Journal of Digital Imaging

Introduction to "Minutes: NEMA Ad hoc Technical Committee and American College of Radiology's Subcommittee on Computer Standards"

Steven C. Horii, MD[1]

KEY WORDS: DICOM, ACR-NEMA, history

REPRODUCED ON THE following pages are the minutes of the first meeting of what would become the American College of Radiology–National Electrical Manufacturers Association (ACR-NEMA) Digital Imaging and Communications Standards Committee. The meeting that generated these minutes took place at the Palmer House Hotel in Chicago, IL, on Saturday, November 12, 1983. Notably, it was convened on a weekend and was not in conjunction with the Radiological Society of North America (RSNA) meeting, as might be expected.

That this meeting took place at all is a surprise as it assembled experts not only from industry (from whence many NEMA standards originate) but also from users of the products of that industry. Stories of the genesis of the joint ACR-NEMA effort have become nearly legends, and parties other than the ACR and NEMA were involved. Besides the organizations that would form the nucleus of the working standards body, the Center for Devices and Radiological Health (CDRH) of the Food and Drug Administration (FDA) and the Institute of Electrical and Electronics Engineers (IEEE) were also instrumental in getting the effort started.

For those not involved in the work of the ACR-NEMA Committee (as its vernacular name rapidly became) a common question is why these two particular organizations combined their efforts to develop standards. The ACR represented (and represents) the professional interests of radiologists and radiological physicists, while NEMA is a trade organization for manufacturers. A part of NEMA, the Diagnostic Imaging and Therapy Division consisted of member companies that manufacture the equipment the radiologists (and other specialists) use. NEMA also provides a very important function; one without which the standards effort would likely not have been possible. Antitrust and anticompetitive laws in the United States make it very risky for representatives of different manufacturers to meet together; such meetings could be construed by those not present as occasions for fixing prices or dividing market share. NEMA provides a meeting environment that avoids such concerns though strict rules governing what may be discussed. Readers will see that the notation, "Reviewed by counsel" is included at the end of the minutes. This provides an assurance that no antitrust restrictions have been violated.

The minutes of the first meeting are brief, but they illustrate interesting points. At the outset, the major areas of interest discussed were the interface issue, storage concerns, and exactly how the Committee would do its work and

From the Department of Radiology, University of Pennsylvania Medical Center, 3400 Spruce Street, Philadelphia, PA 19104.

Correspondence to: Steven C. Horii, MD; tel: 215 349-5183; fax: 215-349-5627; e-mail: steve.horii@uphs.upenn.edu

Online publication 30 December 2004
doi: 10.1007/s10278-004-1028-0

what the extent of that work should be. The first two attachments to the minutes (labeled "Exhibit A" and "Exhibit B" in the right lower corner of the pages) provide a model for the objectives, structure, and governance of the Committee, and an expansion of the subject material of the Committee's efforts. Exhibit A was provided by Dr. Gwilym Lodwick, one of the ACR members present. Exhibit B was submitted by Allan Edwin of General Electric Medical Systems, a member company of NEMA. Dr. Lodwick and Mr. Edwin would later be elected the first co-chairs of the ACR-NEMA Committee.

Of the items described in Exhibit B that Mr. Edwin thought the ACR considered to be needs (see page 2 of Exhibit B), it is interesting to note that only item 4, the "need for specification of type and description of non-image data to be accessed" wound up as a fundamental part of the Standard. The other items are still being debated in the medical imaging community.

Mr. Edwin's assessment of the industry's interest in the objectives of the Committee were much more in line with what would develop as work progressed (see pages 2 and 3 of Exhibit B). It is interesting to note that two of these, however, would not find their way into the Committee's work until the ACR-NEMA Standard became the DICOM Standard. The two are "Standardized definition of subsystems" and "Proposal to define and analyze gateways between digital imaging and other medical information systems."

The longest part of these minutes is Exhibit C, a proposal for a standard device interface that was submitted by Mr. Al Rothlauf (of Picker International) as a revised proposal from the 3M Corporation. This proposal had been presented at the International Society for Optical Engineering (SPIE) Medical Imaging (at the time, the "Applications of Optical Instrumentation in Medicine") meeting. The proposal is a technical one, but readers familiar with the ACR-NEMA Version 1 and 2 Standards will note the similarity between the interface proposed and what ultimately was developed. What did not persist was the idea of a dual-channel interface; a control channel and a data channel. Also, the fixed-length "header" (see page 11 of Exhibit C) would undergo major evolution into the groups and variable-length elements of the ACR-NEMA Standard.

What these minutes alone cannot show is how much effort the Committee members put into the development, first of the ACR-NEMA standards and then the DICOM Standards. The other articles in this special issue of the *Journal of Digital Imaging* should help shed some light on how that effort evolved and what came out of it.

I am honored to have been a participant in the ACR-NEMA and DICOM Committees since the meeting that followed the one these minutes represent. I am grateful to all the manufacturers, professional society members, other standards organization members, and academic institutions for all the work that has resulted in the most successful standards that have been developed for medical imaging.

Notes on the facsimile of the minutes:

The pages of the minute that follows are reproduced in black and white; the original NEMA minutes show the NEMA logo in the then-official blue color. Also, all of the Exhibits of the minutes were originally reproduced on yellow paper. This created problems in scanning the original document, as the color reduced the resulting image contrast. The originals were also xerographic copies and were subject to the quality of the copier. Slight misalignments of the text on the page are a result of the original copying process and were increased in some cases when the originals were copied again to improve contrast and provide black-and-white originals for scanning.

These minutes are reproduced with the permission of the National Electrical Manufacturers Association.

NEMA

National Electrical Manufacturers Association
2101 L Street, N.W. Suite 300
Washington, D.C. 20037 (202) 457-8400
Telex 904077 NEMA WSH

Diagnostic Imaging and Therapy Systems Division

MINUTES

MINUTES:	AD HOC TECHNICAL COMMITTEE (EMERGING TECHNOLOGY COMMITTEE) AND AMERICAN COLLEGE OF RADIOLOGY'S SUBCOMMITTEE ON COMPUTER STANDARDS
PLACE OF MEETING:	PALMER HOUSE CHICAGO, ILLINOIS
DATE AND TIME:	SATURDAY, NOVEMBER 12, 1983 12:00 NOON - 3:00 P.M.

MEMBERS PRESENT

Howard Berke (part-time)	ADAC Laboratories
Hartwig Blume, Ph.D.	Philips Medical Systems, Inc.
Al Dunn, M.D.	American College of Radiology
Allan Edwin	General Electric Company
Mel Hellstrom	CGR Medical Corporation
Richard Lackmond	Siemens Medical Systems
James Lehr, M.D.	American College of Radiology
Gwilym S. Lodwick, M.D.	American College of Radiology
John Moore, Ph.D.	American College of Radiology
Al Rothlauf	Picker International, Inc.
J.P. Steele, M.D.	American College of Radiology
Martin Sonntag	Medical Data Systems

MEMBERS ABSENT

David Stepner	Diasonics, Inc.

