Communications

An Architecture for Naval Telemedicine

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***Abstract*— Navy fleets have a defined overall objective for mission readiness impacted by the health of personnel aboard the ships. Medical treatment facilities on the ships determines the degree of mission readiness. This paper describes the concepts and technologies necessary to establish a Naval telemedicine system, which can drastically improve health care delivery. It consists of various combinations of the following components: Fleet Naval Medical Consultation and Diagnostic Centers, Shipboard Naval Medical Consultation and Diagnostic Centers (hospital ship or combatant ships with medical specialists on board), and Remote Medical Referring Centers such as a ship, a small Naval station annex, or a field hospital. This Naval telemedicine architecture delivers clinical medicine and continuing medical education (CME) by means of computers, video-conferencing systems, or telephony to enhance the quality of care through improved access to research, medical and nonmedical imaging, remote consultations, patient clinical data, and multimedia medical education programs. It integrates the informatics infrastructure and provides a medical telepresence among participants.**

NOMENCLATURE

ATM	Asynchronous transfer mode.
CCD	Charged-coupled device.
CME	Continuing medical education.
CODEC	Coder/decoder.
CPR	Computer-based patient record.
CSU/DSU	Channel service unit/digital service unit.
DAMDW	Dynamically adaptive multi-disciplinary workstation.
DESRON	Destroyer squadron.
DICOM	Digital imaging and communications in medicine.
EKG	Electro-cardiogram.
ENT	Ears, nose, throat.
FDDI	Fiber distributed data interface.
FNMCDC	Fleet Naval medical consultation and diagnostic center.
GUI	Graphical user interface.
HL-7	Health level seven.
HIS	Hospital information system.
ICU	Intensive care unit.
IEEE 802.5	Token ring.
MTBF	Mean time before failure.
NTSC	National television standards committee.
PACS	Picture archiving and communication system.
PPP	Point-to-point protocol.
RGB	Red, green, blue (refers to method of getting a monitor presentation).
RMRC	Remote medical referring center.
SNMCDC	Shipboard Naval medical consultation and diagnostic center.
SLIP	Serial line internet protocol.
SQL	Structured-query-language.
S-VHS	Super-video home system.
TCP/IP	Transmission control protocol and internet protocol.
UPS	Uninterrupted power supply.
VCR	Video cassette recorder.

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I. INTRODUCTION

Telemedicine is the extension of medical service and consultation from one location to another. Using this definition, unsophisticated telemedicine systems rely on at least two services:

1) verbal telephone conversations to convey information;
2) rapid mail delivery for diagnostic media. Usually inexpensive, this method is not always the most time-efficient means of sharing diagnostic information.

Many systems exist to exchange information between two sites, but physicians often demand physical access to diagnostic information. Therefore, either the patient or a copy of a diagnostic study must be brought to the physician in a reasonable time and at a reasonable cost. For example, a hospital in North Carolina explored the use of teleradiology services. Current computer-based telemedicine systems competed with standard procedures. Instead of telecommunications-based solution, an automobile-courier service was used. Despite the fact that if the films were digitized to a 2 K $\times$ 2 K $\times$ 16-bit format, they would have a daily bandwidth approximately equivalent to a T1 line (1.54 Megabits per second), the latency of a 45-min transport was chosen over the other solution with a latency measured in seconds. This decision was made because of low projected use of the teleradiology service. The T1 system was not as cost-effective as paying for the courier service.

Telemedicine has come to limit its scope to clinical medicine or education assisted by the use of computers, video-conferencing systems, and telephones to enhance the quality of care through improved access to research, medical and nonmedical imaging, remote consultations, patient clinical data, and computer/video-aided medical education programs.

