IMPACT OF EMERGING TECHNOLOGY ON HEALTH CARE SYSTEMS

Space Medicine Brought to Earth

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Charles A. Berry, M.D.
NASA Director for Life Sciences
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Presented at the Conference on Technology and Health Care Systems in the 1980's, 19-21 January 1972, San Francisco, California

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Certainly by this stage in the discussion, attempts will have been made to define health and health care. If we are to view the impact of emerging technology on health care, I feel it vital to express my opinion concerning the definition of health at least as one physician sees it. In a multidisciplinary conference entitled "A Challenge to Life" in Basal, Switzerland, I stated this view. Health is defined in the dictionary as "a normal condition of body or mind; that is, with all the parts functioning normally." Such a definition immediately raises questions, for we are faced with a second definition that may be even more difficult to obtain, that of what is normal. In my daily medical activities in support of manned space flight, I deal with "normal" individuals who are being exposed to a rather hostile environment. Normal in this sense could be defined as "free from disease," for many of the individuals the average physician deals with in his daily practice are certainly persons who have some variation of normal in mind and body. They thus seek assistance and are willing to pay for the charges incurred. One of the unseen benefits of the space program is the continuing effort to better define what we mean by "normal" as regards functioning of body and mind. We are all

aware that the range is great, and in general the range and the so-called population at large is used to try to determine whether any given patient has varied from this normal and thus become what could be called diseased. In manned space flight, we are attempting to measure even minute variations in physiologic function and we have resorted to using the individual as his own "normal" or control and thus measuring variation from that baseline. It is very important to carefully define that "normal" baseline by an adequate number of accurate determinations in order that variations from the baseline may be quickly and positively determined and causes ascribed.

The physician generally tends to subscribe to the dictionary definition of health as being one of no measurable alteration of function in body or mind and thus he becomes body or organ oriented for he must think physiologically, pathologically, and, finally, therapeutically in helping his patient achieve this state called health. Thus the physician and much of the world's population today are preoccupied with sickness or illness and much of the medical and health manpower of the world is completely utilized in therapeutic medicine in contrast to preventive medicine which could be of much greater value. The practice of aerospace medicine is principally one of preventive medicine. Great effort is expended in trying to anticipate what might happen and to protect against any occurrence which might result in altered physiology as far as our space crewmen are concerned. This is not always possible, but I view an illness or an injury in one of our crewmen as a preventive medicine failure

and then much effort is expended in failure analysis, much as our engineering counterparts do in analyzing the behavior or failure of the spacecraft and its systems.

Doing the general practice of medicine and being exposed to the medical needs in many of the more undeveloped parts of the world has considerably modified any thoughts that I had relating health merely to the absence of pathology. One very quickly becomes convinced of the fact that no matter what you may do with drugs or surgery, if results could be erased within a period of hours or days by the actions of an uneducated patient then it is impossible to separate the functioning of the body in a normal manner from education, economics, social pressures, etc. It has been stated that the ghetto dweller would define health as a state of physical, mental, and social well-being and not merely the absence of disease and infirmity. Health hazards then include such things as faulty plumbing, lead paints, inadequate nutrition, limited education, the inability to receive employment, police harassment, infestation with rats, and many other problems. In addition to this broadened definition of health, there is increasing concern in the world today about providing it, for it appears to be considered as a right and has been so affirmed by such organizations as the World Health Organization. I firmly believe that every person does have the right to health but this implies a tremendous task. Much has been written concerning the problems in providing health care for the people in our own country and for those around the world. There are too

few professional health care personnel. This means we do not have enough physicians, nurses, and paramedical personnel of all sorts. Attempts are being made to attack these specific problems but nonetheless, there is an obvious need for other hands. In my view, these must include those of medical assistants as rapidly as possible if we are to successfully attack the health care provision problem. Even without the use of advanced technology, medicine today has enough tools and has grown in complexity at a pace to the point the individual practitioner finds himself beset with difficulties. In many instances today, physicians are effective medical managers of medical teams who thus render excellent care to their patients. These teams consist of numerous people who are not trained physicians but who serve certain specific roles in the diagnosis and treatment cycles. Certainly, this must be expanded to the education and preventive medicine cycles as well. The growth of population and the continuing demand for care cannot be met just by providing these health teams, however. We must provide additional eyes, ears, and hands in the form of tools and these tools can be provided by the technology that is and will be available. It must always be remembered that technology is only a tool and it must be utilized by the physician to extend his capabilities. Physicians in general tend to be wary of technology for they feel that it implies either a barrier between them and their patient or control of their actions in the medical sphere by some outside source. The capabilities of technology are not well understood and many physicians cry, "Do

not put a machine between me and my patients," while the patient cries, "How can I have time with the physician so that I may understand my state of health and plan my future?" Both of these concerns must be faced squarely and evaluated and solutions determined.

If we are to provide health care to all, we must determine who needs it. The need to determine who needs health care and to provide an entry into the health care system requires the development of screening techniques. This again has implications for the number of health care professionals who are available and establishes a strong demand for the utilization of technology and paramedical people to help with the screening of the well from the sick and, perhaps more importantly, in defining a baseline of normality for each individual against which he can be compared.

In providing care to larger numbers of people, attention must be directed to efforts to assure that the level or standard of care is not reduced at all. This could certainly be a hazard of trying to provide more care with the same number of people and it is one of the difficulties we face today. Any attempt to utilize technology to provide this care should also direct effort toward elevating all of medical practice to a new level of excellence and accuracy. Technology can assist in this regard but in so doing, there will be some changes which the individuals providing the care must accept.

Communication and the availability of information concerning a patient's medical record and even the timely availability of laboratory and examination data to the physician so that he can make an early diagnostic decision and relay it to the patient continue to be current problems. Technology and data handling techniques can offer much in this area of communication. Again, however, the help offered is not without some cost procedurally, emotionally, and economically.

There continue to be remote areas in our own country where medical care at even rudimentary levels is difficult to obtain. In other parts of the world, the situation is even more staggering. I am convinced that there will continue to be maldistribution of medical personnel because people will remain people. This too is an area where technology can offer great assistance and, at the same time, provide a higher level of medical care in providing means for remote communication, diagnosis, and therapy.

