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PREFACE

This report covers the medically related activities of the NASA Application Team Program at the Research Triangle Institute between August 23, 1971, and August 31, 1972, performed in accomplishing NASA Contract NASW-2273. This work was performed in the Center for Technology Applications of the Research Triangle Institute under the technical direction of Dr. J. N. Brown, Director. Full-time members of the Team who participated in the project are Dr. F. T. Wooten, Director of the Application Team; Mr. Ernest Harrison, Jr.; Mr. E. W. Page; Mr. R. W. Scearce; and Ms. Joyce Rubens. Assistance from other members of the RTI staff was obtained as needed.

Medical consultants who contributed significantly to the project are Dr. E. A. Johnson, Duke University Medical Center, Durham, North Carolina; Dr. George S. Malindzak, Jr., Bowman Gray School of Medicine, Wake Forest University, Winston-Salem, North Carolina; Mr. William Z. Penland, National Cancer Institute, Bethesda, Maryland; and Professor Hal C. Becker, Tulane University School of Medicine, New Orleans, Louisiana.

For the convenience of the reader, the names and addresses of the sources of commercial products are included in this report. This listing does not constitute an endorsement by either the National Aeronautics and Space Administration or the Research Triangle Institute.

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ABSTRACT

This report presents the results of the medically related activities of the NASA Application Team Program at the Research Triangle Institute. This experimental program in technology application was supported by NASA Contract No. NASW-2273 for the reporting period August 23, 1971, to August 31, 1972. The RTI Team is a multidisciplinary team of scientists and engineers acting as an information and technology interface between NASA and individuals, institutions, and agencies involved in biomedical research and clinical medicine. During the reporting period, participants in the Application Team Program included Dr. J. N. Brown, Jr., Electrical Engineer; Dr. F. T. Wooten, Electrical Engineer; Mr. Ernest Harrison, Materials Scientist; Mr. E. W. Page, Electrical Engineer; Mr. R. W. Scearce, Biomedical Engineer; and Ms. Joyce Rubens, Research Assistant. In addition, the Team draws upon the capabilities of other members of the RTI staff as needed.

Fourteen medical organizations are presently participating in the RTI Application Team Program: Bowman Gray School of Medicine, Wake Forest University, Winston-Salem, North Carolina; Duke University Medical Center, Durham, North Carolina; Emory University School of Medicine, Atlanta, Georgia; Institute of Rehabilitation Medicine, New York University, New York, New York; Medical University of South Carolina, Charleston, South Carolina; National Cancer Institute, Bethesda, Maryland; National Heart and Lung Institute, Bethesda, Maryland; National Institute of Environmental Health Sciences, Research Triangle Park, North Carolina; Ochsner Clinic and Foundation, New Orleans, Louisiana; Tulane University School of Medicine, New Orleans, Louisiana; University of Miami School of Medicine, Miami, Florida; University of North Carolina Dental School and Dental Research Center, Chapel Hill, North Carolina; University of North Carolina School of Medicine, Chapel Hill, North Carolina; and Virginia Department of Vocational Rehabilitation, Fishersville, Virginia.

The accomplishments of the Research Triangle Institute Application Team during the reporting period are as follows: The Team has identified 44 new problems for investigation, has accomplished 8 technology applications and 8 potential technology applications, has closed 88 old problems, and reactivated 3 old problems, and on August 31, 1972, has a total of 57 problems under active investigation.

1.0 PROGRAM PHILOSOPHY AND METHODOLOGY

1.1 Introductory Comments

The National Aeronautics and Space Administration (NASA) has been a leader and innovator in the establishment, operation, and assessment of technology transfer programs since that agency was established by the Space Act of 1958. Through its Tech Brief, Special Publication, Technology Survey, and Regional Dissemination Center programs, NASA has been successful in transferring the results of aerospace research to an impressive number of nonaerospace applications.

In 1966, NASA established a program using an active and directed methodology. In this program, Application Teams were established under contract to the NASA Technology Utilization Office. The Application Team methodology is active in that specific problems are identified and specified through direct contact with potential users of aerospace technology. The process is directed in that teams interact only with potential users who are involved in reaching selected national goals. Three teams concentrate in the biomedical area while others work in such fields as air pollution control, water pollution control, transportation, mine safety, and law enforcement. The three teams specializing in biomedicine have been established at the following institutions:

Research Triangle Institute
Post Office Box 12194
Research Triangle Park, North Carolina 27709

Southwest Research Institute
8500 Culebra Road
San Antonio, Texas 78228

Stanford University School of Medicine
701 Welch Road
Palo Alto, California 94304

This report covers the accomplishments and activities of the Team located at the Research Triangle Institute for the period August 23, 1971, to August 31, 1972. In the remainder of Section 1.0, Team objectives and methodology are presented.

1.2 Application Team Program

The NASA Application Team Program specifically seeks to achieve the following goals:

(a) The identification of relevant aerospace technology that can solve major medical problems;

(b) The utilization of the identified technology in order to actually solve the existing medical problems; and

(c) The motivation of members of the industrial community to manufacture technology resulting from this program in order that widest possible use of the technology can be achieved.

Basically, the Team acts as an active interface between medical investigators and the body of scientific and technical knowledge that has resulted from this nation's aerospace research program. The Team attempts to carefully define the technological problems facing the medical community and to identify the relevant aerospace technology that can solve those problems. The problems are those being encountered in medical research programs in major medical schools and in the National Institutes of Health. The Team actively engages in the identification of these problems through direct contacts with the medical research staffs; the identification and specification of the medical problems is then followed by search for technology that can be utilized in solution of the problem.

Generally, technology relevant to specific problems is identified through three approaches: (1) manual and computer searching of the aerospace information bank created by NASA as part of its R&D effort, (2) direct contact with the engineering and scientific staff at NASA Field Centers, and (3) circulation of concise problem statements to a large number of NASA scientists and engineers. Technology representing potential solutions to problems is channeled through the Team to the problem originator for evaluation and implementation as a solution to his problem. Alternatively, and with increasing frequency, the Team establishes a contact between the problem originator and NASA Field Center personnel, and the transfer of information between NASA and the medical field becomes more direct.