OTHERS PRESENT

Dan Gahlon	3M
Richard Hardy	ACR Staff
Robert G. McCune	NEMA Staff
Laura Lee Murphy	NEMA Staff

PRESIDING OFFICERS: Allan Edwin, NEMA's Ad Hoc Technical Committee
Gwilym S. Lodwick, ACR's Subcommittee on Computer Standards

I. INTRODUCTION AND BACKGROUND

The co-chairmen called the meeting to order. The purpose of this committee is to provide a focus between the manufacturers of digital imaging and communications equipment, represented by NEMA's Ad Hoc Technical Committee, and the users, represented by ACR's Subcommittee on Computer Standards. This focus is intended to aid these two groups in working with the IEEE Subcommittee on Computer Standards. Dr. Steele recommended that standard terminology be adopted and that guidelines be set with participation from the government, the industry, and the radiology community. Dr. Steele also stressed his impression that there is an urgent need to get something done. He suggested looking at items which affect the computer's central processing unit; for example, line length and number of lines, gray scale highs and lows, pixel size, etc. Mr. Edwin recommended archiving needs are also a source of concern which should be addressed by this committee. Dr. Lehr added that in addition to considering voluntary guidelines, this committee has to be able to successfully develop a standard. Both Dr. Lehr and Mr. Edwin emphasized the need for careful study in each of these areas before implementing the standardization process. Dr. Blume recommended adoption of standards with care to ensure that manufacturers will not be inhibited in their design of these systems.

II. PROCEDURAL CONSIDERATIONS FOR ACR AND NEMA

Dr. Lodwick asked Dr. Dunn to outline the ACR committees concerned with this effort. Dr. Dunn explained that the ACR Commission on Equipment reports through the ACR Board of Chancellors to the ACR Council. There are seven committees within the Commission on Equipment: The Committees on Equipment, Computers, Quality Assurance, Standards and Specifications, Emergent Modalities, Mammography Equipment, and Departmental Planning. Dr. Lehr heads the Committee on Computers while Dr. Steele chairs the Committee on Quality Assurance. Dr. Dunn coordinates the Committee on Equipment and he feels the effort of the ACR-NEMA committee is a high priority. Ms. Murphy reported that Mr. McCune reports to the Diagnostic Imaging and Therapy Systems Board of Directors and that their approval for this type of effort is necessary. This board meets Tuesday, November 15, 1983.

Dr. Steele added that it may take the government one to two years to publish some sort of protocol while a conference meeting between government, industry, and the users may be able to develop a protocol in six months, with the results published in 30 to 60 days. Dr. Steele suggested storage criteria for the digital data may be a good place to start, regardless of how it gets there. Mr. Edwin commented that the 3M proposal defines an image in digital terms. Dr. Lehr pointed out that different states have various legal requirements for data storage and that each radiologist may use different data storage times.

Mr. McCune reminded the group that the most important objective is to establish a firm basis which is not too large to accomplish effectively. Dr. Lodwick asserted that it is very important to establish the credibility of the group. At this point, Dr. Lodwick introduced a paper he had prepared to describe the interactions between these two organizations. After discussion by the group, this document, Exhibit A, was adopted by the committee following a motion, second, and unanimous affirmative vote. Mr. Edwin then introduced the paper prepared by NEMA to document the roles of each respective organization. After discussion by the group, this document, Exhibit B, was also adopted following a motion which was seconded and approved.

III. AREAS OF INTEREST TO THE COMMITTEE

Upon a request from Mr. Berke, it was emphasized that it was not the intent of this committee to develop design standards. Mr. McCune stated that a strategy is needed for this committee. Dr. Lehr offered to provide the needs and rationale for the areas of ACR interest. In return, NEMA would let the ACR know if their requests are technologically feasible.

It was moved, seconded, and unanimously passed that the sense of the committee is that the first topic for this committee is the interface problem. This issue will be addressed at the next meeting, which should be held very soon. Mr. Rothlauf distributed copies of the revised 3M proposal for data transmission, Exhibit C.

IV. TIME AND PLACE OF NEXT MEETING

The next committee meeting will be on Thursday, January 12, 1984. NEMA will host this meeting at NEMA Headquarters, if possible. The meeting will be an all day effort to start at 9:00 A.M. The following day, the IEEE Subcommittee on Computer Standards will meet at National Center for Devices and Radiological Health, Rockville, Maryland. Comments on the revised 3M data transmission proposal, other areas of interest to the interface issue, and priorities for the committee should be received by Ms. Murphy no later than December 20, 1983.

V. ADJOURNMENT

The meeting was adjourned at 3:00 P.M.

REPORTED BY: LAURA LEE MURPHY
SECTION STAFF EXECUTIVE

REVIEWED BY COUNSEL

LLM:pb

ACR - NEMA DIGITAL IMAGING AND COMMUNICATIONS STANDARDS COMMITTEE

NAME: The name of this body shall be "The ACR - NEMA Digital Imaging and Communications Standards Committee," hereinafter referred to as The Committee. (NEMA=National Electrical Manufacturers Association, ACR=The American College of Radiology.)

OBJECTIVES: The purpose of this committee shall be to establish a stable, effective and mutually beneficial working relationship between NEMA and the ACR with respect to the development of certain digital communication standards. The Committee shall establish standards which will (1) promote ease of communication of digital radiologic image information regardless of source or time of manufacture; (2) facilitate the development of PACS objectives in radiology departments; and (3) allow constitution of information networks in Radiology. In this relationship between ACR and NEMA the principal responsibility for identifying targets and needs for such standardization lies primarily with the ACR; while the evaluation of the acceptability and feasibility of such target areas is the primary responsibility of NEMA.

RESPONSIBILITY: The Committee, in accomplishing the objectives defined above, will be reminded that it is not a Committee authorized to function without regard to its representation, but is one which will be constrained to listen to the counsel not only of the governance of the ACR and NEMA, but also of other parties interested in the establishment of effective standards. The conduct of the Committee will be in recognition of these joint areas of responsibility, including the communication with and observation of outside standards efforts.

MEMBERSHIP: The membership of the Committee shall be members appointed from the Committee on Computers and/or other Committees or Commissions of the ACR and members appointed from the Emerging Technology Committee and/or other Committees of NEMA. The Committee shall be jointly chaired by two members, one each from the ACR and NEMA, presiding alternately at sequential meetings unless otherwise agreed upon.

AD HOC MEMBERSHIP: With mutual agreement of NEMA and ACR, ad hoc members may be named to meet special objectives or to replace regular members unable to be present. Unless otherwise agreed with by the co-chairmen, ad hoc membership terminates with the adjournment of the first meeting at which the ad hoc member is present.

MEETINGS: Insofar as possible meetings will be held at times and places where members would ordinarily be present. Otherwise, meetings will be called no less often than quarterly, unless otherwise agreed upon by members of the Committee. More frequent meetings may be called as needed for conduct of business. Meetings normally will be attended by (1) named members of the Committee, (2) ad hoc members as defined above, and (3) other interested parties, who will be introduced as a part of normal committee procedure. All meetings will be open, but voting will be restricted as defined herein.