Why are we in NASA interested in this terrestrial problem of health care? As a physician, I have been struck by the similarities, on entirely different scales, of course, of our problems in providing care to the crews at long distances from the earth and some of the problems faced in providing medical care here on the surface of the earth. In a recent paper, I attempted to summarize some of the technological benefits to medicine that had evolved from the solutions of some of our space medicine problems. In the provision of an environment that was habitable for the crewmen in the form of both

spacecraft cabin and spacesuit for ventures outside that cabin, many specific items of hardware have been developed which have turned out to have had some additional applications, including such things as the space helmet in pulmonary function testing and the liquid cooled undergarment for both medical and non-medical uses such as treating febrile patients or protecting firemen against the environment. In order to determine the physiologic state of our crewmen at great distances from the surface of the earth, it was necessary to develop sensors which would obtain reliable physiologic information, signal conditioners which would handle that information, telemetry systems which would transmit it, and data systems which would help us analyze data after it had been transmitted for distances as great as 240,000 miles to the surface of the earth. We certainly have been involved in remote medical care and we are in a position where we too have a maldistribution of our medical personnel, in this case, all of them being on the ground. The approaches of miniaturization and specialized packaging of biomedical instrumentation coupled with the provision of markedly increased reliability has given us the opportunity to provide medical diagnosis at a distance.

The necessity for increased reliability of instrumentation is quite obvious where there is little opportunity to tinker with the instrumentation. The provision of a rather astounding communication system utilizing satellites and various means to return the data from the surface of the moon or from orbiting spacecraft back to the Mission Control Center in Houston, was

vital to the successful care of our long distance patients. In addition, it was impossible to rely on eyeballing the many hours of normal data and attempting to separate abnormalities. This called for data handling systems that would aid the physician in the task. In doing the job which has been necessary to support man in the space flight environment, we have used what has come to be known as the systems approach to problems. There is nothing very startling about this approach but it is the systematic review of the causes of the problem or the factors bearing on that problem and then a determination of possible solutions and the tradeoffs in selecting those solutions. Interfaces of various portions of this system are thus reviewed and problems anticipated before they occur. We have also been fortunate to participate in a melding of disciplinary inputs from engineers and physicians such as ourselves. This interplay between engineers and physicians is vital to the future of medicine as is the total team concept that requires many other diciplines heretofore alien to the medical environment. I'm sure that it is evident that there are some things which stand out as having direct relationships between the care of space crewmen at distance and the provision of medical care here on earth. We have utilized technology to assist us in our task where there was no other way to accomplish it. I am equally convinced that there is no other way to accomplish our tasks here on earth and we must find intelligent ways to utilize this technology.

Unfortunately, since the lunar landings, many public figures have used the phrase--if we can land man on the moon, then obviously, with effort we can _____ (almost every American problem has filled this blank at one time or another). We should all realize that there were some key factors making this significant step possible and without them it would have never occurred. First, there was a national commitment to the goal of a lunar landing and this allowed assembling a dedicated and qualified team to do the job and assured adequate funding. The goal caught the imagination and pioneering spirit of the American people. These key items do not exist in the health care field, and a further complication is the sociological implications of any health care program. Therefore, I do not think that simply because we can go to the moon, we can necessarily solve the health care needs of our nation, but we can certainly work at it if we will.

This brings us to the question of whether NASA technology can help and if so, how. There is a unique base of experience in remote care and the use of technology resident within NASA. It is true, however, that the implementation of this technology has been costly if viewed in the context of the average physician.

We are currently planning for much more advanced and detailed medical care in the form of diagnosis, therapy, and also scientific or experimental evaluation of man's physiological responses which will be necessary for very long duration flights in earth orbit or to the planets. This will be still another

test and another extension of our experience in remote medical care. We have been conducting studies for a number of years toward the development of an integrated system which will provide these capabilities. It would seem prudent at the present time to try and develop this system in a way that it could be tried in the arena of a remote medical care problem here on the surface of the earth. There has been a great deal of talk about the capabilities of technology, and, indeed, bits and pieces have been utilized in various forms as some of the speakers have noted. There is still a crying need, however, for demonstration of the workability of total systems, and particularly in the area of defining and working the interfaces between the health care professionals and the new technology in a total health care system. To this end, we have proposed that we develop a remote medical care system which could be utilized in a terrestrial application as a trial of both the technology and these interfaces.

Our space system has been called an Integrated Medical Behavioral Laboratory Monitoring System (IMBLMS) and certainly would not have every feature needed by an earthbound system for remote medical diagnosis and treatment. There are many parallels from the systems point of view, however. Communications, data management, and medical equipment required for long duration space missions and for remote area health services on the ground are very similar. As I have previously stated, there are elements of a remote area health system in several places but there is a distinct need for

an organized total remote area health services system which could provide health services in a comprehensive manner utilizing a communications system to insure quality health service and automatic data processing techniques to reduce the man hours in performing tasks that are done by automatic processing. Producing such a system as a demonstration on the ground will work out many of the problems to be faced in later use in space. The approach to the design, development, and testing of such a system is that which we have used for producing hardware for medical research onboard spacecraft. Figure 1 shows the flow pattern in design, development, and testing which would benefit both ground and space medicine.

The key features of the proposed health services system are the provisions of emergency, primary, and preventive health services; extensive use of communications to provide control, to minimize travel time, and to educate; and the selectively applied action of computer-based data management techniques to implement time saving by using problem-oriented record-keeping and data retrieval systems. An integrated systems design approach with augmented safety, reliability, and quality control at the systems level would be utilized. These are areas where NASA can make significant contributions by applying its skill in bioengineering, total systems engineering, and, specifically, in goal-oriented program management.

The conceptual design for the remote health services system includes the following features:

