

A DICOM Compatible Format for Analytical Cytology Data

Robert C. Leif and Suzanne B. Leif

Ada_Med, a Division of Newport Instruments, 5648 Toyon Road, San Diego, CA 92115;

E-mail rleif@rleif.com

ABSTRACT

The addition of a list mode data type to the Digital Imaging and Communications in Medicine standard, DICOM will enhance the storage and transmission of digital microscopy data and extend DICOM to include flow cytometry data. This would permit the present International Society for Analytical Cytology Flow Cytometry Standard to be retired. DICOM includes: image graphics objects, specifications for describing: studies, reports, the acquisition of the data, work list management, and the individuals involved (physician, patient, etc.). The glossary of terms (objects) suitable for use with DICOM has been extended to include the collaborative effort of Logical Observation Identifier Names and Codes (LOINC) and Systematized Nomenclature of Human and Veterinary Medicine (SNOMED) to create a consistent, unambiguous clinical reference terminology. It also appears that DICOM will be a significant part of the Common Object Request Broker Architecture, CORBA.

Keywords: FCS, Flow Cytometry, Microscopy, DICOM, Software, Database, CORBA, Standards

1. INTRODUCTION

A recent publication¹ described the proposed third version of the International Society for Analytical Cytology, ISAC, Flow Cytometry Standard (FCS) to permit data interchange. Unfortunately, the proposed FCS 3.0 is neither suitable for electronic transmission of data nor as an active data store for flow cytometry data. However, FCS 3.0 is a reasonable format for archiving data. The simplest long term solution² is to replace FCS 3.0 with the Digital Imaging and Communications in Medicine^{3,4,5}, DICOM 3.0 standard. The addition of a list mode data type to DICOM Supplement 15, Visible Light Image, Anatomic Frame of Reference, Accession, and Specimen for Endoscopy, Microscopy, and Photography⁶ will be of use for digital microscopy and will suffice for extending Supplement 15 to include flow cytometry. The use of DICOM directories permits the binary data produced by analytical cytology instrumentation to be stored in and transmitted as multiple files. The utility of employing DICOM for flow cytometry will be demonstrated with an example based on the requirements specified from the clinical flow cytometry literature.

The first steps in designing a medical software project are to determine the requirements and perform a preliminary hazard analysis⁷. Since software standards, such as FCS 3.0 or DICOM 3.0, specify at a detailed level the format and methods (functions and procedures) of data types, these standards are part of the development of medical devices. There has been only one significant change proposed to either the requirements or hazards that we previously published and posted on the ISAC Web Site⁸. There was an unofficial consensus at the International Society for Analytical Cytology, ISAC, Asilomar 1997 meeting that the Flow Cytometry Standard including its third version, FCS 3.0, was not designed for data transfer over the Internet or similar medium. FCS was designed primarily for data storage. Since there is an obvious need to transfer data between laboratories, the requirement for data transfer has been kept and has been expanded to include the use of the Internet.

DICOM Supplement 15, "Visible Light Image, Anatomic Frame of Reference, Accession, and Specimen for Endoscopy, Microscopy, and Photography", requires a small addition to include the data produced by the two major methodologies of analytical cytology, digital microscopy and flow cytometry. The list mode data format, which is presently primarily associated with flow cytometry, must be described as additional DICOM Information Object (class). List mode data is presently described⁹ as "a continuous bit stream with no delimiters". A list mode file can be represented as an array of one to the total number of cells where each element of the array includes the data associated with one cell or particle.

2. ANALYTICAL CYTOLOGY REQUIREMENTS FOR DICOM

- Req.1 Analytical cytology data must be formatted to permit the information to be accessed by multiple programs including those created by third parties.
- Req.2 The analytical cytology data together with other relevant data such as that described in Supplement 15 must be in a form where it can be reliably transferred between computers of the same or different types. The data transfer can be: by the transfer of media, such as CD-ROMs, over an intranet (local area network), or via the Internet.
- Req.3 The analytical cytology data format should facilitate archival storage.
- Req.4 The addition of flow cytometry data should result in minimal additions or changes to the existing DICOM Standard.