HORII

VOTING RIGHTS: Only regular members of the Committee are authorized voting rights. Each participating organization of the Committee shall have an equal number of votes.

AGENDA: Agenda items shall include:

1. Call to order.
2. Introduction of members and guests.
3. Minutes of preceding meeting.
4. Old business.
5. New business.
6. Agenda, location, and time for next meeting.
7. Adjournment.

At the chairman's discretion, Roberts Rules of Order shall apply.

SELECTION OF TARGETS FOR STANDARDIZATION: (1) Target areas shall be agreed upon by vote of the Committee.

PRIORITIES: The policy of the Committee will be to focus upon a single area of highest priority, with the goal of accomplishing meaningful results within tight time constraints.

WORKING COMMITTEES: In order to meet established priorities, the Committee is authorized to appoint working committees for the purpose of focusing specialized talent on the accomplishment of objectives. The membership of such committees may be drawn from the rank and file of science and industry without regard to their membership in NEMA or the ACR. Their tenure will be terminated upon completion of their assigned task, unless otherwise agreed upon by the membership of the Committee.

Exhibit A

A PRELIMINARY PROPOSAL ON THE ROLES OF AND INTER-RELATIONSHIP BETWEEN THE ACR AND NEMA IN DIGITAL IMAGING AND COMMUNICATIONS STANDARDS ACTIVITY

Submitted by:

Allan I. Edwin
Chairman, Ad Hoc Technical Committee
of the Emerging Technology Committee
NEMA, Diagnostic Imaging and
Therapy Systems Division

Exhibit B

At present there are at least two organizations involved in standards activity in the area of Multi-Modality imaging. Each has a legitimate interest in and valuable perspectives to share on the problems and opportunities. In this document we would like to propose a scenario for interaction among the organizations. We recognize that there will be a great effort required on all our parts to being such a plan to fruition. If it can be accomplished, however, the resulting voluntary Standards will be more thoroughly analyzed, perhaps even more quickly developed and adopted, and more widely accepted.

General Roles

Our proposal is based on segmenting the standards requirements into two subsets, with each organization focusing on issues pertaining to their areas of greatest expertise and experience. A joint committee would be formed with each organization represented to assemble the resulting documents into a "complete" proposed Standard for distribution and comment, and finally adoption.

ACR Representation on the Joint Committee

Since the ACR is, among other things, the radiological community's standards organization it seems logical for this subcommittee to focus its efforts on defining the needs and rationale, i.e., "what do radiologists want?". For example, is a Multi-Modality Imaging and Communications System wanted?

Key ACR issues could include:

1) Requirements for Displays.

2) Need for system to handle raw data vs. image data (reconstructed). What if any console processing of Raw Data is required?

3) Image storage - How much for how long?

4) Need for specification on type and description of non-image data to be accessed.

In this way the radiological community would take a leadership role in defining what it requires from a system.

NEMA - Representation on the Joint Committee - Ad Hoc Technological Committee of the Emerging Technology Committee

NEMA's Diagnostic Imaging and Therapy Systems Division represents the diagnostic imaging equipment manufacturers. As such, it is in the best position to liaison with other industry groups to gather input and support from other relevant issues.

Among the obvious key issues for this subcommittee are:

1) Standardized Definition of Subsystems (Model).

2) Glossary of terms with "official definition" to mini disputes.

3) Development of proposed "image" data format.

4) Development of proposed electrical/protocol standard connection.

5) Proposal to define and analyze gateways between digi other medical information systems.

6) Study issues of compatibility with previous generati equipment.

It is recommended that representative of ACR and N their observer roles with the IEEE Working Group 1 on Ima and Exchange Standards.

2) Glossary of terms with "official definition" to minim disputes.

3) Development of proposed "image" data format.

4) Development of proposed electrical/protocol standard : connection.

5) Proposal to define and analyze gateways between digit: other medical information systems.

6) Study issues of compatibility with previous generatior equipment.

It is recommended that representative of ACR and NE their observer roles with the IEEE Working Group 1 on Imag and Exchange Standards.

MEDICAL IMAGING EQUIPMENT
DIGITAL IMAGE TRANSFER INTERFACE STANDARD

1.0 FOREWORD.

A growing interest in the need for the consolidation of medical imaging information obtained from a wide variety of imaging systems has prompted the development of a number of system architectures designed to bring coherence to medical imaging efforts. One major stumbling block to the successful implementation of these systems is the inability to efficiently and effectively interface the various image acquisition devices to a unifying PACS network. In an effort to reduce this difficulty, a proposed Imaging Equipment Interface Standard has been developed which meets the following goals:

1. Applicability across the spectrum of image sources.

2. Absence of manufacturer specificity.

3. Simplicity and ease of implementation.

4. Functional design for future capability.

The standard includes complete and specific details on all aspects required for implementation within an imaging system including image format, electrical characteristics, interface protocol, and provisions for miscellaneous patient-specific data.

2.0 SCOPE

This Standard is applicable to the connection, control and data interchange between an Imaging Equipment (IE) device and a Network Interface Equipment (NIE) at a node of a data transmission medium.

The NIE provides the network-specific conversion between the protocol and format set forth in this standard, and the protocols of a particular network structure and transmission medium. This standard then provides for the exchange of images and data among devices of differing hardware and internal data structure via a standard interface to a network. The protocols of the network itself are not within the scope of the standard, and are considered specific to the manufacturer of the transmission medium and NIE devices.

This Standard establishes specification for the Imaging Equipment to Network Interface Equipment, including:

1. Electrical Characteristics
2. Image Data Format
3. Interface Protocol
4. Mechanical Characteristics

3.0 PURPOSE

This standard establishes an interface common to all manufacturers of Medical Image Acquisition equipment. Acceptance and implementation of this standard will allow a true competative PACS market to develop. Use of this interface will result in products that are more acceptable to the end user and are more flexible in application.

In addition, this standard should be implementable with minimal and straight-forward hardware additions and with minor additions to the Imaging Equipment system software.

4.0 GENERAL DESCRIPTION

The Digital Image Transfer Interface is comprised of two Imaging Equipment communication channels, a high speed 16 bit parallel Data Channel and a 9600 BAUD RS-232 Control Channel. Both channels are bi-directional. The Data Channel provides rapid transfer of the large quantities of blocked and formatted image data while the RS-232 Control Channel provides appropriate communication of Command and Control information via a well-understood and documented RS-232-C interface. The combination provides an efficient and straight forward interface for image transfer.

In addition, a complete image format is included. The image format consists of two parts, the Header which contains machine ID, image format parameters, patient and miscellaneous information, and the Image which contains the image data. Both are comprised of a number of 4096 byte blocks. The Header comprises one or several blocks as required. The Image has enough blocks to contain all the image data.

