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Standard Guide for Computed Tomography (CT) System Selection[1]

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This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This guide covers guidelines for translating application requirements into computed tomography (CT) system requirements/specifications and establishes a common terminology to guide both purchaser and supplier in the CT system selection process. This guide is applicable to the purchaser of both CT systems and scan services. Computed tomography systems are complex instruments, consisting of many components that must correctly interact in order to yield images that repeatedly reproduce satisfactory examination results. Computed tomography system purchasers are generally concerned with application requirements. Computed tomography system suppliers are generally concerned with the system component selection to meet the purchaser's performance requirements. This guide is not intended to be limiting or restrictive, but rather to address the relationships between application requirements and performance specifications that must be understood and considered for proper CT system selection.

1.2 Computed tomography (CT) may be used for new applications or in place of radiography or radioscopy, provided that the capability to disclose physical features or indications that form the acceptance/rejection criteria is fully documented and available for review. In general, CT has lower spatial resolution than film radiography and is of comparable spatial resolution with digital radiography or radioscopy unless magnification is used. Magnification can be used in CT or radiography/radioscopy to increase spatial resolution but concurrently with loss of field of view.

1.3 Computed tomography (CT) systems use a set of transmission measurements made along a set of paths projected through the object from many different directions. Each of the transmission measurements within these views is digitized and stored in a computer, where they are subsequently conditioned (for example, normalized and corrected) and reconstructed, typically into slices of the object normal to the set of projection paths by one of a variety of techniques. If many slices are reconstructed, a three dimensional representation of the object is obtained. An in-depth treatment of CT principles is given in Guide E1441.

1.4 Computed tomography (CT), as with conventional radiography and radioscopic examinations, is broadly applicable to any material or object through which a beam of penetrating radiation may be passed and detected, including metals, plastics, ceramics, metallic/nonmetallic composite material and assemblies. The principal advantage of CT is that it has the potential to provide densitometric (that is, radiological density and geometry) images of thin cross sections through an object. In many newer systems the cross-sections are now combined into 3D data volumes for additional interpretation. Because of the absence of structural superposition, images may be much easier to interpret than conventional radiological images. The new purchaser can quickly learn to read CT data because images correspond more closely to the way the human mind visualizes 3D structures than conventional projection radiology. Further, because CT images are digital, the images may be enhanced, analyzed, compressed, archived, input as data into performance calculations, compared with digital data from other nondestructive evaluation modalities, or transmitted to other locations for remote viewing. 3D data sets can be rendered by computer graphics into solid models. The solid models can be sliced or segmented to reveal 3D internal information or output as CAD files. While many of the details are generic in nature, this guide implicitly assumes the use of penetrating radiation, specifically X rays and gamma rays.

1.5 *Units*—The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units that are provided for information only and are not considered standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the*

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[1] This guide is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.01 on Radiology (X and Gamma) Method.

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***A Summary of Changes section appears at the end of this standard**

responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E1316 Terminology for Nondestructive Examinations
E1441 Guide for Computed Tomography (CT) Imaging
E1570 Practice for Computed Tomographic (CT) Examination
E2339 Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE)
E2767 Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE) for X-ray Computed Tomography (CT) Test Methods

3. Terminology

3.1 *Definitions*—For definitions of terms used in this guide, refer to Terminology E1316 and Guide E1441, Appendix X1.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *purchaser*—purchaser or customer of CT system or scan service.

3.2.2 *scan service*—use of a CT system, on a contract basis, for a specific examination application. A scan service acquisition requires the matching of a specific examination application to an existing CT machine, resulting in the procurement of CT system time to perform the examination. Results of scan service are contractually determined but typically include some, all, or more than the following: meetings, reports, images, pictures, and data.

3.2.3 *subsystem*—one or more system components integrated together that make up a functional entity.

3.2.4 *supplier*—suppliers/owners/builders of CT systems.

3.2.5 *system component*—generic term for a unit of equipment or hardware on the system.

3.2.6 *throughput*—number of CT scans performed in a given time frame.

