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REMOTE MEDICAL DIAGNOSIS SYSTEM (RMDS)

W. T. Rasmussen, et al

Naval Electronics Laboratory Center
San Diego, California

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REMOTE MEDICAL DIAGNOSIS SYSTEM (RMDS)

INTERIM REPORT FOR PERIOD OCTOBER 1972 TO JUNE 1975

W. T. Rasmussen and J. Silva

HUMAN FACTORS TECHNOLOGY DIVISION (CODE 3400)

1 JUNE 1975

Prepared for

NAVAL MEDICAL RESEARCH AND DEVELOPMENT COMMAND

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Shipboard medical needs are identified. Specific elements of medical data needed for diagnosis are determined. Methods for communicating medical information are evaluated. A listing of ships by type and class gives complements, medical facilities, and major equipment. Feasibility testing is continuing at time of publication.

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CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS (Continued)

TABLES

GLOSSARY OF SHIP TYPES

AD	Destroyer tender
AE	Ammunition ship
AF	Store ship
AFS	Combat store ship
AO	Oiler
AOE	Fast combat support ship
AOR	Replenishment oiler
AR	Repair ship
CG	Guided missile cruiser
CGN	Nuclear powered guided missile cruiser
CLG	Guided missile light cruiser
CVA	Attack aircraft carrier
CVAN	Nuclear powered attack aircraft carrier
CVS	Antisubmarine warfare aircraft carrier
DD	Destroyer
DDG	Guided missile destroyer
DE	Escort ship
DEG	Guided missile escort ship
DLG	Guided missile frigate
DLGN	Nuclear powered guided missile frigate
LCC	Amphibious command ship
LKA	Amphibious cargo ship
LPA	Amphibious transport
LPD	Amphibious transport dock
LPH	Amphibious assault ship
LSD	Dock landing ship
LST	Tank landing ship
SS	Attack submarine
SSBN	Nuclear powered ballistic missile submarine
SSN	Nuclear powered attack submarine

INTRODUCTION

BACKGROUND

The Navy, as well as the other military services, is presently experiencing a shortage of physicians. It is foreseen that this shortage will get worse in the future due to the ending of the doctor draft and recent salary increases for interns and residents in civilian hospitals. Because of this shortage and its impact on the delivery of health-care services at Naval hospitals, many of the Navy physicians will necessarily be transferred from shipboard duty to hospitals. As a result, there will be more extensive use of Navy corpsmen to provide total shipboard health care.

The ability to properly diagnose and determine appropriate treatment for illnesses and injuries is a critical part of any medical program. Many of the medical cases aboard ship are presently being diagnosed by corpsmen and given minor or emergency treatment without requiring the services of a physician. However, there are cases in which a corpsman or a physician may be uncertain of a medical diagnosis, or in which a patient's condition may necessitate a decision as to whether or not to air-evacuate him. A Remote Medical Diagnosis System (RMDS) would then enable the corpsman or physician to have a direct communication link with a medical specialist (located on board another ship or ashore) to provide a remote diagnosis and prescribe the proper treatment.

A real-time medical diagnostic system must be able to transmit medical clinical data, records possibly including ECGs and EEGs, and accompanying voice transmissions. It may also be desirable to have a capability to transmit visual information and provide a computer interface for record retrieval and storage.

The use of communication systems to provide health-care delivery to remote areas is not new, although it is a subject receiving rapidly increasing attention. In 1971, a satellite was used to provide reliable radio contact (using a half-duplex voice channel) between native health aids in remote Alaskan communities and a Public Health Service doctor (Feiner [11] and Hudson and Parker [15]). In another case, the feasibility of transmitting ECGs from remote Alaskan villages to the University of Washington Hospital, Seattle, Washington, via hf radio and ATS-1 satellite was tested by Andersen [1] and Willard [33].

In the following year the Department of Health, Education, and Welfare commenced funding several exploratory two-way audiovisual communication systems designed to provide expansions to existing health-care services. Several such systems are now in use. The first was established in 1963 between Massachusetts General Hospital and a medical station located at Boston's Logan Airport, a distance of about 3 miles. It has been extended to include the Veterans Administration Hospital, Bedford, Massachusetts, a distance of about 20 miles (Bird [3], [4], [5], and Dwyer [9], [10]). Other existing interactive television health-care systems include one between a number of small communities in New Hampshire and Vermont with Dartmouth University (Hanover, NH) at the center (Seibert and Sanborn [30]). Another such system is the Arizona Tele-Medicine Network (Levinson et al [18]). This system uses mobile van units with transmitting and receiving equipment to provide medical care at remote areas of the Indian reservations throughout Arizona.

All these systems use broadband communication channels, usually via microwave relay links, to provide a real-time television capability. Present communication capabilities within the Navy do not make this type of system practical at this time. However, slow-scan video systems which use narrowband voice channels exist and have been successfully used to transmit nuclear-radiation-produced images including radioisotope scans and gamma scintigram pictures, although they have not been tested for total health-care delivery.

TASK DESCRIPTION

This study was initiated to determine the medical needs and requirements for a medical diagnosis system to obtain medical diagnoses for shipboard personnel from a remote source; to examine alternative systems for accomplishing this objective; to test the feasibility of a candidate system; to recommend a suitable system if test results justify such a system; and to develop specifications for an operational system.

The approach to this study has been to identify the medical needs and requirements for remote diagnosis aboard ships, determine the present medical and diagnostic capabilities for various classes of ships, determine the communication requirements for a Remote Medical Diagnosis System, evaluate alternative system configurations, and perform a feasibility test of the overall concept of remote diagnosis as it applies to the Navy.

PROGRAM STATUS

This report covers work completed on the RMDS study from October 1972 to June 1975. The following major subtasks have been performed in the implementation of this study.

1. The medical needs and requirements for remote diagnosis aboard ships and submarines have been investigated by analysis of all shipboard morbidity data for fiscal year 1973.

2. The present medical and diagnostic capabilities for various classes of ships have been analyzed and compared to the needs based on the morbidity data in (1) and the corresponding medical technology requirements.

3. Ship population profiles have been determined.

4. The communication requirements for remote medical diagnosis (ie, for the bidirectional transmission of medical data) based on the use of available networks have been determined.

5. Existing equipment capable of demonstrating the technical validity of the remote diagnosis concept has been acquired and a multiterminal prototype system assembled.

6. Preliminary testing by transmitting medical data between the Biosystems Laboratory at NELC and the emergency room at Naval Hospital using landlines (telephone) and a uhf communication link has been performed.

The experiment to test the suitability of existing equipment and to determine the practicality and effectiveness of remote medical diagnosis for Naval vessels is underway. Representative ships that are appropriately equipped have been selected. A diagnostic center ashore has been established and the desired communication procedures have been identified. The existing Naval Telecommunication System (NTS) will be used. Initially, a long-range, high-frequency (hf), narrow-bandwidth communications link will be used to transmit medical data in analog form using voice and slow-scan television. The quality and form of the transmitted information will be recorded and evaluated to determine its acceptability. Finally, the experiment will be repeated using a communication satellite, provided that satellite communications are available during the period of the test and that a uhf communication channel and the necessary hardware can be allocated for this purpose.

SUMMARY

The RMDS study began with an analysis of all shipboard morbidity data to determine representative kinds of ailments and injuries and their frequency of occurrence. Next, the extent of the capability for various classes of ships to provide medical aid was examined. This capability was evaluated in a general way and was based on the complement of ship's medical personnel and the spaces, equipment, instrumentation, and other resources dedicated to medical use. An examination of the correspondence between the ailments and injuries encountered and the ship capability to deal with them effectively was then made. While a shortage of physicians exists (see tables 1 and 2), the medical instrumentation, equipment, and supplies (drugs, biologicals, reagents, etc) are not lacking for most classes of large ships (see table 3). Notable exceptions among the small-ship category are destroyers and submarines.

Although there are some important medical materials and supplies which were not listed on any class of ships (see tables 13 and 14), it appears, on the strength of the information obtained, that the majority of ships have most of the needed medical material resources on board. The capability to provide adequate medical aid, then, depends on whether the medical personnel on board have the necessary skills, knowledge, and diagnostic resources; and whether they can be assisted from a remote source when necessary. Consequently, the next phase of the study was to determine what type of information would need to be communicated and in what form it would be most useful.

Much medical information can be transferred by the use of voice communication alone, and there are several highly successful voice-only remote medical diagnosis systems in operation. However, the belief that "one picture is worth 1000 words" has prompted the development of systems providing a real-time television capability including the transmission of color. While the benefit of providing visual data has been established and the availability of the needed technology poses no constraints, it is not clear that a dynamic, real-time color video system is necessary. Real-time video systems, such as our home television, require a frequency bandwidth of 4.5 MHz, more than 1000 times that required for voice transmission. Because of this broadband requirement, it is not practical at this time to consider the use of already overloaded Navy communication channels for this application. However, slow-scan video systems which use narrowband voice channels are available. Such systems transmit a static picture of the object. The lack of motion information is not considered very restrictive in the exchange of medical information. The evaluation of x-rays, ECG tracings, patient records, charts, prescriptions, and views of the patient's injuries does not require motion information. Important in any video system, however, are the clarity and resolution of the picture. If the viewer cannot figure out what was transmitted, the information is worthless.

Given that a slow-scan video/voice system could adequately test the RMDS concept, it is important to consider whether the information should be transmitted in analog or digital form. Communication links capable of handling either form of data are available. Though there are many advantages to transmitting data in digital form, medical data are inherently analog and must be converted to digital form prior to transmission and restored to analog form after reception. A prototype digital video/voice "system" consisting of two terminals is available at NELC. This equipment is rack mounted and bulky. Shipboard sick bays cannot physically accommodate the equipment in this developmental configuration. In addition, three complete terminals with two backup terminals for the shipboard installations are needed for reliable performance. Though a digital system may ultimately be recommended for use, analog video/voice systems consisting of equipments compatible with shipboard requirements have been commercially available for several years.

These considerations together with the limited time available led to the choice of using analog narrowband video and voice alternately, utilizing a single voice channel (3-kHz bandwidth), for testing medical data transmission during the remainder of the study. Hardware requiring little modification was available on a lease basis for expedient implementation. One RMDS terminal was installed at the emergency room of the Naval Hospital, and a second at the Biosystems Laboratory at NELC. Video/voice information has been transferred successfully between these terminals via three different voice channels: land line (telephone), uhf, and hf via the ICSB (Intra Command Switch Board) network with accompanying phone patch. Video data have also been transferred between these terminals and a terminal at the manufacturer's laboratory in New York City. The data received are remarkably clear, and it is difficult to detect any differences between the same visual data transmitted to the terminal at NELC from the hospital (10 miles) or New York (approximately 3000 miles). Some examples can be seen in figures 12 through 16.

A test designed to roughly simulate the conditions for which the RMDS is intended was recently conducted. Dr. K. Pranikoff, a physician with shipboard experience now assigned to Naval Hospital, brought to the laboratory at NELC sufficient medical data (x-rays, ECG tracings, etc) to simulate several medical cases requiring assistance from specialists. (See fig 10.) Although the clarity of the received pictures of some x-ray negatives (chosen to severely test the system) was not sufficient to permit diagnosis, the overall results were encouraging. This exercise also pointed out problems that must be eventually addressed but are not sufficiently serious to prevent the determination of the concept's usefulness. The problems included nonuniform lighting for the television camera, the lack of a lightbox appropriately located for the physician's use, improperly designed work space, and inconvenient location of system control knobs. It is anticipated that a great deal of constructive criticism will result from the sea trials as well. These problems are being investigated and their solutions will be reflected in the final design and specifications.

It is the consensus of communication personnel (NELC, COMSTAs, ships) that hf communication is, at best, poor. It is not reliable, and signal strengths vary according to geographic location, time of day, weather, activity of the sun, and many other factors. Though it was necessary to use hf for the current tests, the advent of GAPFILLER satellites (first launch August 1975) could provide high-quality, high-capacity channels for transmission of the data. This fact should be kept in mind when evaluating the system's performance as demonstrated in the hf tests. To use these satellites, however, the data must be converted from the present analog form to digital format and encrypted for transmission.

Commercial and Government satellites are presently being surveyed to determine whether it is possible to test the present analog system with a satellite link during the study period. What is needed is an existing satellite with available channels capable of relaying narrowband analog information centered at frequencies which are compatible with the communications equipment on board the ships and COMSTAs engaged in this study. Preliminary information, however, is not promising.

Recent CNO approval has resulted in the selection of two ships, USS JUNEAU (LPD 10) and USS ALAMO (LSD 33). A briefing was given to the medical and communications personnel of both ships. Arrangements have been made for instruction on the use of the system at NELC. These ships are presently undergoing overhaul and are scheduled for release in early fourth quarter FY75. We are investigating the possibility of performing the necessary wiring and modifications on board before the ships are released. This would save valuable time, since it is already clear that the study will not be completed by the end of this fiscal year. This is due primarily to the routine delays encountered in performing the necessary steps to obtain CNO approval to perform the shipboard studies.

After the ships have been released from overhaul, the RMDS will be tested for the remainder of FY75 during local ship operations (within approximately 150 miles of San Diego). However, longer-range communications will be tested by hf communications to Honolulu or San Francisco and back to San Diego. In order to test the system using long-range communications and operating in busy and unfavorable communication situations, it is of vital importance that the feasibility testing be continued during the deployment of the two ships in FY76.

PRESENT SHIPBOARD HEALTH-CARE DELIVERY

Present medical and diagnostic capabilities for various classes of ships were determined first by examination of available documents which inventory the medical complements and instrumentation aboard ships by specific class, and then by shipboard visits to augment these lists. From the compiled lists of medical instrumentation and complements for a class of ships, it is then possible to determine diagnostic capabilities and compare the required medical data and instrumentation for similar diagnoses.

PRESENT METHODS OF REMOTE DIAGNOSIS

When a corpsman or a physician is not sure of a medical diagnosis for a patient, or he needs an outside decision regarding whether or not to air-evacuate the patient, he uses the ship's radio communication system to discuss the problem with a physician at another site (either on board another ship or at a shore station). Whenever it is necessary to communicate, the medical staff member notifies the ship's communication personnel that he wishes to send the message. If the message requires anything above a "routine" precedence classification (see COMMUNICATIONS), he must get the approval of the ship's commanding officer or designated officer with approval authority. A "routine" message is sent via teletype (TTY) using available communication modes to the nearest available medical facility, also advising their chain of command, requesting medical advice. Due to present communication overloads, a response to this message may take as long as 3–4 days. In most medical cases this delay is unacceptable.

In emergency cases, the commanding officer may grant the use of a high-precedence classification, or the use of a voice communication if conditions warrant. In the latter case, the medical staff member (a corpsman or physician) goes to the ship's communications station and carries on the conversation with a physician at a remote location, at which time he describes the patient's condition and symptoms. If additional information is needed, he may have to go back to the treatment center to obtain it and then return to the communication center to relay it to the physician. Past experience has shown that this method of remote diagnosis is very unsatisfactory.

SHIPBOARD MEDICAL COMPLEMENTS

The scope of the RMDS has been limited to ships with a personnel complement of approximately 100 or more, and all submarines. Table 1 lists the major ship types by class, and gives the number of active ships as of January 1, 1975, in each class (force level) and

TABLE 1. FORCE LEVELS (AS OF 1 JANUARY 1975) AND AVERAGE PERSONNEL COMPLEMENTS OF MAJOR SHIP CLASSES.

	Force Level	Personnel Complements	
Aircraft Carriers			
CVAN	1	3100	(2400)*
CVA, CV	13	2700	(2150)*
Cruisers			
CG	2	1000	
CGN	1	1000	
CLG** (CG)	2	1680	
Auxiliary Ships			
AD	9	800 - 1800	
AR	5	700	
Underway Replenishment Ships			
AE, AF, AFS, AO, AOE, AOR	47	300 - 600	
Amphibious Warfare Ships			
LCC	2	688	
LPA	2	400	
LPD	14	490	
LPH	7	2090	
LKA	6	335 - 435	(225 - 320)*
LSD	13	400	(350)*
LST	20	100 - 200	(390)*
Frigates			
DLG** (CG or DDG)	26	400 - 500	
DLGN** (CGN)	3		
Destroyers			
DD	32	275 - 350	
DDG	29	350	
Escort Ships			
DE** (FF)	58	220 - 240	
DEG** (FFG)	6		
Submarines			
SS	12	85	
SSN	63	100	
SSBN	41	112 - 140	

(*) Additional air-wing or troop complements

(**) New ship designators after 1 July 1975 are shown in parentheses the average personnel complements assigned to ships of that class. In some cases, the personnel complements will be given in a range due to different classes of ships within that type. For example, destroyer tenders (ADs) are shown as having 800–1800 personnel aboard since destroyer tenders of the GOMPERS class have 1800 personnel aboard, while destroyer tenders of the KLONDIKE class have approximately 800 personnel aboard.

A sampling of ships within each class (as given in table 1) was used to determine a representative complement of medical personnel aboard ships of that class (see table 2). Medical personnel assigned to each ship in the sampling (both enlisted and officers) were determined by information obtained through Enlisted Personnel Distribution Office, Pacific Fleet (EPDOPAC), North Island, California.

TABLE 2.
REPRESENTATIVE COMPLEMENT OF MEDICAL PERSONNEL ABOARD SHIP.

	DISTRIBUTION OF MEDICAL ENLISTED PERSONNEL ABOARD SHIP																	
	General Service	Nuclear Sub. Medicine Tech.	Sub. Medicine Tech.	Aerospace Medicine Tech.	Nuclear Medicine Tech.	Cardiopulmonary Tech.	Clinical Lab. Asst. Tech.	Clinical Lab. Tech.	Medical Services Tech. — not certified	Medical Services Tech. —certified	Preventive Medicine Tech.	X-ray Tech.	Optician Tech.	Physical & Occupational Therapy Tech.	Pharmacy Tech.	Operating Room Tech.	Approximate Total Number of Enlisted Medical Personnel Aboard Ship	Approximate Total Number of Physicians[1] Aboard Ship
Aircraft Carriers																		
CVAN	X			X	X			X	X		X	X	X	X	X	X	33	2
CVA/CVS	X			X				X	X		X	X			X	X	27	2
Cruisers																		
CG	X							X	X		X	X			X	X	10	1
CGN	X				X		X					X			X	X	10	1
CLG	X										X	X			X	X	8	1
Auxiliary Ships																		
AD	X				X[2]		X			X					X	X	12	1[3]
AR	X							X				X				X	10	1
Underway Replenishment Ships																		
AOE	X									X		X				X	6	1
AOR	X									X							4	1
AFS	X									X							4	1
AE — Suribachi Class	X									X							4	0
AE — Kilauea Class	X									X							4	0
AO, AF, AE — Wrangell Class	X									X							4	0
Amphibious Warfare Ships																		
LPH	X					X		X		X		X			X	X	10	1
LCC	X							X	X	X		X			X	X	12	1
LPD							X			X						X	3	1
LPA	X							X				X				X	11	1
LSD — Anchorage Class	X						X			X							5	0
LSD – Thomaston Class	X									X							4	0
LKA— Charleston Class	X						X			X		X				X	6	1
LKA — Tulare Class							X			X						X	5	1
LST	X									X							2	0
Frigates																		
DLGN	X				X					X							4	1
DLG	X									X							2	0
Destroyers																		
DD, DDG	X									X							2	1[4]
Escort Ships																		
DE, DEG	X									X							2	0
Submarines																		
Conventional			X														1	0
Nuclear		X															1	0[5]

1. Refers to a permanently assigned General Medical Officer except for CVAN and CVA/CVS which staff a Medical Flight Surgeon and either a Medical General Surgeon or a General Medical Officer. Additional physicians are provided by the assigned flight squadrons.

2. "Gompers" class only.

3. "Gompers" class has a Radiation Health Medical Officer in addition to the General Medical Officer.

4. One physician per squadron.

5. Some have a physician.

SHIPBOARD MEDICAL EQUIPMENT

Medical equipment and instrumentation which are used for diagnosis and emergency treatment on board ship were listed for ships by class. This information was obtained from Authorized Medical Allowance Lists (AMALs) for each class of ships, and then augmented by shipboard visits. It was found that many ships may actually have equipment additional to that required by the AMAL for a ship of its class. Thus, there are several inconsistencies ships within each class. However, table 3 lists the diagnostic equipment which is required by the AMAL and any additional equipment which is contained throughout that class of ships. It is not intended as a complete listing of medical diagnostic equipment for all US Naval ships.

TABLE 3.
MEDICAL EQUIPMENT*
BY CLASS OF SHIP.

* The list of medical material used in this table is not intended as a complete listing for all Naval Ships. The equipment was selected with respect to its importance as a diagnostic aid aboard ship.

