

**A STANDARD FORMAT FOR  
DIGITAL IMAGE EXCHANGE**



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# **A STANDARD FORMAT FOR DIGITAL IMAGE EXCHANGE**

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## **Report of the Task Force on Digital Image Data Exchange of the AAPM Science Council**

In 1978 the Science Council of the AAPM formed a Task Force to consider the problem of transferring digital image data between devices. It was apparent that there was a growing need to make such transfers for clinical, research and service reasons. However, incompatibility between the hardware and software used by different manufacturers, and non-uniformity of the formats used for recording the image data on magnetic media, acted as a serious impediment to data transfer.

The Task Force believes that it is impractical, at the present time, to adopt a standard internal representation for digital image data acquired and processed by commercially available equipment. This is because of the wide diversity of data involved, the large investment in hardware and software that has been made, the proprietary nature of much of this software, and the difficulty in obtaining a consensus among manufacturers and users regarding such a standard.

The Task Force does, however, believe that it is possible to facilitate the transfer of data by defining a standard format for exchange purposes. This approach requires that devices be programmed to read or write data in standard form, for exchange purposes, but does not place any restriction on the format used for other purposes. We believe that such a format will certainly be found useful among the research community, and may be found increasingly valuable by the manufacturing community. It is hoped that it will act, to quote one manufacturer, as a "catalyst" for further standardization.

An exchange format must, of necessity, be very flexible to accommodate different types and quantities of data and various parameters of interest including transfer parameters which define the form of the data itself. It must also be amenable to modification to suit special purposes and future needs, without losing compatibility with previous versions. We believe that these objectives can be achieved.

The format which is recommended in this report involves the coupling of each parametric VALUE with a descriptive name, or KEY, as a KEY-VALUE pair. The software must search for these keys in order to obtain their values, or the user may obtain their values from a printed directory listing. This approach is very flexible since it is only necessary to include relevant key-value pairs in the transfer and it is easy to enlarge the list of parameters that may also be transferred, as necessary. Parameters may be used to describe the form of the data, which may therefore be encoded very flexibly. A user who does not have access to a current dictionary of defined key names will generally be able to recognize them and their meaning from the directory listing.

This format is currently recommended for transferring data on magnetic tapes, but individual users are encouraged to apply it to other tasks and media, where appropriate. Future versions of the standard will cover these situations if this is found to be useful.

The current version of the format does not define all of the keys which may be needed for special purposes (for example, treatment planning from CT data). It is assumed that these will be defined by user groups inside and outside the AAPM if the standard is found to be applicable to their problems.

In order to facilitate the application and development of this format, the Task Force will act as a channel of communication between user groups. This will include maintenance of a current dictionary of defined key-value pairs, and periodic revision of

the standard as necessary. The Task Force Chairman should be contacted for further details.

The format which is recommended by the Task Force in this report is the work of Brent S. Baxter, Lewis E. Hitchner, and Gerald Q. Maguire Jr. of the University of Utah, Departments of Radiology and Computer Science, Salt Lake City, Utah. Their work has made this report possible.

The Task Force Chairman wishes to acknowledge the valued contribution of James H. Schimpf of New York University Medical Center, Department of Radiology, in developing an earlier format which was considered by the Task Force. The comments of individual members of the AAPM and manufacturing community, including the members of the AAPM-NEMA liaison committee, chaired by Stephen Baiter, we also acknowledge with thanks.

The following individuals have been active in the Task Force during its work:

Christopher H. Marshal,	Chairman	(current)
Brent S. Baxter,	Co-chairman	(current)
Steven L. Fritz		(current member)
Peter M. Joseph		
Daniel W. Miller		
Badhe Mohan		(current member)
Jonathan Ophir		

## Abstract

This document describes a simple yet flexible magnetic tape format for exchanging digital image information. Multi-dimensional arrays of raster scan data are stored as sequential files, with descriptive information related to these files stored in an initial directory file. Directory information is stored as ASCII "key-value pair" character strings that can be read by people as well as computer programs. Key-value pairs are used for directory searches, also to identify and provide supplementary information about the images. Since the directory is relatively self-explanatory it is possible in many cases to write a program for reading an AAPM tape without reference to a published standard.

This proposal conforms with applicable sections of ANSI standards X3.22-1973 and X3.39-1973, "Recorded Magnetic Tape for Information Interchange" (800 and 1600 BPI) X3.40-1976, "Unrecorded Magnetic Tape for Information Interchange", and X3.27-1969, "Standard Magnetic Tape Labels for Information Interchange".