4. Summary of Guide

4.1 This guide provides guidelines for the translation of examination requirements to system components and specifications. Understanding the CT purchaser's perspective as well as the CT equipment supplier's perspective is critical to the successful acquisition of new CT hardware or implementation, or both, of a specific application on existing equipment. An understanding of the performance capabilities of the system components making up the CT system is needed in order for a CT system purchaser to prepare a CT system specification. A specification is required for acquisition of either CT system hardware or scan services for a specific examination application.

4.2 Section 7 identifies typical purchaser's examination requirements that must be met. These purchaser requirements factor into the system design, since the system components that are selected for the CT system will have to meet the purchaser's requirements. Some of the purchaser's requirements are: the ability to support the object under examination, that is, size and weight; detection capability for size of defects and flaws, or both, (spatial resolution and contrast discrimination); dimensioning precision; artifact level; throughput; ease of use; archival procedures. Section 7 also describes the trade-offs between the CT performance as required by the purchaser and the choice of system components and subsystems.

4.3 Section 8 covers some management cost considerations in CT system procurements.

4.4 Section 9 provides some recommendations for the procurement of CT systems.

5. Significance and Use

5.1 This guide will aid the purchaser in generating a CT system specification. This guide covers the conversion of purchaser's requirements to system components that must occur for a useful CT system specification to be prepared.

5.2 Additional information can be gained in discussions with potential suppliers or with independent consultants.

5.3 This guide is applicable to purchasers seeking scan services.

5.4 This guide is applicable to purchasers needing to procure a CT system for a specific examination application.

6. Basis of Application

6.1 The following items should be agreed upon by the purchaser and supplier.

6.1.1 *Requirements*—General system requirements are covered in Section 7.

7. Subsystems Capabilities and Limitations

7.1 This section describes how various examination requirements affect the CT system components and subsystems. Trade-offs between requirements and hardware are cited. Table 1 is a summary of these issues. Many different CT system configurations are possible due to the wide range of system components available for integration into a single system. It is important to understand the capability and limitations of utilizing one system component over another as well as its role in the overall subsystem. Fig. 1 is a functional block diagram for a generic CT system.

7.1.1 *Pencil-Beam, Fan-Beam and Cone-Beam Type Systems:*

7.1.1.1 *Pencil Beam Systems*—The x-ray beam is collimated to a pencil and the effective pixel size becomes the size of the beam on the detector area. The beam is translated over the object and the object rotated after each pass of the beam over the object or the beam and detector are translated and rotated around the object to build up linear slice profiles. If a three dimensional data set is desired the object or beam/detector

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

TABLE 1 Computed Tomography (CT) System Examination Requirements and Their Major Ramifications

Requirement	Components/Subsystems Affected	Reference
Object, size and weight	Mechanical handling equipment	7.2
Object radiation penetrability	Dynamic range	7.3
	Radiation source	7.3.1
Detectability		7.4
Spatial resolution	Detector size/aperture	7.4.1.1
	Source size/source spot size	7.4.1.2
	Mechanical handling equipment	7.4.1.5
Contrast discrimination	Strength/energy of radiation source	7.4.2
	Detector size/source spot size	7.4.2.1
Artifact level	Mechanical handling equipment	7.4.3
Throughput/speed of CT process		7.5
Scan time	(Spatial resolution)	7.5.1
	(Contrast discrimination)	
Image matrix size (number of pixels in image)	Number/configuration of detectors	7.5.2
	Amount of data acquired	
	Computer/hardware resources	
Slice thickness range	Detector configuration/collimators	7.5.3
	System dynamic range	
Operator interface		7.6
	Operator console	7.6.1
	Computer resources	7.6.2
Ease of use		7.6.3
Trade-offs		7.6.4