Assistance to the problem originator in implementing solutions to problems is an important part of the Application Team Program. This assistance may take any one of a number of different forms. Direct assistance to the problem originator in his efforts to implement a solution is frequently involved. During this reporting period, NASA's

Technology Utilization Division has utilized reengineering or adaptive engineering facilities of various NASA centers in those cases where feasibility had to be demonstrated. The Teams are responsible for identifying the NASA technology that is potentially a solution to a specific problem and for specifying the changes required in this technology. The adaptive engineering activity allows the Teams to demonstrate that the technology is in fact a solution to the problem and allows the problem originator to make use of the NASA technology in his research that might otherwise be impossible.

The successful transfer of information on aerospace technology to an individual or group in the medical field followed by successful implementation of the technology with resulting benefits to the accomplishment of some medical objective is called a "technology application." Also included in the definition of technology application is the constraint that the medical application and objective involved in the technology application be different from the aerospace application and objective for which the technology was originally developed. Thus, the accomplishment of technology applications is indeed a difficult and long-term objective. This objective should be distinguished from that involved in a program to enhance the diffusion or broad utilization of demonstrated applications of technology. The transfer of technology involves crossing what may be thought of as an "application or objective barrier," and it involves complete evaluation of the new application; diffusion involves neither of these requirements.

A specific methodology is applied by the Team in its efforts to effect applications of aerospace-related technology. This methodology is discussed in the following section.

1.3 Methodology

The methodology used by the Team consists of five basic steps: problem definition, identification of relevant technology, evaluation of relevant technology, utilization of technology, and documentation. This methodology can be better understood, however, if it is separated into the steps shown in Figure 1. These steps are described in the following paragraphs.

Problem Screening - Effective problem screening is at least as important to the success of the Application Team Program as any of the operational steps identified in Figure 1. Analysis of the RTI Team's accomplishments in the early days of the program indicates clearly that a very significant fraction of the problems that were investigated unsuccessfully could have been rejected very early in discussions with problem originators. Problem selection criteria have since been developed with the objective being to increase the probability that a technology application can be accomplished for those problems accepted by the Team. At the present the following criteria are being applied:

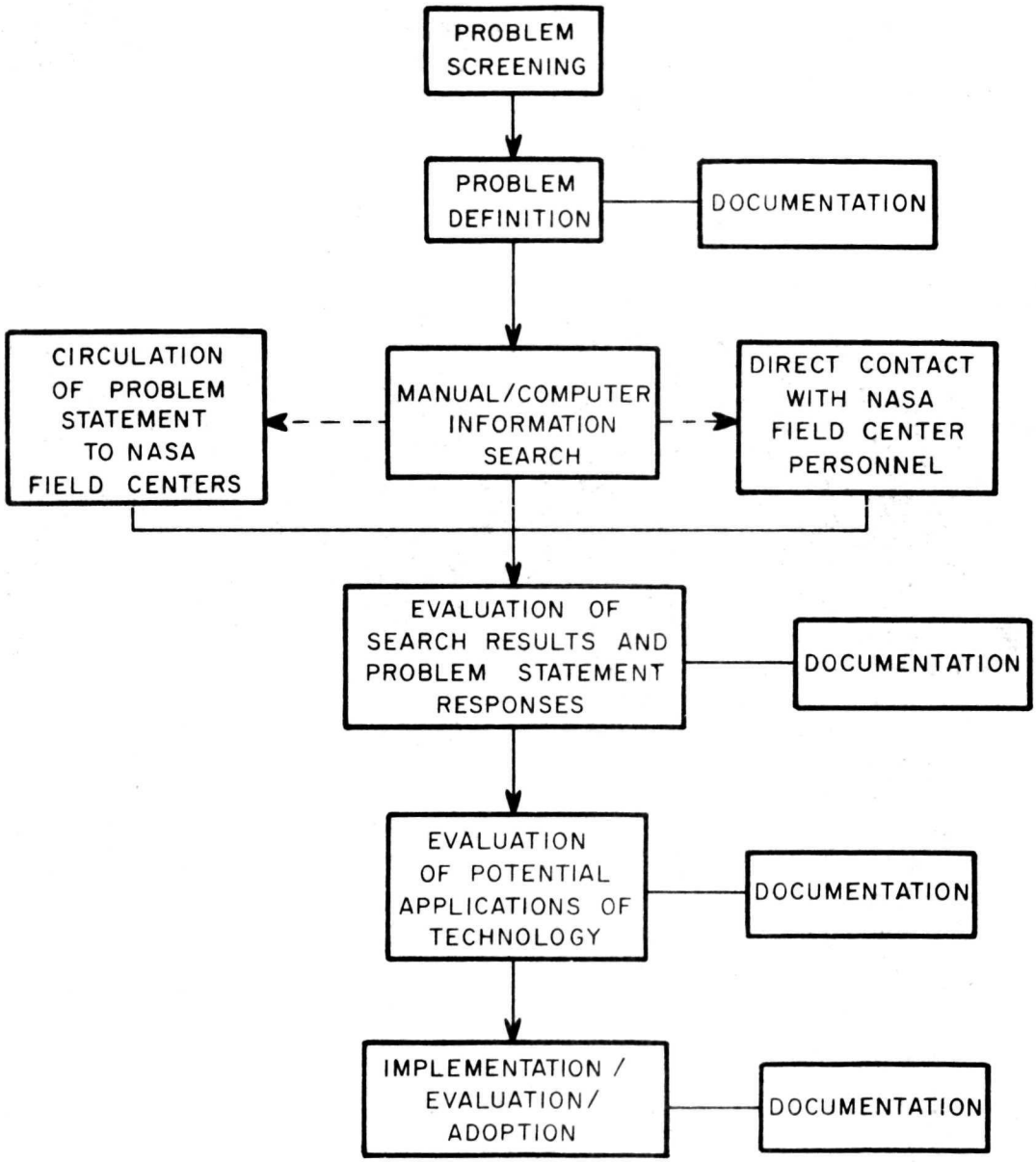

Figure 1. Flow Chart of Application Team Transfer Methodology.

(a) Solving the problem would enhance medical diagnosis, treatment, or patient care to the extent that implementation and adoption would be rapid.

OR

(b) The problem has been encountered in an ongoing research program and is impeding progress of that program.

OR

(c) Either some unique characteristics of the problem or the problem originator indicates that investigating the problem will enhance the overall Team program.

AND

(d) Solving the problem is given high priority by the problem originator.

AND

(e) The problem is one of *at most* two being investigated with an individual problem originator. (This is violated only in the case of large group efforts.)

Problems that do not satisfy these criteria are rejected. Problems may also be rejected following partial completion of the next step, problem definition.