Category	No.	Item	Aircraft Carriers: 1 CVAN	2 CVA CVS CVT	Cruisers: 3 CG	4 CGN	5 CLG	Auxiliary Ships: 6 AD	7 AR	Underway Replenishment Ships: 8 AOE	9 AOR	10 AFS	11 AE Suribachi Class	12 AE Kilauea Class	13 AO, AF, AE Wrangell Class	Amphibious Warfare Ships: 14 LPH	15 LCC	16 LPD	17 LPA	18 LSD Anchorage Class	19 LSD Thomaston Class	20 LKA Charleston Class	21 LKA Tulare Class	22 LST	Frigates: 23 DLGN	24 DLG	Destroyers: 25 DD DDG	Escort Ships: 26 DE, DEG	Submarines: 27 Conventional	28 Nuclear
Drugs Biologicals & Official Reagents	1	Antigen, Lymphogranuloma Venereum			X	X	X	X	X	X	X		X	X			X	X	X						X					
	2	Antigen, VDRL	X	X	X	X	X	X	X	X	X		X	X		X	X	X	X						X					
	3	Basic Fuchsin, Analyzed Reagent	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X		X					
	4	Blood Chemistry Reference & Control	X	X			X	X	X							X	X	X	X											
	5	Blood Detection Tablets	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	6	Blood Grouping Serum, Anti A, Anti B	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
	7	Brain Heart Infusion	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X		X					
	8	Canada Turpentine in Xylene	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X		X					
	9	Crystal Violet, Analyzed Reagent	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
	10	Diluent Cardiolipin Antigen	X	X	X		X	X	X	X	X		X	X		X	X	X	X											
	11	Giemsa's Staining Solution	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
	12	Ehrlich's Reagent	X	X												X														
	13	Methylene Blue, Analyzed Reagent	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
	14	Nitroglycerin Tablets	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	15	Phenolsulfonphthalein Injection	X	X												X			X											
	16	Safranin O, Analyzed Reagent	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
	17	Saponin, Analyzed Reagent	X	X												X			X											
	18	Sodium Citrate	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
	19	Sodium Fluorescein Applicators	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	20	Sodium Phosphate, Monobasic, Monohydrate, Reagent	X	X			X	X	X							X	X		X											
	21	Sodium Sulfobromophthalein Injection	X	X												X			X											
	22	SS Agar	X	X	X	X	X	X	X							X	X	X	X											
	23	Sulfosalicylic Acid, Dihydrate, Analyzed Reagent	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
	24	Tannic Acid, Analyzed Reagent	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
	25	Test Kit, Bilirubin Determination (in urine)	X	X	X		X	X	X							X	X	X	X											
	26	Test Kit, Mononucleosis Determination			X	X	X	X	X																					
	27	Test Strips, Urinary Blood, Glucose, Ketone, Protein, ph	X	X												X														
	28	Typing Serum, Anti RH	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	29	Wright Blood Stain With Methyl Alcohol	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
Medical & Surgical Instruments, Equipment, & Supplies	30	Anoscope	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X					
	31	Anesthesia Apparatus Set	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X			X	X		X					
	32	Audiometer	X	X												X			X											
	33	Cytoscope	X	X																										
	34	Electrocardiograph	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X			X	X		X					
	35	Light Slit, Ophthalmological	X	X												X														
	36	Magnifying Lens	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	37	Manometer, Spinal Fluid	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
	38	Otoscope	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	39	Sigmoidoscope	X	X			X	X	X							X			X											
	40	Sphygmomanometer	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	41	Tube, Stomach, Aspirating	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
	42	Urinometer	X	X						X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
	43	Visual Acuity	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
X ray Equip	44	X ray	X	X	X	X	X	X	X	X		X		X		X	X	X	X	X		X	X		X					
Chemical Analysis Equipment	45	Counter, Blood Cell, differential	X	X	X		X	X	X							X	X	X	X											
	46	Hemacytometer	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
	47	Hemoglobinometer	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
Laboratory Equipment & Supplies	48	Centrifuge, Lab	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
	49	Incubator, bacterial	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
	50	Pipet, Red Corpuscle	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
	51	Pipet, White Corpuscle	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
Optical Instruments	52	Spectrophotometer	X	X	X		X	X	X	X						X	X	X	X			X								
	53	Microscope, Binocular	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
	54	Condenser, Dark field	X																											

MEDICAL REQUIREMENTS

To determine the medical requirements for remote medical diagnosis, we analyzed incidence rates of illnesses and injuries aboard ships and submarines and determined the medical data and instrumentation needed in diagnosing these illnesses and injuries. Visits to shipboard and shore station medical facilities were made to generate listings of specific medical data and associated instrumentation. Discussions with medical personnel on board ships also provided information on special medical needs derived from their experience.

ILLNESS RATES

Morbidity data for all shipboard outpatient visits and inpatient admissions by active duty Navy and Marine Corps personnel, for the period of July 1972 to June 1973 (FY73), were obtained from Naval Medical Data Services Center (NMDSC), Bethesda, Maryland. (On board ships, an inpatient admission is defined as any patient visit which results in the patient's being placed on the sick list and temporarily relieved from his present duties.) These data were obtained for various treatment diagnoses and according to ship type.

Inpatient admission data were received in a coded listing of diagnoses based on the "International Classification of Diseases, Adapted for Use in the United States," (IDCA), Public Health Service Publication 1693. Each ICDA code is considered as indicating a disease or injury classification (denoted for simplicity as an illness classification).

Figure 1 shows the number of illness classifications for inpatient admissions as a function of the number of occurrences (on all ships) for that classification. For example, the first bar of the histogram shows that there were approximately 850 illness classifications having only 1-10 occurrences, the second bar shows that there were approximately 110 illness classifications having 11-20 occurrences, while the last bar shows that there was one illness classification having 801-850 occurrences. Note that the interval width for the number of occurrences is 10 for occurrences between 1 and 100, and 50 for occurrences between 101 and 1000, which explains the increase in the bars at 100 occurrences.

The outpatient data were not obtained in the same complete listing as the inpatient data, but rather were grouped into "selected conditions" by NMDSC as obtained from the Medical Service and Outpatient Morbidity Report NAVMED 6300/1. However, it may be noted that the outpatient visits generally involve problems of lower severity in nature than the inpatient admissions.

The data have been rearranged into 12 major illness categories for eight ship classes similar to those of previous studies on illness patterns on various classes of ships. (See Rahe et al [23], [24] and Rubin et al [28], [29].) A complete data analysis of the FY73 morbidity rate for shipboard inpatient admissions and outpatient visits in the Pacific area, Atlantic area, and combined areas is given in reference [26]. Similar data have been obtained for FY74 and are presently being analyzed for comparison to the FY73 data; a report will be prepared when this analysis is completed.

The following tables (4-11) summarize the FY73 data analysis; tables 4-7 characterize inpatient admissions in the combined Pacific and Atlantic areas, and tables 8-11 are, respectively, similar tables for outpatient visits. Table 4 shows the annual rates of inpatient admissions per 1000 personnel for combined Pacific and Atlantic operating areas. Table 5 shows (for each given ship class) the percentage of the total inpatient admissions (for that ship class) accounted for by each illness category. For example, on Carriers (with a total of 5798 inpatient admissions) infectious and parasitic disorders accounted for 7.66% of the

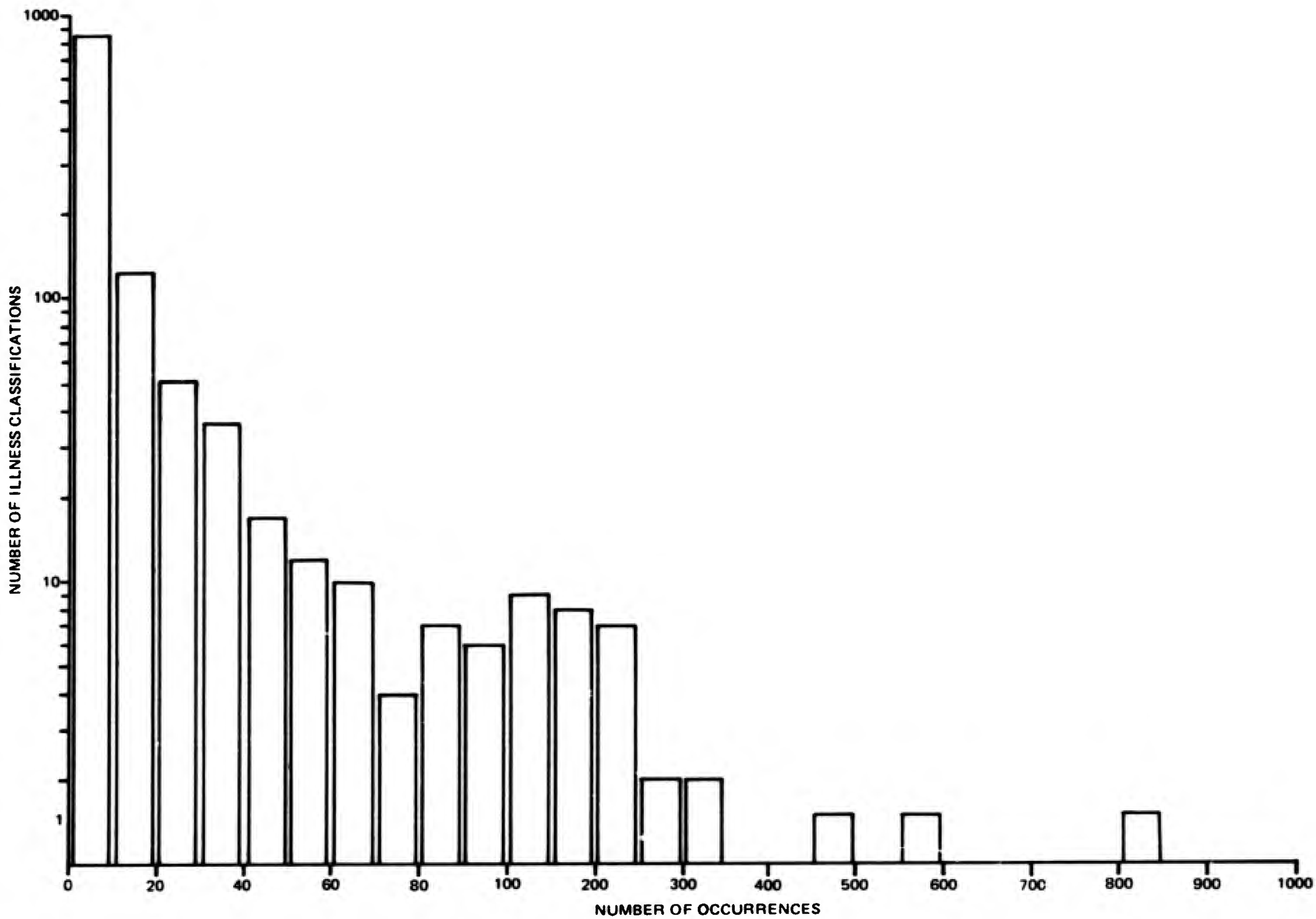


Figure 1. Frequency of occurrences for inpatient visits.

TABLE 4. ANNUAL RATES OF INPATIENT ADMISSIONS PER 1000 PERSONNEL, COMBINED PACIFIC AND ATLANTIC, FY73.

	ALL SHIPS	CARRIERS	SUBMARINES		CRUISERS	DESTR	AMPH	PATROL & MINE	AUXIL
			CON	NUC					
NUMBER OF SHIPS SAMPLED	669	17	32	98	9	241	74	44	154
PERSONNEL STRENGTH	226,064	54,102	2,591	13,321	9,384	61,894	33,146	2,054	49,572
TOTAL INPATIENT ADMISSIONS	79.47	107.17	66.38	67.71	66.50	68.18	58.86	92.02	82.91
1. INFECTIOUS & PARASITIC	4.05	8.21	3.47	2.93	3.94	2.20	2.26	2.43	3.45
2. RESPIRATORY CONDITIONS	8.18	14.21	3.86	6.08	9.06	6.03	5.31	6.82	6.90
3. DERMATOLOGICAL	11.39	16.45	12.35	8.71	11.51	9.37	7.03	16.55	11.74
4. GENITOURINARY	8.88	16.03	3.09	4.95	4.16	5.99	6.61	7.79	8.51
5. GASTROINTESTINAL	10.01	13.20	11.58	9.61	7.67	8.72	7.27	10.71	10.41
6. CRANIAL	2.65	2.18	2.70	2.70	2.98	2.78	2.75	1.46	2.93
7 EYE, EAR, & NOSE	2.57	2.86	2.32	2.25	2.88	2.34	1.96	1.95	3.01
8. CIRCULATORY	2.64	3.01	1.93	3.38	1.92	2.44	1.96	4.38	2.82
9. MET., END., & HEPATIC	2.17	2.38	1.93	1.88	2.56	1.92	1.57	1.46	2.70
10. MUSCULOSKELETAL	12.70	13.22	15.82	15.31	8.53	12.65	9.05	21.91	14.20
11. NEUROPSYCHIATRIC	12.42	13.36	6.18	8.33	10.23	12.25	11.65	14.61	13.86
12. PHYSICAL & CHEMICAL	1.80	2.05	1.16	1.58	1.07	1.49	1.45	1.95	2.38

TABLE 5. SAMPLE SIZE AND PERCENTAGES OF INPATIENT ADMISSIONS BY ILLNESS CATEGORY, COMBINED PACIFIC AND ATLANTIC, FY73.

	ALL SHIPS	CARRIERS	SUBMARINES		CRUISERS	DESTR	AMPH	PATROL & MINE	AUXIL
			CON	NUC					
NUMBER OF SHIPS SAMPLED	669	17	32	98	9	241	74	44	154
PERSONNEL STRENGTH	226,064	54,102	2,591	13,321	9,384	61,894	33,146	2,054	49,572
TOTAL INPATIENT ADMISSIONS	17,966	5,798	172	902	624	4,220	1,951	189	4,110
1. INFECTIOUS & PARASITIC	5.10	7.66	5.23	4.32	5.93	3.22	3.84	2.65	4.16
2. RESPIRATORY CONDITIONS	10.30	13.26	5.81	8.98	13.62	8.84	9.02	7.41	8.32
3. DERMATOLOGICAL	14.33	15.35	18.60	12.86	17.31	13.74	11.94	17.99	14.16
4. GENITOURINARY	11.18	14.95	4.65	7.32	6.25	8.79	11.23	8.47	10.27
5. GASTROINTESTINAL	12.60	12.31	17.44	14.99	11.54	12.80	12.35	11.64	12.55
6. CRANIAL	3.34	2.04	4.07	3.99	4.49	4.08	4.66	1.59	3.53
7. EYE, EAR, & NOSE	3.23	2.67	3.49	3.33	4.33	3.44	3.33	2.12	3.63
8. CIRCULATORY	3.32	2.81	2.91	4.99	2.88	3.58	3.33	4.76	3.41
9. MET., END., & HEPATIC	2.73	2.22	2.91	2.77	3.85	2.82	2.67	1.59	3.26
10. MUSCULOSKELETAL	15.99	12.33	23.84	22.62	12.82	18.55	15.38	23.81	17.13
11. NEUROPSYCHIATRIC	15.62	12.47	9.30	12.31	15.38	17.96	19.78	15.87	16.72
12. PHYSICAL & CHEMICAL	2.27	1.91	1.74	2.33	1.60	2.18	[illegible]	2.12	2.87

NOTE: DUE TO ROUND-OFF ERRORS, THE PERCENTAGES IN EACH COLUMN MAY NOT ADD UP TO EXACTLY 100%

TABLE 6. SAMPLE SIZE AND PERCENTAGES OF INPATIENT ADMISSIONS BY SHIP CLASS, COMBINED PACIFIC AND ATLANTIC, FY73.

	ALL SHIPS	CARRIERS	SUBMARINES		CRUISERS	DESTR	AMPH	PATROL & MINE	AUXIL
			CON	NUC					
NUMBER OF SHIPS SAMPLED	669	17	32	98	9	241	74	44	154
PERSONNEL STRENGTH	226,064	54,102	2,591	13,321	9,384	61,894	33,146	2,054	49,572
PERCENTAGE		23.93	1.15	5.89	4.15	27.38	14.66	0.91	21.93
TOTAL INPATIENT ADMISSIONS	17,966	32.27	0.96	5.02	3.47	23.49	10.86	1.05	22.88
1. INFECTIOUS & PARASITIC	916	48.47	0.98	4.26	4.04	14.85	8.19	0.55	18.67
2. RESPIRATORY CONDITIONS	1,850	41.57	0.54	4.38	4.59	20.16	9.51	0.76	18.49
3. DERMATOLOGICAL	2,575	34.56	1.24	4.50	4.19	22.52	9.05	1.32	22.60
4. GENITOURINARY	2,008	43.18	0.40	3.29	1.94	18.48	10.91	0.80	21.02
5. GASTROINTESTINAL	2,263	31.55	1.33	5.66	3.18	23.86	10.65	0.97	22.80
6. CRANIAL	600	19.67	1.17	6.00	4.67	28.67	15.17	0.50	24.17
7. EYE, EAR, & NOSE	581	26.68	1.03	5.16	4.65	24.96	11.19	0.69	25.65
8. CIRCULATORY	596	27.35	0.84	7.55	3.02	25.34	10.91	1.51	23.49
9. MET., END., & HEPATIC	491	26.27	1.02	5.09	4.89	24.24	10.59	0.61	27.29
10. MUSCULOSKELETAL	2,872	24.90	1.43	7.10	2.79	27.26	10.45	1.57	24.51
11. NEUROPSYCHIATRIC	2,807	25.76	0.57	3.95	3.42	27.00	13.75	1.07	24.47
12. PHYSICAL & CHEMICAL	407	27.27	0.74	5.16	2.46	22.60	11.79	0.98	28.99

NOTE: DUE TO ROUND-OFF-ERRORS, THE PERCENTAGES IN EACH ROW MAY NOT ADD UP TO EXACTLY 100%

TABLE 7. PERCENT DEVIATION FROM EXPECTED, INPATIENT ADMISSIONS, COMBINED PACIFIC AND ATLANTIC, FY73.

	ALL SHIPS	CARRIERS	SUBMARINES CON	SUBMARINES NUC	CRUISERS	DESTR	AMPH	PATROL & MINE	AUXIL
NUMBER OF SHIPS SAMPLED	669	17	32	98	9	241	74	44	154
PERSONNEL STRENGTH	226,064	54,102	2,591	13,321	9,384	61,894	33,146	2,054	49,572
TOTAL INPATIENT ADMISSIONS	0.00	34.85	-16.47	-14.80	-16.33	-14.21	-25.94	15.78	4.32
1. INFECTIOUS & PARASITIC	0.00	102.54	-14.27	-27.75	-2.69	-45.77	-44.16	-39.92	-14.87
2. RESPIRATORY CONDITIONS	0.00	73.69	-52.84	-25.70	10.69	-26.36	-35.12	-16.71	-15.70
3. DERMATOLOGICAL	0.00	44.42	8.43	-23.55	1.04	-17.73	-38.29	45.32	3.07
4. GENITOURINARY	0.00	80.42	-65.24	-44.22	-53.21	-32.52	-25.62	-12.30	-4.16
5. GASTROINTESTINAL	0.00	31.84	15.66	-4.01	-23.35	-12.84	-27.37	7.00	3.98
6. CRANIAL	0.00	-17.82	1.79	1.82	12.42	4.70	3.44	-44.[illegible]7	10.21
7. EYE, EAR, & NOSE	0.00	11.47	-9.90	-12.37	11.95	-8.85	-23.70	-24.23	16.95
8. CIRCULATORY	0.00	14.28	-26.80	28.13	-27.24	-7.46	-25.62	66.20	7.12
9. MET., END., & HEPATIC	0.00	9.78	-11.15	-13.59	17.75	-11.48	-27.77	-32.75	24.46
10. MUSCULOSKELETAL	0.00	4.03	24.56	20.54	-32.90	-0.42	-28.76	72.45	11.78
11. NEUROPSYCHIATRIC	0.00	7.63	-50.27	-32.89	-17.61	-1.37	-6.21	17.63	11.61
12. PHYSICAL & CHEMICAL	0.00	13.96	-35.69	-12.44	-40.81	-17.44	-19.56	8.17	32.22

TABLE 8. ANNUAL RATES OF OUTPATIENT VISITS PER 1000 PERSONNEL. COMBINED PACIFIC AND ATLANTIC, FY73.

	ALL SHIPS	CARRIERS	SUBMARINES CON	SUBMARINES NUC	CRUISERS	DESTR	AMPH	PATROL & MINE	AUXIL
NUMBER OF SHIPS SAMPLED	669	17	32	98	9	241	74	44	154
PERSONNEL STRENGTH	226,064	54,102	2,591	13,321	9,384	61,894	33,146	2,054	49,572
TOTAL OUTPATIENT VISITS (INCLUDING REPEAT VISITS)	1,768,838	398,435	22,529	74,949	57,223	533,332	243,727	17,411	421,232
TOTAL NEW OUTPATIENT VISITS	4,009.2	4,008.83	4,253.18	2,948.88	3,982.84	3,946.67	3,967.42	4,033.11	4,391.59
1. INFECTIOUS & PARASITIC	283.3	366.29	343.50	276.56	320.12	241.48	218.88	333.98	277.37
2. RESPIRATORY CONDITIONS	1,500.7	1,223.10	2,260.90	1,542.00	1,252.34	1,766.65	1,551.11	1,804.28	1,421.53
3. DERMATOLOGICAL	414.3	437.34	329.60	303.43	482.84	371.43	400.98	370.98	474.52
4. GENITOURINARY	370.8	547.13	127.36	56.98	395.46	266.15	444.04	250.24	357.60
5. GASTROINTESTINAL	364.3	331.45	399.46	250.88	396.74	405.13	304.23	452.77	408.27
6. CRANIAL	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7. EYE, EAR, & NOSE	126.4	119.29	145.12	85.73	118.50	117.73	137.00	123.66	149.54
8. CIRCULATORY	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9. MET., END., & HEPATIC	24.2	13.99	77.96	16.59	32.82	28.14	26.85	60.37	24.61
10. MUSCULOSKELETAL	479.2	588.19	301.81	178.97	599.64	319.51	441.08	203.02	663.74
11. NEUROPSYCHIATRIC	95.2	74.69	54.42	56.08	58.40	76.91	111.20	59.40	150.91
12. PHYSICAL & CHEMICAL	350.8	307.36	213.05	181.67	325.98	353.54	332.05	374.39	463.49

TABLE 9. SAMPLE SIZE AND PERCENTAGES OF OUTPATIENT VISITS BY ILLNESS CATEGORY, COMBINED PACIFIC AND ATLANTIC, FY73.