Included are specifications for the electrical and mechanical interfaces between the Imaging Equipment and the NIE for both channels, protocols for the Control Channel, and protocols and data format for the Data Channel.

EXHIBIT C

The data format is Pixel-by-Pixel, raster-scan by plane, in blocks of 4096 bytes. This allows simple, unambiguous data exchange at the Imaging Equipment interface. Network-specific compression and/or reblocking would be handled by the NIE. The image is preceeded by a 4096 byte Header which includes a 512 byte fixed-format section containing basic image information. A space is provided for a specific Imaging Equipment Header to facilitate redisplay of a retrieved image. Space is also provided for installation - Specific keywords and database references. The Header is expandable to multiple blocks via a flag byte. Further, a Header can precede text-only information (e.g., a diagnostic report), again via a flag byte.

This image transfer interface standard requires supporting software in the Imaging Equipment to service the Control Channel Commands and Responses and to take the appropriate action. Further software is needed to expand the image data into standard format, to assemble the Header block, and to support the Parallel data transfer to and from the NIE using two-way data control circuit handshaking. In the ISO model the software needs to provide the Presentation Level and up for the Control Channel and the Transport Level and up for the Data Channel. It is intended that each individual network manufacturer develop an NIE consistent with his network concept and with the goal of minimizing control channel servicing. It is further intended that image transfers can be primarily scheduled by the Imaging Equipment via Network Service Requests to minimize the interference of image transmission with normal Imaging Equipment functions.

4.1 DEFINITIONS

1. ASCII - Acronym for American Standard Code for Information Interchange, the most widely used character code in electronic communication. In this case, Bit USASCII.
2. Bit - Short for Binary Digit. The minimum unit of digital information.
3. Block - The basic data transfer unit. In this standard a block is 4096 bytes.
4. Byte - The number of bits used to represent a character. In this standard, 8 bits.
5. Data - Information within the system, generally distinguished between image data and patient data.
6. DCE - Abbreviation for Data Communications Equipment. See EIA STD RS-232-C.

EXHIBIT C

HORII

7. Digital Image - A group of pixels normally in a rectangular array which contain all the required information to reproduce a visual representation of a picture.

8. DMA - Acronym for Direct Memory Access. A method for transferring data to or from a computer's memory without direct CPU intervention.

9. DTE - Abbreviation for Data Terminal Equipment. See EIA STD RS-232-C.

10. EIA STD RS-232-C - Electronic Industries Association Standard for serial communications equipment in common use throughout the world.

11. Format - The physical arrangement of data items.

12. Handshaking - The process by which two independent hardware devices achieve synchronization in data transfers.

13. Header - An information preamble that normally proceeds a data transmission.

14. Input - Data in to the Imaging Equipment.

15. K - Two raised to the tenth power, 1024. (2K = 2048, 4K = 4096)

16. Network - A group of devices that are connected to each other by communications lines to share information and resources.

17. NIE - Abbreviation for Network Interface Equipment. A proprietary device that interfaces a manufacturers specific network to the Imaging Equipment standard interface.

18. Output - Data from the Imaging Equipment.

19. PACS - Acronym for Picture Archiving and Communications System.

20. Pixel - Abbreviation for "Picture Element". These are definable locations within an image.

21. Protocol - The collection of operating rules under which communication takes place.

22. Raster - The rectangular area of an image that is scanned horizontally and vertically.

23. TTL - Acronym for Transistor Transistor Logic. The most commonly used integrated circuit implementation.

EXHIBIT C

24. Word - A group of bits handled as a single entity. In this standard, 16 bits (2 bytes); Bit 0 is the least significant bit and bits 0-7 define the least significant (lower) byte.

4.2 APPLICABLE DOCUMENTS

The following documents were referenced in the generation of this standard:

1. EIA STD: RS-232-C Serial Communications Interface Standard.

2. 7 Bit ASCII STD:

3. I.E.E.E. STD 422:

5.0 ELECTRICAL CHARACTERISTICS

The two channels will be accessed via two connectors on each piece of Imaging Equipment. The Control channel will be a serial RS-232-C compatible link, and the Data channel will include a 16-bit bi-directional parallel data path plus six control circuits which can support Direct Memory Access (DMA) transfers.

5.1 CONTROL CHANNEL

The electrical and mechanical specifications will be in accordance with EIA Standard RS-232-C, and be equivalent to an asynchronous full duplex interface type D, a subset including:

EIA circuit	Function	D-shell pin assignment
AB	Signal Ground	7
BA	Transmitted Data	2
BB	Received Data	3
CA	Request To Send	4
CB	Clear To Send	5
CC	Data Set Ready	6
CF	Received Line Signal Detector	8
AA	Chassis Ground	1
CD	Data Terminal Ready	20

EXHIBIT C

5.1.1 DESCRIPTION OF SIGNALS -

Transmitted Data - Output from imaging system. Transmit data to network.

Received Data - Output from NIE. Receive data from network.

Request to Send - Output from Imaging Equipment. Imaging Equipment raises this signal when it wants to send on the control channel.

Clear to Send - Output from the NIE. Gives Imaging Equipment permission to transmit on the control channel.

Data Set Ready - Output from NIE. Tells the Imaging Equipment that an NIE is connected to it and that the NIE's power is on.

Received Line Signal Detection - Output from NIE. Always a high level when the NIE's power is on.

Data Terminal Ready - Output from Imaging Equipment. Tells the NIE that it is connected to the Imaging Equipment and that the Imaging Equipment's power is on.

When the Imaging Equipment wants to transmit on the control channel, it raises Request To Send and waits for the NIE to output Clear To Send. Data Set Ready is always a high when power is applied to the NIE. The NIE will not attempt to talk to the Imaging Equipment until it sees a high on Data Terminal Ready. If a simple three wire interface is desired the user must wire Data Set Ready to Request to Send and Data Terminal Ready in the interface cable.

Signal levels will conform to EIA RS-232-C requirements.

The Imaging Equipment will operate as a Data Terminal Equipment, while the Network Interface Equipment (NIE) will operate as a Data Communications Equipment. Characters output on the control channel should not be echoed by the receiving equipment.

The connector is a female DB-25S EIA 25-pin D-shell connector.

5.2 DATA CHANNEL

The electrical specifications for the Data Channel are compatable with the specifications of EIA Standard RS-422A. EIA Standard RS-422A defines a differential, balanced voltage interface. The data channel consists of sixteen bi-directional data circuits, three control circuits driven by the NIE, three control circuits driven by the IE, and signal grounds.

EXHIBIT C

The data circuits, designated D0 through D15, are sixteen bi-directional, differential circuits for data input to and output from the IE. Each of the sixteen circuits is a differential pair of signals designated Dn+ and Dn-. These circuits can be driven by either the IE or the NIE.

The six control circuits; IBSY, ICLR, and IRDY driven by the IE and NDIR, NREQ and NSET driven by the NIE; control the flow of data on the data circuits. Each of these circuits is also a differential pair of signals, for example, IBSY+ and IBSY-. The signal ground circuits should be connected to chassis ground in each equipment via a single link. These signals are presented at the IE and NIE via a 50 pin connector for interconnection via appropriate cables.