In fact, since the proposed list mode data type is useful for digital microscopy, no flow cytometry specific addi-

tions are proposed. The changes to the existing DICOM standard have been minimized by the use of inheritance where the new data structures are derived from already existing data structures. The bivariate histogram and list mode data formats described below are examples of this.

3. Flow Data File Classes:

3.1. Flow Data:

Since the cell parameter data produced by the flow cytometers and cell sorters is most often the largest component of any file or data transmission, it will be discussed first. Flow instruments employ analog to digital converters ADCs to convert information describing the electronic pulses from each of the measured parameters into unsigned integers, which range between 8 and usually 16 bits. An effective increase in this range can be achieved by employing multiple gains on the preamplifier associated with each ADC. In any event, for the present and normal five to ten year period between revision of a standard, unsigned 32 bit integers should be more than sufficient to store the data produced by any flow cytometry or digital microscopy transducer. The dynamic range of available ADCs and of the actual signals is less than 1 to 2^{32} (4 billion). Although, the mathematical functions employed to analyze and combine parameters can result in data that is expressed in a floating point format, the precision of these calculations is still limited to the precision of the original integer data. Therefore, after appropriate scaling, the data in floating point format can be transformed into a suitable unsigned integer format without any loss of precision. In fact, the resolution of transformed or normalized data is usually less than one part per thousand.

FCS presently stores three representations of the data. The first is described⁹ as an “uncorrelated univariate histogram”. This is the very common single parameter histogram of an experimental or calculated value (ordinate) versus an evenly spaced set of values (abscissa), such as integers. For flow cytometry, this is a pulse-height distribution, the number of events that occurred for a given ADC increment. The ordinate values are the number of events with the same ADC value and the abscissa is the ADC values, which corresponding to the number of channels (bins) employed to resolve the data. The second is described⁹ as a “correlated multivariate histogram”. By far, the most common form of this is the bivariate histogram is the familiar x versus y plot. The third is list mode, which was briefly described above. The data is expressed as an array equal to the number of events (individual cells or particles) with each event consisting of one or generally more parameters. The total number of bytes and the layout of the fields which describe each of the events is constant for all events.

3.2. Uncorrelated univariate histograms:

The DICOM Curve class can be used to model these or alternatively, the histograms can be put into a text file. Supplement 23 defines¹⁰ the CURVE Class (Table 1) to be a binary representation of vector (n-dimensional) data. The data types in Table 1 which describe DICOM Curves were abstracted from the Registry of DICOM Data Elements^{3, Part 6}. The Curve class has been provided with only a minimal specification. The Curve class^{3, Part 3} includes all of the information necessary to plot single parameter data and a Curve Directory Record Type which permits the storage of multiple files each of which contains one or more curves. These curves can have up to 2^{16} values, which all are of one data type. The data types for Curves include: unsigned short (unsigned 16 bit integers), signed short (signed 16 bit integers), floating point single precision, floating point double precision, and signed long (signed 32 bit integers). Both ASCII data and Unsigned 32 bit integers, which are standard FCS 3.0 numeric types were omitted from DICOM Curves. However, unsigned 32 bit integers are a standard DICOM data type.

Table 1 Curve Data Types from the DICOM Data Dictionary*

Hexadecimal Tag	DICOM Name	#Val.	Description	Comment	Length in Bytes
(0008,0025)	Curve Date	1	Date Decimal_String	yyyymmdd	8
(0008,0035)	Curve Time	1	Time	hhmmss.frac	16 Max
(0008,1145)	Referenced Curve Sequence	1	Sequence of Items	This permits multiple curves to be in 1 file.	
(0020,0024)	Curve Number	1	Integer String	“0”..”9”, “+”, “-”	12
(50xx,0005)	Curve Dimensions	1	Unsigned Short	16 Bit Unsigned Integer	2
(50xx,0010)	Number of Points	1	Unsigned Short	16 Bit Unsigned Integer	2
(50xx,0020)	Type of Data	1	Code String	Up_Char, “0”..”9”, “ ”, “_” of the Default_Char Rep.	16 Max