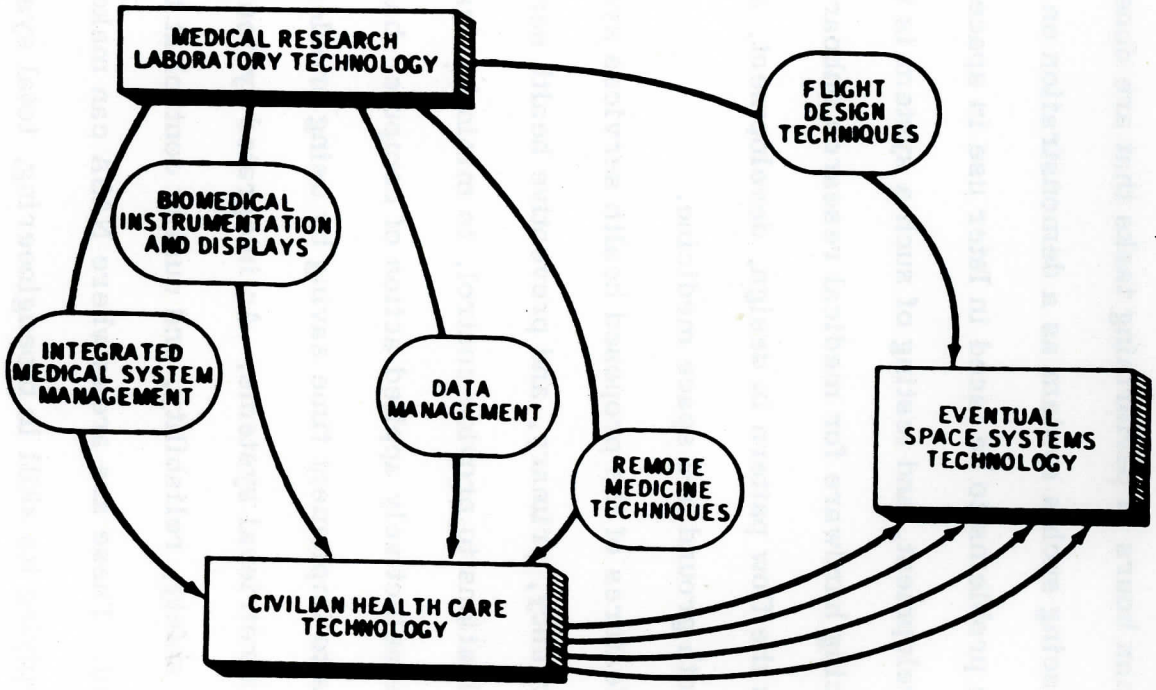
MEDICAL RESEARCH LABORATORY TECHNOLOGY
FLIGHT DESIGN TECHNIQUES
BIOMEDICAL INSTRUMENTATION AND DISPLAYS
INTEGRATED MEDICAL SYSTEM MANAGEMENT
DATA MANAGEMENT
REMOTE MEDICINE TECHNIQUES
EVENTUAL SPACE SYSTEMS TECHNOLOGY
CIVILIAN HEALTH CARE TECHNOLOGY

Figure 1.

1. Accessible points of entry into the health care establishment for people in remote areas.

2. A method to sort and route patients after entry into a health care system so that they are efficiently placed under the supervision and care of the most appropriate health care professional.

3. A mechanism to extend the expertise of health care professionals to compensate for both scarcity and maldistribution.

4. An application of technology and management to relieve health care professionals of time-consuming tasks that require lesser levels of training and knowledge.

5. Adequate disposition of medical and traumatic emergencies.

6. Patient-to-physician/associate-to-physician rapport to establish confidence in the system.

The principal characteristics of the conceptual system are:

1. The use of existing medical establishments.

2. The use of paramedical personnel (such as graduates of MEDEX and physician's assistants programs) as extensions of physicians to increase the number of entry points into health care establishments.

3. The use of communications technology to provide the consultation, supervision, and attention of a physician that would be required for quality health care, and to establish the rapport required to eliminate the stigma of "second-class" health care.

4. The use of appropriate combinations of fixed and mobile facilities to meet the varying needs dictated by population density, terrain, existing transportation systems, and socioeconomic characteristics of different areas.

5. The use of information processing and automation technologies to relieve personnel of burdensome recordkeeping and administrative functions. Automated records will enhance the availability of socioeconomic and health statistics for planning more effective preventive medicine programs. Careful analyses must be performed to avoid over-sophistication and the resulting absence of cost effectiveness.

The technical concept centers about an organization of several elements, collectively called an Area Health Services Field Unit (Figure 2). This field unit is under the direct control, through various communications media (voice, video, facsimile, teletype, and others), of a Health Services Support Control Center and provides the link between the population with health needs and existing health facilities. The support control center is located adjacent to or within an existing medical facility such as a large hospital or medical center. The major requirement imposed upon the support control center is to provide (from its existing staff) ready access to expertise in all fields of health care. Generally speaking, the physician who is primarily responsible for the care of a remotely located patient is on the staff of this institution.

A communications center and, if not already available, an information processing center will be required to upgrade an existing medical facility to the status of a support control center.

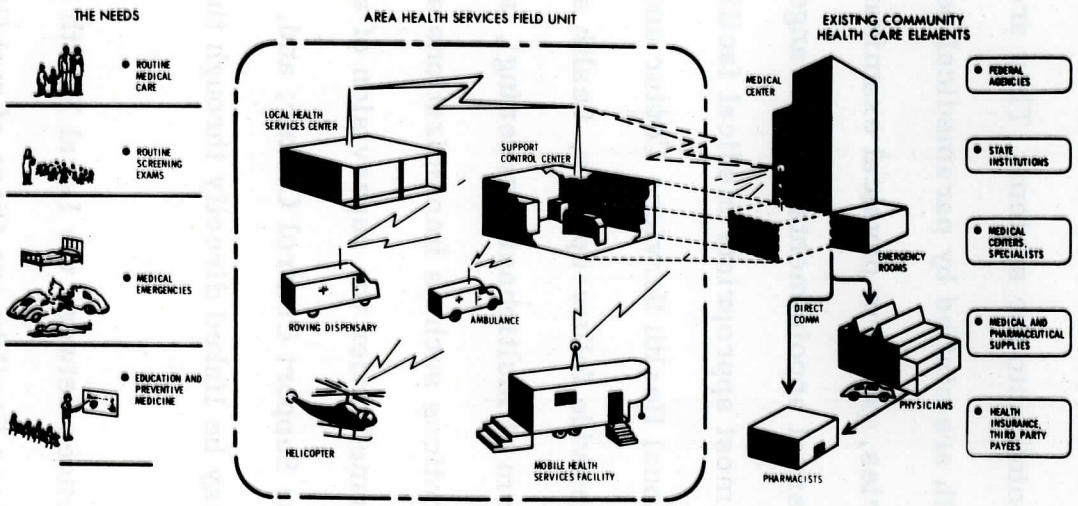
THE NEEDS
ROUTINE MEDICAL CARE
ROUTINE SCREENING EXAMS
MEDICAL EMERGENCIES
EDUCATION AND PREVENTIVE MEDICINE
AREA HEALTH SERVICES FIELD UNIT
LOCAL HEALTH SERVICES CENTER
SUPPORT CONTROL CENTER
ROVING DISPENSARY
AMBULANCE
HELICOPTER
MOBILE HEALTH SERVICES FACILITY
EXISTING COMMUNITY HEALTH CARE ELEMENTS
MEDICAL CENTER
EMERGENCY ROOMS
DIRECT COMM
PHYSICIANS
PHARMACISTS
FEDERAL AGENCIES
STATE INSTITUTIONS
MEDICAL CENTERS, SPECIALISTS
MEDICAL AND PHARMACEUTICAL SUPPLIES
HEALTH INSURANCE, THIRD PARTY PAYEES

Figure 2.

The Area Health Services Field Unit Local Health Services Center and Mobile Health Services Facility are the primary health services delivery components and entry points into the system. They are essentially identical in function--that is, both are staffed by paramedical personnel, both receive patients, acquire histories, perform physical examinations, and provide either treatment or referral appointments (and arrangements for transportation if required) to the most appropriate medical facility for each patient's individual need. The Local Health Services Center and the Mobile Health Services Facility also provide follow-up care, health screening examinations (which may be in the form of multiphasic screening), and other important preventive medicine functions such as immunizations and health education. All activities are performed under the supervision of and with the support of physicians located at the Support Control Center; and, if necessary, the physician and patient may be linked directly through the two-way communications system.