The specifications for the circuit drivers are the same as those specified for RS-422A generators. They have an output differential voltage $V_t \geq 2.0$ volts with a 100 ohm resistor connected between the output terminals. The driver output terminal which is positive with respect to the other output, when a binary "one" is applied at the ~~input of the driver, is designated the positive (+) output terminal~~ and is connected to the + designated connector pin. Examples of this type of driver are MC3487, DS3487, and AM26LS31.

The receiver specifications are the same as those specified for RS-422A receivers. The proper binary output will be sensed when there is a differential voltage of greater than 200 mv on the inputs over a common mode range of -7 to +7 volts. That input terminal which, when positive to the other, produces a binary "one" at the receiver output is designated as the positive (+) input and is connected to the + connector pin. Examples are MC3486, DS3486, and AM26LS32.

The data circuits will have a 390 ohm termination resistor connected between the (+) and (-) inputs of the receivers. The control circuits will have a 200 ohm termination resistor connected between the (+) and (-) input terminals of the receivers. The interconnecting cables should be twisted pair with the (+) and (-) signals of each circuit twisted together. Cables should be limited to less than 30 meters in length.

The IE and NIE interfaces should be capable of supporting a transfer rate of up to 2 mega-words per second. Rise and fall times of the signals should not exceed 10% of the bit width at the highest signalling rate.

EXHIBIT C

The Connector is a 50 circuit female micro-ribbon 57-20500 connector or physical equivalent with the following:

PIN ASSIGNMENTS:

Pin	Signal	Pin	Signal
1	GND	2	GND
3	D0-	4	D0+
5	D1-	6	D1+
7	D2-	8	D2+
9	D3-	10	D3+
11	D4-	12	D4+
13	D5-	14	D5+
15	D6-	16	D6+
17	D7-	18	D7+
19	D8-	20	D8+
21	D9-	22	D9+
23	D10-	24	D10+
25	D11-	26	D11+
27	D12-	28	D12+
29	D13-	30	D13+
31	D14-	32	D14+
33	D15-	34	D15+
35	GND	36	GND
37	ICLR-	38	ICLR+
39	NREQ-	40	NREQ+
41	NDIR-	42	NDIR+
43	IBSY-	44	IBSY+
45	NSET-	46	NSET+
47	IRDY-	48	IRDY+
49	GND	50	GND

DH are the data I/O lines to and from the IE. (Bit 0 is the least significant bit)

ICLR, IBSY, IRDY are control circuits from the IE

NREQ, NDIR, NSET are control circuits from the NIE

GND are signal grounds

6.0 DATA FORMAT

Data will be transferred from or to the Imaging Equipment in one or more blocks of fixed 4096 byte (2048 word) blocks. The first block will be a Header which will contain a 512-byte fixed-format basic image descriptor, a variable length free format Imaging Equipment Header section provided for ease of displaying a retrieved image, and a variable length section of the block for additional free format

EXHIBIT C

ASCII information, such as keywords for database reference. There is an Extend Header Flag which allows additional blocks to be used for header information. There is also a "No Image" Flag (set #bits/Pixel to zero) if the data only contains text information. The end of text information should be terminated with an ETX and the block padded to 4096 bytes with nulls. The number of image blocks plus header blocks is specified in the Header. The last image block should be padded to 4096 bytes with zeroes.

EXHIBIT C

6.1 DATA HEADER FORMAT

byte #	CONTENTS (all ASCII)	Length		Range
	Place and Time			
0- 1	Imaging Equipment ID#	2		00-99
2- 9	Imaging Equip. Name (ASCII)	8		8 char.
10- 11	# images in study or set	2		00-99
12- 15	First, Last Image # in this block	4		0-9999
16- 25	Image date	10		MM-DD-YYYY
26- 31	Image time	6		HH:MM.M
	Patient Data			
32- 63	Patient name	32		left just.
64- 79	ID #	16		left just.
80- 89	birthdate	10		MM-DD-YYYY
90- 91	sex	2		mm/ff
92- 95	race	4		4 char.
	Brief Exam Description			
96-159	Exam type, modality, parameters	64		
160-191	Study ref. (Phys., Tech., Series)	32		
	Image Structure			
192-195	# 4096-byte blocks(image + header)	4		0-9999
196-197	# significant bits/Pixel	2		00-32
198-199	# Pixels/16 bit word	2	**	2.U/2.L/1./.5
200-203	# columns (Pixels/line)	4		0-4096
204-207	# rows (lines)	4		0-4096
208-211	# planes (Projections)	4		0-4096
212-213	Code - 1 for 3D, 0 for Study Set	2		0/1
214-223	Spares - plane #, angles, etc.	10		
	Display Parameters			
224-225	Code (0 for gray scale)	2		
226-233	Reference mean	8		
234-241	window	8		
242-251	Spares	10		
252-255	# bytes of Imaging Machine Header	4		0-3582
		256 bytes		
	Misc. Data			
256-511	Spares for add'l data, keywords	256		
512- *	Machine Header			
* -4093	Spares for additional data			
4094-4095	Extend Header (0 for End)	2		
	Total Header Block	4096 bytes		

** 2U = Highbyte first
2L = Lowbyte first
Bit 0 = Least Significant Bit
Bits 0-7 = Low (Least Significant) byte

EXHIBIT C

If the data transmission contains just text information (such as Patient Data), include Exam information so it can be filed properly, and place a 00 in "# bits/Pixel". Bytes 512 to 4094 could then contain the information. It is anticipated that specific network installation will use data retrieval software (databases) which will require further specification of formats and fields in the header sections denoted here as spares. This standard only specifies a common core of information for image handling.

6.2 IMAGE DATA FORMAT

The image data will be represented as a rectangular array of binary 16 bit words signifying intensity or other appropriate information for each Pixel. Bit 0 is the least significant bit and bits 0-7 define the least significant (lower) byte. The data shall be uncompressed and unpacked except in the case where the Imaging Equipment uses Pixel values of 8 bits or less. Then one Pixel value may be placed in each half-word (byte). A "2" would be placed in the first byte of "# pixels/word" in the Header. If the data is presented Low byte first, then the second byte of # of pixels/word is L. If the data is presented High byte first, then the second byte is U. The image data will be contained in an integer number of 4096 byte (2048 16-bit words) blocks, the total number of blocks being specified in the Header. The last block will be padded to 4096 words with (binary) zeroes.

The Image Data shall be presented to the interface in 4096 byte blocks. The overall image data shall be a serial Pixel stream scanned from the image(s) in the following order:

1. Left to right as the image is viewed.
2. Top to bottom as the image is viewed.
3. For multiple slices, Head to Toe, Front to Back, or Left to Right depending on the orientation of the slices.