Recent advances in computer and communications technologies have made it possible to share information over a wide geographic area using standards or developing standards in computer software, computer hardware, and communications. Telemedicine applications are emerging as a means to facilitate the practice of medicine and to enhance patient access. Using a wide-area digital network to connect computers, physicians can share visual, auditory, and alphanumeric data in real time. Currently, most remote medicine is accomplished with telephones, overnight mail, and fax machines. Remote consultation consists of sending diagnostic information stored on videotape, X-ray film, or microscopic slides via overnight mail. These technologies, though inexpensive, do not allow for physician-physician interaction, and patients often have to travel great distances for specialty care and medical intervention. Telemedicine systems

TABLE I
SOME OF THE TELECONFERENCING STANDARDS PROMOTING INTEROPEROBILITY

Standard	Description
H.320	Visual Telephone System Standard.
H.231	Standard for multipoint control units (MCUs) defining how three or more H.320-compatible systems link together in a single conference.
H.322	An enhanced version of H.320 optimized for networks that guarantee Quality of Service (QoS) for isochronous traffic such as real-time video. It is expected to be first used with IEEE 802.9a isoEthernet LANs.
H.323	H.323 extends H.320 to Ethernet, Token-Ring, and other packet-switched networks that don't guarantee QoS. It will support both point-to-point and multipoint operations.
T.120	T.120 covers document sharing protocols. Whiteboard applications are covered in this standard.

are being installed that use information coder/decoders (CODEC's). These systems are usually proprietary and centralized. They are often expensive, costing upwards of $75 000 for an entry-level system; yet they provide only a video-conferencing mechanism with some data-sharing capability. The proposed architecture is intended to demonstrate a telemedicine paradigm that will be more cost-effective than current telemedicine implementations and will provide physicians with enhanced diagnostic modalities, such as the telepathology system discussed later.

With regard to the information revolution currently taking place, several models clearly demonstrate that enhanced communications can truly facilitate medical disciplines. These are lagging behind applications in many other disciplines, mainly because of technical demands inherent in the practice of medicine. For instance, an enormous amount of information in the form of multimedia sequences must be processed and transported in a reliable, reproducible manner that will allow physicians to use the information accurately. Dropped echocardiogram frames or corrupted stethoscope audio packets can affect a diagnosis. The reason is a video sequence may look fine and the audio sequence sound acceptable, however, health of the patient may not be properly represented by either if information is missing or out of order temporally. This possibility of misdiagnosis has medical and legal implications.

The ability to transport video data has been available for some time. Initially, the equipment required was proprietary, expensive, and cumbersome to operate. Developments of teleconferencing companies have motivated the International Telecommunications Union-Telecommunications (ITU-T) Standards Section to produce the teleconferencing standards promoting interoperability. Among the important ones are these five shown in Table I.

A telemedicine workstation encompassing multiple functions and medical disciplines is advantageous, as one or two telemedicine workstations can be initially deployed. As they support several medical disciplines, medical center decision-makers can observe workstation utilization by the various specialty areas. As utilization in an area increases, more units can be deployed as needed. To purchase a system to accommodate each medical specialty would be expensive, and the underutilized equipment would take up valuable space and logistical support. Another alternative is to get a teleconferencing system like those supplied by CLI, PictureTel, and V-Tel with telemedicine devices attached where needed. The CODEC's of these systems along with the control functions cost more than workstation-based systems.

Another advantage of having a less expensive multiple-functionality system is apparent when telemedicine services are provided by doctors who are on rounds and on call. In the CODEC-based systems, when a physician is called to a telemedicine session, that individual would have to go to a telemedicine room, which may not be in an optimal location. In this system, the physician goes to a less expensive telemedicine system which can be placed in additional, more convenient locations for the price of the single telemedicine room. The telemedicine workstation must adapt to a physician's in this situation to further ease of use. When the physician logged on to the general telemedicine workstation, its functions would be altered specifically for the requirements of his specialty as described in an earlier paper [1].

Computers now can digitize a video signal and transport it just about anywhere. This functionality allows physicians to view a patient at a remote site and render an opinion. Additionally, the performance of modern desktop workstations allows physicians to share near-broadcast-quality video and vital signs telemetry, as well as data from electronic patient records, which is an emerging technology. The workstation in the proposed architecture adapts to the needs of the physician using it. This was prototyped, without the final GUI, at the Armed Forces Institute of Pathology's Telemedicine '95 Conference in Washington, DC, January 4–11, 1995, and again at the 1994 RSNA Conference in Chicago, IL, where a DS-3 ATM link between Chicago and Winston-Salem, NC connected early prototypes of this architecture's workstations demonstrated teleradiology and telemedicine services. Therefore, one machine can serve an entire hospital, if necessary.