Table 1 Curve Data Types from the DICOM Data Dictionary*

(50xx,0022)	Curve Description	1	Long String	No '\ Delimiter	64 Max
(50xx,0030)	Axis Units	1-n	Short String	No '\ Delimiter	16 Max
(50xx,0040)	Axis Labels	1-n	Short String	No '\ Delimiter	16 Max
(50xx,0103)	Data Value Representation	1	Unsigned Short	16 Bit Unsigned Integer	2
(50xx,0104)	Minimum Coordinate Value	1-n	Unsigned Short	16 Bit Unsigned Integer	2
(50xx,0105)	Maximum Coordinate Value	1-n	Unsigned Short	16 Bit Unsigned Integer	2
(50xx,0106)	Curve Range	1-n	Short String	No '\ Delimiter	16 Max
(50xx,0110)	Curve Data Descriptor	1	Unsigned Short	16 Bit Unsigned Integer	2
(50xx,0112)	Coordinate Start Value	1	Unsigned Short	16 Bit Unsigned Integer	2
(50xx,0114)	Coordinate Step Value	1	Unsigned Short	16 Bit Unsigned Integer	2

* The first column contains the unique 32 bit unsigned number which is the Hexadecimal Tag that uniquely identifies the data type. The column labeled #Val. specifies the number of values for the item. For instance, one axis can have multiple labels. The last column, Length in Bytes, shows either a constant or the maximum, Max., number of bytes for the data type.

3.2.1. Tab Delimited Format: Often, multiple histograms of the same length are best kept together in the same file. The simplest solution is to employ the standard commercial software format that is employed to import text files into spreadsheets. The total number of events for each parameter will be placed sequentially on one line and be separated by a “Tab”. Table 2 is a simple example of this. The first line has the name of each parameter. The number of lines minus one will equal the range (length) of the histograms. The total number of events or other ordinate value is expressed as either a DICOM Integer String (12 bytes) or a Decimal String (16 bytes). This is equivalent to but simpler than the FCS 3.0 use of the ASCII data type. Although this proposed Tab Delimited Format data type is not absolutely essential for or even specific to analytical cytology, it would facilitate the exchange of data.

Table 2 Tab Delimited Format

Chan_Num	Tab	LowAngle	Tab	WideAngle	Tab	DAPI	Tab	CD4_Fluor
0	Tab	10	Tab	0	Tab	5	Tab	150
1	Tab	20	Tab	7	Tab	20	Tab	75
2	Tab	50	Tab	17	Tab	30	Tab	50
100	Tab	750	Tab	250	Tab	500	Tab	300
255	Tab	75	Tab	29	Tab	0	Tab	0

3.3. Correlated Multivariate Histogram:

As stated above, the most common version of this is the ubiquitous two dimensional graphs which are present in scientific publications. These are also generated by conventional off-the-shelf software, such as spreadsheets. They can be described employing DICOM, PART 3: Information Object Definitions, Section C.7.6.3.1 Image Pixel Attribute Descriptions with two changes. The origin (0.0, 0.0) must be set at the lower rather than the upper left hand corner. For two dimensional graph data, the order of pixels sent for each image plane will be left to right, bottom to top (lower left pixel, followed by the remainder of row 1, followed by the remainder of the columns). Concerning Samples per Pixel, the DICOM Standard allows but does not define more than 4 separate image planes per pixel. Since often, flow data is presented with each cell population being assigned a different color and more than 4 different types of cells are present, an extension to the standard is required. This increase in the number of image planes is also required for presenting the data from digital microscopes, which often produce a greater number of parameters than flow cytometers.

An increasingly common display in Analytical Cytology is a rotating cube. Three of the parameters correspond to the x, y, and z axes. Three or more additional parameters can be displayed as colors. The data for these displays is often in list mode format (Section 3.4).

The capacity to label human or algorithm selected areas of a bivariate distribution is provided by Part 3, Section A.1.2.7. It defines an overlay as being able to be represented in bit-mapped, graphics or text formats and being “used to indicate such items as region of interest, reference marks and annotations.”

3.4. List Mode Files:

Neither the DICOM Visible Light Image Supplement nor Part 3 describes a data structure which could be used for list mode data. Two existing data types, Pixel Data Type and CURVE, can be extended or modified to include list mode data.