The serial data stream shall be:

1. Pixel by Pixel
2. Uncompressed
3. Unpacked
4. 16 Bit words

EXHIBIT C

6.3 INFORMATION DATA FORMAT

Textual information may be sent in the free format ASCII portion of the header. The header will be extended to multiple blocks as necessary. Text will terminate with an ETX character. The last block will be padded to 4096 bytes with nulls.

7.0 INTERFACE PROTOCOLS

7.1 VOCABULARY OF CONTROL CHANNEL COMMANDS AND RESPONSES

All commands from the NIE and responses by the Imaging Equipment (IE) will be single ASCII characters with the exception of Messages, which will be preceded by the appropriate ASCII character prefix.

7.1.1 NIE COMMANDS -

The following is the list of NIE Commands:

1. Status Request (SRQ) - The NIE asks the Imaging Equipment to report its status. The Status Request is coded as an ASCII ENQ.

2. Send Data (SDC) - Tells the Imaging Equipment to send data to the NIE over the parallel Data Channel. ASCII SOH.

3. Acknowledge (ACK) - Tells the Imaging Equipment that the current data transfer is complete. ASCII ACK.

4. Abort (ABC) - Tells the Imaging Equipment to abort the current image or data transfer. The abort command also dissolves a linked condition if the NIE is linked to the imaging equipment. ASCII CAN.

5. Data Ready (DRC) - Tells the Imaging Equipment that the NIE has data that it wants to output over the parallel output Data Channel. If the Imaging Equipment is in the Linked condition, DRC dissolves the Link. ASCII ETB.

6. Set Link (SLC) - Tells the Imaging Equipment to establish a link with its Operator over the Serial Control Channel. ASCII DLE.

7. Operator Message (OMC) - Tells the Imaging Equipment to display a message to the Imaging Equipment Operator. Messages are of the form:

EXHIBIT C

STX/ Message Text (in ASCII) / ETX

7.1.2 IMAGING EQUIPMENT RESPONSES TO NIE COMMANDS -

The following is the list of Imaging Equipment responses to NIE commands:

1. No Action Required (NAR) - Response to Status Request. Tells the NIE that the Imaging Equipment has no traffic for the network. ASCII NAK.

2. Picture To Send (PTS) - Response to Status Request or Imaging Equipment Status Output. Tells the NIE that the Imaging Equipment has an image that it is ready to send to the network. ASCII DC1.

3. Information To Send (ITS) - Response to Status Request or Imaging Equipment Status Output. Tells the NIE that the Imaging Equipment has Patient Information that it is ready to send to the network. ASCII DC2.

4. Request For Picture (RFP) - Response to Status Request or Imaging Equipment Status Output. Tells the NIE that the Imaging Equipment Operator is requesting an image from the network. ASCII DC3.

5. Request For Information (RFI) - Response to Status Request or Imaging System Status Output. Tells the NIE that the Imaging Equipment Operator is requesting Patient Information from the network. ASCII DC4.

6. Waiting For You (WFY) - Response to Status Request. Tells the NIE that the Imaging Equipment is waiting for an input from the NIE. ASCII VT.

7. Link Set Status (LSS) - Response to Status Request or Link command. Tells the NIE that the Imaging Equipment has entered the Link mode. Note: While in Linked status, the IE needs to recognize five special control characters; ENQ, ETB, CAN, STX, ETX as control channel command characters. ASCII DLE.

8. Send Data Status (SDS) - Response to Status Request or Data Ready Command. Tells the NIE that the Imaging Equipment is ready to receive a data block over the parallel Data Channel. ASCII ETB.

9. Transferring Data Status (TDS) - Response to Status Request. Tells the NIE that the Imaging Equipment is in the process of transferring data over the parallel interface. ASCII EM.

EXHIBIT C

10. Acknowledge Data Transfer (ADT) - Response to Status Request. Tells the NIE that the data transfer from the network to the Imaging Equipment is complete. ASCII ACK.

11. Abort Status (ABS) - Response to Status Request. Tells the NIE to abort the data transfer that is currently in process. ASCII CAN.

12. Message From Operator (MFO) - Response to Status Request or Operator Message. Tells the NIE that the data is a message from the Imaging Equipment Operator. This only occurs when the Imaging Equipment is in the Link mode. Messages are of the form:

    STX / Message Text (in ASCII) / ETX

7.1.3 CONTROL CHANNEL PROTOCOLS -

Interchanges between the NIE and the Imaging Equipment (IE) happen in one of two ways. Either the NIE outputs a Command or Status Request and the Imaging Equipment responds appropriately from the vocabulary of Responses or the Imaging Equipment can output status directly to the NIE without waiting for a status request.

In the normal idling state the Imaging Equipment can output one of five statuses.

1. NAR - No Action Required
2. PTS - Picture To Send
3. ITS - Patient Information To Send
4. RFP - Request For Picture
5. RFI - Request For Patient Information

The protocols for these are described as follows:

1. When the Imaging Equipment responds to a Status Request with a NAR status, the NIE simply returns to the idling state and will ask for status again at a later time.

2. When the Imaging Equipment outputs a PTS status, it signals that it has an image that it is ready to send to the network. On receiving a PTS status the NIE sets up for data transfer via its parallel input Data Channel. If the NIE asks the Imaging Equipment for status at this time, it responds with a Waiting For You (WFY) status. After setting up the Data channel the NIE

EXHIBIT C

7.2.2 DESCRIPTION OF DATA TRANSFER -

7.2.2.1 DATA OUTPUT FROM IMAGING EQUIPMENT -

The data transfer is prepared for via the Control channel by a PTS (Picture To Send) or ITS response to the NIE. The IE sets ICLR high. The network must then prepare for the transfer and then send the BSC (Begin Sending) Control Channel Command. When this occurs the NIE will set the NDIR data control circuit low, set NSET low, and set NREQ low. When the IE sets IRDY low the NIE will then strobe NREQ high (and back low after 1 microsecond) to signal that it is ready for the first word. The IE meanwhile must prepare a 4096 byte block for transfer (including assembly of the header block and expansion of compressed or packed data if necessary). When ready, and after NSET is low the IE will set IRDY low. When the first low to high strobe of NREQ occurs the IE will set IBSY low, place the first word to send on the Data Out circuits, and then set IBSY high. The NIE will accept the word and when ready for the next, it will again strobe NREQ high. The IE will set IBSY low, place the next word on the output circuits, set IBSY high. This cycle will repeat until the block of 2048 words has been transferred. The IE will then set IRDY high, and the NIE may set NSET high (depending on its buffer, network access, etc.). When the NIE is ready for another block it will set NSET low. When the IE sets IRDY low NIE will strobe NREQ high and the next block transfer will commence.

When the complete image has been transferred the network (NIE) will send the acknowledge (AKC) command on the control channel. If the Imaging Equipment must service a higher priority task during the transfer of a block it will set ICLR low and IRDY high. If this occurs the IE should consider that the full image transfer was aborted, and start over at a later time. An abort status should be output to the NIE. Likewise if the NIE sets NSET high during a block transfer this aborts the image transfer and an abort command should be output to the Imaging Equipment.