This paper concentrates on the telemedicine workstations that are part of the overall Naval telemedicine architecture and gives an overview of its possible operation. The next section of this paper describes the organization and interrelationships of the telemedicine architecture. The results section describes the telemedicine system and is followed by a discussion of implementation.

II. MATERIALS AND METHODS

A. The Naval Telemedicine Architecture

The Naval Telemedicine Architecture serves three main organizational entities:

1) Fleet Naval Medical Consultation and Diagnostic Center (FN-MCDC),

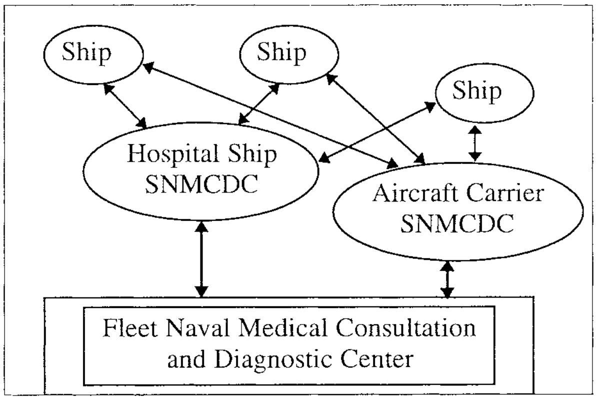

Fig. 1. RMRC's (ships and SNMCDC's supported by the FNMCDC).

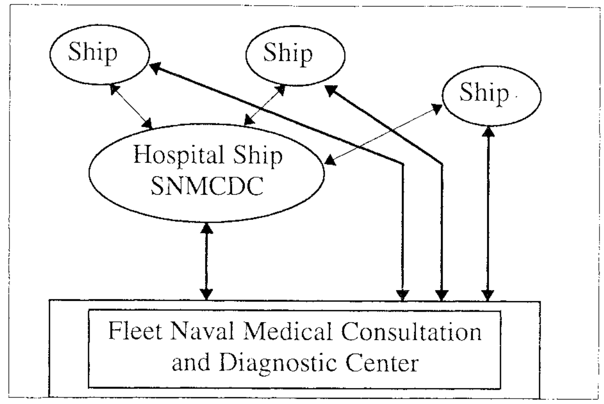

Fig. 2. DESRON RMRC's supported by an SNMCDC and the FNMCDC.

2) Shipboard Naval Medical Consultation and Diagnostic Center (SNMCDC), and
3) Remote Medical Referring Center (RMRC).

These three organizational entities are differentiated by the services they provide and the telemedicine workstations they use. These workstations adapt to the physician's specialty, the medical task, and the communications bandwidth available, without the physician's interaction. The task is to provide telemedicine services, not to test a physician's computer expertise. Therefore, the architecture employs a dynamically adaptive multidisciplinary workstation (DAMDW). This workstation is also designed to present the physician with a minimal number of buttons and widgets so that users with limited computer experience will not be overwhelmed. The architecture can be implemented on most workstations and has support for personal computers [1], [2].

The support core of the Naval telemedicine architecture consists of the tertiary-care Naval hospitals, the Fleet Naval Medical Consultation and Diagnostic Centers (FNMCDC's), and the hospital ships and those vessels with medical officers on board that are designated as Shipboard Naval Medical Consultation and Diagnostic Centers (SNMCDC's). Taking advantage of the services of SNMCDC's is the Remote Medical Referring Center (RMRC), which could be any Naval vessel, Naval station, Naval annex, or field hospital. If the communications infrastructure supports ship-to-shore connectivity more readily than ship-to-ship connectivity, the RMRC's are supported by the FNMCDC's.