# 1. Introduction

## 1.1 Background

The data format described in this document provides a simple yet powerful means for exchanging digital images stored on magnetic tape. The primary goal is to facilitate the exchange of data between groups having otherwise dissimilar equipment. Every effort has been made to keep the proposed format simple and easy to use while anticipating the need for future additions and modifications.<sup>1</sup> It is not intended as a substitute for the working file system provided by the manufacturer of the computer equipment. Several criteria which have strongly influenced the document are as follows:

Simplicity	The tape format should comprise a small number of easily understood structures. Directory information should be self explanatory and should be readable by people as well as by computers. Complex data formats should be avoided.
Extensibility	It should be possible to include a variety of descriptive information in the directory and to add new items as needed. Commonly used image data types should be easily accommodated by the standard. Revisions of the standard should not obsolete tapes conforming to earlier versions of the standard. There should be no more constraints than necessary.
Addressability	Directory searches, based on matching one or more keys such as "date", "image number", "patient name", etc., should enable one to locate the image data by skipping directly to the required file.
Adaptability	Computer hardware requirements, record lengths, etc., should be such as to allow the widest possible distribution of tapes meeting the standard.

These criteria are reflected in the organization of the tape and the directory, as well as in the structure of the key-value mechanism.

## 1.2 Hardware Considerations

Industry standard 1/2 inch, nine track tape written in odd parity is the prescribed medium. The recording density may be 800 or 1600 bits per inch, and the record size must be 2048 bytes (the largest record size allowed by ANSI X3.221. Records of this length utilize approximately 75% of the tape surface at a recording density of 1600 BPI and an even greater percentage at 800 BPI. The ASCII character code is to be used.<sup>2</sup>

Characters are to be recorded on the tape in the order they appear on a printed page. Numeric data are recorded most significant byte first. Thus, a byte swapping program may be required on some machines, particularly on DEC PDP-11 equipment. The record length (2048 bytes), the recording density, and the volume ID (if an ANSI standard tape label is used) must all be affixed to the tape reel.

An explanation of the directory and data file structures may be found in the next section. Appendix material includes a sample tape directory, a list of suggested AAPM format type key-value pairs, and a glossary of magnetic tape terminology.

---

<sup>1</sup> This document is an outgrowth of an earlier proposal by Schimpf [2].

<sup>2</sup> Machines which use other codes internally generally provide conversion programs to and from ASCII, while most small machines only support ASCII.

## 2. Tape Organization

### 2.1 Directory File Structure

Descriptive information is contained in a directory at the beginning of the tape. Directory information is placed there, rather than in file headers scattered throughout the tape, to make searches and directory listings quick and easy. The directory consists of one or more 2048 byte records followed by an end of file mark (EOF).

Directory information is in the form of key-value pairs<sup>3</sup>, with a key beginning a line, possibly with leading spaces or tabs<sup>4</sup> followed by a colon equal (:=), followed by the value, and terminated by <CR LF>. A line should be no longer than 80 characters to prevent wrap-around problems on standard width terminals. No more than one key-value pair may appear on a single line of text. Both upper and lower case text is acceptable. Lower case and upper case test are considered equivalent when searching.

There are several advantages to this arrangement in comparison with a fixed format approach. First, the directory can be read and understood without reference to a published standard. Second, the directory can be examined and manipulated using widely available file system utilities and text editors. Third, variable length names and comments are easily accommodated. Fourth, new key-value pairs may be adopted as the need arises.

### 2.2 Directory Header

Certain key-value pairs which pertain to the entire tape are located at the beginning of the directory ahead of any other directory entries. These serve to identify the tape, its owner, his/her institutional affiliation, the AAPM tape format version number, etc. This section of the directory begins with the "Tape Standard" key-value pair (required) followed by any of the optional key-value pairs. The header is terminated by the appearance of the first "image number" key-value pair or, in the case of an empty directory, by the end of the directory.

### 2.3 Directory Entries

Directory entries follow the directory header. Each entry begins with the required "image number" key-value pair:

image number := N

where the number N refers to the Nth image file. Other key-value pairs associated with this entry follow in any order (see section 2.3.1). A directory entry is terminated by a succeeding "image number" key-value pair or by the end of the directory. The end of the directory is at the end of the last record. This is followed by the EOF. The directory is stored in file 0, the first image data file is found in file 1, the second is file 2, ...

---

<sup>3</sup> See [3] for details of a "name-type-value" system similar to the key-value structure outlined here.

<sup>4</sup> Tabs may be converted to sequences of spaces before writing text on the tape. See [1] page 23 for details of how this may be done.