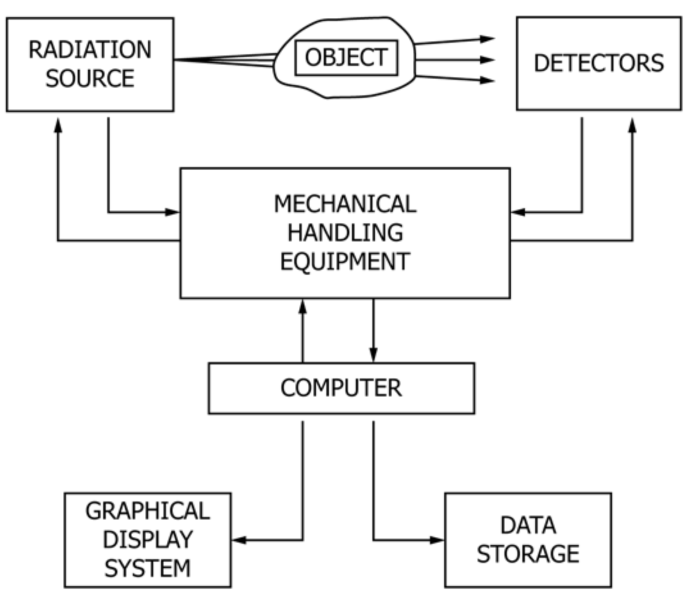

FIG. 1 Functional Block Diagram for a Generic CT System

must elevate so that multiple slices are generated. The advantage of this method is detector simplicity and scatter rejection with the primary disadvantage being long scan times.

7.1.1.2 *Fan-Beam Systems*—The x-ray beam is collimated to a fan and detected by a linear detector array that usually has a collimator aperture. The pixel size is defined by the width of the fan-beam on the detector height (vertically) and by the detector element pitch (horizontally). Linear profiles are captured as the object or beam/detector rotates. If three dimensional data is desired the object or beam/detector must elevate to capture multiple slices. The advantage of this method is faster scan times than pencil-beam systems and some scatter rejection with the primary disadvantage being long scan times for 3D data.

7.1.1.3 *Cone-Beam Systems*—The x-ray beam is usually collimated to the entire or a selected portion of the active area of a two dimensional detector array and full 2D images are captured as the object or beam/detector rotates. In this manner multiple slices are generated without needing to elevate. The primary advantage of this technique is speed or acquiring 3D data, with the primary disadvantage being increased scatter due to larger field of view.

7.2 *Object, Size and Weight*—The most basic consideration for selecting a CT system is the examination object's physical dimensions and characteristics, such as size, weight, and material. The physical dimensions, weight, and attenuation of the object dictate the size of the mechanical subsystem that handles the examination object and the type of radiation source and detectors, or both, needed. To select a system for scan services, the issues of CT system size, object size and weight, and radiation energy must be addressed first. Considerations like detectability and throughput cannot be addressed until these have been satisfactorily resolved. Price-performance tradeoffs must be examined to guard against needless costs.

7.2.1 The maximum height and diameter of an object that can be examined on a CT system defines the equipment examination envelope. Data must be captured over the entire width of the object for each view. If the projected x-ray beam through the object does not provide complete coverage, the object or beam/detector must translate. Some specialized algorithms may allow the reduction of this requirement but detectability and scan time may be affected. The weight of the object and any associated fixturing must be within the manipulation system capability. For example, a very different mechanical sub-system will be required to support and accurately move a large, heavy object than to move a small, light object. Similarly, the logistics and fixturing for handling a large number of similar items will be a much different problem than for handling a one-of-a-kind item.

7.2.2 *Two Most Common Types of Scan Motion Geometries*—Both geometries are applicable to 2D fan beam or 3D cone beam systems.

7.2.2.1 *Translate-Rotate Motion*—The object or detector is translated in a direction perpendicular to the direction and parallel to the plane of the X-ray beam. Full data sets are obtained by rotating the article between translations by the fan angle of the beam and again translating the object until a minimum of 180° of data have been acquired. The advantage of this design is simplicity, good view-to-view detector matching, flexibility in the choice of scan parameters, and ability to accommodate a wide range of different object sizes, including objects too big to be subtended by the X-ray fan. The disadvantage is longer scan time. Reconstruction software must correctly account for fan/cone beam effects which can be complicated by translation of the object.

7.2.2.2 *Rotate-Only Motion*—The object remains stationary and the source and detector system is rotated around it or the object rotates and the source and detector remain stationary. A complete view is generally collected by the detector array