	ALL SHIPS	CARRIERS	SUBMARINES		CRUISERS	DESTR	AMPH	PATROL & MINE	AUXIL
			CON	NUC					
NUMBER OF SHIPS SAMPLED	669	17	32	98	9	241	74	44	154
PERSONNEL STRENGTH	226,064	54,102	2,591	13,321	9,384	61,894	33,146	2,054	49,572
TOTAL NEW OUTPATIENT VISITS	906,326	216,886	11,020	39,282	37,375	244,275	131,504	8,284	217,700
1. INFECTIOUS & PARASITIC	7.07	9.14	8.08	9.38	8.04	6.12	5.52	8.28	6.32
2. RESPIRATORY CONDITIONS	37.43	30.51	53.16	52.29	31.44	44.76	39.10	44.74	32.37
3. DERMATOLOGICAL	10.33	10.91	7.75	10.29	12.12	9.41	10.11	9.20	10.81
4. GENITOURINARY	9.25	13.65	2.99	1.93	9.93	6.74	11.19	6.20	8.14
5. GASTROINTESTINAL	9.09	8.27	9.39	8.51	9.96	10.27	7.67	11.23	9.30
6. CRANIAL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7. EYE, EAR, & NOSE	3.15	2.98	3.41	2.91	2.98	2.98	3.45	3.07	3.41
8. CIRCULATORY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9. MET., END., & HEPATIC	0.60	0.35	1.83	0.56	0.82	0.71	0.68	1.50	0.56
10. MUSCULOSKELETAL	11.95	14.67	7.10	6.07	15.06	8.10	11.12	5.03	15.11
11. NEUROPSYCHIATRIC	2.38	1.86	1.28	1.90	1.47	1.95	2.80	1.47	3.44
12. PHYSICAL & CHEMICAL	8.75	7.67	5.01	6.16	8.18	8.96	8.37	9.28	10.55

NOTE: DUE TO ROUND-OFF ERRORS, THE PERCENTAGES IN EACH COLUMN MAY NOT ADD UP TO EXACTLY 100%.

TABLE 10. SAMPLE SIZE AND PERCENTAGES OF OUTPATIENT VISITS BY SHIP CLASS, COMBINED PACIFIC AND ATLANTIC, FY73.

	ALL SHIPS	CARRIERS	SUBMARINES		CRUISERS	DESTR	AMPH	PATROL & MINE	AUXIL
			CON	NUC					
NUMBER OF SHIPS SAMPLED	669	17	32	98	9	241	74	44	154
PERSONNEL STRENGTH	226,064	54,102	2,591	13,321	9,384	61,894	33,146	2,054	49,572
PERCENTAGE		23.93	1.15	5.89	4.15	27.38	14.66	0.91	21.93
TOTAL NEW OUTPATIENT VISITS	906,326	23.93	1.22	4.33	4.12	26.95	14.51	0.91	24.02
1. INFECTIOUS & PARASITIC	64,032	30.95	1.39	5.75	4.69	23.34	11.33	1.07	21.47
2. RESPIRATORY CONDITIONS	339,255	19.51	1.73	6.05	3.46	32.23	15.15	1.09	20.77
3. DERMATOLOGICAL	93,653	25.26	0.91	4.32	4.84	24.55	14.19	0.81	25.12
4. GENITOURINARY	83,833	35.31	0.39	0.91	4.43	19.65	17.56	0.61	21.15
5. GASTROINTESTINAL	82,360	21.77	1.26	4.06	4.52	30.45	12.24	1.13	24.57
6. CRANIAL	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7. EYE, EAR, & NOSE	28,579	22.58	1.32	4.00	3.89	25.50	15.89	0.89	25.94
8. CIRCULATORY	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9. MET., END., & HEPATIC	5,464	13.85	3.70	4.04	5.64	31.88	16.29	2.27	22.33
10. MUSCULOSKELETAL	108,331	29.37	0.72	2.20	5.19	18.26	13.50	0.38	30.37
11. NEUROPSYCHIATRIC	21,526	18.77	0.66	3.47	2.55	22.11	17.12	0.57	34.75
12. PHYSICAL & CHEMICAL	79,293	20.97	0.70	3.05	3.86	27.60	13.88	0.97	28.98

NOTE: DUE TO ROUND-OFF ERRORS, THE PERCENTAGES IN EACH ROW MAY NOT ADD UP TO EXACTLY 100%.

TABLE 11. PERCENT DEVIATION FROM EXPECTED, OUTPATIENT VISITS, COMBINED PACIFIC AND ATLANTIC, FY73.

	ALL SHIPS	CARRIERS	SUBMARINES		CRUISERS	DESTR	AMPH	PATROL & MINE	AUXIL
			CON	NUC					
NUMBER OF SHIPS SAMPLED	669	17	32	98	9	241	74	44	154
PERSONNEL STRENGTH	226,064	54,102	2,591	13,321	9,384	61,894	33,146	2,054	49,572
TOTAL NEW OUTPATIENT VISITS	0.00	0.00	6.09	-26.45	-0.66	-1.56	-1.04	0.57	9.54
1. INFECTIOUS & PARASITIC	0.00	29.32	21.27	-2.36	13.02	-14.74	-22.72	17.57	-2.07
2. RESPIRATORY CONDITIONS	0.00	-18.50	50.66	2.75	-16.55	17.72	3.36	20.23	-5.28
3. DERMATOLOGICAL	0.00	5.57	-20.44	-26.76	16.55	-10.34	-3.21	-10.45	14.54
4. GENITOURINARY	0.00	47.54	-65.66	-84.64	6.64	-28.23	19.74	-32.52	-3.57
5. GASTROINTESTINAL	0.00	-9.02	9.65	-31.14	8.90	11.20	-16.49	24.28	12.06
6. CRANIAL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7. EYE, EAR, & NOSE	0.00	-5.64	14.79	-32.19	-6.27	-6.87	8.37	-2.18	18.29
8. CIRCULATORY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9. MET., END., & HEPATIC	0.00	-42.11	222.56	-31.36	35.79	16.44	11.09	149.77	1.82
10. MUSCULOSKELETAL	0.00	22.74	-37.02	-62.65	25.13	-33.32	-7.96	-57.63	38.51
11. NEUROPSYCHIATRIC	0.00	-21.56	-42.85	-41.11	-38.67	-19.23	16.79	-37.62	58.49
12. PHYSICAL & CHEMICAL	0.00	-12.37	-39.26	-48.21	-7.06	0.79	-5.33	6.74	32.14

admissions, and respiratory conditions accounted for 13.26% of the visits. Table 6 gives the percentage of an inpatient illness category accounted for by each ship class. The personnel strength assigned to each ship class is also shown as a percentage of all shipboard personnel. For example, of the 916 inpatient admissions for infectious and parasitic disorders (from all ships), 48.47% occurred on Carriers (which accounts for only 23.93% of the total personnel). Thus, it appears that a disproportionate number of inpatient admissions for infectious and parasitic disorders occurred on board Carriers.

In order to determine whether a given class of ships had more or fewer inpatient admissions than would be expected (based on a proportionate share of personnel strength), the percent deviations from expected were calculated and are shown in table 7. In other words, if it is assumed that he occurrence rate is the same throughout all ships, then the number of occurrences will depend only on the number of personnel assigned to a class of ships. Based on this assumption, table 7 shows the percent deviation from the expected number of occurrences for inpatient admissions. For example, Carriers had 102.54% more than the expected rate of admissions for infectious and parasitic disorders since they had 8.21 per 1000 personnel compared to 4.05 per 1000 personnel as an average for all ships (see table 4). On the other hand, Destroyers deviated –45.77% from the expected for infectious and parasitic disorders; ie, they had only about half the rate (2.26 per 1000 personnel) of all ships on the average.

Table 7 shows that Carriers and Auxiliary ships had higher incidence rates than expected for most illness categories, while Submarines (both nuclear and conventional), Cruisers, Destroyers, and Amphibious had lower incidence rates than expected for most categories. Chi-squared tests for goodness-of-fit (at a 95% confidence level) indeed show that none of the ship classes have the same illness distributions; and, of the illness categories, only cranial, and eye, ear, and nose categories may have the same incidence rate for all classes of ships. A detailed analysis can be found in reference [26]. It should be noted that this will not affect the Remote Medical Diagnosis System, but only points out that varying illness incidence rates may be expected from one class of ships to another.

For outpatient visits, no data were assigned to the cranial or circulatory categories. Of the 10 illness categories for outpatient visits, table 11 shows that Carriers exceeded the expected rate in only four categories, and that only nuclear Submarines were below or close to the expected incidence rates in most illness categories. Again, chi-squared tests show that the incidence rates are not the same for all classes of ships, and that the ship classes do not have the same illness distributions (see [26]).

Tables 5 and 9 show very different distributions of illness categories for inpatient and outpatient data. For inpatient admissions overall, musculoskeletal has the highest percentage of occurrences with osteomyelitis, fractures, dislocations, and sprains being the major contributors. The neuropsychiatric category had about the same percentages of occurrences with personality disorders, alcoholism, and drug dependency or improper use being the major factors. Dermatology is the third ranking category with infections of the skin and subcutaneous tissue, lacerations, and contusions having the highest occurrences.

Venereal disease (VD) has been found to be a major health problem in the Navy, accounting for about 10% of all illnesses in first-term naval enlisted personnel (Plag and Phelan [21]). The data obtained in this study show that, overall, VD accounts for only 4.3% of all illnesses. This lower incidence rate may be due to several reasons. First, the data being obtained are for all active duty Navy and Marine Corps personnel assigned to ships rather than just first-term naval enlisted personnel. Second, not all cases treated are reported. Finally, there have been more thorough programs of VD prevention in recent years.

Reference [26] contains more detailed analyses for both inpatient admissions and outpatient visits for each of the Pacific and Atlantic areas. These analyses have shown, for example, that in the combined Atlantic and Pacific areas nuclear Submarines, Destroyers, and Amphibious vessels had significantly low incidence rates of inpatient admissions for nearly all illness categories; while Carriers and Auxiliary vessels had higher than expected incidence rates for most illness categories. However, considering the Atlantic and Pacific areas separately, the above trend is not quite so evident. In the Pacific, Carriers were higher than expected in all categories except cranial, but Auxiliary vessels had six categories higher than expected and six categories lower than expected. Nuclear Submarines, Destroyers, and Amphibious vessels in the Pacific were below expected values in nearly all illness categories. On the other hand, in the Atlantic, Auxiliary vessels had higher than expected incidence rates in all but one category, while Carriers had seven categories below expected values. Similarly, both nuclear Submarines and Destroyers in the Atlantic had five illness categories above expected values.

Table 12, a composite from references [23], [24], [28], and [29], shows the percentage of illnesses for various illness categories aboard a sample of ships during a given deployment. Some of the percentages, as given in the references, have been adjusted to reflect the illness category definitions as used in this study. Where information was not available, it was not possible to adjust all categories. (See footnotes on table 12). The study of an Attack Carrier, CVA, consisted of one third of the enlisted crew (738 personnel) during a 6-month deployment to Vietnam. The study of Cruisers consisted of two heavy Cruisers and one light Cruiser from the same West Coast home port. Two of the Cruisers were engaged in combat support operations off the coast in Vietnam, one for 6 months and one for 8 months. The third Cruiser took part in preparedness exercises in the Mediterranean during a period of 6 months. The study of a Battleship was taken from a 7-month deployment of USS NEW JERSEY to Vietnam.

These studies have shown results similar to those of other studies of a given population for 1-year periods: that approximately 50% of the population accounts for 75–95% of the reported illnesses, and 10% of the population accounts for approximately 25–50% of the illnesses.

TABLE 12. PERCENTAGE OF ILLNESSES BY MAJOR CATEGORY, FROM THREE PREVIOUS STUDIES (RAHE, ET AL [23], [24] AND RUBIN, ET AL [28], [29]).

		ATTACK CARRIER	CRUISERS	BATTLESHIP
	SAMPLE GROUP SIZE	738	2684	1223
	TOTAL PATIENT VISITS	795	1819	2940
1.	GEN. INFECTIOUS & PARASITIC	5.9[a]	3.4	7.5[b]
2.	RESPIRATORY CONDITIONS	19.7	20.9	25.7
3.	DERMATOLOGICAL	36.6[c]	24.5[c]	29.9[c]
4.	GENITOURINARY DISORDERS.	5.9	14.1	11.7
5.	GASTROINTESTINAL DISORDERS	10.1	11.2	7.7
6.	CRANIAL	1.0	2.3	7.9[d]
7.	EYE, EAR, NOSE	7.8	6.5	
8.	CIRCULATORY			
9.	METABOLIC, ENDOCRINE & HEPATIC . .	0.5	1.5	
10.	MUSCULOSKELETAL	9.8	11.9	7.7
11.	NEUROPSYCHIATRIC	2.7	2.6	1.9
12.	PHYSICAL & CHEMICAL.			
13.	OTHER		1.0[e]	

(a) Also includes injuries from flights, and tumors

(b) Also includes injuries from flights, allergies, obesity, tumors, and alcoholism

(c) Also includes trauma and foreign bodies

(d) Also includes category 7.

(e) Includes category 8, dental, and congenital conditions

MEDICAL DIAGNOSIS DATA AND INSTRUMENTATION: SHIPBOARD DIAGNOSTIC CAPABILITIES

Using the incidence rates for illnesses as developed in illness rates, the medical data and associated instrumentation needed for diagnosis were determined for selected illnesses and injuries. Illnesses and injuries selected for consideration were those which had 10 or more occurrences annually. Inpatient data only were used, since an extensive breakdown of the outpatient data was not available. In addition to the above selected illness classifications, illnesses and injuries having a high "seriousness" were also considered.

Medical data and instrumentation required or sufficient to diagnose these selected illnesses and injuries were determined by use of the Merck Manual of Diagnosis and Therapy, Clinical Diagnosis by Laboratory Methods, by Davidsohn and Henry, and by discussions with shipboard and shore station medical personnel. These data are shown in table 13. "History" refers either to the patient's past medical history, or to a history of the patient's present illness symptoms.

The medical equipments used for the diagnosis of an illness are treated in two categories: first, the equipment that is listed on at least one class of ships (numbered entries corresponding to equipment listed in table 3); second, the equipment which is not listed on the AMAL of any class of ships (lettered entries corresponding to equipment listed in table 14). For example, diagnosis of German measles uses equipments 11, 29, and 53, to be used conjunctively, and Y. Table 3 shows 11, 29, and 53 to be Giemsa's staining solution, Wright blood stain with methyl alcohol, and a binocular microscope, respectively. Table 3 also shows which classes of ships are listed as having this equipment. Table 14 lists Y as "viral antibody tests and/or virus isolation," which is not listed in the AMAL of any class of ships. These tables (3, 13, and 14) can then be used to determine any deficiencies for a certain class of ships, or for any particular ship.

TABLE 13. SELECTED AILMENTS AND MEDICAL MATERIAL USED FOR DIAGNOSIS.

	Examination and evaluation of clinical signs and symptoms	History	Numbered entries represent medical material that is listed on the AMAL of at least one class of ships (see table 3 for name and distribution of item)	Lettered entries represent medical material that is not listed on the AMAL of any class of ships (see table 14 for name of item)	Remarks
1. INFECTIVE AND PARASITIC					
German measles	√*		(11,29,53)	Y	
Aseptic meningitis	√*			G,Y*	
Chickenpox	√		(11,53)	Y	
Mumps	√*		(11,29,53)	Y	
Measles	√	√	(11,29,53)		
Infectious mononucleosis	√		(8,11,29,53)*26*		
Viral infection (general)	√		(3,8,11,29,53)44	Y*	
Sarcoidosis	√*		44	B*,E,M	
Influenza	√*		(8,11,29,53)		
Fever and chills	√		(3,8,9,11,13,29,53)5,25,27,40,42,44,45,46,47,(7,49)56,57	B,N	
Lymphadenitis	√*		(8,11,29,53)		
Plague (pneumonic form)	√		(7,49)		
Diptheria	√		49	V	49 and V for use together
2. RESPIRATORY					
The common cold	√*		(8,11,29,53)		
Acute pharyingitis	√*		44		
Acute tonsillitis	√*		(49,54)53		
Acute bronchitis	√*		(3,9,16,53)		
Mycoplasma & viral pneumonia	√*		(11,29,53)44*	Y	
Pneumococcal pneumonia	√*		(11,29,53)44*(7,49)		
Bronchial asthma	√*	√*	(29,53)44	D,F	
Adenoid hypertrophy	√				
Peritonsillar abscess	√				
Serofibrinous pleurisy	√*	√*	44(7,49)	B,AA,J	
Hemoptysis	√				

*Primary means of diagnosis.

Items within parentheses indicate equipment that is to be used conjunctively.

TABLE 13. (Continued).

2. RESPIRATORY (Contd)					
Hay fever	√*	√*	8,11,29,53		
Fibrinous pleurisy	√*				
Pneumothorax	√		44*	Z	44 and Z for use together
Pulmonary embolism/infarction	√		34,44		
Hypoxia	√*	√*	47,52		
Streptococcal sore throat	√		(7,49)		
3. DERMATOLOGICAL					
Cellulitis	√	√			
Infantile eczema	√				
Acute sunburn	√				
Erythematosis condition	√				
Psoriasis	√				
Ingrowing nail	√				
Acne	√				
Sebaceous cyst	√				
Urticaria; angioedema	√				
Follicular infections	√		36		
Dermatomycoses	√*		53		
Herpes simplex	√				
Warts	√				
Epithelioma	√				
Angiomas	√				
Pilonidal cyst	√				
4. GENITOURINARY					
Pyelonephritis	√*		5,(8,11,29,53)*33,44,(7,49)		
Calculus of kidney, ureter, bladder or urethra	√		33,44	Z	44 and Z for use together
Cystitis	√*	√*	33,44		
Stricture of urethra	√			D	
Urethritis, prostatitis, semiual & vesiculitis	√		53		
Hydrocele	√				
Epididymitis & orchitis	√				
Paraphimosis	√	√			
Sterility, male			53		
Spermatocele	√				
Urethritis (non-gonoccal)	√				
Gonorrhea	√*		(3,9,53)*	W	
Chancroid	√		(2,10)54		

TABLE 13. (Continued).

4. GENITOURINARY (Contd)					
Lymphogranuloma venerum	√		1,*(53,54)		
Granuloma inguinale	√		(2,10)*(3,9,11,13,29,53)*(53,54)*		
Syphilis	√		(2,10)*(53,54)*		
Orchitis & epididymitis	√	√			
Hematuria	√		5		
Undescended testis	√				
5. GASTROINTESTINAL DISORDERS					
Peptic ulcer	√		44,*41	C,X,*BB	44 and X for use together
Perforated peptic ulcer	√				
Appendicitis	√				
Peritonitis	√*	√*	(8,11,29,53)44(7,49)		
Hernia	√				
Acute gastroenteritis	√		(8,11,29,53)(22,49)39		
Fissure in ano	√				
Fistula in ano	√				
Anorectal abscess	√				
Gastritis	√	√		C,K	
Hemorrhoids	√				
Amebiasis	√				
Regional enteritis	√		5,(8,11,29,53)18,(22,49)30,44*	X*	44 and X for use together
Abdominal pain	√	√	(3,9,11,13,29,45,53)4,12,18,46,47,30,25,27,42,44	S,X,Z,CC	X,Z and CC for use with 44
6. CRANIAL					
Intracranial neoplasms	√		32,43,44	H	
Fracture of skull	√		44		
Aneurysm (intracranial)	√		44*	G,Z*	may be impossible to diagnose
7. EYE, EAR, & NOSE					
Inflammation of uveal tract	√				
Conjunctivitis & opthalmia	√				
Acute external otitis	√*		(7,49)		
Otitis media	√		*38	A	
Myringitis	√				
Impairment of hearing	√		32		
Deviated septum	√				
Sinusitis, chronic	√		44		
Nasal polyps	√				

TABLE 13. (Continued).

8. CARDIOVASCULAR & CIRCULATORY					
Primary hypertension			34,40*	U	
Atrial fibrillation			34		
Unspecified disorders of heart rhythm			34		
Varicose veins	√				
Venous thrombosis	√				
Arterial embolism & acute thrombosis	√				
Myocardial disease	√		34,44	I	
Cardiac arrest	√*		34		
Ventricular fibrillation	√*		34,40		
Angina pectoris	√*		14*,34		
Myocardial disease	√*		(8,11,29,53)34	L	
Shock	√	√			
Congestive heart failure	√*		34,44		
Neurocirculatory asthenia	√*		34		
Lymphadenitis	√				
9. METABOLIC, ENDOCRINE, & HEPATIC					
Diabetes mellitus	√		4,27		
Obesity	√	√			
Hepatitis (infectious, toxic and other)	√*		12,(8,11,29,53)21	L*,M,O,R,S	
Cholecystitis	√	√*	25,44		
Acute pancreatitis	√		(11,29,53)44		many cases diagnosed only at operation
Cholelithiasis, choledocholithiasis	√	√	21*,41*		
Portal vein thrombosis	√	√			
Ascending cholangitis and suppurative cholangitis	√*	√*	(8,11,29,53)25		
10. MUSCULOSKELETAL					
Rheumatoid arthritis	√		44,57	N*,P	6 to 12 months observation is required before illness may be classified

TABLE 13. (Continued).