The major differences between the Local Health Services Center and the Mobile Health Services Facility are those of mobility and size; the Local Health Services Center has more equipment and is located in a permanent structure. The requirement for two types of units (fixed and mobile) is based upon differences in population density. For example, a Local Health Services Center can be dedicated to a small town lacking adequate medical care but having sufficient population density. Conversely, the Mobile Health

Services Facility accommodates fewer patients per unit of time, but can be deployed in accord with an established schedule to many different sites. In this manner, access (although not continuously available at one site) can be provided to a large, sparsely populated geographical area. Furthermore, mobility allows the seasonal extension of health services, such as might be required by vacationers and campers in remote areas or by migrant labor populations following the seasonal dictates of agriculture.

A third level of Field Unit components is composed of the Health Services Transport Equipment which consists of the usual emergency vehicles and a special-purpose vehicle, a roving Dispensary Ambulance. Generally, locally available emergency vehicles would be employed and supplemented as required.

The roving Dispensary Ambulance can best be described as less than a Mobile Health Services Facility, but more than an ambulance. It is vastly more mobile than the Mobile Health Services Facility and is capable of extending entry into health care services to even more remote areas. One of its principal functions is to provide a capability for stabilizing and maintaining emergency patients as well as for providing the receiving institution with more detailed information on the patient's condition than could be accomplished by using ambulances. The unit also provides a capability for performing excellent health screening and preventive medicine services.

A fourth level of components is made up of Portable Health Services Equipment. One type of portable equipment permits extension of health services to the bedridden, chronically ill, and to the elderly populations. A second type augments the equipment usually provided in emergency vehicles and also supplies the equipment needed to convert nonemergency vehicles--such as private, industrial, and governmental helicopters; boats; and land vehicles--into adequate emergency vehicles.

Each different geographical area would require different selections and numbers of these components; and, until a suitable area for a demonstration is selected, establishment of exact requirements is impossible. It is expected, however, that the requirements for the Support Control Center will not be significantly different whether it is supporting one or many remotely located Field Units. Hence, the more satellite Field Units, the more cost effective the system.

The Area Health Services Field Unit provides a system for health services that could be tailored uniquely to the geographical, social, economic, and health needs of a defined area. The design concept for the Area Health Services Field Unit includes the following facilities.

The Health Services Support Control Center will be housed within an existing, well-equipped, and well-staffed medical facility that lies within the defined area serviced by the field unit. The location will enable ready access by a professional staff on a 24-hour-per-day basis for consultation,

supervision, and direction of health services personnel working in other elements of the Area Health Services Field Unit that are located at relatively distant sites. Because it will be necessary at times to monitor and direct activities at several distant locations simultaneously, the audiovisual communication and data management systems to be provided will enhance this function. A nonphysician but medically trained operator will monitor and funnel incoming data to the proper area. A physician can be in contact through two-way video as shown in Figure 3. The Support Control Center would perform the following major functions.

1. Medical
    a. Consultation and direction
    b. Supervision of physician's assistants
    c. Patient direction and traffic routing
    d. Area management
    e. Continuing education
    f. Epidemiological analyses
    g. Trend analysis
2. Systems support
    a. Overall systems management
    b. Central communications
    c. Data management and display
    d. Calibration, maintenance, and repair

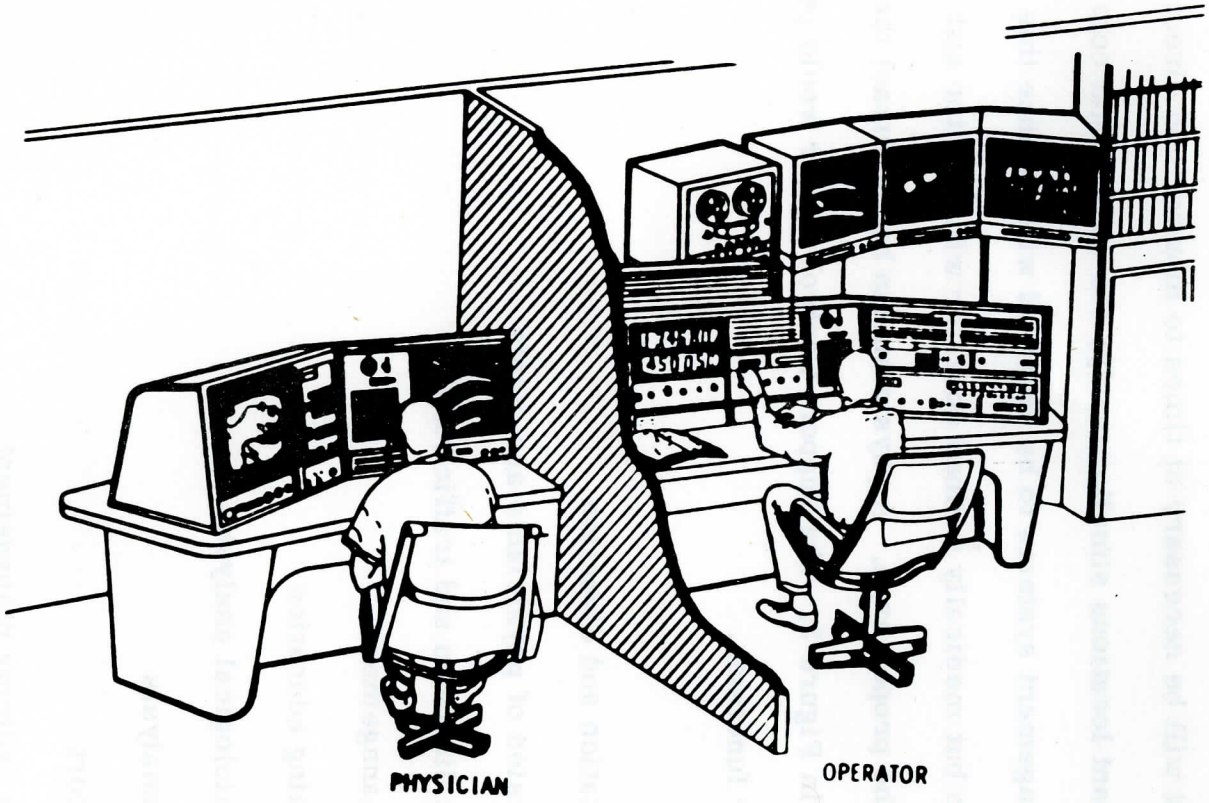

Figure 3.