7.2.2.2 DATA INPUT TO THE IMAGING EQUIPMENT -

The data transfer is prepared via the Control channel by a RFP (Request For Picture) or RFI response by the IE to the NIE. The NIE sets up a link to the network, sends a Set Link Command to the IE after dialog, the NIE sends a Control Channel Data Ready Command. The IE then breaks the Linked status, sends Send Data Status and sets Data Control Circuit ICLR high. The NIE sets NDIR high, sets NSET and NREQ low, and when IRDY is low strobes NREQ high to signal that it has data ready on the Data In circuits. The IE meanwhile must prepare to receive data (including interpretation of the Header block and possible reformatting of the data). Then the IE sets IRDY low to signal it is ready to accept words. When NREQ is strobed high the

EXHIBIT C

Information file is generally only one or two blocks.

7.2 DATA CHANNEL PROTOCOL

The Data channel will operate as a half-duplex, 16-bit parallel word interface, with data passing either from or to the Imaging Equipment (IE) as set up via the Control Channel. Transfer is under full handshake control by the Data Control circuits. The Interface Circuits should be capable of supporting data rates at least one word per microsecond, and be able to send and receive 4096 byte (2048 16-bit word) blocks of data as a unit.

7.2.1 DEFINITION OF DATA CONTROL CIRCUITS - In these definitions and descriptions, a "low" refers to a binary zero and a "high" refers to a binary one as defined in Section 5.2.

Name	From	Function
NDIR	NIE	Sets direction of data transfer; set low for data transfer from IE (output); set high for transfer to IE (input).
NSET	NIE	Normally high; set low by NIE to signal that transfer of a block of words can start; set high when block is transferred or to signal an interrupt of transfer.
ICLR	IE	Normally High; set low by IE to signal an interrupt during a block transfer.
IRDY	IE	Normally high; set low by IE to signal that transfer of a block of words can start; set high when block is transferred.
NREQ	NIE	Used by NIE to control flow of data; set low after NSET set low; set high for at least 1 microsecond to signal that the NIE is ready to accept the next word (output) or that the next word is ready (input).
IBSY	NIE	Used by IE to control flow of data; set low by IE when a memory access is in progress and to acknowledge the NREQ strobe; set high when IE has next word on Data OUT circuits or is ready to accept another word on Data IN circuits.

EXHIBIT C

7.2.2 DESCRIPTION OF DATA TRANSFER -

7.2.2.1 DATA OUTPUT FROM IMAGING EQUIPMENT -

The data transfer is prepared for via the Control channel by a PTS (Picture To Send) or ITS response to the NIE. The IE sets ICLR high. The network must then prepare for the transfer and then send the BSC (Begin Sending) Control Channel Command. When this occurs the NIE will set the NDIR data control circuit low, set NSET low, and set NREQ low. When the IE sets IRDY low the NIE will then strobe NREQ high (and back low after 1 microsecond) to signal that it is ready for the first word. The IE meanwhile must prepare a 4096 byte block for transfer (including assembly of the header block and expansion of compressed or packed data if necessary). When ready, and after NSET is low the IE will set IRDY low. When the first low to high strobe of NREQ occurs the IE will set IBSY low, place the first word to send on the Data Out circuits, and then set IBSY high. The NIE will accept the word and when ready for the next, it will again strobe NREQ high. The IE will set IBSY low, place the next word on the output circuits, set IBSY high. This cycle will repeat until the block of 2048 words has been transferred. The IE will then set IRDY high, and the NIE may set NSET high (depending on its buffer, network access, etc.). When the NIE is ready for another block it will set NSET low. When the IE sets IRDY low NIE will strobe NREQ high and the next block transfer will commence.

When the complete image has been transferred the network (NIE) will send the acknowledge (AKC) command on the control channel. If the Imaging Equipment must service a higher priority task during the transfer of a block it will set ICLR low and IRDY high. If this occurs the IE should consider that the full image transfer was aborted, and start over at a later time. An abort status should be output to the NIE. Likewise if the NIE sets NSET high during a block transfer this aborts the image transfer and an abort command should be output to the Imaging Equipment.

7.2.2.2 DATA INPUT TO THE IMAGING EQUIPMENT -

The data transfer is prepared via the Control channel by a RFP (Request For Picture) or RFI response by the IE to the NIE. The NIE sets up a link to the network, sends a Set Link Command to the IE after dialog, the NIE sends a Control Channel Data Ready Command. The IE then breaks the Linked status, sends Send Data Status and sets Data Control Circuit ICLR high. The NIE sets NDIR high, sets NSET and NREQ low, and when IRDY is low strobes NREQ high to signal that it has data ready on the Data In circuits. The IE meanwhile must prepare to receive data (including interpretation of the Header block and possible reformatting of the data). Then the IE sets IRDY low to signal it is ready to accept words. When NREQ is strobed high the

EXHIBIT C

first word is valid on the Data In circuits. The IE then set IBSY low, stores the word, then sets IBSY high again. The next strobe of NREQ high signals the next word is valid, and so on until the block of 2048 words are transferred. The IE will then set IRDY high until it is ready to receive the next block and the HIE has set NSET low. Transfer of succeeding blocks proceed as above. When the complete image has been received the IE will respond on the Control channel with Acknowledge Data Transfer (ADT).

8.0 MECHANICAL CHARACTERISTICS

8.1 CONNECTORS

The Following connectors, or their physical equivalents, shall be used:

1. RS-232: Standard 25 pin MODEM D-shell female connector (DB-25S or physical equivalent).
2. DATA: The mechanical connector is a 50-circuit female micro-ribbon connector such as an AMP 57-20500 or equivalent.

8.1.1 PIN ASSIGNMENTS - CONTROL CHANNEL -

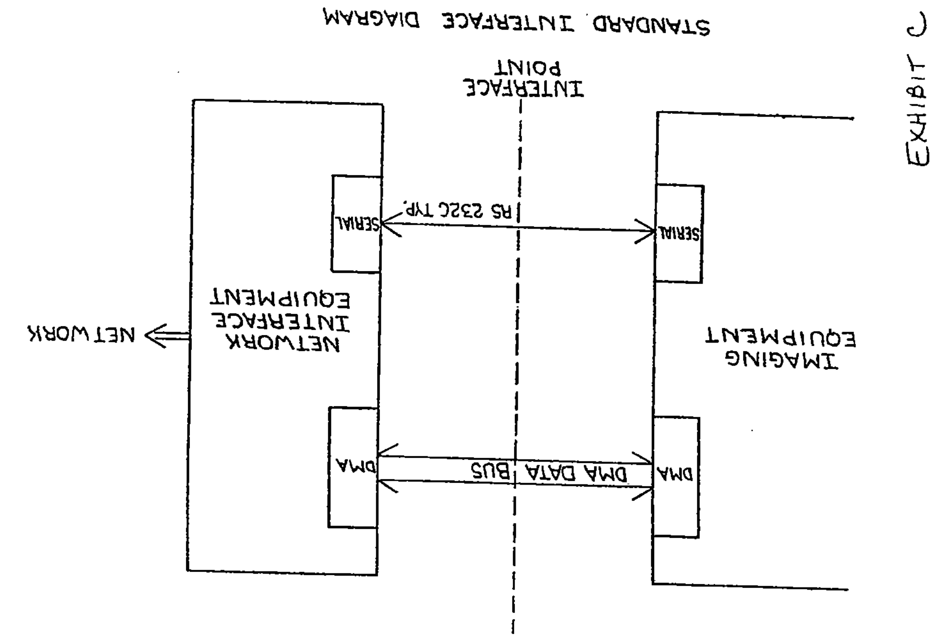
1. GND
2. Transmit Data
3. Receive Data
4. Request To Send
5. Clear To Send
6. Dataset Ready
7. Ground
8. Receive Line Signal Detect
20. Data Terminal Ready