The full FNMCDC uses DAMDW's with the following four subsystems: teleradiology, telemedicine, telepathology, and an informatics subsystem, which provides integrated access to standards-based (such as Health Level Seven or HL-7) [3] hospital information systems. These subsystems are explained below. The FNMCDC workstation is based on existing computer, communications, and medical imaging standards. This system contains a superset of the other systems. If implemented properly, the RMRC and SNMCDC DAMDW's are subsets of this FNMCDC DAMDW, providing controlled logistic and training support of the overall telemedicine system. If ship-to-shore communications cannot be accomplished, information and support are handled as shown in Fig. 1, utilizing communications links available on SNMCDC's.

The SNMCDC and RMRC take advantage of point-to-point communications. Depending on the staffing of the SNMCDC and the communications available to the task force or squadron, the SNMCDC could be outfitted as an FNMCDC. Given that ship-to-shore communications are available, the flow of telemedical information for a destroyer squadron (DESRON) is shown in Fig. 2. Finally, the RMRC has the minimal set of equipment, although it does have more of the diagnostic equipment, which digitizes and sends its information flow to an SNMCDC.

B. Functional Subsystems: Teleradiology, Telemedicine, and Telepathology

The teleradiology subsystem supports diagnostic and consultative digital radiology from one site (usually a primary care provider or hospital referral center) to a radiology department that is normally separated geographically from the first site. The full teleradiology system has an integrated access method to the information systems of the hospital.

This subsystem can be expanded to support direct or networked radiograph filming, as well as providing interfaces to older modalities. In addition, it can be upgraded to a picture archiving and communication system (PACS) at a later date if desired. Features of this system can be obtained from other sources [4]–[8].

The telemedicine subsystem supports telediagnostic procedures including general internal medicine examinations (e.g., eyes/ears/nose/throat, visual, and visual dermascopic examinations). It is conducted from one site to another site that is normally separated geographically from the first site. The full telemedicine subsystem has an integrated access method to the information systems of the hospital.

In the telepathology subsystem, anatomic pathology and cytology are supported with a nonrobotic system. This system provides the same functionality at one-tenth the cost of the robotic systems such as the Roche telepathology system. The increase in cost is mainly due to the cost of the robotics hardware and remote control hardware and software. In the telepathology, an RMRC physician, corpsman, or laboratory technician takes a mounted slide and places it on the microscope, providing the means for the FNMCDC pathologist to navigate through the slide using low-resolution imaging. When areas of interest are determined, the RMRC operator obtains a high-resolution image for the FNMCDC pathologist. This process continues until a diagnostic decision is made [9]. The full telepathology subsystem also has the requisite information system integration.

These subsystems should be integrated with the hospital information systems to be useful. The integration is not easy. HL-7 is one of the most popular methods of harmonizing extant hospital information systems. However, differences in HL-7 implementations require harmonization services from companies such as STC and Mitra.

III. Results

Telemedicine systems can be defined as integrated computer and telecommunications systems that are used as aids to monitor, diagnose, treat, educate, and manage patients by medical staff located in different geographic locations. Telemedicine systems can provide medical services by collecting, analyzing, and storing information concerning patients on board a ship.

It is important to control capital equipment and operational costs while maintaining or improving health care delivery. It is equally important to optimize the reliability and maintainability of the health-care-delivery infrastructure while facilitating physician productivity. To control costs, the architecture must provide easy integration with the numerous front-end information systems and must be able to do so with different workstation and computer vendors. It must be standards-based, using available computer and public communications systems. In addition, there must be usable application programming interfaces to allow the information processing programs to change without dramatically altering the graphical user interface (GUI) and application calls. This idea is discussed in more detail elsewhere [1], [2]. By making what the physician sees constant over computer platforms, the DAMDW allows implementors a wider selection of underlying hardware from which to choose equipment.

A common GUI should not be cluttered with nonessential functions, so that physicians are not overwhelmed by technology. The physician then concentrate on his specialty, and the result is higher productivity. Having too many interfaces presents the physician with functions that distract by encouraging exploration of operating systems or nonessential applications, thereby impeding productivity. The proposed architecture requires a GUI that can also accommodate more intricate system calls (such as data file structures and CPU process status) if a physician wishes to use them. The important thing is that the initial use is very straightforward.