3. Administrative

   a. Documentation, including patient records

   b. Training

   c. Supply and property management

   d. Third-party interfaces (legal, press, etc.)

   e. Procurement

   f. Payroll and accounting

Patients who enter a distant element of the Field Unit and require referral for care beyond the capability of that element will be routed by the Support Control Center to an appropriate health care facility. Arrangements for the patient's transportation, admission, and care also will be made.

The Support Control Center also will be responsible for all medical-legal records. Information from many sources, including Support Control Center medical records will be collected and analyzed to provide an epidemiological data base. Both the preventive medicine aspects of the Area Health Services Field Unit and the evaluation of the merit of this program depend upon the accuracy and completeness of these health statistics.

The Local Health Services Center would be a fixed facility to be located in a medically deprived area. As the primary "first-line" patient entry portal, the Local Health Services Center would perform the following major functions.

1. Medical

   a. Identification and classification of patients

   b. Physical examinations

   c. Preliminary diagnoses

   d. Routine outpatient care

   e. Emergencies (dedicated space)

   f. Health screening examinations

   g. Preventive medical care

   h. Health education

2. Systems

   a. Data management and display

   b. Communication and consultation with the Support Control Center

   c. Communications relay between other facilities and the Support Control Center

3. Administration

   a. Scheduling and traffic control of transport and portable equipment

   b. Training

   c. Field maintenance of transport and portable equipment

   d. Supply of odd property

   e. Documentation

A typical examination room in the Local Health Services Center is shown in Figure 4.

Medical history. Entry of medical history would be made by the patient through an automated data terminal if the volume of patients processed or other factors warranted. Health services personnel would aid in this procedure if needed. The entry format would permit the inclusion of narrative supplementary information when required. The display format will permit comparison of data by the physician and the physician's assistant. Access to medical records, whether in writing or stored within the data processing system, would be limited to authorized medical personnel.

Physical examination. Audiovisual communication between examination and treatment rooms of the Local Health Services Centers and the Support Control Center, together with private communications (audio) between the Local Health Services Center physician's assistant and the Support Control Center physician, would provide the direction and control required by the responsible physician. Adequate patient privacy during examination and treatment would be provided.

Procedures for systematic, rapid examinations for routine medical illness and medical emergencies as well as procedures for comprehensive regular health maintenance physical examinations would be provided. Data entry terminals would be available within each treatment and examination area.

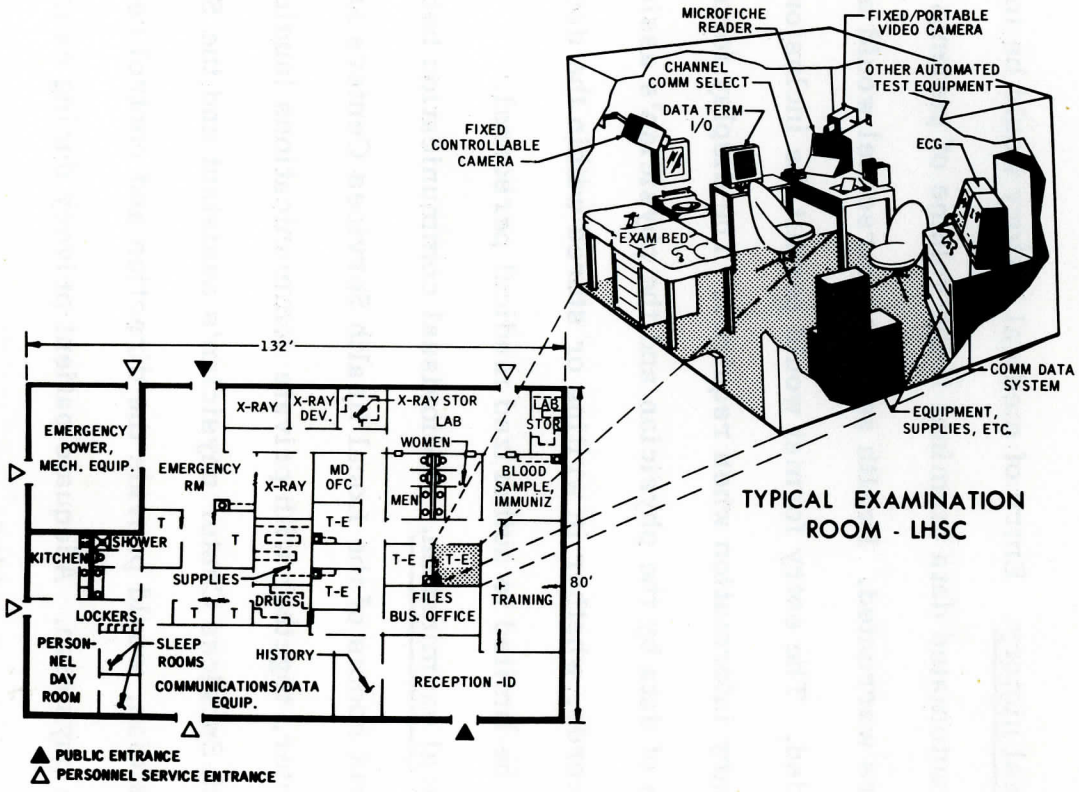
MICROFICHE READER
FIXED/PORTABLE VIDEO CAMERA
CHANNEL COMM SELECT
OTHER AUTOMATED TEST EQUIPMENT
DATA TERM I/O
FIXED CONTROLLABLE CAMERA
ECG
EXAM BED
COMM DATA SYSTEM
EQUIPMENT, SUPPLIES, ETC.
TYPICAL EXAMINATION ROOM - LHSC
132'
80'
X-RAY
X-RAY DEV.
X-RAY STOR
LAB
LAB STOR
EMERGENCY POWER, MECH. EQUIP.
EMERGENCY RM
X-RAY
MD OFC
WOMEN
MEN
BLOOD SAMPLE, IMMUNIZ
T
T-E
SHOWER
KITCHEN
SUPPLIES
DRUGS
FILES BUS. OFFICE
TRAINING
LOCKERS
PERSONNEL DAY ROOM
SLEEP ROOMS
HISTORY
COMMUNICATIONS/DATA EQUIP.
RECEPTION -ID
PUBLIC ENTRANCE
PERSONNEL SERVICE ENTRANCE

Figure 4.

An auditory examination to be performed by using an automated audiometer would be included. Visual examination would include intraocular tension (applanation technique), acuity, depth perception, color perception, phorias, and visual field mapping.

The X-ray equipment would provide the capability for exposing and developing diagnostic films (standard chest, fracture detection, and abdominal).

Facilities for collecting fecal waste, urine, and vomitus specimens for laboratory analyses should be provided for both nonambulatory and ambulatory patients.