3.4.1. Pixel Data Approach: Removing the columns from the Pixel Data type⁶ results in a single row. Presently, the number of pixels in a row is equal to the number of columns. Both the number of columns and rows are 16 bit unsigned Integers. The number of cells or particles often exceeds 2^{16} . Therefore the range must be extended to 32 bit unsigned integers. The individual values for each cell can be treated as described for Planar Configuration which can be set to color-by-pixel. Each pixel has a multiparameter color vector. The present standard, as stated above, does not define more than four parameters. This increase will also be needed for modern multiparameter digital microscopes and confocal microscopes, particularly those equipped with spectrometric capabilities.

3.4.2. DICOM Curve Approach: The changes to the DICOM Curve class required for use with list mode data are: 1) all of the 16 bit unsigned integer types in Table 1 need to also be available as 32 bit unsigned Integers; and 2) the requirement^{3, Part 3}, "All dimensions shall have the same value representation." must be changed to permit the parameters associated with cells to be of different data types.

3.4.3. Measured parameters: The limitation of representing the measured parameters by unsigned integers described above is deliberately inconsistent with the present Flow Cytometry Standard which includes: unsigned binary integer (either 16 or 32 bits), single precision IEEE floating point, double precision IEEE floating point, and ASCII. As was argued in Section 3.1, unsigned 16 bit or 32 bit integers are sufficient to represent the data produced by all of the transducers of a flow cytometer. These transducers include: light scattering at different angles to determine cell size and granularity, fluorescence to measure the amount of a given molecular species and sometimes the state of that species, and the two electronic parameters, cell volume (DC) and radio-frequency impedance. The electronic parameters are presently used for commercial hematology analyzers, which are a specialized version of a flow cytometer. Two other parameters are the acquisition time of the individual cells and an enumerated type which describes the assignment to a cell class produced by a previous analysis of the data. The acquisition time starts at the beginning of an experiment and increases linearly.

3.4.4. Digital microscopy: Although List mode data is presently associated with flow cytometry, it is directly relevant to digital microscopy. As defined in Supplement 15, the X and Y offsets in millimeters from the Origin of the Slide Coordinate System of each cell can be included as two parameters, which can be used to relocate individual cells. These cells can have specific values for individual parameters or have previously been classified. The data type of these offsets is a Decimal String of up to 16 characters, which is well in excess of the mechanical precision of positioning a microscope stage. In fact, the entire digital pixel data absorbance and/or fluorescence data obtained for individual cells could be stored. Present automated cytological screening systems do this for a limited number of cells, which are saved to be displayed on a high resolution color monitor for human review¹¹. The separation of analytical cytology into flow cytometry and digital microscopy breaks down with laser scanning cytometry, which scans a conventional microscope slide with a laser to produce data similar to that produced by a flow cytometer¹².

3.4.5. List Mode Data Compression: Packing the multiparameter color vector for each cell would be desirable for expediting the transmission of and minimizing the space for archiving the list mode data. The data describing each parameter can be organized to begin and end on other than 8 bit boundaries and to only occupy the number of bits required for the data. However, this is antithetical to Req.2. However, it would be practical for data that is archived for private use.

4. DICOM DIRECTORIES

Our previous² two major criticisms of FCS 3.0 were: 1) its structure is recursive. An FCS 3.0 Header section can point to a Text section which in turn can point to another Header section. and 2) placing multiple, large data files together significantly decreased the probabilities of error free transmission and even of achieving a successful transmission.

Part 10, Section 8.1 specifies the formats for DICOM Directories. "Another example is to map the File ID naming space to a directory and its tree of subdirectories. In this case it could offer the possibility to support multiple File-sets (one per directory) on the same physical medium. Each File-set would have its own DICOMDIR File. To ensure interoperability, PS 3.12 shall specify these specific mapping rules between the directories and the File ID naming space of a File-set (including the rules to unambiguously locate the DICOMDIR File)."