10. MUSCULOSKELETAL (Contd)					
Osteomyelitis	√	√	(8,11,29,53)18,(7,49)44*		presumptive diagnosis is often necessary
Osteitis deformans			44*,52	M,O	52 and 0 for use together
Diseases of spine	√	√	37,44	G	
Synovitis; bursitis; tenosynovitis	√	√	44		
Hallux valgus; bunion	√				
Degenerative joint disease	√*		(8,11,29,53)18,44*	N	
Derangements; displacements; deformities; fractures; sprains	√		44		
Benign neoplasms of bone			44	B*	
Fibromyositis	√				several months observation
11. NEUROPSYCHIATRIC					
Headache (cephalalgia & migraine)	√	√	*8,11,29,45,53)4,43,44,46,47	G,G,Z	
Sciatica	√*	√*	44*,57,2,27,42	G,M	
Psychotic disorders	√				
Alcoholism	√				
Drug dependence	√				
12. PHYSICAL AND CHEMICAL					
Anaphylactic shock	√	√			
Drug reaction	√				
Heat hyperpyrexia	√	√			
Venomous bites	√	√			
Electric shock	√	√			
Poisoning	√	√			

TABLE 14. MEDICAL MATERIAL NOT LISTED ON THE AMAL OF ANY SHIP BUT IMPORTANT AS A DIAGNOSTIC AID FOR SELECTED DISEASES.

A	Retinoscope
B	Needle, Biopsy
C	Gastroscope
D	Endoscope
E	Spirometer
F	Tomograph
G	Lumbar Puncture Kit
H	Electroencephalograph
I	Catheter, Cardiac
J	Aspirating Tube, Bronchial
K	Wood Suction Biopsy Tube, Rubin Tube or Crosby Capsule
L	Test Kit, Serum Transaminase
M	Test Kit, Alkaline Phosphate
N	Test Kit, Rheumatoid Arthritis
O	Test Kit, Calcium Determination
P	C-Reactive Protein Test
Q	Thymol Turbidy or Cephalin Flocculation Test
R	Prothrombin Time Test
S	Serum Bilirubin Determination
T	Sera Antistreptolysin O Titer Determination
U	Phentolamine Mesylate
V	Loeffler's Medium
W	Vancomycin, Colistin, Nystatin and G.C. Medium Base
X	Barium Sulfate
Y	Viral Antibody Tests and/or Virus Isolation
Z	Meglumine Iothalamate, Meglumine Diatrizoate – Sodium Diatrizoate and Sodium Iothalamate Injections
AA	Gram Stain
BB	Topfer's Reagent
CC	Meglumine Iodipamide Injection

SHIP POPULATION PROFILE SUMMARY

Present force levels (ie, the number of ships in each class), their assignment to either the Pacific or Atlantic operating area, typical task force compositions, and geographical operating and transiting areas are discussed in appendix A. From this information, the probable communication ranges can be determined on a geographical basis. Typical task force compositions will determine what type of communication network will be necessary; for example, if the task force includes a CVA, then the CVA will serve as a primary remote diagnosis site for all other ships in the task force. If additional diagnostic consultation is still needed, it will be necessary to communicate to some shore-based medical facility which serves as a remote diagnosis site. Future force level and operational change prediction will result in predicted profiles for future illness incidence rates, which may affect the predicted requirements for a remote medical diagnosis system.

COMMUNICATIONS

PRESENT COMMUNICATIONS SYSTEM

The present Naval Telecommunications System (NTS) is essentially an hf/mf ship-to-shore radio network that evolved as long-range hf communication links were introduced into the Fleet. This network is augmented by multifrequency broadcast links including vlf/lf components, as well as hf/mf. Ship-to-ship and ship-to-aircraft networks extensively use uhf for limited-range communications.

Each Navy ship is provided a basic capability to fill the communications needs associated with its operations and to support operational commands which may be embarked. The basic communications suite today uses hf and mf radio for over-the-horizon communications and vhf and uhf for line-of-sight communications.

The basic capability to communicate is fulfilled by several modes of transmission, which are:

CW (10–35 words/min)

Teletype (100 words/min, with a few 60 words/min)

Voice (3–4-kHz channels AM-SSB or FM)

Digital data (1364, 2250, and 2400 bits/sec)

Facsimile (various rates)

These modes will continue to be used in the Fleet for the next several years. Table 15 shows the general characteristics of the most common Naval communication systems.

Naval teletype messages are of two broad categories – Operational and Administrative; and four basic levels of precedence – Flash, Immediate, Priority, and Routine. Messages relating to medical matters are considered Administrative. Administrative messages normally cannot be sent with a precedence higher than Priority. The fastest turnaround time for one exchange of messages is typically more than 2 hours.

Voice transmission is not dedicated for medical matters for ship-to-ship or ship-to-shore transmissions. However, communication networks which are a part of the Marine Corps landing force operations are specifically dedicated or shared for medical purposes.

TABLE 15. PRESENT NAVAL COMMUNICATIONS SYSTEMS (GENERAL CHARACTERISTICS OF MOST COMMON SYSTEMS).

Mode	Data Rate	Maximum Band Width	Frequency Band
TTY Single Channel	60 or 100 words/min	1.24 kHz	vlf/lf/mf/hf/uhf
TTY Multichannel	100 words/min	3.00 kHz	lf/mf/hf/uhf
CW	35 words/min	0.10 kHz	mf/hf/uhf
Digital Data	1364/2250/2400 bits/sec	3.00 kHz	mf/hf/uhf
Voice	—	3-4 kHz	mf/hf/uhf/vhf
Facsimile	90 lines/min	3.00 kHz	mf/hf/uhf

The use of voice circuits for medical matters is dependent on the doctrine of each ship when operating independently, or when in a task force within the rules specified in the task force Communications Plan (COMPLAN).

The availability of digital data links for the transmission of medical information in the near future is questionable. Ship-to-ship data links presently in the Fleet are dedicated to operational tactical data exchange. Sharing any of these data links would seriously degrade the service for which the NTDS links are now being used. Even if this concern were overlooked, extensive computer software programming would be necessary to permit the intermixing of tactical and narrative medical data, and new hardware would have to be developed to permit access to the data links for medical information exchange. After the FLTSATCOM is introduced into the Fleet, and common user data terminals become widely installed on ships, the digital data exchange of medical information will become practical.

Facsimile communication systems provide the capability of single-channel reception and transmission of graphic and pictorial material. This mode of communication is primarily used for the transmission of environmental charts from shore to Fleet units. Although many classes of ships are equipped to receive facsimile, the capability to transmit is provided only on the very largest ships. As presently configured, facsimile offers very little for medical personnel to employ for in-the-Fleet information exchange.

MEDICAL COMMUNICATION REQUIREMENTS

Medical data are generated in several different forms which can be subdivided into the following data categories:

- alphanumeric
- analog
- graphical
- photographic

The alphanumeric data will primarily be narrative, plain-language information, such as patient histories, laboratory tests, and medical reports. Analog data include directly recorded physiological signals such as electrocardiogram (ECG) and electroencephalogram (EEG) potentials; audio signals such as speech and heart sounds; and video information such as a view of the patient or microscope images. Graphical data include information in the form of ECG, EEG, phonocardiography, spirometry, and blood pressure tracings, medical charts, printed material, and line graphs. Photographic data will consist of x-ray negatives and pictures of the patient and/or injury sites, as well as printed material and graphical information.

The telecommunication of medical data via radio or land line can employ the following modes:

- Teletype circuits
  - Any data that can be reduced to alphanumeric characters
- Voice circuits
  - Telemetered physiological potentials
  - Physiological sounds
  - Voice commentary
  - Slow-scan televised x-ray negatives, views of the patient and tracings of physiological waveforms
  - Facsimile transmission of graphics, photographs, etc
- Digital data circuits
  - Any data that can be reduced to a digital format, such as:
    - Alphanumeric information
    - Analog signals
    - Graphics and photographs
- Broadband circuits
  - High-resolution pictures of x-ray negatives
  - Dynamic, real-time views of the patient

A comprehensive collection of physiological measurements and signal properties is given in appendix B for completeness. Although most of the measurements tabulated are not used in this study, it is possible that they will be needed in future systems. Table B1 shows, for different physiological parameters, the types of measurement required, the sensing devices used, and the parameter frequency characteristics. Table B2 gives the signal ranges of the physiological measurements.

COMMUNICATION NETWORKS FOR RMDS

This section discusses feasible communication networks that could be used for RMDS.

SHIP-TO-SHORE AND SHIP-TO-SHIP RADIO CIRCUITS SUITABLE FOR TRANSMISSION OF 3-kHz VOICE AND GRAPHICS

HIGH COMMAND (HICOM) CIRCUIT. This hf voice circuit links major Navy commanders with ships at sea. Using prearranged frequencies, most ships constantly monitor the frequencies on this circuit (a channel guard); larger ships (VSs, CLs, LCCs, DLGs) may also dedicate a transmitter to the guard channel if communication assets permit.

The communication stations (COMMSTAs) provide a HICOM operator who is able to interconnect any ship or shore command via hf and land line. One advantage in using this circuit for RMDS is that all COMMSTAs and most ships monitor it constantly. Coordination to effect two-way communications is minimal. A major disadvantage is that the circuit is dedicated primarily for command use. Other applications that might prevent immediate access by commands are not permitted.

INTRA COMMAND SWITCH BOARD (ICSB). ICSB, formerly known as Navy Operational Radio Telephone System (NORATS) is a network designed to provide voice communications between Navy ships at sea and shore-based telephone subscribers. Standard receive and transmit frequencies for operation day and night are in use. All Navy ships have the capability of subscribing to this network, but most do not continuously monitor it nor dedicate a transmitter to this use.

ICSB operators at COMMSTAs maintain a constant monitor on the assigned frequencies and can connect ships via phone patch to land line and cable subscribers. ICSB utilizes uhf (6 kHz) or hf (3 kHz, single sideband) and is used for unclassified communications only. Half-duplex and full-duplex modes may be used; however, full duplex requires the use of two different frequencies.

The advantages of ICSB for RMDS use are: (1) it provides direct and immediate access by a ship to a shore-based facility (since COMMSTAs maintain a constant monitor of the frequencies and possess phone-patch capability), and (2) the handling of unclassified medical traffic over the network is considered permissible by COMMSTA personnel. A disadvantage is that shore-to-ship communications require coordination by other means, such as teletype or HICOM, to alert the ship of the frequency of the incoming communication.

SPECIAL CIRCUITS. Upon request, special frequencies may be assigned for use by RMDS. These dedicated frequencies can be used at any time by medical subscribers for ship-to-shore-to-ship or ship-to-ship transmission of voice and graphics. However, arrangements must be made for NAVCOMMSTA monitoring if the service is to be on call at all times.

Such circuits can be operated on hf (3 kHz, single sideband) or, if in line-of-sight range, vhf or uhf (6 kHz, AM or FM). Vhf and uhf modes have the capability of being encrypted. The normal operation is half duplex. The advantage of using a special circuit is that it would be dedicated to RMDS full time and would not be shared by other users who could preempt the circuit for higher-precedence traffic. The disadvantage is that operators and equipment over and above the normal mission would have to be dedicated.

TACTICAL VOICE NETS. For ship-to-ship communications of RMDS data, tactical voice circuits normally employed by a ship in a task force may be used. An example would be the Task Force or Task Group common network. Tactical voice network may be hf (3 kHz, single sideband) or uhf (6 kHz, AM) depending on the range of coverage needed to include all subscriber ships in the operating area. Several key uhf circuits have the capability of being encrypted. The normal operating mode is half-duplex.

The advantages of using these circuits are that all net subscribers maintain continuous monitoring and that additional communications assets do not have to be committed to implement RMDS. The disadvantage is that RMDS must compete with other users. Also, the transmission of medical data over present-day networks would be contrary to their functional purpose.

SATELLITE VOICE CHANNELS. At some future date, satellite voice channels may provide the most error-free long-haul communication medium for RMDS. Present systems, such as the one employed by the Sixth Fleet in the Mediterranean operating area are used predominately for high-precedence voice and teletype classified traffic and would not normally be available for medical use.

COMMUNICATION NETWORK FOR RMDS PRELIMINARY TESTS

Figure 2 represents a configuration of the RMDS preliminary test communication network. This network provides the capability for small ships to consult with medical personnel aboard a senior ship in the Task Force or Task Group using already-assigned radio assets. Either the senior ships or junior ships (when necessary) may consult with medical personnel at a Navy hospital via ICSB or assigned frequencies and phone patch. If the ships are not within communication range of a COMMSTA near a shore station medical diagnosis center (Navy Hospital), it may be necessary to relay the communications through some other COMMSTA.

Existing Navy communication networks (HICOM, ICSB, and TACTICAL VOICE) provide a capability for any Navy ship to access a land-line connection to a medical facility ashore from most locations in the world for an emergency situation. However, for a remote medical diagnosis system to be used on a more regular and routine basis, specially assigned hf, vhf, and uhf frequencies are recommended. Table 16 summarizes the characteristics of the several radio links involved.

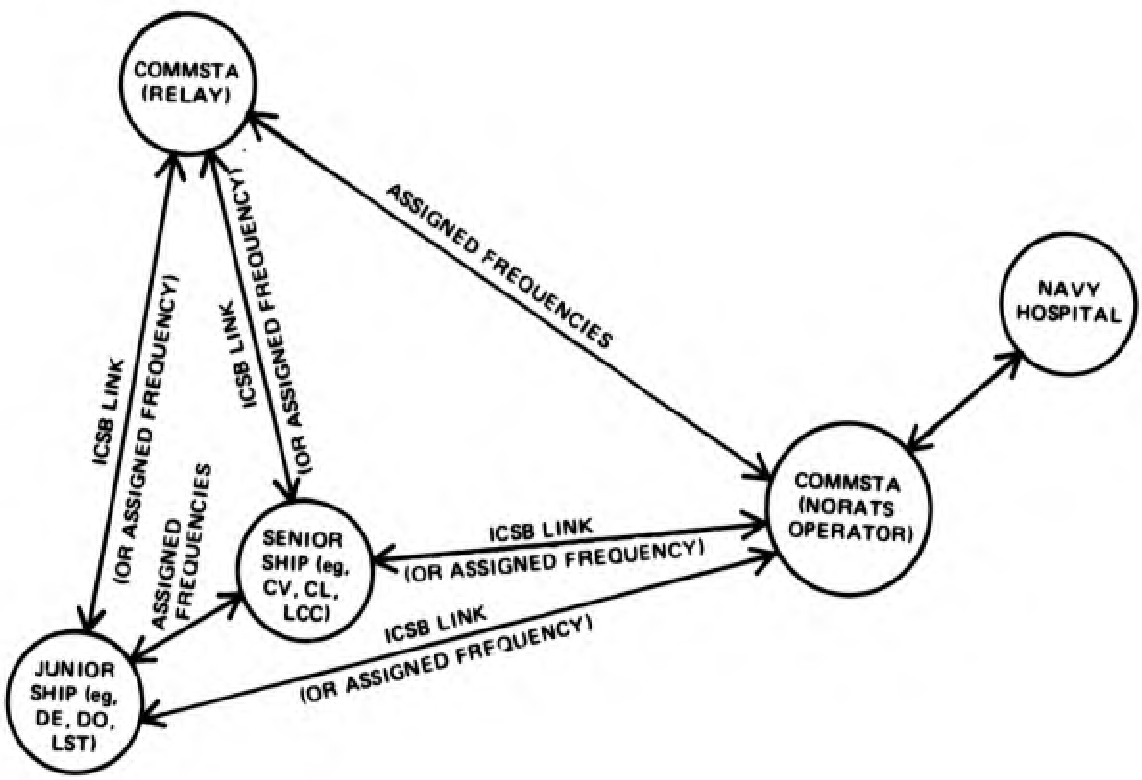


Figure 2. RMDS communication network configuration.

TABLE 16. SUMMARY OF COMMUNICATIONS LINK CHARACTERISTICS.

Ship	Band	Modulation	Operate	Coordination
ICSB	hf uhf	SSB, 3 kHz AM/FM, 6 kHz	Half duplex Full duplex	TTY Broadcast or Termination
TACTICAL VOICE	vhf hf	AM, 6 kHz SSB, 3 kHz	Half duplex Full duplex	Comm Coordination Net TF/TG Common TF/TG Teletype Orestes
Land Line (telephone)	vf (300-3000 Hz)	—	Full duplex	ICSB Operator

SHIPBOARD REMOTE MEDICAL DIAGNOSTIC TERMINAL

A Remote Medical Diagnosis Terminal (RMDT) will enable Navy medical personnel aboard ship to interface with the communications assets of the ship in order to obtain external professional medical assistance for the diagnosis and treatment of injuries or disease. To determine the feasibility of providing this capability, it was necessary to identify the overall communications requirements of the RMDT and then compare these requirements with the capabilities of available hardware, communication channels, and operational procedures.

SYSTEM CONSTRAINTS

It is beyond the scope of this document to study communications operational doctrine; therefore, it will be assumed that the operation of a RMDT will be within the constraints imposed by such doctrine. Additional constraints are placed on the RMDT by practical economic and facility considerations. Most important, RMDT must be relatively inexpensive in order to facilitate broad implementation; ie, it cannot be an expensive toy. Second, it must not occupy an unreasonable amount of physical space or use a large amount of electrical power. Preliminary limitations would be to occupy no more than 8 cubic feet of space and consume less than 1000 watts of power. Finally, terminals must have off-the-shelf availability or be capable of being fabricated from off-the-shelf functional subsystems such as keyboards, cathode ray tube systems, signal conditioners, and magnetic tape systems. Extensive use of these off-the-shelf subsystems will minimize design time and costs and improve serviceability and reliability. A comprehensive survey of available hardware components indicates that recent technological advances have made low-cost, low-power data acquisition equipments possible. Such equipment, either procured as a modified subsystem component or specifically designed and built for the application, provides the capability for monitoring multiple physiological waveforms and other input signals. For the RMDS application, a simple system designed from existing components is the most cost-effective approach. The forms of medical data most likely to be communicated during the next few years will be speech, narrowband analog signals, alphanumeric information, graphics, and photographs. For this type of data, most of the communication links presently available are adequate. Therefore, the RMDT will require components that will interface with the existing communication systems.

SYSTEMS OPTIONS

The RMDT may be implemented with various options, such as voice communications, graphic displays, a structured reporting format, information displays, local mass storage, and physiological data acquisition and processing components.

VOICE COMMUNICATIONS

The easiest and least-expensive alternative is to provide a readily accessible voice communication capability within the sick bay area. With existing technology, this can be augmented with slow-scan video (still using only a narrowband voice channel) to provide imagery transmissions of such data as x-rays and ECG strips. This system will be discussed in more detail in NARROWBAND AUDIO-VIDEO SYSTEM.

STRUCTURED REPORTING FORMAT

Formatted medical records such as PROMIS are relatively expensive to implement. Although they have the benefit of logically organizing the medical information and protocols, their benefit to the small ship is uncertain. Most Navy Hospital corpsmen can handle the standard situations (broken bones, colds, etc) without the need of external assistance other than perhaps medical evaluation. Therefore, a RMDT would be used in a difficult or unusual situation. In such a situation, the efficient transfer of medical information is essential for proper medical diagnosis. Efficient transfer is contingent upon using structured reporting formats, whether it is done manually by having the corpsman follow a set of instructions for reporting the clinical information or automatically by having a PROMIS-like terminal asking questions of the corpsman.

INFORMATION DISPLAYS

Candidate displays for the RMDT are the cathode ray tube (CRT), printers, and teletypes.

The CRT display is capable of displaying both alphanumeric and analog (such as physiological waveforms) information. At a significant increase in cost and electronic circuitry, it can display graphic information. Unfortunately, information displayed on the CRT is not in a hard-copy form, hence it is perishable. This problem may be overcome through the use of a hard-copy output device, such as a camera, printer, teletype, or strip recorder. Another drawback to the CRT is its fragility; therefore, specially designed CRTs must be utilized for shipboard installation.

Printers and teletypes which are particularly suited for alphanumeric message presentation are available for information display at moderate cost. Teletypes require a small computer (microprocessor) in order to provide an editing capability; printers have no editing capability. CRT displays usually have this editing capability built-in or available at moderate cost.

LOCAL MASS STORAGE

Several types of mass storage are available. The first is magnetic tape. This comes in several forms: large open-reel type used on most commercial machines; DECtape, a small open-reel tape; and cassette tape, similar to the commercial audio type. Due to the physical constraints of the RMDT, the cassette tape is the only feasible type. The tape serves as a relatively large, low-speed mass-storage medium.

Additional mass storage is most commonly in the form of disks. Disks are currently available in various forms and with various characteristics. For this application, a small disk would be the most applicable. In the past, the disks required a stable horizontal base upon which to operate. However, recent advancements such as the "floppy disk" have eliminated this requirement, making a shipboard disk storage capability available at low cost. The advantage of disk storage over magnetic tape storage is speed of data transfer. The disk has less data storage capacity than does a comparably priced magnetic tape unit; however, the disk can be replaced and easily stored. Other forms of mass storage, such as holographic memory, are not cost-effective enough at present to be considered in this document.

The present communication capabilities within the Navy and operational demands on the existing communications system render any alternative other than voice and slow-scan video (using a voice channel) infeasible at this time. Even for this alternative, another consideration is whether the system needs to use secure or nonsecure communication links. Even for a system using nonsecure links, care would have to be taken by medical personnel to avoid referring to the ship's position, movements, and schedules over any of the links. The NORATS circuit, in particular, is extensively monitored throughout the world for breaches in security.