Laboratory analyses. Laboratory analyses for routine screening examinations, patient follow-up visits, and other specific diagnostic procedures would be available. Automated procedures will be used wherever appropriate. Results of laboratory analyses would be expeditiously entered into the data management system for the physician's early review. The capability to prepare specimens for storage and transport to either the Support Control Center or another designated area for special analyses should be included.

Treatment capability. The Local Health Services Center would be capable of performing limited treatment or referral in the medical, surgical, dental, neuropsychiatric, and obstetric/gynecologic areas.

1. Medical - Drugs would include the therapeutic agents that are necessary for the routine and emergency treatment of illnesses and physical injuries.

The inventory would be based on the predicted needs of the community and would provide both comprehensive treatment capability and flexibility to meet the physician's preference. Dispensing of prescription drugs would be under the direct control of the physician at the Support Control Center. Drugs would be stored in areas or containers in a manner that prohibits free access by nonmedical personnel and that preserves therapeutic effectiveness.

2. Surgical - Surgical instruments and supplies would be provided for the performance of all anticipated routine and emergency minor surgical procedures. A capability to include a patient bed would be provided for short-term patient supportive therapy. Casting and cast-removal equipment would be included to permit emergency immobilization of fractures and directed follow-up replacement of casts. Provision would be made for sterilizing surgical instruments and other nondisposable items of equipment and supplies.

3. Dental - Equipment for routine dental examinations and for treatment of dental emergencies should be provided.

4. Neuropsychiatric - Neuropsychiatric disorders would be referred. Follow-up treatment directed by the Support Control Center would be provided whenever practical.

5. Obstetric/gynecologic - A routine gynecological examination capability would be provided and would include the preparation of Papanicolaou smears. Pathological interpretation would be performed by a pathologist at

the Support Control Center. Routine prenatal and postnatal care would be provided. An immunization program would be incorporated as part of routine postnatal well-baby care.

The Mobile Health Services Facility, from the medical view, would be a scaled-down version of the Local Health Services Center. Although it would be mobile (with minimal requirements for local utility support) and would have an increased outreach, the basic medical functions it would satisfy are identical to those of the Local Health Services Center. Therefore, the basic medical requirements would be the same, with one notable exception. The reduced volume available for health care would not permit the dedication of space solely for medical emergencies. The Mobile Health Services Facility would not be required to process medical emergencies simultaneous with its outpatient and physical examination functions. Any medical emergency arriving at the Mobile Health Services Facility would immediately take precedence over all other activities. This precedence would remain in effect until the disposition of the emergency was complete. An artist's conception of the Mobile Health Services Facility is shown in Figure 5.

The Health Services Transport Equipment would consist of mobile units, a Dispensary Ambulance, and ambulances.

The Dispensary Ambulance would perform the following major functions.

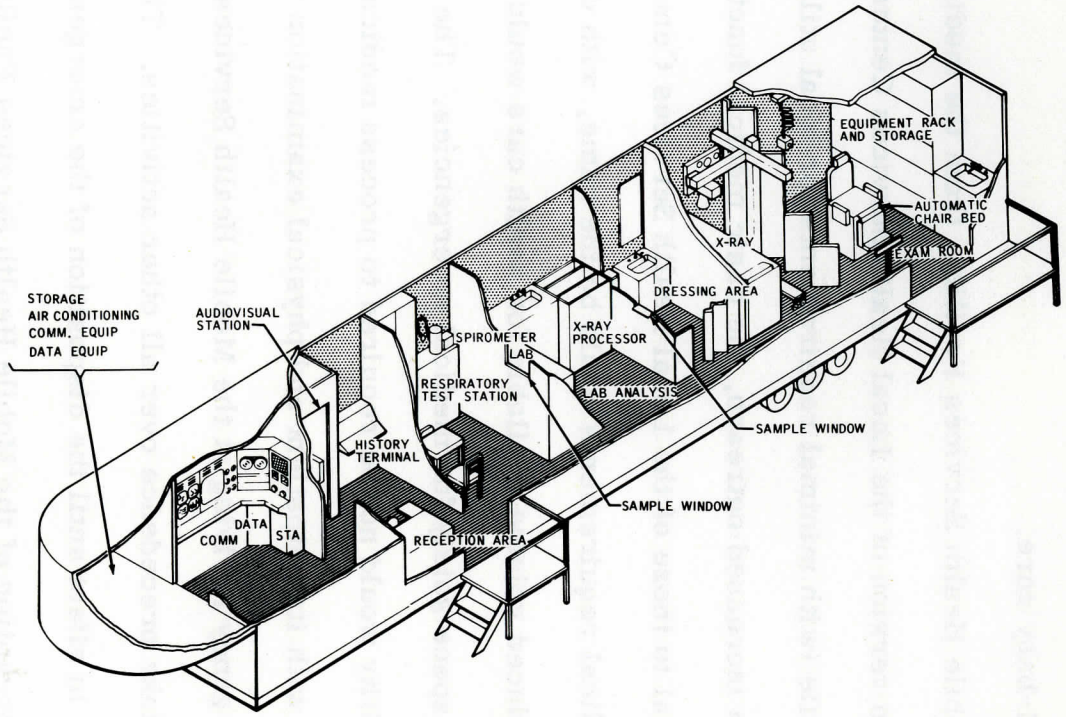
STORAGE
AIR CONDITIONING
COMM. EQUIP
DATA EQUIP
AUDIOVISUAL STATION
HISTORY TERMINAL
DATA COMM
STA
RESPIRATORY TEST STATION
SPIROMETER LAB
X-RAY PROCESSOR
LAB ANALYSIS
RECEPTION AREA
DRESSING AREA
X-RAY
EQUIPMENT RACK AND STORAGE
AUTOMATIC CHAIR BED
EXAM ROOM
SAMPLE WINDOW
SAMPLE WINDOW

Figure 5.

1. Outreach - a scheduled route of stops in remote rural areas

2. Limited examinations within the scope of the personnel staffing the vehicle and with the onboard support capability (have at least voice communication with the Support Control Center)

3. Education and preventive medical care

4. Immunizations

5. Emergencies

6. Limited outpatient treatment

7. Communications (voice only in test-bed program)

The medical requirements imposed for the Dispensary Ambulance would necessitate inclusion of emergency medications, cardiorespirators, and monitoring and recuperation equipment, including supplies of medical grade oxygen, a respirator cardiac defibrillator, and a pacemaker. The Dispensary Ambulance would provide a separate patient support area capable of sustaining and conditioning two seriously injured persons while awaiting emergency transportation or while actually en route within the Dispensary Ambulance.