Problem Definition - The objective of this step is to define precisely and accurately the characteristics of the technology required to solve a problem. In many cases, following the characterization of required technology, it is found that the problem should be rejected or closed for any of a number of reasons. These reasons include, as examples, the following: (1) the problem can be solved using commercially available equipment; (2) the problem cannot be solved, so that an entirely different approach is indicated; (3) the real problem is medical and not technical in nature; and (4) the requirements cannot be specified because insufficient information exists on the objective involved.

The end result of problem definition is the preparation of a problem statement. This statement, to be complete, must contain (1) a complete characterization of what is required to solve the problem, and (2) the related medical problem or objective and the benefits to be realized by solving the problem.

Identification of Relevant Aerospace Technology - Aerospace technology that may be relevant to the solution of a problem is identified by

three approaches. First, a manual or computer search is made of the aerospace information bank. These searches are made at one of NASA's six Regional Dissemination Centers (RDC). The RDC used by the RTI Team is the North Carolina Science and Technology Research Center (NCSTRC) located in Research Triangle Park, North Carolina. In addition, searches are made utilizing the NASA Scientific and Technical Information Facility in College Park, Maryland. The information that can be assessed through the information bank consists of approximately 700,000 documents, articles, and translations that have been abstracted in the Scientific and Technical Aerospace Reports (STAR) and the International Aerospace Abstracts (IAA). Second, the Team contacts individuals at the Field Centers directly without circulating problem statements. This is done when a Team member can identify a relatively few individuals at the Field Centers who are likely to have a good overview of all work being done that is related to the requirements of a specific problem. Third, problem statements are circulated to engineers and scientists at NASA Field Centers who may be able to identify relevant technology and suggest possible solutions to problems. These statements are circulated in a highly selective manner with the distribution being determined by the Team, Technology Utilization Officers (TUO) at the NASA Field Centers, and other individuals at the Field Centers.

Evaluation - All potentially relevant technology identified in the preceding step is evaluated by the Team to determine whether a potential solution to a specific problem has been found. Those items of technology that represent potential solutions to problems are presented to problem originators along with available supporting data and information. Any required reengineering and details of implementing the potential solutions are discussed with the problem originator.

The problem originator must then evaluate potential solutions. His decision to implement a proposed solution will depend upon a number of factors: (1) his assessment of the validity of the proposed potential solution, (2) the cost of implementing the potential solution, (3) the potential benefits to be gained, etc. The Team may be asked to supply additional information and technical details in this evaluation.

Implementation, Final Evaluation, Adoption - The final step in the technology application process is the implementation and the experimental evaluation of potential solutions. This critical phase must occur in order for a technology application to be complete. The team is available for assistance in this step when required, and attempts to identify the resources necessary to meet the implementation requirements. In many cases the actual implementation can be carried out by the problem originator and his staff. In some cases, however, skills not immediately available to the problem originator are required for implementation and, in these cases, some other resource is utilized. This may require the use of a NASA capability at one of the Field Centers or at a NASA contractor. In other cases the implementation may be carried out by an industrial concern under contract to the problem originator. In general, the team attempts to determine the most appropriate means of implementation and to make recommendations to the problem originator as required.

Documentation - Documentation is an integral part of the Team methodology; it is involved at most steps in the process, as indicated in Figure 1. Documentation allows analysis of the technology application process and assessment of the program in general. At present, the Teams report on a weekly, monthly, and semiannual schedule. Effective communication is required between Teams, potential problem originators, and other individuals who are in a position to make use of information resulting from technology applications accomplished by the Teams.

1.4 Application Team Composition and Participating Medical Institutions

The RTI Team is a multidisciplinary group of engineers and scientists. The educational backgrounds of the group are in physics and electrical engineering; their experience includes industry, education, and research at both basic and applied levels. The individuals who have participated in the Application Team Program during this reporting period are:

Name	*Background*	*Responsibility*
Dr. J. N. Brown, Jr.	Electrical Engineer	Laboratory Supervisor
Dr. F. T. Wooten	Electrical Engineer	Team Director
Mr. E. Harrison, Jr.	Materials Scientist	Solution Specialist
Mr. E. W. Page	Electrical Engineer	Solution Specialist
Mr. R. W. Scearce	Biomedical Engineer	Solution Specialist
Ms. Joyce Rubens	Research Assistant	Documentation

The experience and special capabilities of other individuals at RTI--particularly in the Engineering and Environmental Sciences Division -- are frequently used as needed in the Application Team Program.

At present, 14 medical institutions are participating in the RTI Application Team Program. These institutions are as follows:

Bowman Gray School of Medicine, Wake Forest University, Winston-Salem, North Carolina;

Duke University Medical Center, Durham, North Carolina; (Including Veterans Administration Hospital, Durham, North Carolina);

Emory University School of Medicine, Atlanta, Georgia;

Institute of Rehabilitation Medicine, New York University, New York, New York;

Medical University of South Carolina, Charleston, South Carolina;

National Cancer Institute, Bethesda, Maryland;

National Heart and Lung Institute, Bethesda, Maryland;

National Institute of Environmental Health Sciences, Research Triangle Park, North Carolina;

Ochsner Clinic and Foundation, New Orleans, Louisiana;

Tulane University School of Medicine, New Orleans, Louisiana;

University of Miami School of Medicine, Miami, Florida; (Including Veterans Administration Hospital, Miami, Florida);

University of North Carolina Dental School and Dental Research Center, Chapel Hill, North Carolina;

University of North Carolina School of Medicine, Chapel Hill, North Carolina;

Virginia Department of Vocational Rehabilitation, Fishersville, Virginia.

Figure 2 shows the geographical distribution of the RTI Application Team user institutions as well as the location of the major NASA resources.