The architecture supports various levels of security, from that which Unix provides to the same levels of protection available in custom telephone systems. It encompasses an enterprise network capable of communicating with the various off-the-shelf Naval computers, e.g., SUN, SGI and x86-based workstations. Unix workstations provide some degree of security which can be enhanced by using password aging, the Kerberos computer security, and data encryption if performance permits. The point is that by using Unix workstations, security is already a part of the architecture and can be increased as the physician acceptance of proper password and encryption schemes increases. Finally, these systems can use data link layer encryptions schemes if desired.

A. Architectural Advantages

The advantage of the FNMCDC DAMDW is that it is scalable to the task; therefore, the training and logistic costs are lower than those of a system made up of dissimilar system components, (e.g., personal computers on one operating system and viewing subsystems and mainframe computers in another, unrelated environment which is the hybrid environment in most hospitals today). With a DAMDW, the platform upon which individuals are will have the same interface, regardless of the underlying hardware. The only difference is the speed of operation which is determined by the hardware [1], [2].

When the Unix DAMDW is used, trouble-shooting and software maintenance can be done remotely using variable levels of security. DAMDW's can be used at all locations. The physician logs in, and the equipment and the software installed optimize its function for the user. This is done in the following manner:

1) An interface is determined for each specialty of physicians using the system.
2) Base on the desired interface, login profiles and X Window defaults are created to accommodate the specific interface.
3) A file in the user's directory flags the setup utility as to whether the physician has logged in previously.
4) If this is the first login, the physician chooses a default environment or can customize the environment.
5) Applications and the user environment are then customized to the physician specialty.

In this way, a visiting physician on an SNMCDC can log onto a DAMDW and provide services for the first time at the SNMCDC. Similarly, the DAMDW can be easily configured to support an RMRC, an FNMCDC, or an SNMCDC. The RMRC can be supported by an SNMCDC (Fig. 1), but with proper ship-to-shore communications, it can be supported by the FNMCDC directly (Fig. 2).

This is a federated system, that is each unit can operate with some autonomy, although functions of each do not completely overlap. In this system, the removal of an SNMCDC does not necessarily deny all medical services and the system may be reconfigured to resupply necessary services. The DAMDW can be specified to cover a narrower system focus, so that the acquisition costs can be more easily controlled and future expansion will be possible at a lower cost, as computer technology continue to decline. For example, the FNMCDC specifications can be tailored to provide only teleradiologic services initially, while reserving an upgrade to full FNMCDC functionality when funding becomes available. It also can be configured for functional teleradiology, telemedicine, or telepathology, which provide the medical service without the facilitated connection that integrates it with the information systems of a hospital or medical facility. This approach provides an easy evolutionary path toward a full FNMCDC.

The architecture provides the following benefits to an RMRC and an SNMCDC:

- Reduced MEDEVAC expenditures because the patient remains within the ship or shore facility unless evacuation is deemed necessary on the basis of more precise diagnostic information [10].
- Enhanced shipboard providers coverage of medical services for the RMRC.
- Continuous availability of academic medical center clinical and educational expertise to clinicians.
- Continuing education credits convenient to the provider and, usually, under good learning conditions.

The architecture provides the following benefits to an FNMCDC:

- Extends the clinical and educational expertise of the FNMCDC beyond the usual geographic referral area.
- Reduces or eliminates travel to tertiary-care facilities [10].
- Can be extended to other multimedia training for the fleet.

B. Telemedical Service Offerings

The Naval Telemedicine Architecture provides the following services:

- Pathology
- Telepresence (teleproctoring) for surgical procedures
- Video-conferenced general internal medicine
- Dentistry
- Ultrasonography
- Dermatology
- Psychiatry
- ICU telemetry

C. Architectural Expansion/Growth

There are four features of this architecture:

1) flexibility to support any combination of physician specialties;
2) flexibility to support any combination of communication bandwidths although some procedures are not possible at lower bandwidths;
3) ability to support planning its implementation;
4) ability to support controlling its growth so that the initial system evolves into to a fully integrated one as funds become available.

Based on extant computer and communication standards, and adapting to emerging standards such as HL-7 and the Computer-based Patient Record (CPR), the FNMCDC can be platform neutral; that is to say, it could run on workstations from Sun Microsystems, Hewlett Packard, IBM, Digital Equipment, or Silicon Graphics to personal computers. The workstations mentioned have excellent support for the available data communications.