A conceptual design for a RMDT using secure communications is shown in the block diagram of figure 3, which identifies the interface components necessary to implement such a terminal. The frame storage memory is shared by the ship sensor inputs (eg, radar, sonar, EW), the facsimile terminal, the television camera, and the interactive CRT terminal. The data from the frame storage memory are compressed, synchronized, encrypted, and interconnected with the communication channel with the appropriate modem hardware. Voice data are interfaced at the synchronizer. The slow-scan digital video data are decompressed and converted to analog form for the television monitor. A digital tape recorder is used for video data storage and replay.

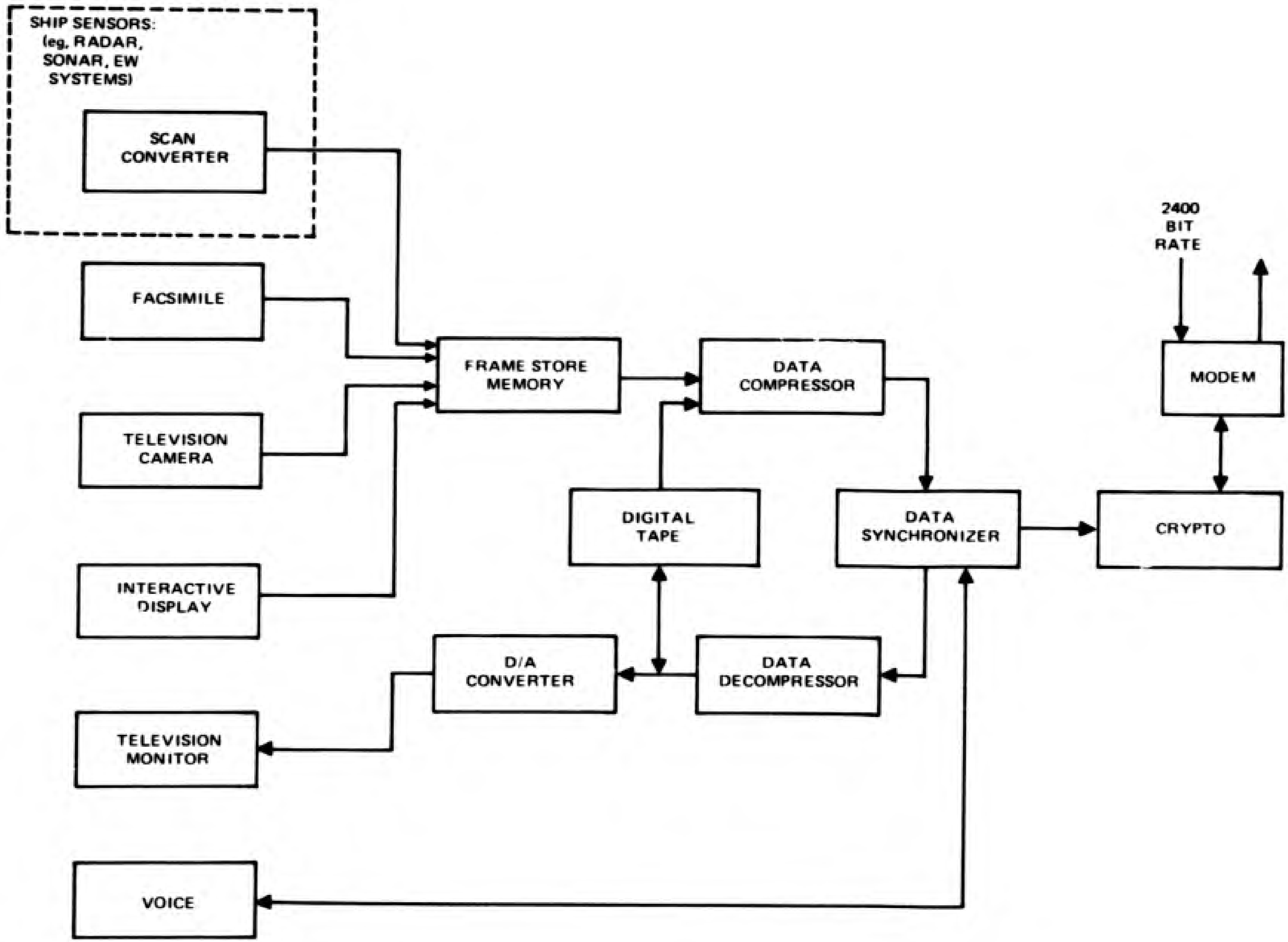


Figure 3. Secure shipboard remote medical diagnosis terminal, conceptual design.

EVALUATION OF MEDICAL DIAGNOSIS VIA DIFFERENT COMMUNICATION MODES

Conrath et al [7] performed an experimental evaluation of alternative communication systems for making a medical diagnosis. They compared the effectiveness, the time required for consultations, and the physician's and patient's attitudes toward four alternative systems: physical presence (ie, the normal physician/patient encounter), color television, black and white television, and hands-free telephone. An intuitive hypothesis was made: that the rank ordering for diagnostic accuracy; for the least amount of time required for diagnosis, and for preference of both doctors and patients would be the same – (1) physical presence, (2) two-way color television, (3) two-way black and white television, and (4) hands-free telephone.

Their sample consisted of 32 patients each with existing medical problems. Eight doctors and six nurses participated in their study. Each patient was examined via all four communication modes by a different doctor for each mode. Each of the doctors participated in consultations via all four communication modes.

Although the sample size in their study is small, they showed that there was no statistical significance between the physicians' ability to correctly diagnose critical ailments and the selection of communication system. Similarly, they found there was no statistically significant difference in the time required to complete a diagnosis. There was, as expected, a positive correlation (for all systems) between the time required and the number of complications within a case.

However, they did find (regardless of the above results) that the physicians and patients both preferred the physical encounter consultation over any of the other three systems, and that the hands-free telephone was the least preferred system. Yet, the results of the effectiveness and the time requirements showed essentially no difference among all four methods. From this, there does not appear to be any inherent advantage to the use of broadband live-video/audio communications over that of narrowband audio and slow-scan video capability for a Remote Medical Diagnosis Terminal.

NARROWBAND AUDIO-VIDEO SYSTEM

In communications, communication networks for RMDS, feasible narrowband (3 kHz) communication networks were discussed which could be used for a Remote Medical Diagnosis System. Off-the-shelf equipment presently exists which provides both audio and slow-scan video capabilities using only a half-duplex voice channel. One of the present existing systems is the RCA Global Communications Videovoice; this system is described immediately below. Feasibility tests using this equipment on board two ships and at a shore station hospital will be performed during FY75; this testing is described below in FEASIBILITY TESTING.

RCA GLOBAL COMMUNICATIONS VIDEOVOICE

Videovoice makes possible the inclusion of TV-type picture information as part of a duplex communications link using standard voice-bandwidth facilities for transmission of video and TV monitors for viewing. It provides the capability of transmitting pictorial information derived from television video signals over any voice-bandwidth network, or over a C2-conditioned voice-grade circuit. Viewing a subject is performed with a commercial television camera operating at the normal TV scanning rate, then converting to a much lower rate for transmission; storing the received picture at the slow rate; and then presenting it for display on a TV monitor. This system is also compatible with closed-circuit TV and pictures can, therefore, be retransmitted, at the receive terminal, over a local closed-circuit TV system, thereby extending the scope of system participation.

Videovoice, unlike wideband broadcast TV, does not present motion in the display. However, many video requirements can be met without the need for instantaneous transmission, and motion may not be required in the received display. The Videovoice transmission process takes either 30 or 55 seconds for each frame of video, depending on the desired resolution. Still subjects such as equipment, objects, documents, charts, blackboard information, and scenic views can be transmitted with a live camera (high resolution, 55-second transmission). Subjects in motion have the motion stopped for the duration of the transmission period by means of a "frame freeze" unit, which stops the action in a single frame period and holds that frame for transmission (normal resolution, 30-second transmission). When a new frame is desired, the frame freeze unit is activated to store another frame, erasing the preceding frame. The frame freeze capability is made possible by a silicon target storage tube which stores the information electronically, allowing it to be processed for transmission.

The normal operation of the RCA Videovoice over land lines (telephone lines) provides full-duplex audio capability while no video is being transmitted (ie, standard phone line connection) and half-duplex capability while a video signal is being transmitted. That is, while a video signal is being transmitted, no voice communications can be carried on. Modification of the equipment (four-wire operation) will allow for voice transmission from the receive terminal during a video transmission from some other terminal, but voice from the transmit terminal will still be blocked. For use ship-to-ship and ship-to-shore, the Videovoice will operate in half duplex at all times, both voice and video. This will require the use of only one transmitter and one receiver at each end of the communication link. In order to provide continued voice communications during video transmission, it would be necessary to use two transmitters and two receivers, on two different frequencies, at each site. The small advantage to be gained from this does not seem to warrant such an expenditure of communication resources.

The Videovoice Half-Duplex System, type VV-1, consists of a camera/monitor assembly, an electronics package which contains the various components required for Videovoice operation, and a telephone control set which is used to select the desired mode of operation (see fig. 4). The auxiliary equipment consists of a photographic hard-copy printer, a desk-sized tape recorder for recording both audio and visual data for storage or playback, an auxiliary large television monitor, and a tripod unit for operating the camera remotely (see fig 5). The electronic circuitry is packaged in a desk measuring approximately 3 x 5 x 2½ feet. The electrical requirements are 115 Vac, 60 Hz, at 5 amperes.

On board ship, the proposed location for this equipment is in the sick bay area to allow for easy access for the medical personnel and to allow the capability to transmit a picture of the patient. The proposed location for this equipment at the hospital facility is in or near the emergency room. This will ensure the availability of a physician 24 hours a day.

In order to interface this unit with the ship's communications system, a remote phone unit (RPU) will have to be installed in sick bay. The RPU interconnects with the audio switchboard in communication control so that the graphic terminal may be patched to the ship's transmitters and receivers. Prior modification will have to be made to the RPU

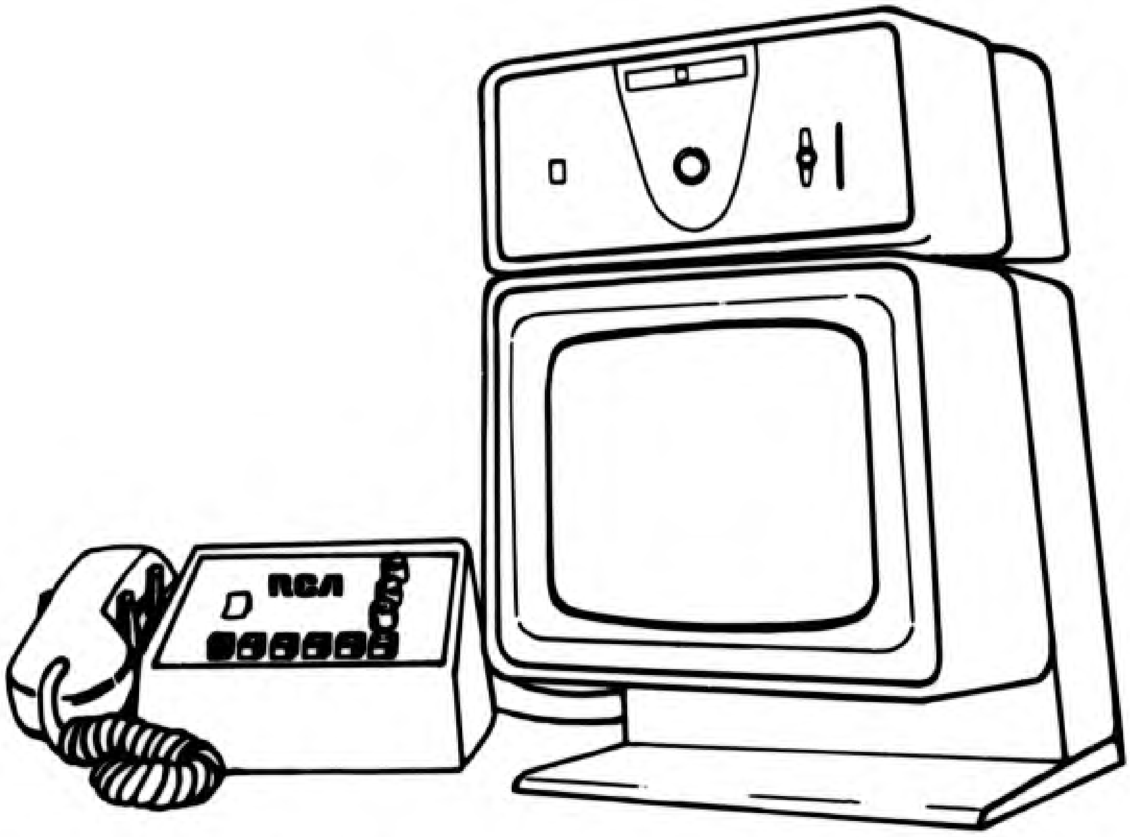


Figure 4. Videovoice camera/monitor and phone control unit.

to interface with the control unit of the graphic terminal. The RCA terminal is designed to interface with conventional telephone systems via an acoustic coupler; this kind of installation is all that is required to bring the Navy hospital into the network.

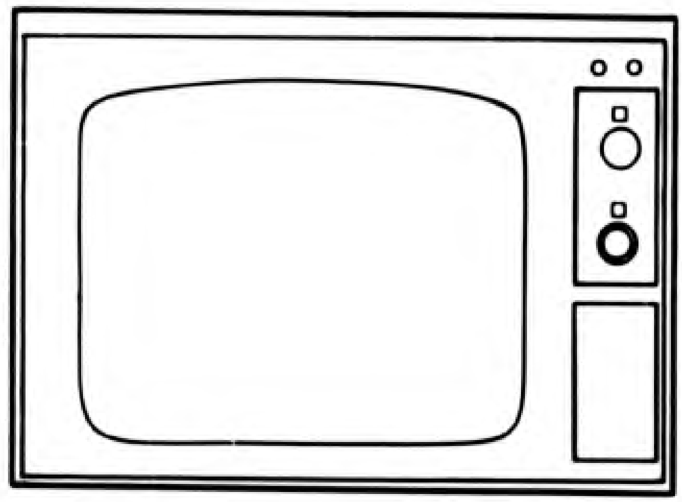
Briefly, the system operates as follows. When medical personnel on board a ship want to communicate to either another ship or a shore facility, they notify the ship's communication officer. An attempt to establish a communications link via NORATS, or an appropriate ship-to-ship link is made. This procedure may take approximately 15 minutes. When the link has been established, the communications are turned over to the medical personnel.

He then rotates his camera to the subject material (or pulls out the 90° reflecting mirror, if the material is on the desk), viewing it on the monitor. The camera is essentially prefocused, so only minimal adjustment of that control is required in most cases. If the subject is a document or other motionless object, all he does then is press his TRANSMIT button and the video is sent out over the line in high-resolution format. If the subject is capable of movement after the camera is set, he presses his FRAME FREEZE button and views the stopped-action frame which appears on his monitor, Then he presses TRANSMIT, and the picture is sent out with normal resolution.

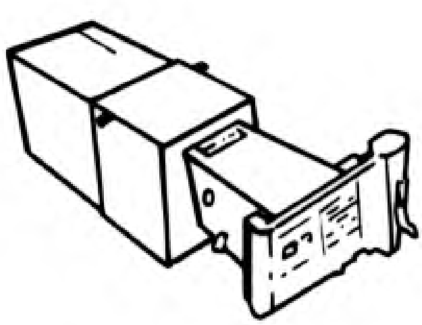
At the other end, the terminal will automatically set up to receive the video in the proper resolution format. However, the operator can adjust his monitor for contrast and brightness as he would his home TV.

When the full picture has been received, the system will remain on display as long as required, and will be erased only for presentation of a succeeding frame. Voice

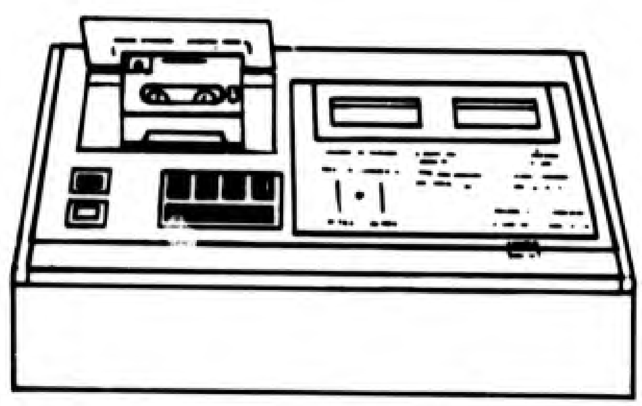
REMOTE-CAMERA KIT



TELEVISION MONITOR



HARD-COPY PRINTER (PHOTOGRAPHIC)



STEREO TAPE RECORDER

Figure 5. Videovoice auxiliary equipment.

conversation stops only during video transmission, but can continue in the half-duplex mode during the no-video transmission period, so that the image being viewed can be discussed.

As illustrated in figure 4, the TV camera and monitor are housed in a pedestal-type desk-top unit. The camera is capable of 360° rotation, enabling the operator to select for transmission any subject in the surrounding area. In addition, a special pull-out type, 90° reflecting-mirror arrangement is incorporated in the camera assembly, to provide for focusing on documents and small objects placed on top of the desk. This arrangement eliminates the requirement for tilting the camera itself. However, vibrations in the mirror assembly cause poor image resolution in transmission. Therefore, because of the constant vibration and motion of a ship, a display mechanism is being designed to allow straight-ahead viewing of documents, ECG tracings, and x-rays. This display mechanism will also contain its own variable lighting and light box for x-rays. This will eliminate the use of the mirror. The same monitor is used to display the received picture. Provision is made for external monitors, including larger-screen types which allow for convenient viewing by a number of people (fig 5).

Because the Videovoice system is intended for "executive" operation, the design philosophy is toward a minimum of manual control and maximum automation. In the camera, for example, only two controls are accessible for manual adjustment: a focus control and a lens tilt control. All other operating controls are contained in the desk-mounted telephone control units (see fig 6).

The microphone switch on the telephone control unit is a rocker type and is used for microphone on-off. The STANDBY, etc, switches are pushbutton types. The pushbuttons are illuminated when energized. The STANDY and VIDEOVOICE pushbuttons are interlocked so that depressing STANDBY releases VIDEOVOICE, but not vice versa. The remaining pushbuttons are not interlocked, so that several may be illuminated at the same time; for example, the TRANSMIT and VIDEOVOICE buttons will be lit when video transmission is in progress, as will either the LIVE CAMERA or FRAME FREEZE button, depending on the type of picture being transmitted. The RECEIVE pushbutton lights up only; it is not an operating control.

Many functions are automatic, including switching from local mode into receive mode upon receipt of a start-of-frame signal; blocking the voice in the direction of video transmission for the duration of such transmission; switching the monitor between the camera and the frame freeze unit; switching the scan converter between camera and frame freeze unit; switching between the telephone handset (if used) and the loudspeaker system; switching from standby power on the video equipments to full power when Videovoice is actuated; and camera enlargement of the subject matter.

During the receive cycle, all functions are automated. When a terminal initiates a video transmission, it transmits a code which contains synchronization and picture resolution information. When detected at the other terminal, the code starts the receive cycle which consists of receiver setup in proper resolution mode; storage tube "erase," "write," and "read" cycling; and "start of frame" synchronization.

The balance of the electronic equipment is contained in a standard equipment enclosure. The equipment enclosure also contains a combination circuit-breaker/on/of switch (accessible at the rear interior of the cabinet), which provides for either automatic or manual shut-off of the system, or for continuous standby power to be applied, permitting "instant on" operation.

The silicon storage tube is a small, low-cost, long-persistence-readout storage device. The video is recorded at TV speeds and read off at slower rates or, conversely,

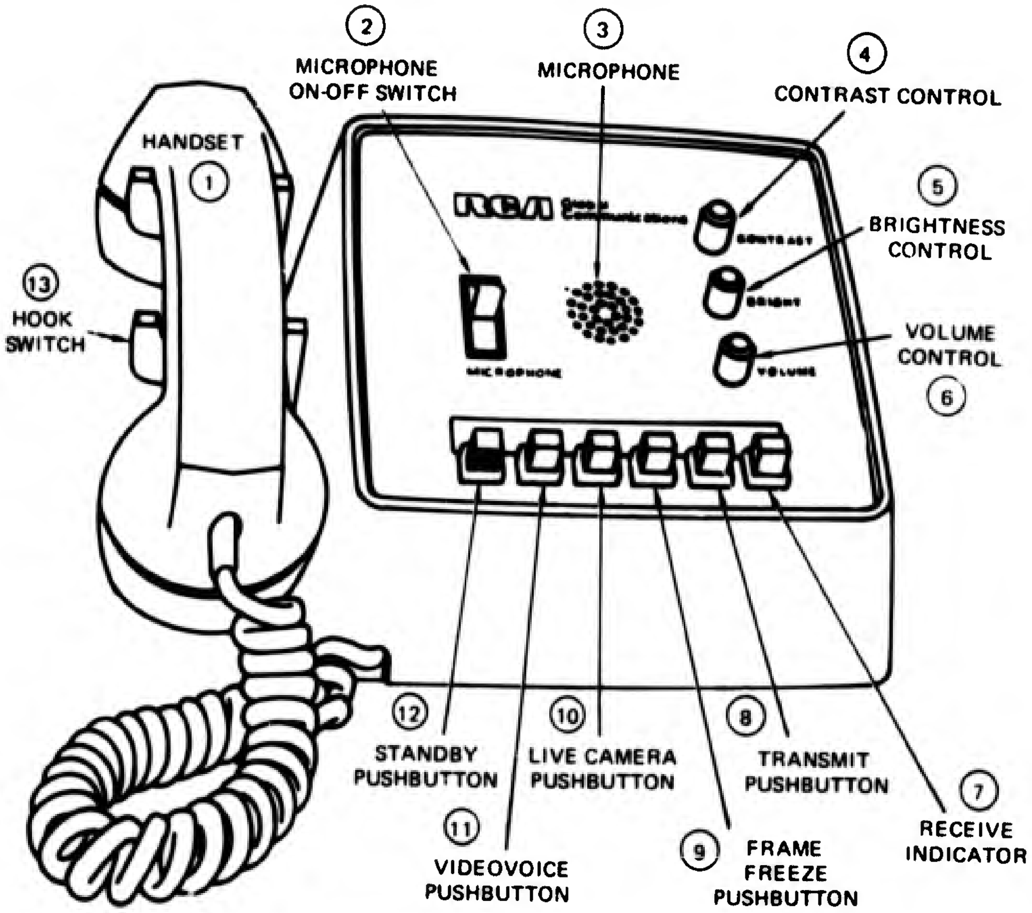


Figure 6. Videovoice phone control.

written at slow rates and read off at TV speeds for viewing on a TV monitor. A video frame is written onto the target in 1/30 of a second (one TV frame); it can then be continuously read out for display for periods of 15 minutes or more. At the end of this time, the stored message can be erased in fractions of a second. A limiting resolution capability of 1000 TV lines is typical.