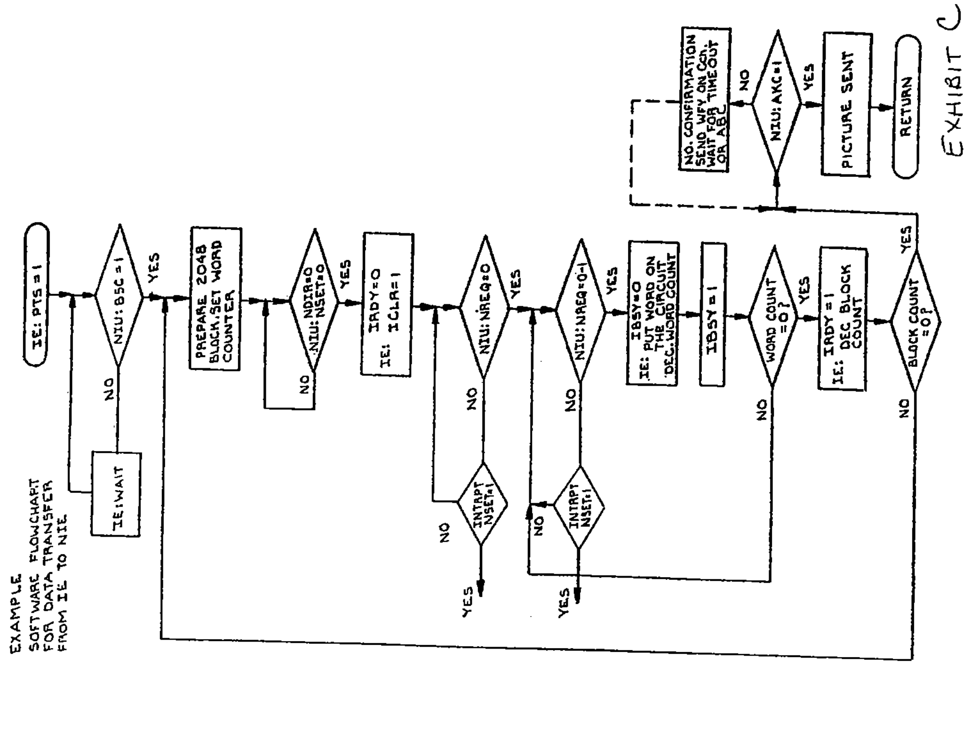
EXHIBIT C

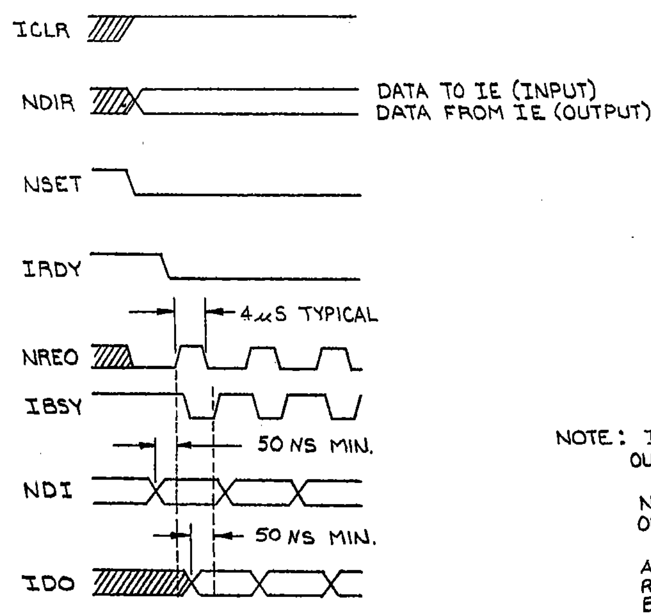
8.1.2 PIN ASSIGNMENTS - DATA CHANNEL -

Pin GND Signal	Pin GND Signal
1 - GND	2 - GND
3 - D0-	4 - D0+
5 - D1-	6 - D1+
7 - D2-	8 - D2+
9 - D3-	10 - D3+
11 - D4-	12 - D4+
13 - D5-	14 - D5+
15 - D6-	16 - D6+
17 - D7-	18 - D7+
19 - D8-	20 - D8+
21 - D9-	22 - D9+
23 - D10-	24 - D10+
25 - D11-	26 - D11+
27 - D12-	28 - D12+
29 - D13-	30 - D13+
31 - D14-	32 - D14+
33 - D15-	34 - D15+
35 - GND	36 - GND
37 - ICLR-	38 - ICLR+
39 - NREQ-	40 - NREQ+
41 - NDIR-	42 - NDIR+
43 - IBSY-	44 - IBSY+
45 - NSET-	46 - NSET+
47 - IRDY-	48 - IRDY+
49 - GND	50 - GND

EXHIBIT C


STANDARD INTERFACE DIAGRAM
INTERFACE POINT
NETWORK INTERFACE EQUIPMENT
NETWORK
SERIAL
RS 232C TYP.
SERIAL
IMAGING EQUIPMENT
DMA
DMA DATA BUS
DMA
EXHIBIT C


EXAMPLE SOFTWARE FLOWCHART FOR DATA TRANSFER FROM IE TO NIE
IE: PTS=1
NIU: BSC=1
YES
NO
IE: WAIT
PREPARE 2048 BLOCK, SET WORD COUNTER
NIU: NDIR=0 NSET=0
IE: IRDY=0 ICLR=1
NIU: NREQ=0
INTRPT NSET=1
IE: IBSY=0 PUT WORD ON THE CIRCUIT DEC. WORD COUNT
IBSY=1
WORD COUNT =0?
IE: IRDY=1 DEC BLOCK COUNT
BLOCK COUNT =0?
NIU: AKC=1
PICTURE SENT
RETURN
EXHIBIT C



NOTE: I --- SIGNALS ARE OUTPUT FROM THE IE

N --- SIGNALS ARE OUTPUT FROM THE NIE

ALL SIGNALS ARE RS-422A COMPATABLE BALANCED DIFFERENTIAL LEVELS

TIMING DIAGRAM FOR DATA CHANNEL TRANSFER

EXHIBIT C