The Supplement^{3, Part 10} notes that, in the case of personal computer media, "a File-set ID may be defined to be identical to a volume label". It further describes the conditions for storing data, such as list mode, which are presently not part of the DICOM Standard. "Non-DICOM Files (Files with a content not formatted according to the requirements of this Part of the DICOM Stan-

ard) may be present in a File-set.” However, such files “may not be referenced by the DICOM Media Storage Directory”. The DICOM File Service permits hierarchical directories. The Supplement provides a familiar example, “A DICOM File ID is equivalent to the commonly used concept of “path name” concatenated with a “file name”. An example of a valid DICOM File ID with four components shown separated by backslashes is: SUBDIR1\SUBDIR2\SUBDIR3\ABCDEFGH”. Since DICOM permits foreign data formats to be included in its directories, the list mode (Section 3.4) and the tab delimited single parameter (Section 3.2.1) data formats proposed above could be presently included with other DICOM data.

5. DICOM EXTENSIONS

DICOM has been expanded to include Logical Observation Identifier Names and Codes (LOINC)¹³ & the Systematized Nomenclature of Human and Veterinary Medicine (SNOMED)^{14,10}. LOINC and SNOMED are supporting a collaboration with each other and DICOM that will ensure a consistent, unambiguous clinical reference terminology that builds upon the strengths of each. Both LOINC and SNOMED will be briefly described below.

5.1. LOINC:

LOINC objects are described as fields in a database¹³. Seven abbreviated examples from the 9,316 items of the LOINC database are given below in Table 3. The LOINC¹³ standard includes the timing of the assay, which can be a single point, for the length of a study, a fixed interval, such as 1 hour, or variable. All of the items in Table 3 are single point measurements. The LOINC code has no relation to the DICOM Hexadecimal Tag. The column, Property Measured, has values of Arbitrary Conc., which means arbitrary units. The word Length is used to describe a numeric statistic for the erythrocyte size distribution. A method is not specified for many of the tests. The column CLASS below contains terms with specialized meanings. For instance, Hematology excludes coagulation and differential counts. Serology pertains to antibodies and most antigens except blood bank and infectious agents. Cell counts include blood, CSF, and pleuritic fluid.

Table 3 LOINC Examples

Code	Component (analyte)	Property Measured	System	Method	Class
5473-4	CD4+CD8+	Arbitrary Conc.	WBC		Cellmarker
4679-7	Reticulocytes	Number Fraction	RBC		Hematology
6927-8	Platelet AB.IGG	Arbitrary Conc.	Serum	Flow Cytometry	Serology
9440-9	Lymphocytes.IGA/100 Lymphocytes	Number Fraction	WBC	Flow Cytometry	Cell Count
788-0	Erythrocyte Size Distribution	Length	RBC	Automated Count	Cell Count
10351-5	HIV 1 RNA	Arbitrary Conc.	Plasma	Amp/probe	Microbiology
5131-8	DNA Native AB	Arbitrary Conc.	Serum	Immuno Fluor.	Serology

5.2. SNOMED:

SNOMED consists of 11 separate modules which contain more than 144,000 terms and termcodes. These include:

1. Topography, A functional anatomy for human and veterinary medicine. (12,803 records)
2. Morphology, Terms used to name and describe structural changes in disease and abnormal development. (5,672 records)
3. Function, Terms used to describe the physiology and pathophysiology of disease processes. (18,027 records)
4. Living Organisms Living organisms of etiological significance in human and animal disease. (24,480 records)
5. Chemicals, Drugs, and Biological Products Including pharmaceutical manufacturers. (14,275 records)
6. Physical Agents, Activities, and Forces, A compilation of physical activities, physical hazards, and the forces of nature. (1,410 records)
7. Occupations Developed by, and used with permission from, the International Labour Office in Geneva, Switzerland. (1,947 records)

8. Social Context, Social conditions and relationships of importance to medicine. (845 records)
9. Diseases/Diagnoses, A classification of the recognized clinical conditions encountered in human and veterinary medicine. (34,377 records)
10. Procedures, A classification of health care procedures. (28,685 records)
11. General Linkages/Modifiers, Linkages, descriptors, and qualifiers to link or modify terms from each module.(1,373 records).

6. CLINICAL FLOW CYTOMETRY EXAMPLE

Recently, Braylan et al.¹⁵ described the information requirements for a flow cytometry laboratory. The major information categories were: Patient, Sample, Sample preparation /staining, Cell Analysis, Data analysis, and Additional elements. The first column of Table 4, item, is from the items defined as the Patient category of Table 1 of Braylan et al. Some the items from Braylan et al. were split because they were equivalent to two DICOM data types. The other columns of Table 4 contain the mapping of the Items in the first column to DICOM, which now effectively includes both LOINC and SNOMED. Many of the items in the other categories were previously mapped in Table 4 of Leif and Leif² to the microscopic image data items described in DICOM Supplement 15.