HL-7 is being deployed by hospitals and is used by AGFA, Cemax, Lockheed/Martin as an interface language for their Picture Archival and Communications Systems. CPR, however, is still in development. Guidelines and standards for the content and structure of the CPR systems are being developed within ASTM Subcommittees E31.12 and E31.19 [11].

Therefore, this architecture is adaptable to the best emerging technologies available; as a result, the system can be upgraded without discarding and replacing components, a process that strains not only capital equipment funds but also the concomitant logistics and support resources.

The fact that the proposed architecture is based on extant and emerging standards also maximizes the lifetime of a system implementation. For imaging and viewing, X Windows is used, as it supports personal computers, workstations, and supercomputers. In communications, the Internet protocols are used:

- Transmission control protocol [12], [13] and Internet protocol [14] (TCP/IP).
- User datagram protocol [15] (UDP).
- Point-to-point protocol [16] (PPP).
- Other Internet Engineering Task force protocols for isochronous data streams as they emerge.

The Digital Imaging and Communications in Medicine (DICOM) [17] documents provide a structure supporting most radiology modalities and rely on TCP/IP for data transport, which is the protocol used in the proposed architecture. The system architecture supports HL-7 for communications with most modern hospital informatics systems. There is also a client-mediator-server subsystem for integration with many legacy hospital information systems. Netscape Communique is being used for video-conferencing, as it is incorporating emerging video-conferencing standards such as the Visual Telephone System Standard, H.320, and the Video Coding Algorithm, H.261, of the International Telecommunications Union-Telecommunications Standards Section. Communique also provides video-conferencing software that runs on most workstations and personal computers. As video teleconferencing standards mature, there will be more v video-conferencing vendors from which to select.

X Windows is providing a networked solution for visualization of many types of scientific data. Medical applications benefit from the graphical features and applications available with this standard, which was designed for network use among all workstations and personal computers that are in compliance with the open standard.

The Internet protocol suite provides full connectivity with the following:

- Any standard DoD Advanced Research Projects Agency Internet.
- Any standard DoD Internet.
- Any standard University Internet.
- Any standard commercial Internet.
- Any TCP/IP intranet.

Because of the use of TCP/IP, it is possible to connect to legacy networks such as Ethernet (IEEE 802.3), token ring (IEEE 802.5), fiber distributed data interface (FDDI), and public telecommunications networks via the PPP when TCP/IP is not available. Thus, this architecture is positioned to use existing telecommunications, as well as the emerging asynchronous transfer mode (ATM) switches, which permit the highest transmission speeds and bandwidths. This factor is important because certain real-time clinical ultrasound and fluoroscopy applications may require ATM technology [18], [19].

TABLE II
FNMCDC OR SNMCDC EQUIPMENT COSTS

Data Item	Cost
Clinical Station with one 2K x 2K diagnostic monitor	$53,000
Video conferencing software and video card	$10,000
CCD camera	$1,500
Uninterrupted power supply (UPS)	TBD
Communication termination equipment	TBD
Cables and adapters	$200
Equipment total	$64,700

TABLE III
REMOTE MEDICAL REFERRAL CENTERS

ITEM	COST
Radiology quality assurance workstation dual 1K x 1K monitors	$18,000
Video-conferencing software with parallax video board NTSC, S-Video input, and video output	$13,500
Remote-controlled camera and software-controlled pan-tilt-zoom high-resolution camera with auto focus	$2,100
CSU/DSU: Motorola T1 interface with cables	$1,500
Router: Cisco 2500 ethernet router with serial interface	$2,500
VCR: SVHS recorder/player	$1,200
Monitor:	$1,000
Cart. for 27-inch RGB monitor:	$800
Total per Hospital:	$40,600

This architecture provides the necessary DICOM services for teleradiology, as well as, a PACS. It supports DICOM image service and can provide DICOM printing service. The native architecture provides even greater flexibility and service than specified by DICOM while keeping up with this evolving standard. Its HL-7 compliance allows it to communicate with modern radiology information systems and hospital information systems.