The RTI Team is assisted at various stages of the technology application process by consultants who are on the medical staffs at participating institutions. These consultants or communicators coordinate Team activities at their institutions and assist Team members primarily in problem definition and evaluation of potential solutions. At present, the following individuals are consultants to the RTI Team:

Name	*Specialty*
Dr. E. A. Johnson Duke University Medical Center	Cardiac Physiology
Dr. George S. Malindzak, Jr. Bowman Gray School of Medicine, Wake Forest University	Physiology
Professor Hal C. Becker Tulane University School of Medicine	Radiology
Mr. William Z. Penland National Cancer Institute	Engineering

Problems at each institution are coded by a letter and number symbol (e.g., DU-49); the coding for each institution or special problem area is as follows:

CP - Computer software-type problem
DU - Duke University Medical Center
EU - Emory University School of Medicine
IRM - Institute of Rehabilitation Medicine, New York University
MISC - Miscellaneous
MUSC - Medical University of South Carolina
NCI - National Cancer Institute

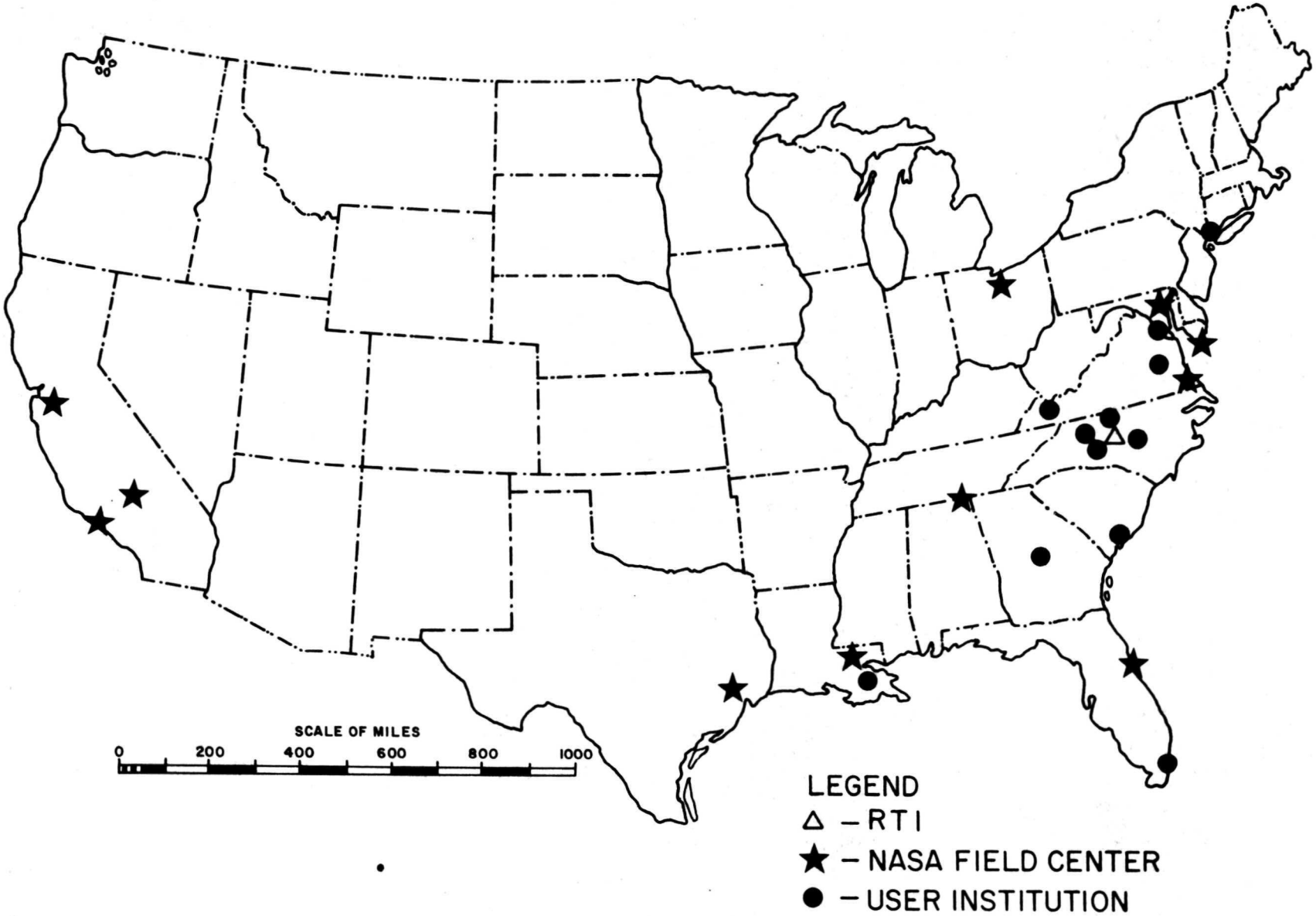

Figure 3. Team Activity Centers in the United States.

NEHSC - National Institute of Environmental Health Sciences
NHLI - National Heart and Lung Institute
NIMH - National Institute of Mental Health
OF - Ochsner Clinic and Foundation
TU - Tulane University School of Medicine
UNC - University of North Carolina School of Medicine
UNCD - University of North Carolina Dental School and Dental Research Center
VAM - University of Miami School of Medicine
WF - Bowman Gray School of Medicine, Wake Forest University

1.5 Definition of Terms

In the Application Team Program, a number of terms have evolved that describe the elements and processes in this program. Because of their number and unfamiliarity to many readers, these terms are listed and defined in this section for reference.

Problem Originator or Researcher - An individual actively involved in an effort to reach a specific objective in biology or medicine and faced with a specific technological problem that is impeding progress toward that objective.

Participating Institution - A medically oriented educational institution, hospital, medical center, or government agency having as one of its organization objectives the improvement of medical health care.

Consultant - A member of the biomedical staff at a participating user institution who has committed a portion of his activities to assist the Team in identifying appropriate problem originators at his institution, in understanding and specifying problems in biology and medicine, and in evaluating technological solutions to problems.

Application Team (Team) - A multidisciplinary group of engineers and scientists engaged in problem-solving activities in medicine with the specific objective of effecting the transfer of aerospace technology to solve problems in medicine. The methodology used by the Team involves (1) problem selection, definition, and specification; (2) identification of potential solutions to problems by manual and computer information searching, circulation of problem statements to NASA Field Centers, and contacts with NASA engineers and scientists; (3) evaluation of potential solutions; (4) implementation and adoption by problem originators of aerospace technology as solutions or partial solutions to medical problems; and (5) documentation.

Problem - A specific and definable technological requirement that cannot be satisfied by commercially available equipment or by application of information available to the problem originator through routinely used information channels.

Technology Application - This is the implementation and adoption of aerospace technology that solves a problem in biology or medicine. The medical application involved is one that is different from that application for which the aerospace technology was originally developed.

Problem Statement - This is a concise, written statement of a problem used for communicating (1) sufficient details to allow a computer search to be performed by the information search specialists, and (2) sufficient information to enable NASA engineers and scientists to consider possible solutions to the problem.