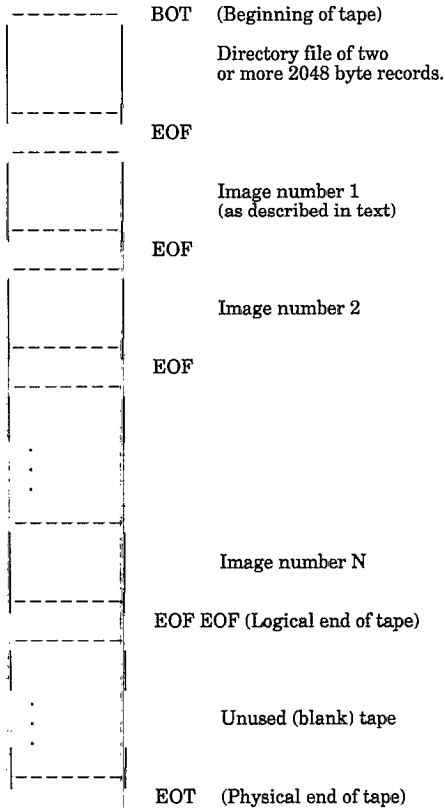


Figure 2-1: Tape Organization

### 2.3.1 Image Format Keys (required)

The minimum information necessary to locate individual picture elements (pixels) is contained in the following required key-value pairs:

Image number :=  
 Bytes per pixel :=  
 Number of dimensions :=  
 Size of dimension 1 :=  
 Size of dimension 2 :=  
 .  
 .  
 .

Picture elements are recorded by exhausting the first index first, then the second index . . .

etc. Indexing begins with one. In the following example pixel (27,33,3) will be found in bytes 53 and 54 of record 36 in image number 1.

```
Image number := 1
Bytes per pixel := 2
Number of dimensions := 3
Size of dimension 1 := 128
Size of dimension 2 := 128
Size of dimension 3 := 8
```

These keys must always be present in a directory file entry because they are needed to locate picture element data within an image file. Other optional annotation key-value pairs may also be present as described in the next section.

Color and other multiband images may be treated as three dimensional arrays with either the first or third dimension indicating the band. If the data are arranged on the tape in a pixel interleaved fashion then the dimensions might be as follows:

```
Size of dimension 1 := 3
Size of dimension 2 := 128
Size of dimension 3 := 128
```

If bands are recorded in sequence with one band appearing in its entirety before the next, the directory entry would appear as follows:

```
Size of dimension 1 := 128
Size of dimension 2 := 128
Size of dimension 3 := 3
```

Image files too large to fit on a single reel of tape should be placed on a multi tape volume using the ANSI standard tape volume label mechanisms. The directory will be at the beginning of the volume.

### 2.3.2 Annotation Keys (optional)

Annotation keys appear following the image format keys described above, or they may be omitted at the option of the person preparing the tape. A collection of key-value pairs to be used by AAPM users is included as Appendix I. Any key-value pair may be used for a directory search though annotation keys will probably be most useful for this purpose. Most revisions and changes to the standard will be accomplished by updating the list of annotation keys (Appendix I).

### 2.3.3 Comments

Free field comments may appear anywhere in the directory except on lines containing key-value pairs. Lines not containing a "!=" sequence are ignored during directory search operations.

## 2.3.4 Directory Inquiries

Directory searches will be performed by locating the required key and examining its value. If the value matches, the image number is returned to allow skipping ahead to the proper image file. A small library of AAPM routines will be provided to assist with certain elementary directory access operations. These are:

- |                           |   |
|---------------------------|---|
| List the directory header | This routine simply lists the directory header. Note that this could be done on most systems with their file utilities, merely by printing the contents of the first file.  |
| List a directory entry    | This routine lists the specified directory entry. This operation could also be done on most systems by means of a text editor.  |
| Key search                | This routine searches through the directory stopping on the next match with the key-value pair. The file number is returned along with the result of the search. Possible search outcomes might include: a match, no match, or no such key. Matches require exact spelling but disregard case shifts and extra tabs and spaces. A match returns the appropriate image number. |

## 2.4 Image File Format

Data files are recorded as rectangular arrays of numeric data padded with zeros where necessary to fill out the array. A single datum is stored in one or more bytes (most significant byte first, see 2.3.1). The recommended numeric formats are two's complement integer and positive integer format. Data compression such as run length encoding, DPCM, chain coding, etc., is not recommended to avoid complicating the task of exchanging image data.

## 2.5 Data Transfer Operations

A minimum number of data transfer operations are envisioned because the standard is intended primarily for data interchange. General purpose data base management is not within the scope of this standard.

- |                      |  |
|----------------------|--|
| Initialize the tape  | This operation records the tape header information at the beginning of the directory tile and fills the remainder of the directory with null characters. One extra unused record is added to the end of the directory to minimize the possibility of problems with the append operation. This extra record provides leeway for variations in recording density and inter-record gap length on different tape drives. |
| Append an image file | An image file is appended to the tape and a directory entry is appended to the directory file.   |
| Read an image tile   | The required number of image files is skipped, then data is read from the specified image file.  |

No explicit provision is made in the AAPM programs for deleting or updating images. These more complex operations are outside the scope of a standard intended primarily for image data exchange.