The scan converter at the transmit end provides for converting the composite video signal of the TV camera (or a repetitive version of the stored single frame output from the frame-freez unit) to a slow-scan signal suitable for transmission. In the transmit mode, the video scan converter reproduces the repetitive single video frame, scanning vertically from line to line to produce a filtered audio signal suitable for transmission by an analog modem over voice-bandwidth facilities.

The picture can comprise either of two formats: normal resolution (frame freeze mode), which consists of 512 horizontal elements and 262 vertical elements; or high resolution (live camera mode), which consists of 512 horizontal elements and 525 vertical elements. The received picture in both formats exhibits eight shades of gray. The procedure is to sample vertically across each of the horizontal lines in a specified sequence, proceeding across the target horizontally so that the received picture builds up from left to right. The receive display is totally blanked during transmission, except for a thin, vertical-line cursor which moves horizontally, indicating the instantaneous position of the scanner. Synchronization is maintained by independent, highly stable crystal oscillators at each terminal.

In the receive mode, the incoming audio signal is demodulated, fed through a low-pass filter, and then sampled in the same manner as at the transmitter and deposited in the storage tube. Synchronizing signals are provided by the local crystal oscillator system. At the end of the transmission, the picture is read from the storage tube for display with a standard TV raster. Transmission time for a full video frame is basically a function of the modem. The modem used has base-bandwidth of approximately 200 Hz, resulting in a per-frame transmission time of 30 seconds for normal resolution and 55 seconds for high resolution. Figure 7 is a block diagram of the RCA Videovoice design and shows the relationships between components of the equipment discussed above.

FEASIBILITY TESTING

Medical diagnostic experiments have been conducted via satellite from the hospital ship HOPE to Project Hope headquarters in Washington, DC, using Videovoice equipment (Riggs [27]). The results of these tests, as well as past experience with Videovoice via satellite from mainland China, Europe, and the Satcom inauguration, show that satellite communication provides excellent results. Although HOPE was docked during the experimentation, there is further evidence that satellite communications would give similar results for ships at sea.

Noise and multipath phenomena associated with hf radio links do affect the performance of the Videovoice system by creating picture drop-outs and some vertical ghosting. Figure 8 presents photographs of the best of the received pictures from mainland China. The effects of noise and echo are evident, but the pictures are usable. When propagation characteristics are poor, the result is unusable pictures. This, however, is due to the deteriorated channel, since voice communications are also disrupted. Figure 9 represents a satellite circuit to China. The improved performance is noticeable.

It should be noted, also, that the resolution of these pictures is not sharp, due to the distance between the camera and the subject. In other words, for medical purposes, the cameras would be used much closer to the subject, showing a smaller area and, thus, providing better resolution. When the hf link is usable, the video transmissions are good, but this link is quite variable depending on atmospheric conditions and solar activity. Satellite communications are much more stable.

Before the end of FY75, an RMDS using the RCA Videovoice will be tested between two ships, USS JUNEAU (LPD 10) and USS ALAMO (LSD 33), and a shore station hospital, Naval Hospital, San Diego. The proposed tests will examine the feasibility of a remote medical diagnosis system using voice and slow-scan video communication links ship-to-ship

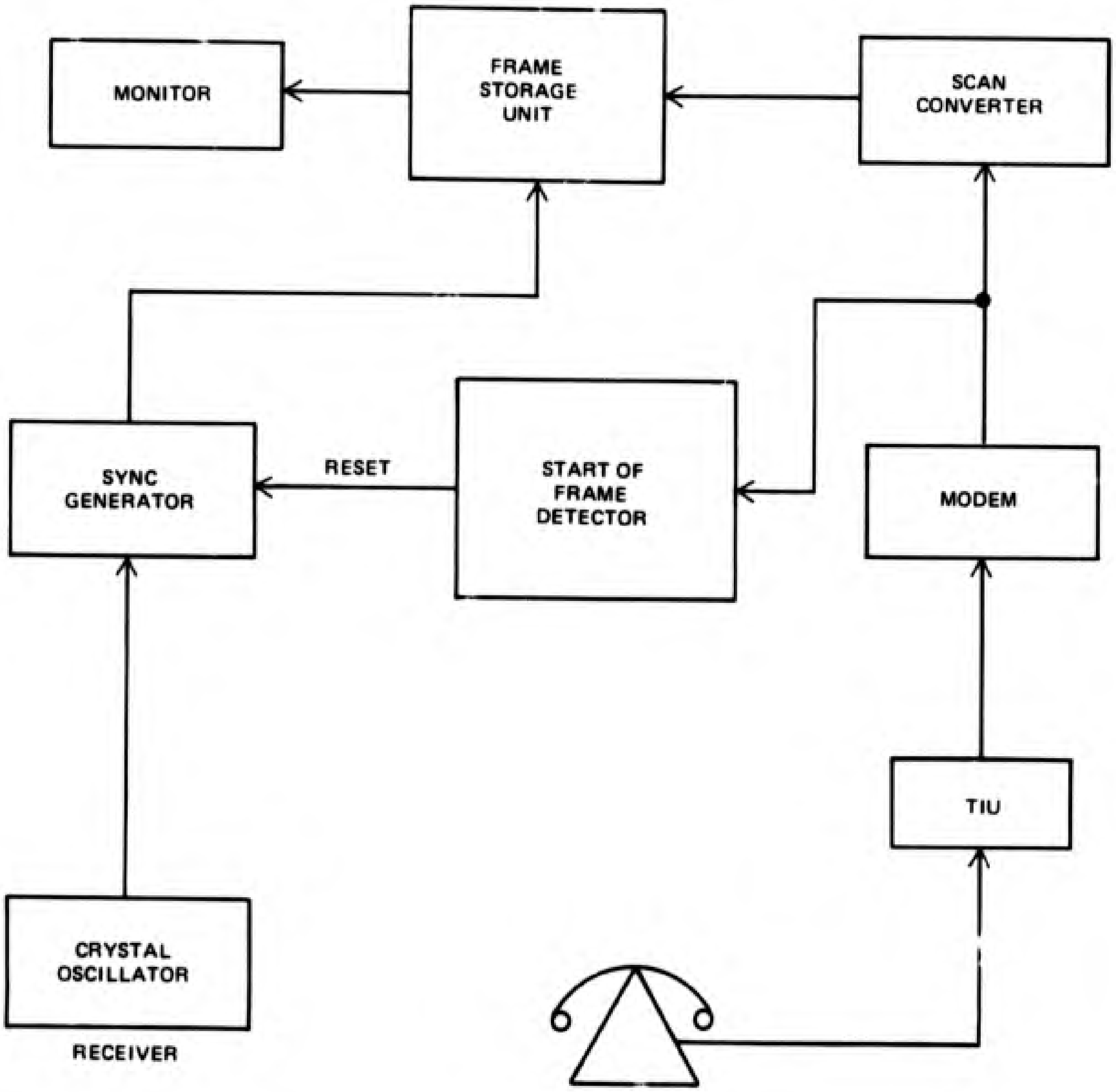


Figure 7. Block diagram of RCA videovoice design.

Figure 8. Videovoice images via hf from mainland China.

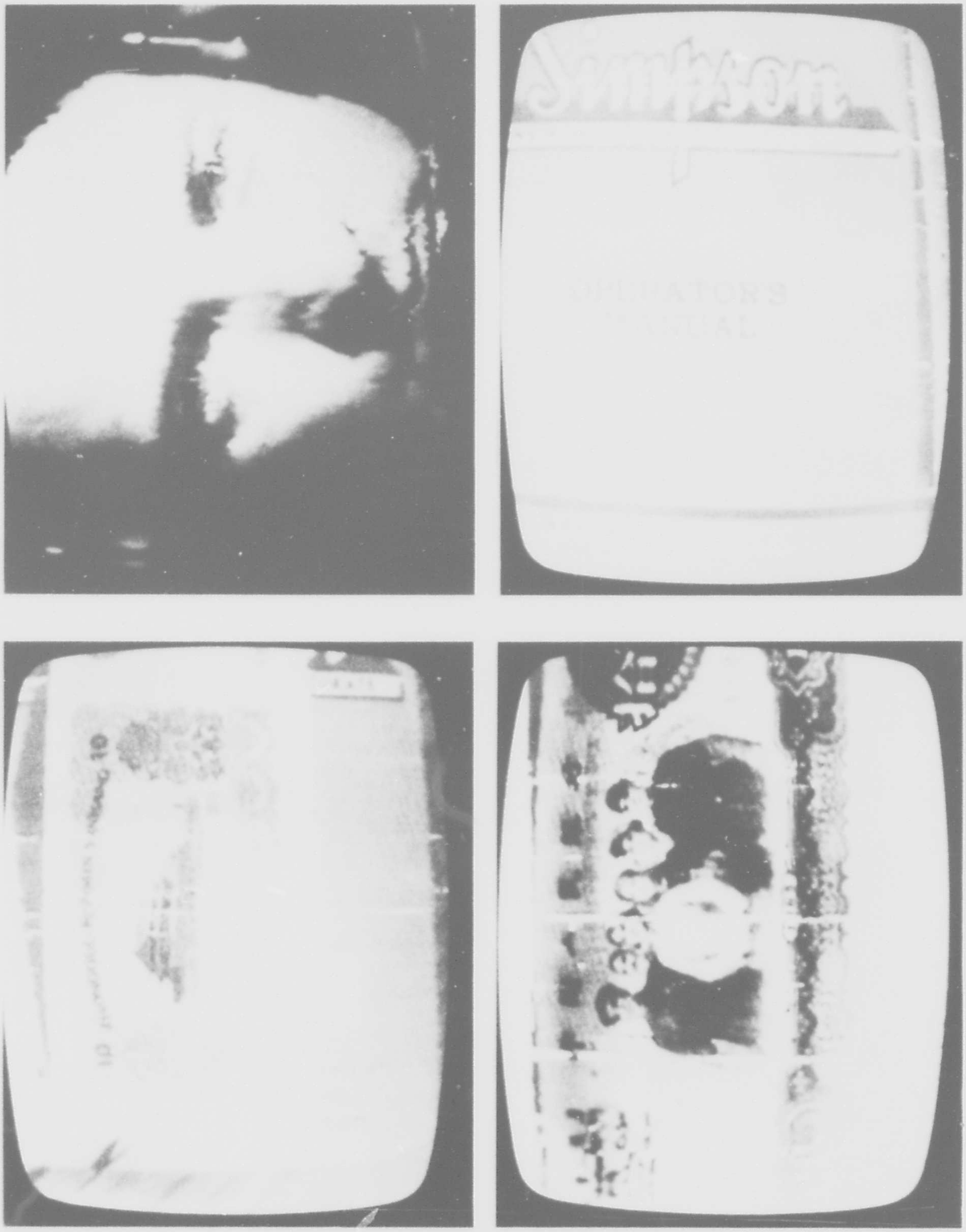


Figure 8. (Continued).

Figure 9. Videovoice image via satellite from mainland China.

and ship-to-shore-to-ship. The tests will use patients as available as well as simulated medical cases. Specific test objectives include:

1. Determine the feasibility of obtaining accurate medical diagnosis with voice-bandwidth communication links alone. The tests will include determination of diagnostic capabilities realizable with voice only or with voice and slow-scan video.

2. Determine appropriate data format to be used to rapidly transmit the necessary patient and medical data.

3. Examine the quality, reliability, and resolution of transmissions of graphic material such as ECG tracings, medical records and x-rays using different communication frequencies: uhf ship-to-ship, hf ship-to-shore-to-ship, and uhf via satellite (if available) ship-to-shore-to-ship.

4. Determine the optimum location of the communication equipment within the shipboard sick bay area with respect to available space limitations and proximity to patients and medical equipment.

5. Determine the optimum routing and type of wiring between the communications and sick bay areas.

6. Determine whether there are any special lighting requirements in the sick bay area for use of the video equipment.

The equipment to be used in these tests is designed to use standard telephone lines; tests will include determination of any interference between the equipment being used on board and other shipboard electronic equipment, and determination of any requirements for high-quality shielded lines on board ship, between two NAVCOMMSTAs and between the NAVCOMMSTA and the hospital.

Presently, feasibility testing is being conducted between NELC and the Naval Hospital, San Diego (NHSD). LT K. Pranikoff, MC, attached to NHSD, brought several examples of medical data, including ECG tracings and x-rays, to be transmitted from NELC to NHSD via telephone lines (see fig 10). Although these first tests did not show enough transmission resolution for difficult-to-read x-rays, the results with ECG tracings were encouraging. Since then, the RCA equipment has been readjusted, some defective components have been changed, and the quality of video transmissions is much better. The system has now been tested by use of radio transmissions (uhf and hf) as well as land lines. Figure 11 shows the communication control switching for the feasibility testing now being conducted between NELC and NHSD. The system can be used via land line (telephone lines) or by radio communication using uhf or hf; switching for these alternatives is controlled at NELC. When using radio communications, the system is switched to a land-line link between the RCA unit and the radio transmitters and receivers at NELC. Voice communications are accomplished with a push-to-talk microphone and a Motorola line buffer-amplifier. In addition, a video transmit switch allows bypassing the microphone and telephone handsets during video transmission in order to eliminate any extraneous noises.

The voice or video data are then transmitted from the NELC transmitters to COMMSTA, San Diego, via uhf, where a phone patch is made onto a commercial phone line to the hospital. Communication from the hospital to NELC is accomplished through the reverse of the above.

Hf transmission was tested by going directly from NELC to COMMSTA, San Diego, via telephone line, and a phone patch was made to a dedicated phone trunk to COMMSTA-San Francisco and then back to San Diego via hf. At San Diego another phone patch was made to the hospital. Two-way, half-duplex communications were, thus, carried on between NELC and NHSD over hf.

Examples of the video communications can be seen in figures 12 through 16. All photographs were taken at NHSD from the monitors as the transmissions were received by land line (telephone), uhf, or hf. Figures 12–14 are all transmissions of the same ECG (showing different leads), diagnosed as a Left Bundle Branch Block (LBBB). Figure 12 shows transmissions of the AVL lead; 12a was transmitted via land line, 12b via hf, and 12c via uhf (over a noisy channel). Note that the hf transmission shows some additional distortion (upper portion) due to some background tones during the transmission. This same distortion is evident in all the transmissions via hf. (All hf transmissions shown here were done during one test period, and hence, the same background tones were present.)

Figure 13 shows lead II of the same ECG; 13a was transmitted via land line and 13b via hf. Figure 14 shows two transmissions via hf of lead I of the same ECG. These figures show that there is little difference between the land line (telephone), uhf, and hf except for some background tone distortion.

Figures 15a, 15b, and 15c show transmissions of an x-ray negative via land line, uhf, and hf, respectively. Comparison of figure 15b with figure 12c shows that better transmissions can be achieved via uhf when the channel is clear. Figures 16a and 16b show transmissions of an x-ray positive via land line and hf. Figures 15c and 16b show the same background tone distortions as evident in the hf transmissions of the ECG; however, the distortions appear to be more serious in the transmission of x-rays than in the transmission of an ECG.

Figure 10. RMDS terminal at NELC.

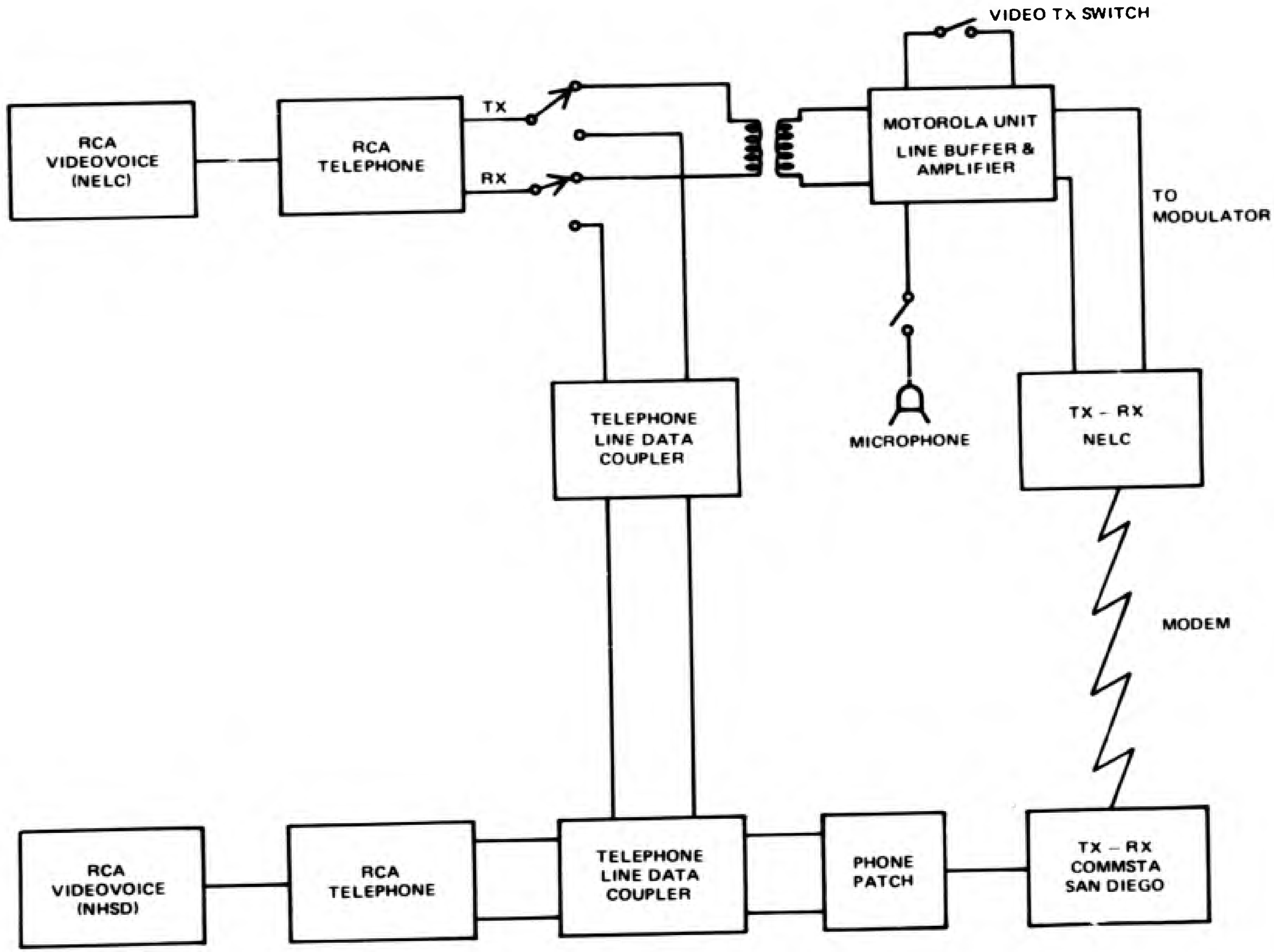


Figure 11. Block diagram of communication control switching for RMDS feasibility testing.

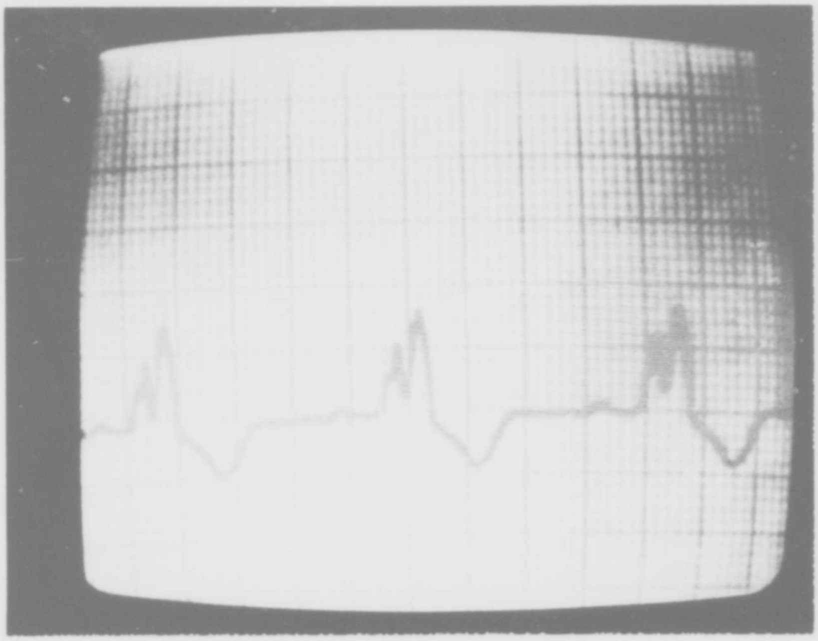


Figure 12a. ECG (lead AVL) transmission via land line.