Computer Information Search - This is a computerized information search of the aerospace information bank established by NASA and made available through six Regional Dissemination Centers in the United States. This information bank consists of the approximately 700,000 documents that have been indexed and abstracted in the Scientific and Technical Aerospace Reports (STAR) and International Aerospace Abstracts (IAA).

Impact - Information is given to a problem originator with the result that he changes his activities in a way that enhances his progress toward a medical objective. An impact is thus analogous to a technology application except that one or more of the requirements for a technology application are not satisfied.

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2.0 TECHNOLOGY APPLICATIONS, POTENTIAL TECHNOLOGY APPLICATIONS, AND IMPACTS

2.1 Technology Applications

During the reporting period, eight applications of aerospace technology were accomplished and are discussed in the following summaries:

PROBLEM WWRC-14 *An Improved Axillary Strap*

A material developed for use in spacecraft cushions has been used to improve a widely used arm prosthesis.

Commonly used upper extremity prostheses employ a cabling arrangement to operate the hook that achieves pinch, thus permitting items to be grasped and transported. In operation, the cable is passed across the back of the patient, then around the arm near the shoulder joint so that, by flexing the shoulder muscles, the cable can be pulled, causing the hook to close. Usually, a saddle-type arrangement to which the cable is attached is used around the arm at the shoulder. It is not infrequently constructed of canvas to which padding has been added. Unfortunately, when the wearer of the prosthesis flexes his shoulders to achieve pinch on the prosthetic hand, the saddle tends to roll up or curl up until it actually resembles a rope, causing concentration of all force being exerted by the shoulder and arm on a very small area. This frequently results in tender spots caused by the excess pressure being exerted and reduces the effectiveness of the patient in operating his prosthesis. Basically, a means of distributing the force exerted on the axillary strap over a larger surface area is desired in order to reduce the force per square unit of area on the arm and shoulder. In order to be economically feasible, the strap must essentially be a universal device that can be applied to any patient requiring an upper extremity prosthesis. This means that individually fitted straps that might be contoured to the patient's arm or shoulder would not be acceptable. This strap must be capable of being used by a large number of people.

The NASA-developed polyurethane foam material (Temperfoam by Dynamic Systems, Route 2, Leicester, N. C.) proposed by Ames Research Center was felt to offer the possibility of solving this particular problem. (See Figure 3). The foam is a special material that has some unique characteristics. It absorbs energy, which would make it attractive in this application because cushioning and spreading of the force exerted by the shoulder is considered to be the primary means whereby this problem can be solved. The material will mold to the form of the body with which it is in contact. Because of its thermal characteristics, the material, when used in a shoulder strap such as this,

would conform to the body and with the application of pressure would deform to yield uniform pressure across the pad rather than concentrating the pressure, which is the source of the problem. A sample of the material was obtained for the medical researcher who then initiated an evaluation program. Evaluation has proved that this material is better than anything previously tested in preventing soreness caused by the axillary strap.

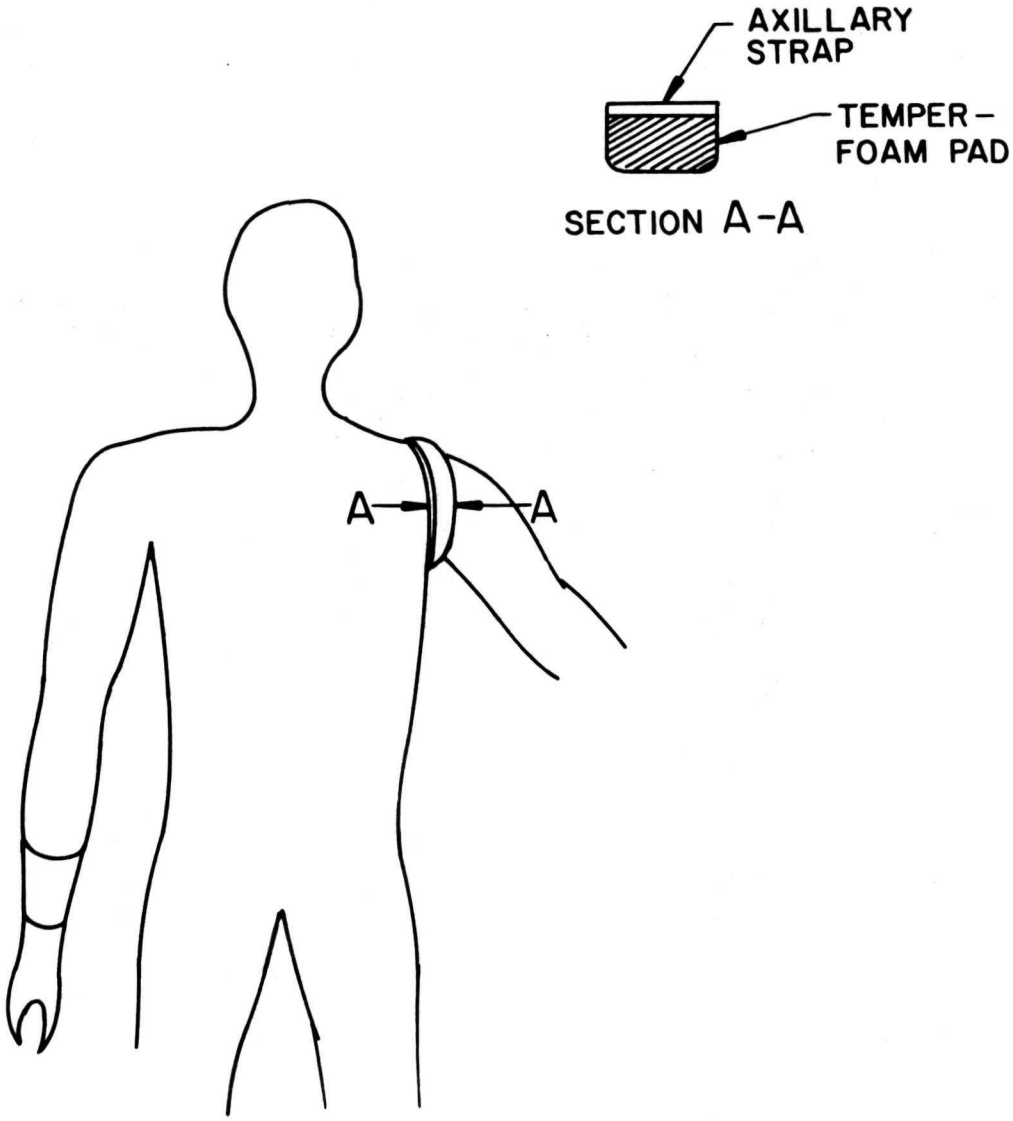

Figure 3. Axillary Strap Pad.