Other common operations such as rewinding and copying tapes, writing ANSI standard volume labels, etc., are to be left to utility programs supplied with each computer system.

### 3. Conclusion

The standardized tape file system described here provides features needed for a convenient image interchange medium between computer equipment of different manufacturers. Descriptive annotation information is provided to identify image files and to permit rapid searches of the tape for images identified by name. A limited amount of data structure information is included to indicate the number of bytes per picture element, number of rows, columns, etc. This descriptive information is recorded in a form understandable by people as well as by computers.

### 4. References

- [1] B.W. Kernighan and P. J. Plauger.  
Addison and Wesley, Reading, Massachusetts, 1976.
- [2] J. H. Schimpf.  
AAPM Tape Format Standard.  
Internal Draft Dated July 9,1979. (NYU).
- [3] P. G. Selfridge.  
*A Flexible Data Structure for Accessory Image Information.*  
Technical Report TR-45, Department of Computer Science, University of Rochester, May, 1979.

## I. Directory Keys for use by the AAPM Community

The AAPM directory keys and their associated values are described in this appendix. Keys are placed at the beginning of a line followed by a colon equal sequence, followed by the value, followed by a carriage return/line feed sequence. Note that a key must begin on a new line, and no more than one key may appear on a single line.

(Directory Header.....)

Tape Standard := <decimal-number> (required)  
The first release will be 1.00 and updates will  
be published as appropriate.

Directory header := <character string>  
Description of the tape.

Institution := <character string>  
Name of the institution.

Department := <character string>  
Further identification of institutional affiliation.

Date created := <day>,<month>,<year> (decimal integers)  
The calendar date the tape was created.

(Directory entries .....)

Image #	:= <integer>	(required)
Bytes per pixel	:= <integer>	"
Number of dimensions	:= <integer>	"
Size of dimension 1	:= <integer>	"
Size of dimension 2	:= <integer>	"

Date written := <day>,<month>,<year> (decimal integers)  
This value is the calendar date the image  
was recorded on this tape.

Writer := <character string>  
The name of the person who created the file.

Grid 1 units := <decimal-number>  
The grid spacing in cm. in the "X" direction

Grid 2 units := <decimal-number>  
The grid spacing in cm. in the "Y" direction

Grid 3 units := <decimal-number>  
The grid spacing in cm. in the "Z" direction

Number representation := <character string>  
Number system used to record image data  
Common choices might include:

Two's complement integer  
Positive integer

Patient name := <character string>  
Patient's name.

Patient number := <character string>  
Patient's local hospital code.

Exam type := <character string>  
Identifies the type of examination.

## II. Sample Tape Directory

Tape Standard number := 1.00

Directory header := Sample AAPM digital image tape

Institution := University of Utah Medical Center

Department := Radiology Department, Nuclear Medicine Division

Date created := 17,3,80

.....  
Note that the preceding line of periods will be treated  
as a comment, as will this explanation.

Image number := 1

Bytes per pixel := 2  
Number of dimensions := 3  
Size of dimension 1 := 128  
Size of dimension 2 := 128  
Size of dimension 3 := 8

Date created := 17,3,80  
Date written := 20,3,80  
Patient name := Sam Jones  
Exam type := Liver spleen study

This is a very inter&in case because Jones has no liver1  
Note the absence of any key or colon equal sequence in this  
free field comment.

Image number := 2

This is a test image.

Bytes per pixel := 1  
Number of dimensions := 2  
Size of dimension 1 := 64  
Size of dimension 2 := 64

Image number := 3

·  
·

·EOF·

### III. Glossary of Magnetic Tape Terminology

BOT	Beginning of tape. This point is identified by a reflective marker at the beginning of a reel of magnetic tape.
BPI	The recording density in bits per inch, describes the recording density.
BYTE	A group of 8 binary bits often used to encode one alpha/numeric
EOF	End of file marker. This is a pattern recorded on magnetic tape to mark the end of a file. Typically, a tape drive can both sense these and skip to the next EOF to locate specific files on the tape. End of tape. A reflective marker at the end of a reel of magnetic tape identifies the physical end of the tape.
FILE	One or more records followed by an EOF.
IRG	Inter-record gap. A short length of blank tape used to separate a file into small units that can be manipulated in the computer's memory.
RECORD	A set of data bytes between inter-record gaps. The record must be greater than some minimum set by the tape drive hardware and smaller than the attached computer's memory. This standard specifies 2048 byte records.