Table 4. Patient Information Items

Item	DICOM Name	#Val.	Hexadecimal Tag	DICOM Ref.	Comments	Length in Bytes
Name	Patient's Name	1	(0010,0010)	Part 6	Person Name	64 Max
Id #	Patient ID	1	(0010,0020)	Part 6	String, no "\ " delimiter	64 Max
Date of birth	Patient's Birth Date	1	(0010,0030)	Part 6	yyyymmdd	8
Sex	Patient's Sex	1	(0010,0040)	Part 6	Patient's Sex, "M", "F", or "O"	1
Referring physician name(s)	Referring Physician's Name	1	(0008,0090)	Part 6	Person Name	64 Max
Referring physician phone	Referring Physician's Telephone Numbers	1-n	(0008,0094)	Part 6	String, no "\ " delimiter	16 Max
Referring institution	Institution Code Sequence	1	(0008,0082)	Part 6		
	Institution Name	1	(0008,0080)	Part 6	String, no "\ " delimiter	64 Max
	Institution Address	1	(0008,0081)	Part 6	One or more text paragraphs.	1,024 Max
History/relevant clinical information and diagnoses				Sup. 23	& SNOMED & LOINC	
Reason for FCM request	Reason for Study	1	(0032,1030)	Part 6	String, no "\ " delimiter	64 Max
Previous relevant therapy				Sup. 23	& SNOMED	
Previous FCM studies	Referenced Results Sequence	1	(0008,1100)	Part 6	& LOINC	
Other lab results (WBC, differential count)	Referenced Results Sequence	1	(0008,1100)	Part 6	& LOINC	

7. CORBAmed¹⁶

The standardization of medical informatics including digital microscopy and flow cytometry presently is waiting for the selection by the Object Management Group of the specification for implementing CORBAmed¹⁷. The two parts of this specification are 1) the data types and classes and 2) the transmission format. DICOM in its answer to the CORBAmed Request for Proposal offered Supplement 23, STRUCTURED REPORTING. The other serious contender is the use of XML/EDI¹⁸, which

is an extension of SGML for commerce. This leads to three possibilities for transmitting data: 1) The standard CORBA Interface Definition Language, 2) present DICOM syntax, and 3) the XML syntax, which is similar to the ubiquitous HTML. Interface Definition Language is an object based language, which although it suffers from a C like syntax has improved semantics including the advantages of specifying whether objects are in (read), out (written), or inout (read-write). DICOM has the very significant advantage of simplicity. Parsing is significantly facilitated by having its types and classes described by an unsigned 32 bit integer, which can serve as a primary key. Another DICOM advantage is since it is independent of both the Object Management Group and Microsoft, it might serve as an acceptable compromise to these two competing groups. XML has the advantage of Web hype and perhaps support from Microsoft, which employs DCOM, its own proprietary product for distributed computing.

The support by the College of American Pathologists and other groups should assure that, at least, the DICOM-LOINC-SNOMED data and class definitions are used for both CORBAmed and a future medical standard based on DCOM.

8. CONCLUSIONS

1. No need to maintain a unique standard for flow cytometry.
2. FCS 3.0 should be an interim standard, which should expire 1 January, 2000.
3. Minimal additions to DICOM Supplement 15 will permit DICOM to be the standard for analytical cytology and its two modalities, digital microscopy and flow cytometry.

9. ACKNOWLEDGEMENTS

We wish to thank Professor U.J. Balis for his explanation of DICOM data types. The encouragement and critical discussion by our fellow analytical cytologists at Asilomar, 1997 and on the Web is gratefully acknowledged.