An examination and treatment area would be equipped with a treatment table, which will serve as a portable litter transfer and examination table. Surgical instruments and equipment would be provided for the treatment of accident victims, and obstetrical instruments and equipment would be provided for precipitous delivery.

Supervision and direction would be obtained by means of voice communications only from the Support Control Center.

Ambulance transport would generally provide for treatment and diagnosis functions that would be supportive for the emergency. The Support Control Center would use the existing emergency vehicle communications frequency assignments to monitor the patient's condition and to issue treatment directions. Additional equipment and supply requirements would be filled by Portable Health Services Equipment.

The medical functions served by the Portable Health Services Equipment would be the augmentation of emergency equipment usually carried by ambulances, the provision of emergency equipment for vehicles (station wagons, helicopters) not ordinarily used for this purpose, and the extension of health services to bedridden patients by providing the trained physician's assistants or nurses with suitcase-sized equipment modules for making house calls.

The Ambulance Module would be a portable case containing combined cardiac monitoring, defibrillating, and pacemaking equipment; respiratory resuscitating equipment; a supply of medical grade oxygen with regulator and mask; and aspirating equipment. The module would be self-contained and would be powered by rechargeable batteries. Supplies such as splints, dressings, and emergency drugs would be included.

The Portable Examination Module would provide head-lamp illumination and examining instruments such as a combined ophthalmoscope/otoscope, aneroid sphygmomanometer, and stethoscope for performing routine follow-up examinations. In addition, a one-channel recorder and a supply of medical oxygen with regulator and mask would be provided. Emergency drugs would be included, as would storage space for prescribed maintenance medication to be administered to patients with well-controlled chronic diseases. A supply of dressings also would be provided.

The primary technology which makes such a scheme possible is communications. At this time, three primary modes are being considered:

1. Voice/Data (V/D), which provides voice communications, a data link (up to 7.2 kilobits per second), and a facsimile service.

2. Dispatcher voice (D), which provides the means for communicating with moving vehicles.

3. Television (TV), which will be used to transmit visual information.

Much planning is going into requirements in each of these areas.

One other key technology, information processing, employed in this conceptual system, saves time, permits ready access to and review of medical records, acquires a data base to facilitate development of health care statistics and the data required to evaluate the performance of the system.

The data management system focuses on data entry, retrieval and control of data communications. In addition to processing medical records,

the system can also accomplish administrative functions such as billing, logistic inventorying, and scheduling.

The current planning centers about utilization of low cost mini-computer preprocessing, low bit rate transmissions (to utilize the capability of existing voice lines), provision of redundancy without excessive cost, maximum utilization of existing software, and flexible low cost multiple access, interactive terminals, and microfilm technology to meet medical, legal, and administrative requirements. The information processing capabilities of each element of the system is shown in Figure 6.

The level of health care available from the described Area Health Services Field Unit far exceeds that available to most persons in rural or remote areas and that available to many of those in urban slums. To accomplish this level of care, however, the Field Unit must be capable of performing a wide range of services from screening health examinations and preventive medicine to prompt and efficient care of emergencies. The basic application of the described system is to provide a service where none now exists, thereby increasing the productivity of the health care delivery service.

There are a number of real and potential problems which may evolve from employing any such system.

1. Cost. Obviously, this system requires a fair amount of new equipment being brought to bear in the medical area. Much of this equipment is costly and one of the prime purposes in conducting a trial would be to

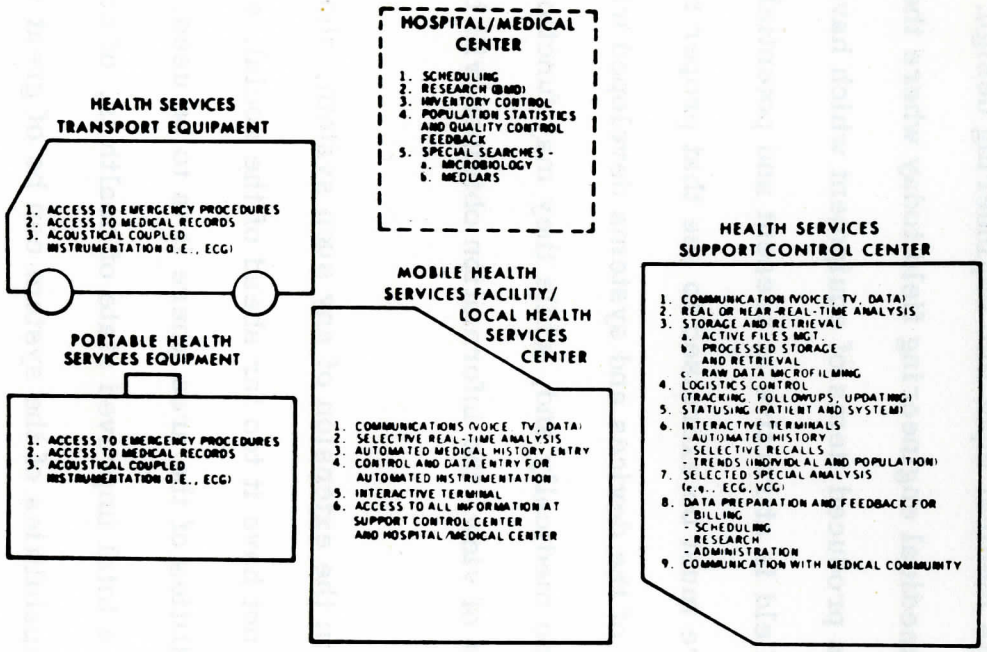
HOSPITAL/MEDICAL CENTER
1. SCHEDULING
2. RESEARCH (BMD)
3. INVENTORY CONTROL
4. POPULATION STATISTICS AND QUALITY CONTROL FEEDBACK
5. SPECIAL SEARCHES -
a. MICROBIOLOGY
b. MEDLARS
HEALTH SERVICES TRANSPORT EQUIPMENT
1. ACCESS TO EMERGENCY PROCEDURES
2. ACCESS TO MEDICAL RECORDS
3. ACOUSTICAL COUPLED INSTRUMENTATION (I.E., ECG)
MOBILE HEALTH SERVICES FACILITY/ LOCAL HEALTH SERVICES CENTER
1. COMMUNICATIONS (VOICE, TV, DATA)
2. SELECTIVE REAL-TIME ANALYSIS
3. AUTOMATED MEDICAL HISTORY ENTRY
4. CONTROL AND DATA ENTRY FOR AUTOMATED INSTRUMENTATION
5. INTERACTIVE TERMINAL
6. ACCESS TO ALL INFORMATION AT SUPPORT CONTROL CENTER AND HOSPITAL/MEDICAL CENTER
HEALTH SERVICES SUPPORT CONTROL CENTER
1. COMMUNICATION (VOICE, TV, DATA)
2. REAL OR NEAR-REAL-TIME ANALYSIS
3. STORAGE AND RETRIEVAL
a. ACTIVE FILES MGT.
b. PROCESSED STORAGE AND RETRIEVAL
c. RAW DATA MICROFILMING
4. LOGISTICS CONTROL (TRACKING, FOLLOWUPS, UPDATING)
5. STATUSING (PATIENT AND SYSTEM)
6. INTERACTIVE TERMINALS
- AUTOMATED HISTORY
- SELECTIVE RECALLS
- TRENDS (INDIVIDUAL AND POPULATION)
7. SELECTED SPECIAL ANALYSIS (e.g., ECG, VCG)
8. DATA PREPARATION AND FEEDBACK FOR
- BILLING
- SCHEDULING
- RESEARCH
- ADMINISTRATION
9. COMMUNICATION WITH MEDICAL COMMUNITY
PORTABLE HEALTH SERVICES EQUIPMENT
1. ACCESS TO EMERGENCY PROCEDURES
2. ACCESS TO MEDICAL RECORDS
3. ACOUSTICAL COUPLED INSTRUMENTATION (I.E., ECG)