PROBLEM WF-103 *Liquid Crystal Sterilization*

The kidney is supplied with blood by the renal artery, which consists of at least two major branches, a larger anterior and a smaller posterior. The former supplies the anterior part of the kidney exclusively, and the latter supplies the posterior part exclusively. Consequently, a line exists, called Broedel's line, which passes between the two main arterial divisions in which there are no large blood vessels. When it is necessary to open the kidney surgically, it is desirable to make the incision along this line for obvious reasons. It is difficult to locate the boundary line between the various regions visually, however. The researcher raised the question of the applicability of liquid crystals to determine these boundaries. Samples of encapsulated liquid crystals were obtained by the researcher from a commercial supplier and from Marshall Space Flight Center (MSFC). Tests were made on dogs, and the researcher reported that the liquid crystal films were very effective in establishing these boundaries. It is now necessary to establish methods for sterilization of the liquid crystal films before they can be used in procedures. The Team has been requested to assist the researcher in determining a suitable sterilant for the liquid crystal films that will not impair their effectiveness.

The Team contacted MSFC with respect to this problem since MSFC has been active in using liquid crystals for nondestructive testing purposes. The medical researcher was placed in contact with personnel at MSFC, and the overall problem was discussed. The encapsulated liquid crystals developed for MSFC's use under NASA contract were considered to be an ideal solution to this particular problem. Mr. Juan Pizarro of the Technology Utilization Office at MSFC obtained a variety of liquid crystal materials in encapsulated form. Also, personnel at MSFC who had experience in working with liquid crystals were consulted concerning the best means of sterilizing the encapsulated liquid crystals. Gas sterilization was suggested by the researchers at MSFC. Evaluation proved this to be the best solution to the sterilization problem. The liquid crystal material obtained from MSFC was used by the researcher in several animal experiments to perform surgery on the kidney of dogs. The results of these tests indicated that the technique was very effective.

The tests were performed in the following manner. The kidney of the dog was surgically exposed and then one of the arteries leading to the kidney was ligated. Then the kidney was placed in a cooling bath. Upon removal from the cooling bath, the artery not ligated furnished blood to the kidney, heating that portion of the kidney. The researcher was then able, using small strips of liquid cystals, to trace out the line of demarkation between the two arterial supplies. (See Figure 4). The juncture between the light and dark areas of the liquid crystal strips indicates the location of Broedel's line. This permitted incision into the kidney to be made without severing any major arteries.

Figure 4. Liquid Crystal on Canine Kidney.

The advice on sterilization and the encapsulated liquid crystals supplied by MSFC was vital in the accomplishment of this transfer. The researcher is currently discussing, with Hoffman-LaRoche Inc., Cranburg, N. J., the possibility of obtaining prepackaged sterile liquid crystal strips for general use in this surgical application.

PROBLEM OF-1 *Blood Embolism Detection*

Blood flow measurement techniques developed by Ames Research Center have solved a problem in open heart surgery. The last decade has shown a dramatic increase in the use of open heart surgery as a tool for correction of heart defects. Many of these defects, such as valvular disorders, septal defects, shunts, patent ductus, and tetralogy of Fallot, can be corrected by open heart surgery. When the heart is opened, a heart-lung machine must be used to provide the pumping action of the heart and oxygenation of the blood supply. Many specialists feel that the weakest link in the machine is the oxygenator--one of the difficulties being the production of gas embolism, which can stop blood circulation if they become lodged in a small artery. In addition, surgery can break loose small particles, which can stop blood circulation. It has been estimated that, at present, 20 percent of open heart surgery cases result in a neurological deficiency (reduction of blood flow to the brain); thus, a means of detecting the embolism as it occurs is vital for successful open heart surgery.

For years, various types of oxygenators have been used with those presently used being divided into three categories: film, bubble, and membrane. The film oxygenator works by providing a free flowing film of blood with turbulent flow while exposed to a screen of oxygen. The bubble oxygenator operates by introducing very small bubbles of oxygen into a container of blood. Although oxygenation is easily obtained, a significant number of embolisms result from this device. The third oxygenator is the membrane type in which the blood and oxygen are separated by a thin membrane. The basic difficulty to date with membrane oxygenators has been the inadequate amount of oxygenation for high flow rates.

In all types of oxygenators, the basic problem of embolisms is significant, even though the problem is most severe using a bubble oxygenator. Because the embolisms can be trapped in very small blood passages, it is desirable to be able to detect embolisms with sizes as small as one micrometer.

A computer search of the NASA document file was conducted and seven documents were ordered. Although these documents were of general interest, the specific solution to this problem came when the team contacted Mr. Sal Rositano of Ames Research Center, who had experience in the measurement of blood flow. Mr. Rositano advised the team that the Ames Research Center had developed an ultrasonic blood flowmeter using the Doppler technique. In this blood flow unit, developed under contract by L & M Electronics, Inc. of Daley City, California, the flow is measured by utilizing the change in frequency of an ultrasonic signal that is associated with the velocity of the liquid through which the sound is propagating. Mr. Rositano pointed out that an embolism traveling with the flowing blood would generate a loud return signal, which in the case of a flow measurement would be an error signal, but in the case of embolism detection, would be precisely the signal of interest. This information was given to the problem originator who carefully studied Mr. Rositano's idea.

The problem originator modified his existing system to incorporate a membrane oxygenator from the previously used bubble oxygenator. This significantly reduced his embolism problem and, concurrently, he installed a Doppler flowmeter and, using the technique suggested by Mr. Rositano, he was able to detect the existence of embolisms. This device is currently in clinical use at the Ochsner Clinic where the problem originator is the Chairman of the Department of Anesthesiology.