10. REFERENCES

1. L. C. Seamer, C. B. Bagwell, L. Barden, D. Redelman, G. C. Salzman, J. C. S. Wood, and R.F. Murphy, "Proposed New Data File Standard for Flow Cytometry, Version FCS 3.0.", *Cytometry* **28**, 118-122, 1997.
2. R. C. Leif and S. B. Leif, "Evolution of Flow Cytometry Standard, FCS3.0, into a DICOM-Compatible Format". *Optical Diagnostics of Biological Fluids and Advanced Techniques in Analytical Cytology*, Ed. A. V. Priezzhev, T. Asakura, and R. C. Leif. A. Katzir Series Editor, Progress Biomedical Optics Series, SPIE Proceedings Series **Vol. 2982**, pp 354-366, 1997.
3. "DICOM (Digital Imaging and Communication in Medicine) Standard" consists of multivolumes:
 3. Part 1: Introduction and Overview
 3. Part 2: Conformance
 3. Part 3: Information Object Definitions
 3. Part 4: Service Class Specifications
 3. Part 5: Data Structures and Encoding
 3. Part 6: Data Dictionary
 3. Part 7: Message Exchange
 3. Part 8: Network Communication Support for Message Exchange
 3. Part 9: Point-to-Point Communication Support for Message Exchange
 3. Part 10: Media Storage and File Format for Data Interchange
 3. Part 11: Media Storage Application Profiles
 3. Part 12: Media Formats and Physical Media for Data Interchange
 3. Part 13: Print Management Point-to-point Communication Support

The DICOM Standard is available from: The National Electronic Manufacturers Association, 2101 L Street, NW, Suite 300, Washington, DC 20037 or ASTM Committee E-31 on Computerized Systems, Chairman Donald A. Nelson, Cedar Rapids Medical Education Program, 1026 A Ave. NE Cedar Rapids IA 52402-5098, (319) 369-7393. All current NEMA Standards including DICOM 3.0 are now available from the Nema Web Site <http://www.nema.org/nema/cgi-bin/stsearch.pl>, last visited 1 January, 1998.

DICOM home page: http://www.xray.hmc.psu.edu/dicom/dicom_home.html, last visited 1 January, 1998.

From Frequently Asked Questions: <http://www.xray.hmc.psu.edu/dicom/faq.html>, last visited 1 January, 1998.

"All of the final draft versions of the standard can be obtained by anonymous ftp from [ftp.xray.hmc.psu.edu](ftp://ftp.xray.hmc.psu.edu). They are located in the directory /dicom_docs. There are subdirectories that contain the documents in postscript (/dicom_docs/dicom_3.0/postscript), FrameMaker (/dicom_docs/dicom_3.0/frame), and Microsoft Word (/dicom_docs/dicom_3.0/word_hqx).

"The electronic copies of all DICOM documents are final drafts. Official printed standards documents are only available

from: NEMA, Office of Publications, 2102 L Street, N.W., Washington, D.C., 20037, USA.”

4. W. D. Bidgood Jr., S. C. Horii, F. W. Prior, and D. E. Van Syckle. “Understanding and Using DICOM, the Data Interchange Standard for Biomedical Imaging”, JAMIA. Vol. 4, pp.199-212, 1997.

5. W. D. Bidgood Jr., Y. alSafadi, M. Tucker, F. W. Prior, G. Hagan, and J. E. Mattison. “The Role of DICOM in an Evolving Healthcare Computing Environment: The Model is the Message”, Accepted for publication in the Journal of Digital Imaging. 1997 (estimated publication date: February, 1998).

6. U.J. Balis, W. D. Bidgood, Jr., S. B. Dove, L. Korman, and D. Snaveley, “Digital Imaging and Communications in Medicine (DICOM) SUPPLEMENT 15, Draft for Public Review, Visible Light Image, Anatomic Frame of Reference, Accession, and Specimen for Endoscopy, Microscopy, and Photography”, Version: 1.1a. Filename: sup15_fz.doc Date: December 23, 1997, <http://www.mcis.duke.edu:80/standards/HL7/sigs/image-management/DICOM/> Last visited 27 December, 1997.

7. FDA, “ODE Guidance for the Content of Premarket, Submission for Medical Devices Containing Software, draft 1.3”, dated 12 August 1996; <http://www.fda.gov/cdrh/ode/dtswguid.html>, last visited 1 January, 1998.