HL-7 is being used to communicate with the modern hospital information system (HIS). Where this is not possible because the HIS is not HL-7 compliant, a structured-query-language (SQL) server is provided. Where this is not possible because the existing HIS is not an SQL data base, a client-mediator-server system provides a means to make appropriate conversions from a modern interface to a legacy HIS.

IV. DISCUSSION

This section presents a representative implementation of the Naval telemedicine architecture. Realize that implementations based on the next-generation technology will be superior to this implementation. Tables II–V give the configurations.

In addition, any or all of the following equipment may be installed at the remote site, depending upon the clinical applications chosen.

Therefore, the RMRC can be outfitted from a suite of telemedicine equipment that can be acquired over several fiscal years if necessary. Note also that because the computer system is mobile, it can be brought to the patient if necessary (this is not to imply that it is battlefield portable).

This implementation utilizes off-the-shelf equipment, and readily available commercial telephone service. It has reasonably low startup and maintenance costs and serves numerous medical specialties with the same equipment. It consists of a CEMAX digital radiology workstation with multimedia capabilities which on a roll-about cart. Accompanying the computer will be a digital camera, a video recorder/player, a camcorder, and a television monitor. At an FNMCDC or SNMCDC, the workstation will be diagnostic quality (2 K $\times$ 2 K resolution). At an RMRC, it will be a clinical workstation with a

TABLE IV
REMOTE SITE DIAGNOSTIC TOOLS

ITEM	COST	ITEM	COST
Diagnostics		**Pathology**	
Electronic stethoscope	$2,500	Video cable	$216
Vascular Doppler stethoscope	$2,650	3 chip, CCD video microscope	$11,500
Sony 3 chip CCD camera	$4,620	Adapter to microscope	$700
Dermatology		**Subtotal**	**$33,147**
Sony 3 chip CCD camera	(See above)		
Cardiology		**Radiology-Diagnostic**	
EKG	$4,500	Lumisys Lumiscan digitizer*	$29,000
ENT		Software interface	$18,000
Videoscope w/diagnostics	$6,461		
		Total	**$80,147**

TABLE V
REMOTE SITE DIAGNOSTIC TOOLS

ATM	Asynchronous Transfer Mode	ICU	Intensive Care Unit
CCD	Charged-Coupled Device	IEEE 802.5	Token Ring
CME	Continuing Medical Education	MTBF	Mean Time Before Failure
CODEC	Coder/Decoder		
CPR	Computer-based Patient Record	NTSC	National Television Standards Committee
CSU/DSU	Channel Service Unit/Digital Service Unit	PACS	Picture Archiving and Communication System
DAMDW	Dynamically Adaptive Multi-disciplinary Workstation	PPP	Point-to-Point Protocol
DESRON	Destroyer Squadron	RGB	Red, Green, Blue (refers to method of gettin a monitor presentation)
DICOM	Digital Imaging and Communications in Medicine	RMRC	Remote Medical Referring Center
EKG	Electro-Cardiogram	SNMCDC	Shipboard Naval Medical Consultation and Diagnostic Center
ENT	Ears, Nose, Throat	SLIP	Serial Line Internet Protocol
FDDI	Fiber Distributed Data Interface	SQL	Structured-Query-Language
FNMCDC	Fleet Naval Medical Consultation and Diagnostic Center	S-VHS	Super-Video Home System
GUI	Graphical User Interface	TCP/IP	Transmission Control Protocol and Internet Protocol
HL-7	Health Level Seven	UPS	Uninterrupted Power Supply
HIS	Hospital Information System	VCR	Video Cassette Recorder

film digitizer. These computers can accommodate NTSC and S-Video broadcast signals. The camcorder will utilize the NTSC input and will be used as a multifunctional mobile/document camera. The S-Video input will be used to interface with existing medical equipment such as ultrasound machines. In addition, the video recorder/player can be used to store examinations and replay them during a consultation. Therefore, the patient does not have to be present when physicians are consulting. The computer also has the ability to handle up to four simultaneous audio inputs. CD-quality sound is achievable, and can be used to transmit sounds obtained from a stethoscope, or a Doppler exam. The computer is also capable of outputting an NTSC signal to a remote television monitor. Thereby avoiding problems associated with looking at small images on a high-resolution computer monitor. The video recorder will also allow recording of telemedicine sessions for medical-legal records. Finally, ICU step-down monitors will output results including electrical heart signals, noninvasive blood pressure, invasive blood pressure, saturated oxygen, and carbon dioxide.