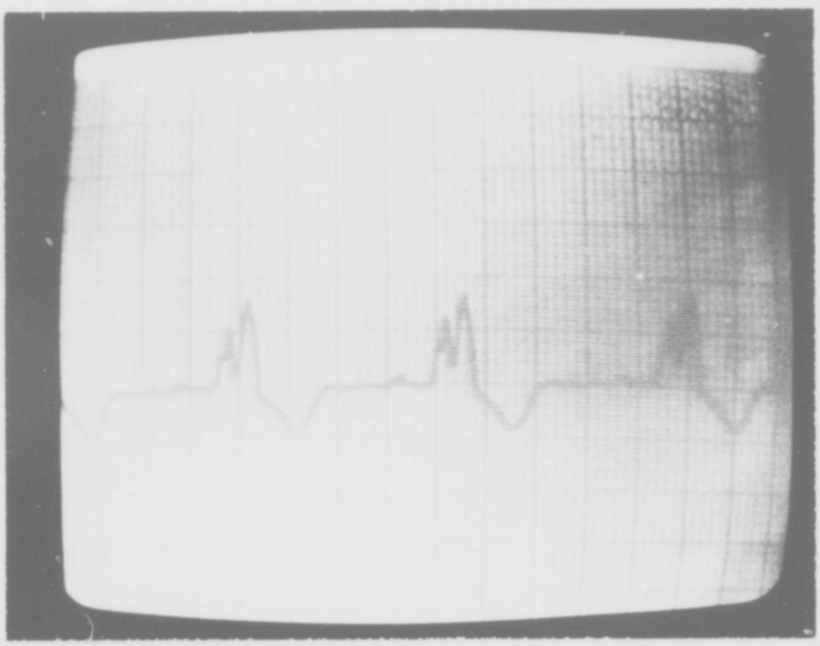


Figure 12b. ECG (lead AVL) transmission via hf.

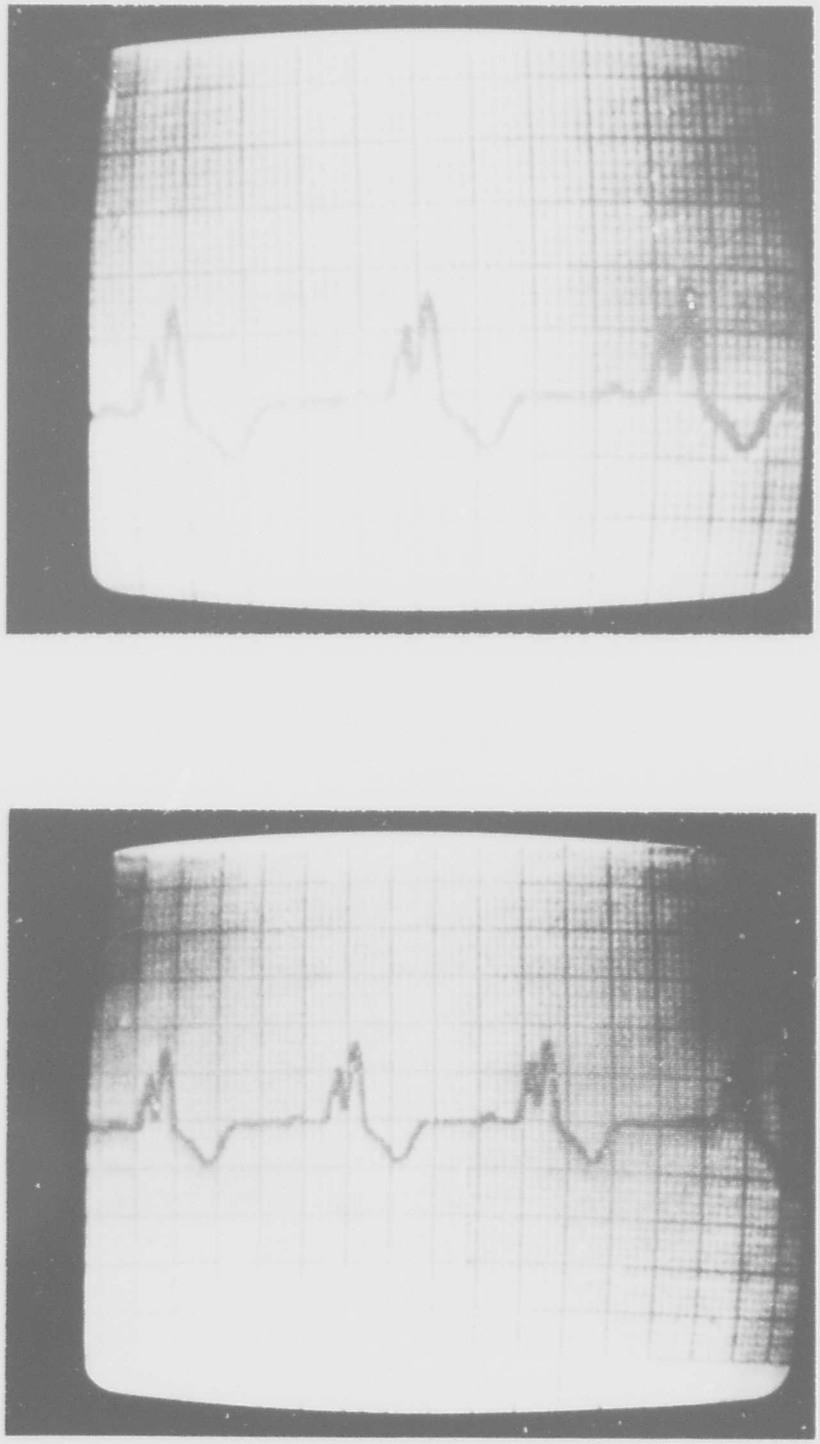


Figure 12c. ECG (lead AVL) transmissions via uhf.

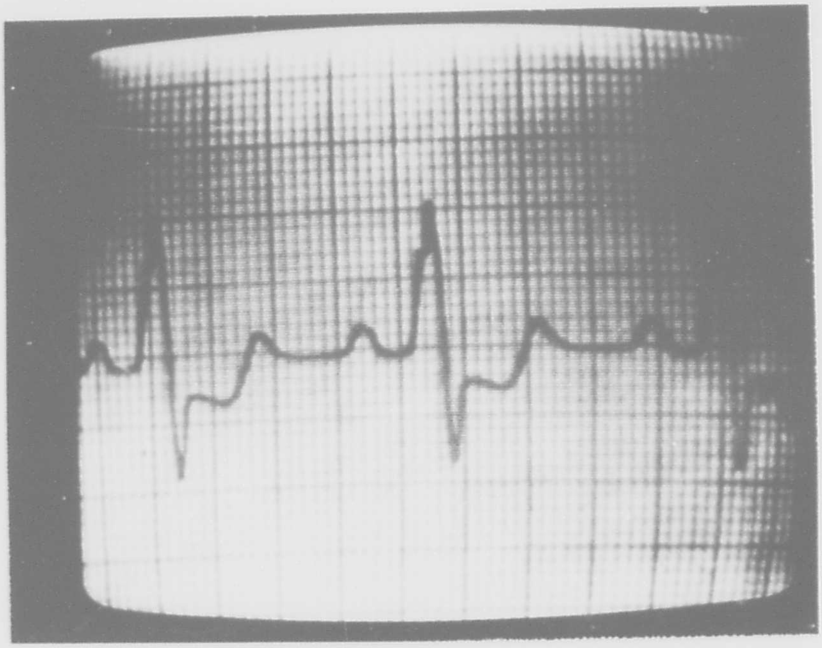


Figure 13a. ECG (lead II) transmission via land line.

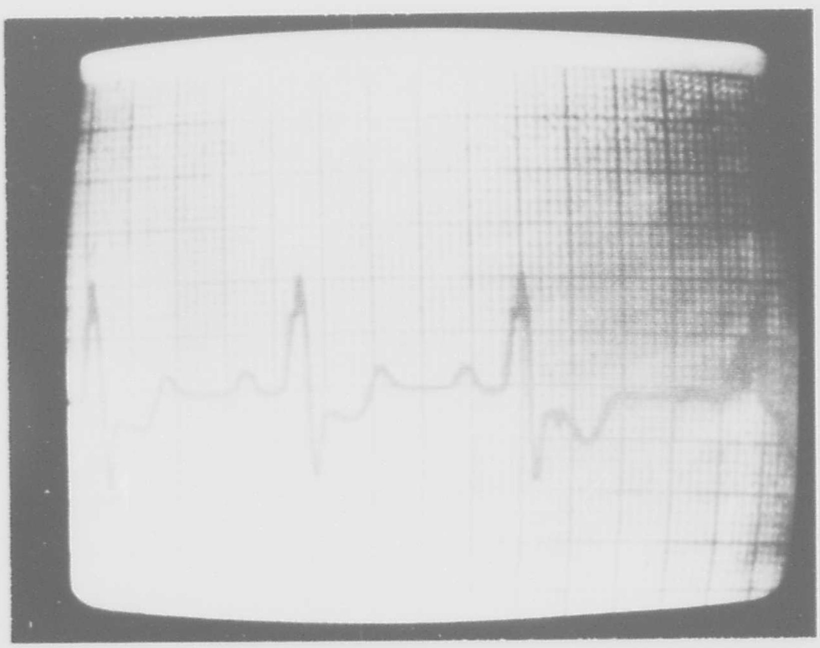


Figure 13b. ECG (lead II) transmission via hf.

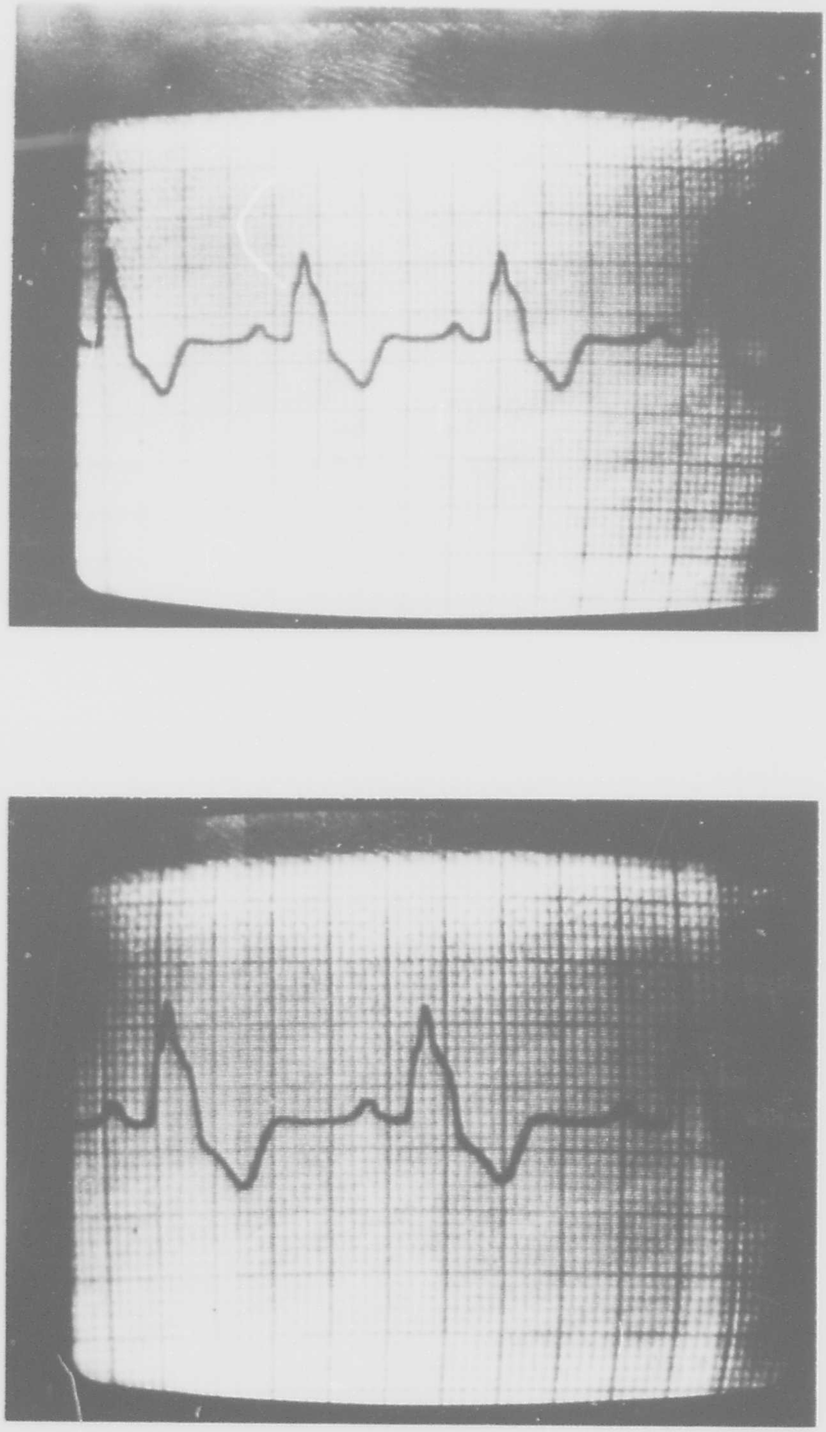


Figure 14. ECG (lead I) transmission via hf.

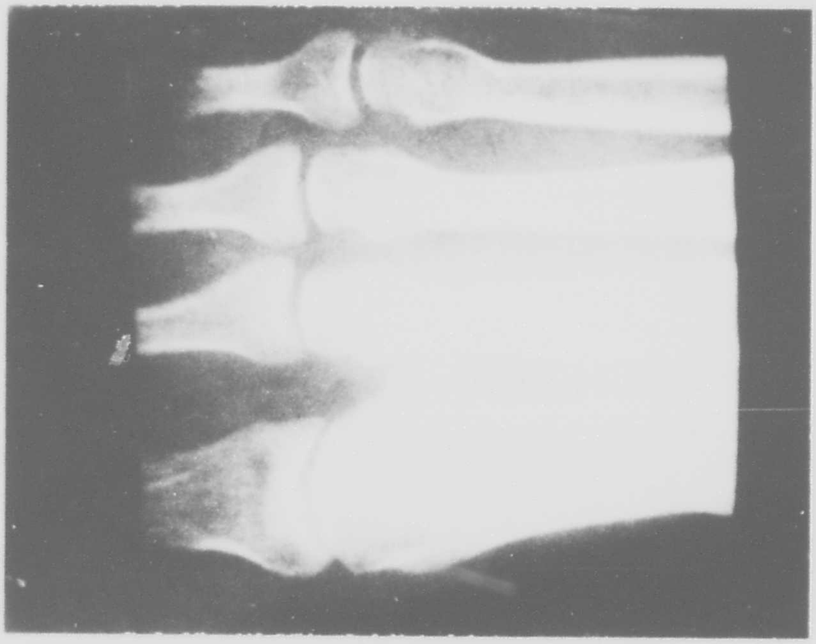


Figure 15a. Transmission via land line of x-ray negative of metatarsal bones.

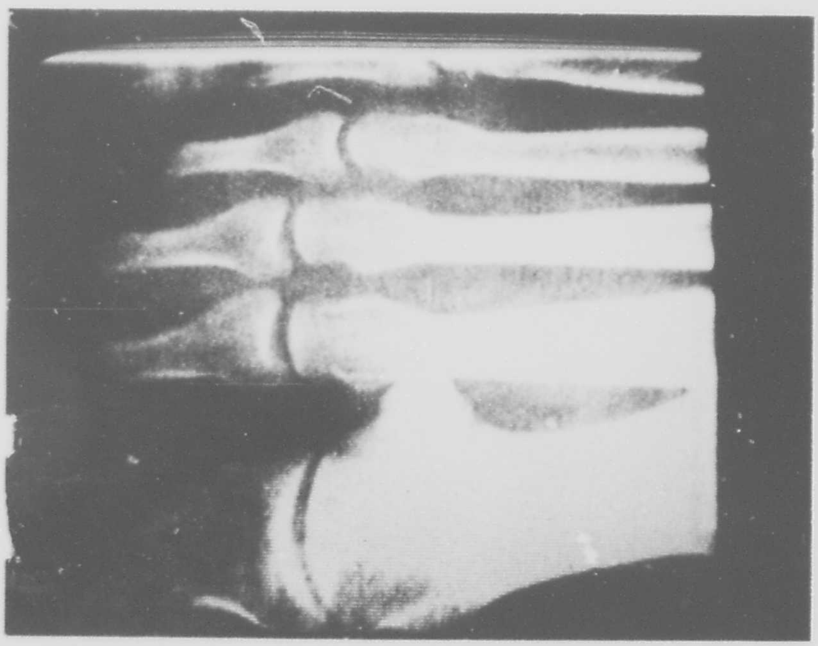


Figure 15b. Transmission via uhf of x-ray negative of metatarsal bones.

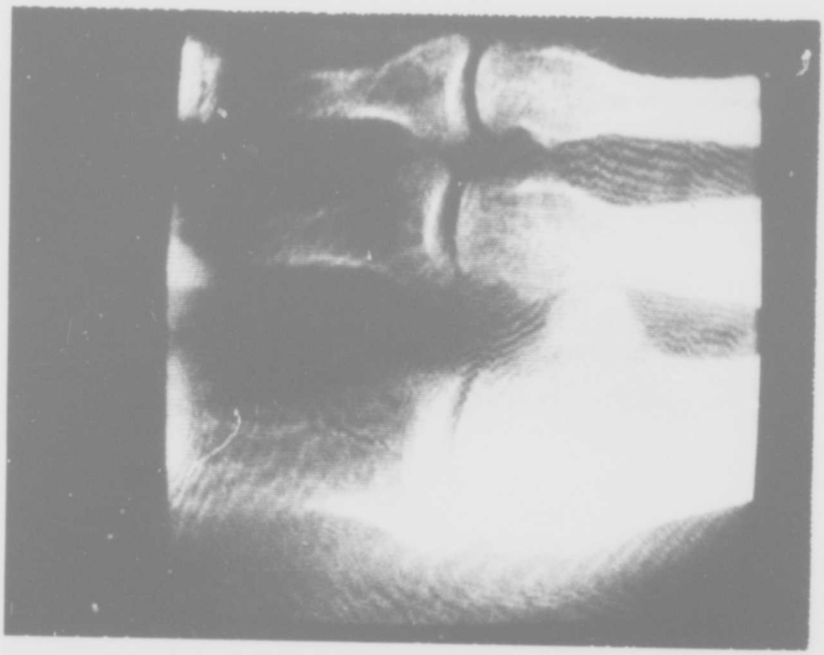


Figure 15c. Transmission via hf of x-ray negative of metatarsal bones.

Figure 16a. Transmission via land line of x-ray positive of hand.

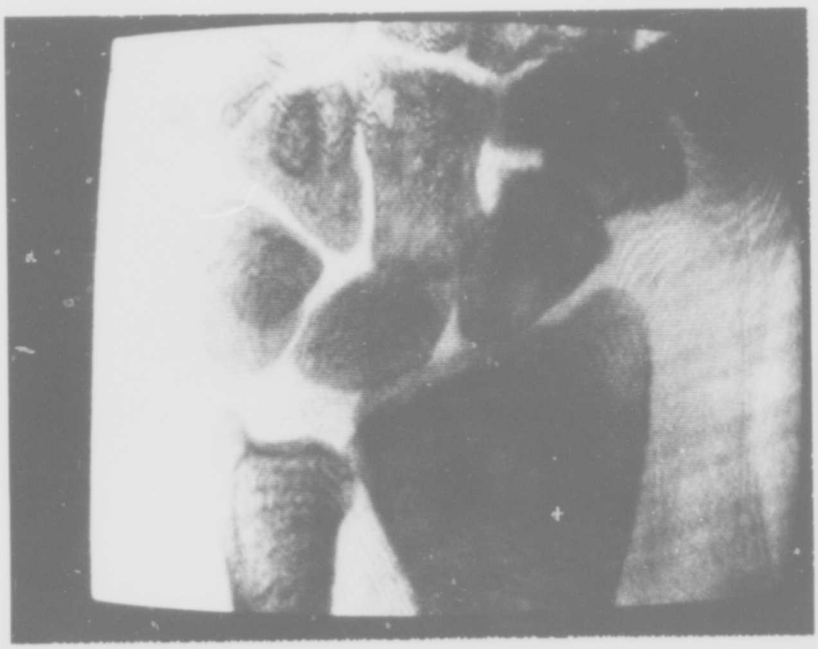


Figure 16b. Transmission via hf of x-ray positive of hand.

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APPENDIX A: SHIP POPULATION PROFILES

In this appendix ship population profiles are discussed. Present force levels (ie, the number of ships in each class) are given by their geographical locations, typical task force compositions are discussed, and geographical operating and transiting areas are delineated. From this information probable communication ranges for remote medical diagnosis can be determined on a geographical basis. Future force level and operational change predictions will result in a profile for future illness incidence rates and, hence, the predicted requirements for a remote medical diagnosis system.