Figure 6.

determine more accurate cost effective figures for such a system. The regional use of such equipment may certainly render it more cost effective. I think it would be premature at this time to try and ascribe these costs.

2. The need for adequate medical input into engineering design. There are many examples in the biomedical engineering field today where the rapid blossoming of this activity has produced items of equipment which have had only engineering input. The field is attractive at present and potentially economically rewarding. Care must be exercised to see that proper medical input occurs, otherwise many of the devices and systems developed will not do what they are supposed to do medically and, while they may function perfectly from an electronic point of view, the information obtained will be valueless.

3. Care must be taken in the extension of any such system, should it prove feasible in the trial, to not have it too far ahead of the social, economic, and educational capabilities of the area where it is to be used. Anything it may do to help create a total improved state of health is, of course, excellent. The educational capabilities of the system can be of great value in this regard. Contrasts with people in oxcarts and modern satellite communications and medicine are not always bad, for the use of such systems may help the individual to get rid of his oxcart. Indeed, I personally feel that the underdeveloped countries with areas of no medical care at all probably need systems of this sort even worse than portions of our own country.

We must also be careful in the development of such medical care systems not to repeat the cobalt facility, heart surgical facility story as it is currently being enacted by our hospitals, each trying to keep up with the Joneses. The systems must be used on a regional basis.

4. Perhaps the most important problem to be faced is the change that must take place in the medical care system if technology is truly to work to improve the health status of our own or any other country. Both the providers and the consumers of medical care and the ancillary services contributing to health must be willing to effect this change. Many speakers have correctly noted this to be so. I thoroughly agree that it does require a change in attitude and behavior on the part of both provider and consumer. Technology is merely a tool much like X-ray is a tool and should be added to the physician and health care team's armamentarium in exactly that manner. As with any tool, the provider of care must want to use it and the consumer must understand that use and that it does him good at reasonable cost. The physician's attitude probably must change most in this regard for he must become an effective part of a team and, I think, the manager of that team. His attitude must change and he must be directly involved as team leader and function properly to control the system. I would add here that if this attitude change does not occur and the physician does not take his proper place as the team leader in this effort, the change in medical care probably will occur in some undesirable manner without him.

5. Some thought must be given to the possibility that such a system would end up increasing patient loads in some areas as patients are identified on the basis of good examinations in the local units. This may possibly balance out by those individuals who could be handled by paramedical personnel and not have to go further in the system.

6. One of the more long-term problems involved in any good preventive medicine activity is the hope that it results in a longer life for the persons involved. Much has been said about the possibilities of longer life, which seems like a desirable goal. I personally feel very strongly that this is a desirable goal if you add life to years and not merely add years to life. The latter may be very unproductive for the individual and for society as a whole.

7. The other long-range problem is the possibility of increased population. Obviously, this is a possible result of any good preventive medical program but preventive medical programs should be designed to make this problem clear through the educational process and to try and handle it with birth control. This is at least a more positive rather than a negative result of medical efforts and I feel that the population problem is one that is amenable to solution.

Lastly, I would like to discuss the probable impact of this type of technology on health care as we look at the 1980s.

1. I am sure that efforts will be exerted during the remaining years of this decade to develop trial systems of the type I have described. I believe

that we will continue to see more of these demonstrations, improved by experiences with the first and that such systems will gradually spread into wider use in our own country and in other countries about the world. I think this is possible in the 1980s but it will require item 2 to occur.

2. The changes to the system implied for both the providers and the consumers must be understood and accepted. This is the hardest part to predict as I think other speakers have noted. Some have been pessimistic and few optimistic. I have great faith in people when they are given adequate knowledge upon which to decide and I tend to be optimistic in regard to what can be accomplished in this change. It may be delayed by various social and economic pressures but I think we will see government support to try and make the changes occur. I would like to emphasize that I feel the prime point that must be made clear in looking at the use of technology in medical care is the fact that it does not have to take away the consideration of the patient as a whole and as an individual. The importantly needed humaness of medicine which is difficult to describe but has, at times, been labeled a doctor-patient relationship, can also be adequately maintained. I too agree that this term has been very badly handled and frequently maligned. Nonetheless, as a physician, I know it exists and is vital to good medical care. It must be expanded to a relation between the health team and the patient, with care and understanding for the individual in the same manner. Technology will not take that away! Indeed, it will give time for it to occur and, and at

the same time, give the health team the needed information to be more beneficial to the patient in a shorter time period.

3. The 1980s should see better entry into the health care system through the use of multiphasic screening and some of the Local Health Care Centers as outlined. Education of the public as consumers of medical care will occur and lead to more equality of care.

4. There will be an elevation of the overall standards in medical care and a general increase in excellence of the care provided. The technology utilized will provide more accuracy and more rapid information to the physician and health care team. This will provide for more scientific diagnoses and more scientific determination of proper follow-up care in such patients as post-coronaries, hypertensives, etc. These techniques cannot help but give the patient more information about his illness and thus better understanding of it, leading to increases in preventive medicine activity.

5. Medical records and their availability to the health team that needs them will improve. Eventually, worldwide systems of communication that will allow storage and retrieval of medical records will occur and proper safeguarding of these records will be managed. I doubt that this will come about in the 1980s but steps will be made toward this end.

6. All of the above has implied that we will see development of health care teams and a move toward the physician becoming a medical manager of a very effective health care team. This team will undoubtedly include engineers.

In conclusion, I remain very optimistic about man's interest and desire to better his life. One of the ways he may do this is to help in bettering his health status. I believe he will in the 1980s and that technology will be his handmaiden in this regard.