8. R. C. Leif and S. B. Leif, “ISAC Flow Cytometry Standard Version 3, FCS3.0”, <http://nucleus.immunol.washington.edu/ISAC/fcs3/leif.html>, Last visited 1 January, 1998.

9. L. C. Seamer, C. B. Bagwell, L. Barden, M. Christofferson, L. E. Magruder, G. Malachowski, R. F. Murphy, D. Redelman, G. C. Salzman, and J. C. S. Wood, (Data File Standards Committee of the International Society for Analytical Cytology (ISAC)), “Data File Standard for Flow Cytometry, Version FCS 3.0”, <http://nucleus.immunol.washington.edu/ISAC/fcs3/FCS3.html>, last visited 1 January, 1998.

10. “Digital Imaging and Communications in Medicine (DICOM) SUPPLEMENT 23: STRUCTURED REPORTING (Frozen Draft*)”, <http://dumccss.mc.duke.edu/standards/HL7/sigs/image-management/HTML/dicom-home.html#ReportingTag>, last visited 8 December, 1997.

11. L. J. Mango, and J. M. Herriman, “The Papnet Cytological Screening System”, *Compendium on the Computerized Cytology and Histology Laboratory*, Ed. G. L. Wied, P. H. Bartels, D. L. Rosenthal, and U. Schenck, Tutorials of Cytology, Chicago, IL pp. 320-334, 1994

12. L. A. Kamensky, L. D. Kamensky, “Microscope-based Multiparameter Laser Scanning Cytometer Yielding Data Comparable to Flow Cytometry Data”, *Cytometry* **12**, 381-387, 1991.

13. Logical Observation Identifier Names and Codes (LOINC) Users' Guide vs. 1.0, Release 1.0i, 01/08/97

Please send questions and comments to: Regenstrief Institute c/o Kathy Hutchins 1001 West 10th Street, RG-5, Indianapolis, IN 46202

Internet: loinc@regenstrief.iupui.edu

This and other relevant documents are available via FTP/Gopher:www.mcis.duke.edu/standards/termcode/loinclub/ (Lab LOINC)

<http://www.mcis.duke.edu/standards/termcode/loinc.htm>, last visited 1 January, 1998.

14. The SNOMED DICOM Microglossary files are now available by FTP from the following location: <ftp://dumccss.mc.duke.edu/standards/HL7/committees/image-management/SNOMED/> and <http://www.snomed.org/sdm/sdm.htm>, last visited 1 January, 1998.

“The most recent version of SNOMED International (ver. 3.3) contains more than 144,000 terms and term codes in 11 separate modules. SNOMED International is rapidly being accepted worldwide as the standard for indexing medical record information. The American Veterinary Medical Association and the American Dental Association have recognized SNOMED's virtues and have adopted/endorsed SNOMED for their use. In addition, SNOMED is specified as the controlled terminology and message standard for interchange of biomedical images and image-related information in the DICOM (Digital Imaging and Communications in Medicine) standards.”

“The College of American Pathologists, due to the acceptance of SNOMED International far beyond pathology, was able to reduce the price dramatically in January 1995 -- from the original single-user price of US \$1,400 to US \$300, the realistic minimum that will allow for ongoing maintenance and future enhancements.”

“Both the complete SNOMED International dataset and the Microglossary for Pathology are included in the \$300 price (\$275 for CAP members). It is available on 3.5" disks and CD-ROM.”

15. R. C. Braylan, S. K. Atwater, L. Diamond, J. M. Hassett, M. Johnson, P. G. Kidd, C. Leith, and D. Nguyen, “U.S.-Canadian Consensus Recommendations on the Immunophenotypic Analysis of Hematologic Neoplasia by Flow Cytometry: Data Reporting”, *Cytometry (Communications in Clinical Cytometry)* **30**, pp 245-248, 1997.

16. CORBAmed home page: <http://www.omg.org/corbamed/>, last visited, 1 January, 1998.

17. CORBAmed voted to extend the due date on the RFI until 7 November, 1997. http://www.omg.org/library/schedule/CORBAmed_RFI3.htm, last visited, 1 January, 1998.

18. XML/EDI Group Web site: <http://www.geocities.com/WallStreet/Floor/5815>, last visited 1 January, 1998.