PRESENT SHIP POPULATION

Table A1 lists major ship classes and gives the number of active ships in each class (force level) as of 1 January 1975 by their geographical locations (Pacific Fleet and Atlantic Fleet). As in present shipboard health care delivery, shipboard medical complements, this listing is limited to ships with a personnel complement of approximately 100 or more.

TABLE A1. FORCE LEVELS OF MAJOR SHIP CLASSES BY FLEET ASSIGNMENTS (1 JANUARY 1975).

	PACFLT	LANTFLT
Aircraft Carriers		
CVAN	1	0
CVA	6	3
CV	1	3
Cruisers		
CG	1	2
CGN	1	0
CLG* (CG)	1	1
Auxiliary Ships		
AD	4	5
AR	3	2
Underway Replenishment Ships		
AE, AF, AFS, AO, AOE, AOR	25	22
Amphibious Warfare Ships		
LCC	1	1
LPA	1	1
LPD	7	7
LPH	3	4
LKA	4	2
LSD	7	6
LST	10	10

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TABLE A1. (Continued)

	PACFLT	LANTFLT
Frigates		
DLG* (CG or DDG)	10	16
DLGN* (CGN)	2	1
Destroyers		
DD	12	20
DDG	17	12
Escort Ships		
DE* (FF)	30	28
DEG* (FFG)	3	3
Submarines		
SS	10	2
SSN	24	39
SSBN	12	29

*New designators after 1 July 1975 are shown in parentheses.

FORCE DISPERSION

The operational assignment of a ship depends upon many factors. Typically, ships remain in port 60% of the time. Several factors influence the amount of time a particular ship may spend at sea, such as:

Level of readiness

Budget constraints; eg. funds available for fuel

Flag aboard

Number of exercises

Change of home port

Deployment status

Yard periods

Geopolitical situation

Mission and task assignments

The operational deployment of ships is discussed in the three following subsections.

LOCAL OPERATIONS

During those periods that a ship is in its home port or in its deployed operating port or base, various maneuvers may be required which will involve sailing in the local operating area, or steaming to a local operating area. Such activity may be required for:

Predeployment readiness

Individual ship exercises

Fleet exercises

Underway training in general

There are only a few "official" local operating areas:

Southern Califonria

East and Gulf coasts

Hawaii

Philippines

TRANSITING

Forces transiting to a new duty station, new home port, yard, or overseas deployment usually have ample time to preplan all aspects of their movement. Overseas deployments are planned at least 1 year in advance, and other movements may have up to 2 years' lead time. Short-notice movements will normally result from search and rescue requirements, severe storms, national emergencies, police actions, etc. These occur from time to time, but the majority of ship movements are well considered with ample advance planning to ensure smooth and trouble-free sailing.

It can be said that "good navigational practice" applies to Navy vessels as it does to commercial, fishing, and pleasure craft. Tracks taken for any destination will follow the best navigable routes, taking into consideration weather, currents, ice floes, international agreements, etc. Tracks will follow a great circle, rhumb line, or composite route. Sea lanes exist between important ports of the world. It should be noted, however, that navy vessels (of any country) do not necessarily follow prescribed shipping routes.

Hydrographic Office Publication 151, Distance Between Ports, contains tables of distances in nautical miles between ports and junction points around the world. The distances presented are between positions that most represent each port or junction point and are generally over routes that afford the quickest passage. Most of the distances represent the shortest navigable routes, but in some cases longer routes that take advantage of favorable currents or avoid unfavorable currents and thus gain quicker passage have been used. In other cases, increased distances result from routes selected to avoid ice or other dangers to navigation or to take advantage of aids to navigation. In addition, many of the distances between North Atlantic ports reflect increased mileage due to the use of the North Atlantic Lane Routes which have been established to avoid ice and to promote safety of life at sea in that area of congested traffic. Distances over routes of a navigator's own selection may differ from those given.

It is impractical to give distances for every possible combination of ports in the volume; however, the use of junction points greatly increases the number of distances that may be included by affording a means of connecting routes in adjacent areas. These points are in a position where many routes converge and through which ships pass when sailing from one major area into another. Tracks in most cases accommodate bidirectional traffic; a minority of the tracks contain only eastbound or westbound shipping. When Navy ships are sailing in the commercial sea lanes, they usually stay to one side or the other of the lane, rather than sailing in high-density traffic. Table A2 presents the approximate distance between selected Navy ports and other points of probable interest.

REPRESENTATIVE FORCE COMPOSITIONS

In general, ships do not transit alone; one exception is the oilers (AO). Typical transiting groups are:

3 LST

4 DD

3 DD and 1 DLG

1 CVA, 3 DD, and 1 CLG

1 LPH, 1 DLG, and 1 DD

LPD/LSD/AKA/APA alone or in groups of 2 to 5

AOE/AOR/AO/AFS/AE alone or in groups of 2 or 3

Task Forces and Task Groups will vary widely in composition, depending upon such factors as:

Mission and task assignments

Ships available

Geographical location

Expected duration

Typical and representative force compositions are:

Amphibious Task Unit – 1 LKA, 1 LPH, and 1 LPD

AAW/ASW screening group, close air support, and Naval gunfire support – 1 CVA, 2 DE, 3 DDG, and 1 DLG

Carrier Strike Group – 1 CVA, 4 DE, 3 DD/DDG, 1 DLG, and 1 CLG

Underway Replenishment Group – 1 AOE, 1 AOR/AO, 1 AFS, and 1 AE

Transport Group – 2 LPA, 1 LKA, 2 LSD, and 1 LST

Mine Warfare Unit – 4 MSO

Major Fleet Exercise – 3 DLG, 1 CLG, 2 DDG, 8 DD, 2 DE, 1 CVA, 4 MSO, 1 LCC, 2 APA, 2 LST, 1 LSD, 1 AKA, 1 AOE, 1 AF, 2 ATF, and 1 LPH

Force dispersion will be dependent upon several factors, such as:

Likelihood of air or submarine attack

Likelihood of nuclear attack

TABLE A2. SELECTED TRACKS, APPROXIMATE DISTANCES IN NAUTICAL MILES.

San Diego, California, to:		
	Pearl Harbor, Hawaii	2285
	Panama, Panama	2843
	Punta Arenas, Chile (The Horn)	5801
	Wilson Promontory, Australia	6873
	Manila, Philippines	6604
	Seward, Alaska	2150
Norfolk, Virginia, to:		
	Inishtrahull, Ireland (Track C)	3100
	Strait of Gibraltar	3335
	Panama, Panama	1882
	Punta Arenas, Chile (The Horn)	6900
	Cape of Good Hope	6802
	Guantanamo, Cuba	1117
	Diego Garcia (Via Cape of Good Hope)	10500
Napoli, Italy, to:		
	Strait of Gibraltar	1001
	Port Said, U.A.R	1116
	Istanbul, Turkey	785
	Beirut, Lebanon	1198
	Haifa, Israel	1194
	Norfolk, Virginia	4336
	Diego Garcia (Via Cape of Good Hope)	9300
Piraieus (Athens), Greece, to:		
	Strait of Gibraltar	1451
	Port Said, U.A.R	599
	Napoli, Italy	667
	Haifa, Israel	650
	Beirut, Lebanon	642
	Istanbul, Turkey	364
Pearl Harbor, Hawaii, to:		
	Panama, Panama	4692
	Punta Arenas, Chile (The Horn)	6414
	Apra, Guam, Mariana Islands	3318
	Yokosuka, Japan	3391
	Manila, Philippines	4869
	Sundra Strait (Djakarta, Indonesia)	5881
Yokosuka, Japan, to:		
	Manila, Philippines	1752
	Sundra Strait	3300
	Pusan, Korea	1402
Manila, Philippines, to:		
	Sundra Strait	1578
	Hong Kong, BCC	631
	Krung Thep (Bangkok, Thailand)	1435
	Pusan, Korea	1402
	Diego Garcia (Chagos Archipelago)	4300

EMCON condition

Underway exercises

Mission and task assignments

Geographical location

Depending upon conditions and operational scenarios, force dispersions will typically be:

Task Groups, nonnuclear environment: 10–15 miles between ships and 40 miles across the Group

Task Forces, composed of two or more Task Groups, nonnuclear environment: 10–15 miles between ships, 40 miles across a Group, and 100–200 miles between Groups

Independent movements and Task Force and Task Group movements will normally run at a speed selected to ensure economy of fuel consumption without taking an unusually long time. Typical transit speeds are:

Combat ships will transit at 16 knots.

Service Force, Amphibious Force, and other single-screw ships will transit at speeds less than 12 knots. However, modern merchantmen would not impose such a restriction.

APPENDIX B: PHYSIOLOGICAL MEASUREMENTS

This appendix contains a comprehensive collection of physiological measurements (table B1) and signal properties (table B2). Most of the measurements shown in tables B1 and B2 are not used in this study, but are given here for completeness, since it is possible that they will be needed in future systems. Table B1 shows, for different physiological parameters, the types of measurement required, the sensing devices used, the typical peak-to-peak values, and the frequency characteristics. Table B2 shows, for each physiological parameter, the primary signal ranges and characteristics.

TABLE B1. PHYSIOLOGICAL MEASUREMENTS.

PHYSIOLOGICAL PARAMETER	MEASUREMENT REQUIRED	SENSING DEVICES USED	PARAMETER TYPICAL P-P VALUE	PARAMETER FREQUENCY CHARACTERISTICS: FUNDAMENTAL Hz	PARAMETER FREQUENCY CHARACTERISTICS: SPECTRUM F(-3) Hz
CIRCULATORY SYSTEM					
HEART POTENTIALS	ELECTROCARDIOGRAM	SURFACE ELECTRODES	2mv	1.3	.05 - 80
		HEART ELECTRODES	50mv	1.3	.05 - 80
	VECTORCARDIOGRAM	SURFACE ELECTRODES	2mv	1.3	.05 - 80
	FETAL ELECTROCARDIOGRAM	SURFACE ELECTRODES (MOTHER)	10µv	2.5	2 - 100
BLOOD PRESSURE	DIRECT ARTERIAL PRESSURE AT BRACHIAL ARTERY	PRESSURE TRANSDUCER	120mmHg	1.3	DC - 20
	OR FEMORAL ARTERY	MERCURY MANOMETER	100mmHg	"	"
	DIRECT VENOUS PRESSURE	PRESSURE TRANSDUCER	9mmHg	1.3	DC - 20
		WATER MANOMETER	12cmH₂O	1.3	-
	INDIRECT ARTERIAL PRESSURE	SPHYGMOMANOMETER WITH	120/80mmHg	-	-
		KOROTKOFF MICROPHONE	150mv	1.3	30 - 500
	RELATIVE ARTERIAL PRESSURE	PLETHYSMOGRAPH	RELATIVE	1.3	.05 - 10
		IMPEDANCE PLETHYSMOGRAPH	0.1% CHANGE	1.3	.05 - 10
BLOOD FLOW (AND BLOOD VELOCITY)	PERIPHERAL FLOW	ELECTROMAGNETIC FLOWMETER	1000cc/min	1.3	DC - 50
		ISOTHERMAL FLOWMETER	"	"	"
		ELECTROTHERMOMETER	"	"	"
		ULTRASONIC FLOWMETER	"	"	"
	CARDIAC OUTPUT	FLOWMETER AT AORTA	5000cc/min	1.3	DC - 50
		DYE DILUTION	5000cc/min	-	-
BLOOD VOLUME	BLOOD VOLUME	MODIFIED DYE DILUTION	5500cc	-	-
MITRAL VALVE FUNCTION	ULTRASONIC ECHO	TIME MODE ULTRASONICS	[illegible]cm/s	1.3	DC - 50
RESPIRATORY SYSTEM					
BREATHING	PNEUMOGRAM	THERMISTOR PNEUMOGRAPH	500cc/BREATH	0.25	.05 - 2
		IMPEDANCE PNEUMOGRAPH	"	"	DC - 2
		ELASTIC FORCE GAGE	"	"	"
RESPIRATORY FLOW	PNEUMOTACHOGRAM	PNEUMOTACHOGRAPH WITH PRESSURE TRANSDUCER	20,000cc/min	"	"
RESPIRATORY VOLUME	SPIROGRAM	SPIROMETER	4000cc	"	DC - .5
BRAIN FUNCTIONS					
ELECTRICAL ACTIVITY	ELECTROENCEPHALOGRAM	SCALP ELECTRODES	50µv	10	.5 - 100
		INTRACRANIAL ELECTRODES	500µv	"	"
EVOKED RESPONSES	INTRACELLULAR POTENTIALS	MICROELECTRODES	100mv		1 - 10,000
	EXTRACELLULAR POTENTIALS	NEEDLE ELECTRODES	50µv		1 - 1000
EYE RESPONSES	ELECTRORETINOGRAM	CONTACT LENS ELECTRODE	100µv		.05 - 20
BRAIN MIDLINE POSITION	ULTRASONIC ECHO	"A" SCAN ULTRASONICS			
MUSCULAR FUNCTIONS					
MUSCLE EXCITABILITY	S-D CURVE	STIMULATE WITH SURFACE ELECTRODES			
MUSCLE STRENGTH	MYOGRAM	NEEDLE OR SURFACE ELECTRODES	300µSTRAIN	.5	DC - 50
MUSCLE POTENTIALS	ELECTROMYOGRAM	NEEDLE OR SURFACE ELECTRODES	1mv		10 - 5000
	ELECTROMYOGRAM WITH STIMULATION	NEEDLE OR SURFACE ELECTRODES STIMULATE WITH SURFACE ELECTRODES	"	"	"
NERVE CONDUCTION	H REFLEX RESPONSE	AS ELECTROMYOGRAPH WITH REDUCED STIMULATION			
	CONDUCTION VELOCITY	AS ELECTROMYOGRAPH			
SMOOTH MUSCLE ACTIVITY	ELECTROGASTROGRAM	SURFACE ELECTRODES	20mv	.25	.05 - 2
AUTONOMIC NERVOUS SYSTEM					
SWEAT GLAND ACTIVITY	GALVANIC SKIN REFLEX	LEAD SURFACE ELECTRODES	50kΩ		
	ELECTRICAL SKIN RESISTANCE	" " "	"		
BODY TEMPERATURE	TEMPERATURE	THERMISTOR PROBE THERMOMETER	98°F		
ANATOMY					
INTERNAL ORGAN POSITION	ULTRASONIC ECHO	ULTRASONIC SCANNING SYSTEM			

TABLE B2. SIGNAL RANGES OF PHYSIOLOGICAL MEASUREMENTS.

	PRIMARY SIGNAL RANGES AND CHARACTERISTICS
CARDIOVASCULAR SYSTEM	
BLOOD PRESSURE, DIRECT METHOD	FREQUENCY RANGE: DC TO 200Hz; DC TO 60Hz USUALLY ADEQUATE. PRESSURE RANGE, ARTERIAL 40 TO 300mmHg; VENOUS 0 TO 15mmHg.
BLOOD PRESSURE, INDIRECT METHOD, INTERMITTENT SYSTOLIC AND DIASTOLIC	AUSCULTATORY CRITERION (KOROTKOFF SOUNDS): 30 TO 150Hz USUALLY ADEQUATE. PALPATORY CRITERION: 0.1 TO 60Hz. BOTH REQUIRE ADDITIONAL SIGNAL SHOWING OCCLUDING PRESSURE.
PULSE WAVES, DIRECT METHOD, ARTERIAL	(SEE BLOOD PRESSURE, DIRECT)
PULSE WAVES, INDIRECT METHOD, PERIPHERAL ARTERY	FREQUENCY RANGE: 0.1 TO 60Hz USUALLY ADEQUATE. PULSE TRACE SIMILAR TO BLOOD PRESSURE, DIRECT, BUT WITHOUT BASELINE ZERO.
PHONOCARDIOGRAM	FREQUENCY RANGE: 5 TO 2000Hz; MAJOR DIAGNOSTIC COMPONENTS LIE IN 20 TO 200Hz RANGE.
PLETHYSMOGRAM (VOLUME MEASUREMENTS)	FREQUENCY RANGE: DC TO 30Hz.
BALLISTOCARDIOGRAM	FREQUENCY RANGE: DC TO 40Hz.
HEART RATE	AVERAGE RATE, HUMAN: 45 TO 200 BEATS/min, LAB ANIMAL, 50 TO 600 BEATS/min.
OXIMETRY	FREQUENCY RANGE: 0 TO 60Hz; 0 TO 5Hz USUALLY ADEQUATE.
CARDIAC OUTPUT	FREQUENCY RANGE: 0 TO 60Hz; 0 TO 5Hz USUALLY ADEQUATE
BLOOD FLOW	FLOW RANGE, HUMAN: 5ml/min TO 10 LITERS/min. FREQUENCY RANGE: 0 TO 60Hz; 0 TO 20 USUALLY ADEQUATE.
HEART SHUNT DETECTION	ELECTRODE SIGNAL RANGE, PO_2: 0 TO [illegible]mmHg. HYDROGEN AND SODIUM ASCORBATE: QUALITATIVE
ELECTROCARDIOGRAM	FREQUENCY RANGE: 0.05 TO 80Hz. SIGNAL RANGE: 10µV TO 5mV INCLUDES FETAL RANGE.
RESPIRATORY SYSTEM	
FLOW RATE (PNEUMOTACHOGRAM)	FREQUENCY COMPONENT: TO 40Hz. NORMAL FLOW RANGE: 250 TO 500ml/s, MAXIMUM 8 LITERS/s.
BREATHING RATE (CALCULATED FROM WAVEFORM WITH APPROXIMATE RELATIVE RESPIRATORY VOLUME)	AVERAGE RATE: HUMAN, [illegible] TO [illegible] BREATHS/min, LAB ANIMAL, 8 TO 60 BREATHS/min.
TIDAL VOLUME (MEASURED PER BREATH OR INTEGRATED TO PROVIDE VOLUME/min)	TYPICAL VOLUME, ADULT HUMAN: [illegible]ml/BREATH; 6 TO 8 LITERS/min.
[illegible] (CHANGE CONCENTRATION IN RESPIRED AIR)	NORMAL RANGE, CO_2: 0 TO 10%; END-TIDAL CO_2, HUMAN: 4 TO 6%. N_2O: 0 TO 100%. HALOTHANE: 0 TO 1%.
[illegible] NITROGEN	NORMAL RANGE OF NITROGEN CONCENTRATION DIFFERENTIAL: 0 TO 10%.
PULMONARY DIFFUSING CAPACITY (USING CARBON MONOXIDE)	NORMAL RANGE, HUMAN: 16 TO 35ml O_2/mmHg/min.
BLOOD GASES AND pH	
PARTIAL PRESSURE OF DISSOLVED O_2, [illegible] IN VITRO	FREQUENCY RANGE: [illegible] USUALLY ADEQUATE. NORMAL MEASUREMENT RANGE: 0 TO [illegible]mmHg PO_2. HYPERBARIC PO_2 RANGE: [illegible] TO 3000.
pH, IN VITRO	SIGNAL RANGE: 0 TO ±700mV, COVERS pH RANGE.
PARTIAL PRESSURE OF DISSOLVED CO_2, IN VITRO	NORMAL SIGNAL RANGE: 0 TO ±150mV, COVERS RANGE FROM 1 TO 1000mmHg PCO_2.
BIOELECTRIC POTENTIALS	
ELECTROENCEPHALOGRAM	FREQUENCY RANGE: DC TO 100Hz, MAJOR DIAGNOSTIC COMPONENTS LIE IN 0.5 TO 60Hz RANGE. NORMAL SIGNAL RANGE: 15 TO 100µV.
CEREBRAL POTENTIALS, INTRACRANIALLY RECORDED	NORMAL SIGNAL RANGE: 10µV TO 100mV. PULSE DURATION: [illegible]ms TO 20ms.
ELECTROMYOGRAM (PRIMARY SIGNAL)	FREQUENCY RANGE: 10 TO 2000Hz. PULSE DURATION: [illegible]ms TO 20ms.
ELECTROMYOGRAM (AVERAGED)	AN AVERAGE OF THE PRIMARY SIGNAL, AFTER FULL WAVE RECTIFICATION.
SMOOTH MUSCLE POTENTIAL (e.g., ELECTROGASTROGRAM)	FREQUENCY RANGE: DC TO [illegible]Hz. NORMAL SIGNAL RANGE: 0.5 TO 80mV.
ELECTRORETINOGRAM	FREQUENCY RANGE: [illegible] 20Hz ADEQUATE. NORMAL SIGNAL STRENGTH: 1µV TO 1mV.
ELECTROCARDIOGRAM	(SEE LISTING UNDER CARDIOVASCULAR SYSTEM)
ELECTRONYSTAGMOGRAM	DIRECT: FREQUENCY RANGE, 0 TO 20Hz. TYPICAL SIGNAL STRENGTH, 100µV/10° EYE MOVEMENT. DERIVATIVE OR VELOCITY: FREQUENCY RANGE, 0 TO 20Hz. SIGNAL DERIVED FROM DIRECT READING.
PHYSICAL QUANTITIES	
TEMPERATURE	FULL RANGE OF SIGNALS.
VOICE	FREQUENCY RANGE: 20 TO 20,000Hz.
SKIN RESISTANCE (GSR)	RESISTANCE RANGE: 1k TO 500k.
ISOMETRIC FORCE, DIMENSIONAL CHANGE, BODY FLUID AND BODY CAVITY PRESSURES	FULL RANGE OF SIGNALS.

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