This hardware platform will provide the tools necessary for physicians from various specialties to perform remote consultations. This will be accomplished through a software interface, so that the physician is removed from the inherent complexity of the task. A computer-based GUI can adapt dynamically to the task at hand. Since all telemedicine systems will transmit a limited amount of information based solely on the capacity of the communication circuit, the ability of a system to adjust resource utilization is vital. This system can adapt the resource utilization.

With the proposed system, the functionality of video and sound resources can be adjusted with a simple click on a icon. For instance, a physician may not be as concerned with seeing real-time video when listening to patient's lung sounds, but the audio quality of the system needs to relay accurate diagnostic information. Clicking on an icon representing a stethoscope sets the audio sampling to an adequate rate of 44 kHz for doppler stethoscope, and the utilization of the phone resources by the video application will be decreased while use by the audio application will be increased. Furthermore, the applications presented to an individual physician will be based on that physician's specialty. For example, a pathologist, unlike a cardiologist, does not require the functionality of a stethoscope. Therefore, the environment of the pathologist will not include a stethoscope icon. These functions are provided by a DAMDW.

Finally, the commercial telephone service will form the communication backbone of shore-to-shore facilities. Hospitals will be connected to a digital network that will allow communications with FNMCDC's and SNMCDC's as well as among themselves. In addition to public communications, the DAMDW can use available fleet communications systems supporting TCP/IP connectivity. However, the fleet communication bandwidth is generally difficult to obtain. As telemedicine services become more commonplace, the communication bandwidth for telemedicine becomes part of the communication plan of a battle force deployment.

The costs associated with the wide-area networks are the recurring maintenance costs needed to keep the telemedicine links operational. For this reason, communications costs will directly affect the long-term viability of the proposed architecture. Since this will be a digital network, numerous possibilities are available to make this system preferable to a conventional telemedicine system. In short, this architecture will allow delivery of telemedicine services from anywhere to an FNMCDC or an SNMCDC. A hospital will need a local area network with sufficient capacity so that the portable station can be rolled around and plugged into the network connection where needed. Additionally, medical consultants can conduct telemedicine sessions from their desktops. The physician will not be required to travel to a specialized room, and up to seven sessions can be conducted simultaneously over this network although only four simultaneous sessions have been tested. The computer system is scalable in that it can be utilized on any type of network with the proper interface card.

With these stations, live video and audio signals is sent over a digital network. Functionally, the system is able to send near-real-time video, CD-quality sound, and high-resolution 24-bit still images that are necessary for diagnostic cytology or pathology. It is important to note that the remote hospital will have complete autonomy in deciding how best to utilize the system.

This system can be used in one of four ways.

1) It can be used to enhance physician-physician interactions. This function is expected to be the primary use for these systems. Physicians and their consultants will be able to share data of various types, such as an X-ray film, a microscopic slide, or a videotape of a procedure (e.g., an ultrasonogram).
2) The system can be used for physician-patient interactions, such as scheduled consultations that require the consultant to interview the patient and patient follow-up, so that the patient is not required to travel and can visit the physician by going to the local hospital. Remote consultation during performance of a procedure is another possible use. For instance, a patient can have the procedure performed locally, and the data can be transmitted for interpretation. If the technologist is uncertain about an examination, the remote physician can be called to evaluate the situation while the patient is still in the room and can recommend techniques to improve the examination.
3) The system will be to help support ancillary services such as pharmacy, social work, and physical therapy at the remote hospital. Since this is a movable system, personnel needing these services will also be able to bring the cart into their areas.
4) This system will be to provide continuing medical education. The video out feature of this system will permit display of conferences on any standard video output device to large and small audiences alike. Incidentally, this system is flexible enough to handle general multimedia-based training and ship-to-ship or ship-to-shore conferencing.

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