E 747 Standard Practice for Design, Manufacture and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology
- E 1000 Guide for Radioscopy
- E 1025 Standard Practice for Design, Manufacture and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiology
- E 1254 Standard Guide for Storage of Radiographs and Unexposed Industrial Radiographic Films
- E 1255 Standard Practice for Radioscopy
- E 1316 Standard Terminology for Nondestructive Examinations
- E 1411 Standard Practice for Qualification of Radioscopic Systems
- E 1441 Guide for Computed Tomography (CT) Imaging
- E 1453 Standard Guide for Storage of Media that Contains Analog or Digital Radioscopic Data
- E 1475 Standard Guide for Data Fields for Computerized Transfer of Digital Radiological Examination Data
- E 1647 Standard Practice for Determining Contrast Sensitivity in Radiology
- E 1695 Standard Test Method for Measurement of Computed Tomography (CT) System Performance
- E 1742 Standard Practice for Radiography Examination

E 1817 Standard Practice for Controlling Quality of Radiological Examination by Using Representative Quality Indicators (RQIs)

E 2002 Standard Practice for Determining Total Image Unsharpness in Radiology

E 2007 Standard Guide for Computed Radiology (Photostimulable Luminescence (PSL) Method)

E 2033 Practice for Computed Radiology (PSL Method)

E 2339 Standard Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE)

E 2445 Standard Practice for Qualification and Long-Term Stability of Computed Radiology Systems

E 2446 Standard Practice for Classification of Computed Radiology Systems

E 2597 Standard Practice for Manufacturing Characterization of Digital Detector Arrays

E 2446 Standard Practice for DICONDE Ultrasonic Test Methods

E 2xxx Standard Practice for DICONDE Digital Radiography Systems

E 2xxx Standard Practice for DICONDE Computed Tomography Test Methods

10.4. Aerospace Industries Association Document:

NAS 410 NAS Certification and Qualification of Nondestructive Test Personnel

10.5. ASNT Documents:

SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing

10.6. Government Standard:

MIL-STD-746 Radiographic Testing Requirements for Cast Explosives

10.7. Other Government Documents:

NIST Handbook 114 General Safety Standard for Installations using Non-Medical and Sealed Gamma Ray Sources, Energies up to 10 MeV

10.8. SMPTE Specification:

RP 133 Specifications for Medical Diagnostic Imaging Test Pattern for Television Monitors and Hard-Copy Recording Cameras

10.9. ISO/IEC Standards

ISO/IEC 10995, 2008. "Information technology -- Digitally recorded media for information interchange and storage -- Test method for the estimation of the archival lifetime of optical media."

10.10. Journal Articles or Texts

James G. Hewlett, "The Operating Costs and Longevity of Nuclear Power Plants," Energy Policy, 20(7), 1992, pp. 608-622.

Greenberg, Jr., Sydney J., "Wear and tear adds up on military aircraft," National Journal, March 21, 2008.

Zimmermann, Stan, Submarine Technology for the 21st Century, 2nd edition, Trafford Publishing, 2000.

Moses, Fred, "Bridge Reliability Concepts and Methods," in Dan M. Frangopol, Bridge Safety and Reliability, Dan M. Frangopol (ed.), American Society of Civil Engineers (ASCE) Publications, 1999.

Oosterwijk, Herman, DICOM Basics, 3rd edition, OTech, Inc., Aubrey, Texas, 2005.

Rothenberg, Jeff, "Ensuring the Longevity of Digital Information," Scientific American, vol. 272, No. 1, pp. 42-47, 1995