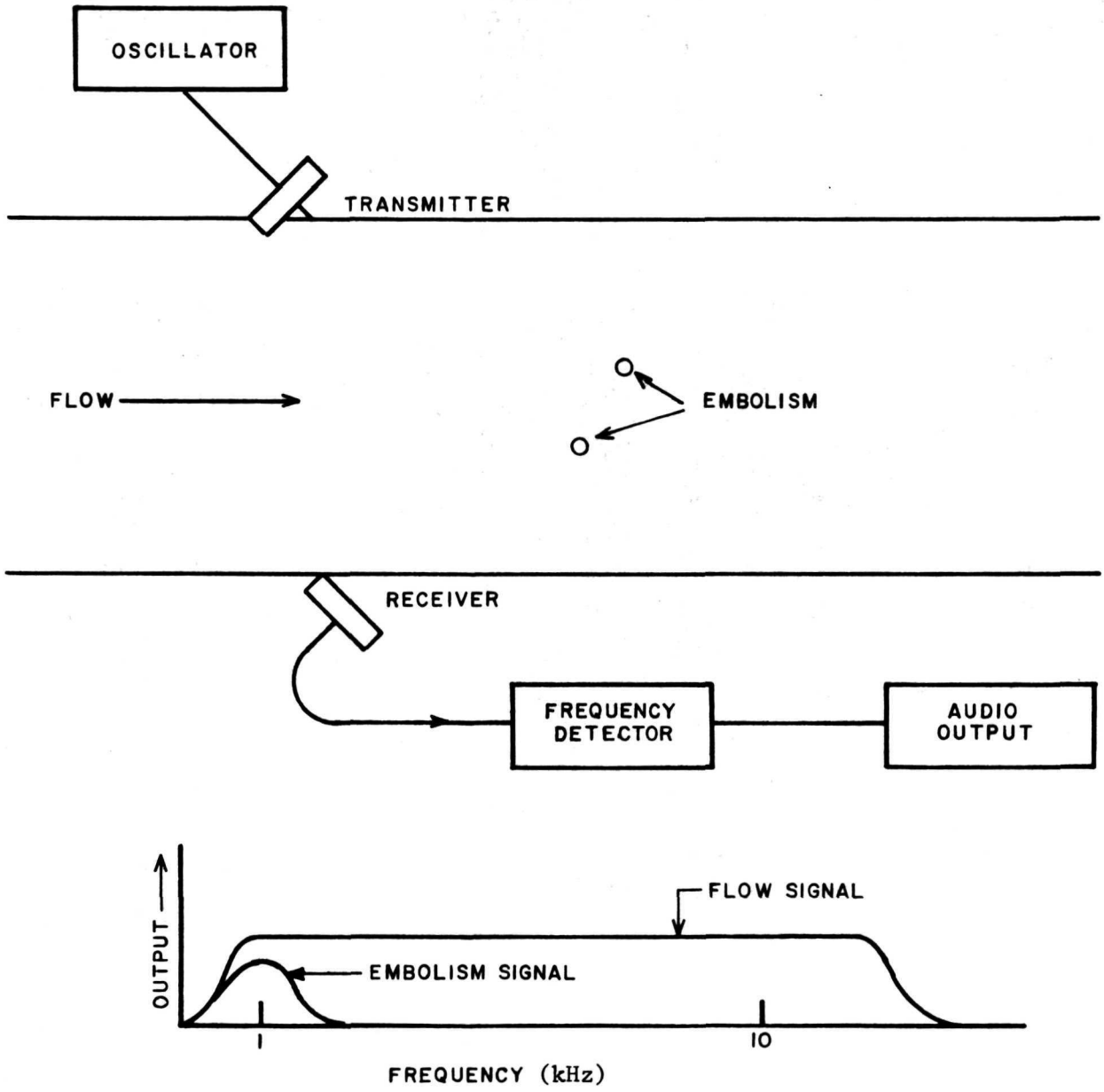

Figure 5. Doppler Detection of Embolism.

PROBLEM NCI-8 *Elliptical Lens*

An optical design computer program developed by NASA has been used to design an unusual lens necessary for basic cancer research.

In many advanced medical research studies (e.g., cancer studies), the basic unit of study is the human cell. As medical science has demanded more information on cellular activities, technology has frequently played a critical role in extracting the information from regions within each cell.

An excellent example of this fact is a study being conducted by the National Cancer Institute (NCI) in which an optical microscope is controlled by a digital computer in order to get quantitative microspectrophotometric histochemical data. This study could not be conducted otherwise because of the limitations on the human eye as a colorimeter. In addition, this same system can be used to obtain three-dimensional microarchitecture of human tissue.

Although this study has been underway for some time, a difficulty has been encountered in obtaining sufficient light intensity from the monochrometer which is focused on the specimen. The light source has been increased in intensity to the maximum possible.

One possible solution is to use an eliptical lens between the monochrometer and the specimen, which will make more effective use of the available light.

This improvement in efficiency results because an elliptical lens converts the rectangular beam of light from the monochrometer to a more circular shape and thus more of the monochrometer output is focused on the sample. The researchers have been unable to locate a commercial source for the desired lens. The National Bureau of Standards Optical Shop has indicated a willingness to grind the lens if procedures for grinding elliptical lenses can be obtained.

Two circular 60-millimeter diameter lenses are required. One lens has a focal length in the X-direction of 150 millimeters and a focal length in the Y-direction of 40 millimeters. The second lens has a focal length in the X-direction of minus 500 millimeters and a focal length in the Y-direction of 50 millimeters. The wavelength of light used varies from 220 to 700 nanometers.

A direct contact was made with Juan Pizarro at Marshall Space Flight Center who suggested a NASA-developed computer program that is used for designing complex optical systems. This program has not been used for elliptical lenses, but NASA personnel believed that the program would perform the desired design. The Fortran language program documentation and tapes were obtained from COSMIC and shipped to the researcher. The program, resulting from a study funded by the Jet Propulsion Laboratory,

was capable of designing optical systems containing up to 100 planes, conic or aspheric surfaces, seven object points, six colors, and 200 rays. The program was written in Fortran IV for use on the IBM 7094 computer.

The NCI researcher used the program in order to design the desired lenses. The National Bureau of Standards Optical Shop will grind the lenses.

The availability of the lenses will improve the ability of the NCI research team to extract detailed histochemical data from human cells. This will be used in a system for automatic microspectrophotometric analysis of biological specimens.

PROBLEM MISC-11 *Electrodes for Emergency Coronary Care*

Suggestions from an aerospace research team has contributed to the solution of an electrode problem that was critical in a dramatic new concept of emergency coronary care.

It is estimated that of the approximately 600,000 deaths that occur each year from acute heart attacks in the United States, 350,000 deaths occur before the patient reaches the hospital. This means that a number of people equivalent to the population of the State of Wyoming die each year from heart attacks before reaching a medical facility. The National Heart and Lung Institute is funding a study by Survival Technology, Inc., Bethesda, Maryland, that offers a dramatic and innovative concept to reduce this large number of deaths by bringing medical care to the patient instead of the patient to a medical care facility. The basic concept is to provide a kit that consists of a portable ECG monitor and two drugs contained in automatic injectors. The pocket-sized ECG monitor will be attached to the patient in order to determine which of the drugs is needed. This portable field package will be provided for emergency personnel such as ambulance and rescue squads, and in addition, will be provided on a prescription basis to patients with a high risk of heart attack. These patients can transmit their ECG to a physician by a telephone link and the physician can provide the necessary diagnosis.

The concept is based upon the fact that the most common cause of death due to heart attack is ventricular fibrillation, i.e., the totally uncoordinated contraction of the heart muscle, which results in an immediate cessation of the effective pumping of the heart. Ventricular fibrillation usually occurs in the period immediately after a heart attack and, at present, unless this is corrected by medical personnel using a defibrillator, the result is death. In the confines of an alert coronary care unit, mobile or otherwise, the patient can be defibrillated. If he is not attended or not defibrillated, the patient dies. Recent advances have been made in the understanding and management of ectopic beats (abnormal heart rhythms) and ventricular fibrillation involving not only defibrillation, but also the use of pharmacologic agents, or drugs to suppress or abolish ectopic beats. The concept now under study

involves a method of providing the pharmacologic agent to the patient well before he is attended by a physician in the hospital.

If a patient in the early minutes of a heart attack experiences bradycardia--a heart rate below 60 beats per minute--then the patient can be treated using the drug atropine. Bradycardia is well known to predispose to ectopic beats, which in turn, can lead to ventricular fibrillation. If the ectopic beat occurs without bradycardia, then the drug lidocaine is an effective method for supression or abolition of the ectopic beat. Lidocaine is credited for having saved the lives of two presidents of the United States as well as many thousands of other Americans who have had acute heart attacks. [The use of these two new drugs is discussed in detail in the May 1972 issue of Archives of Internal Medicine, which is published by the American Medical Association.]

Selection of the appropriate drug depends upon the rapid detection of the existence of bradycardia or ectopic beats. The small monitor used for the detection of this condition must be a highly reliable instrument that can be easily used by paramedical personnel. The electrodes must be quickly attached to the body, and the electronic detector must display by a simple mechanism the existence of either of the two dangerous conditions, or be capable of transmitting an ECG by a telephone link to a physician. Survival Technology, Inc., has developed an appropriate monitor (See Figure 6), but some difficulty was encountered with the electrodes. At the time that the problem was posed to the team, the electrodes were a weak link in the total system of detection and treatment.

Because of the Biomedical Application Team experience with two NASA field centers involved in developing electrodes, the Team contacted Mr. Maxwell Lippitt of the Manned Spacecraft Center and Mr. Sal Rositano of the Ames Research Center to discuss various techniques in their respective field centers regarding new electrode techniques. Mr. Lippitt graciously consented to supply several new rapid response-time electrode pastes for evaluation. These pastes were evaluated by the problem originator and were found to be inadequate for quick attachment by untrained personnel. The Team then obtained from Mr. Sal Rositano samples of his flexible electrodes, including those with built-in amplifiers, which are being used at Ames Research Center. The electrodes, constructed of a conducting elastomer material, are attached to the chest without a requirement for electrode paste. The problem originator evaluated these electrodes and found that, while they met many of the requirements for the problem, they required some improvement in reliability of the contact as well as improvement in ease of attachment. Hence, the problem originator modified the NASA electrodes by using a different conducting elastomer, and by placing the electrodes under the arm instead of on the chest. This new material and attachment procedure have worked with a high degree of reliability and allow a simplicity of attachment that can be utilized by inexperienced personnel.

This system is currently being studied at the following medical schools: University of Pennsylvania, Duke University, Yale University, and the University of Amsterdam. These universities have demonstrated that the basic concept of the use of these drugs is a viable concept, and the initial tests of the cardiac monitor have proven to be successful. The importance of this new concept is demonstrated by the fact that Dr. Stanley J. Sarnoff, President of Survival Technology, Inc., was invited to present the idea before the House Subcommittee on Public Health and Environment of the Committee on Interstate and Foreign Commerce on June 14, 1972, during the deliberations on a bill pertaining to emergency medical care. In this presentation, the electrocardiogram of James Symington was taken using the portable monitor and transmitted by telephone to a remote location where the electrocardiogram was analyzed. This test demonstrated that the system has high potential for a significant breakthrough in the fight against heart disease. If Food and Drug Administration approval is obtained, Survival Technology, Inc., can be producing these kits within 6 months and providing them to physicians throughout the country. The physicians will, in turn, prescribe these for patients with a high risk of heart attack. In addition, the kits can be carried by police cars, ambulances, and rescue squads. This dramatic concept may well be the step necessary to make a significant reduction in heart attack mortality in this country.

Figure 6. Portable Heart Monitor.

PROBLEM WWRC-13 *A Remotely Controlled Device to Pick Up and Transfer Single Sheets of Paper*

A NASA employee has built a device that may provide the key to employment of severely handicapped patients. This problem involves the vocational rehabilitation of severely disabled quadriplegics. The number of vocations available to such handicapped people is extremely limited. Many such patients maintain so little control of their musculature that only the basic proficiency that they can acquire is to punch pegs or to depress keys on a keyboard. The Training Division of the Woodrow Wilson Rehabilitation Center, Fisherville, Virginia, is constantly seeking vocations for which these patients can be trained. The Friden Business Machine Company has a bookkeeping machine called Add-Punch. With this machine, a bookkeeping function can be accomplished by merely entering data into the proper categories on the Add-Punch machine keyboard.

Quadriplegics can operate the machine insofar as entering the data is concerned, but generally the data is not in a form that is readily visible to them. In most instances, businesses that would employ a quadriplegic to do this sort of activity (perhaps in his home) would bring a stack of tickets to the quadriplegic for him to enter into the machine. This poses a difficulty since the quadriplegic cannot reach over and remove the tickets from the stack. Consequently, he cannot gain access to the tickets underneath the top ticket unless someone is present to transport the top ticket off the pile and into another pile as he enters the data. A simple device that can be remotely controlled by means of a single button is required to pick up or attach to the top ticket on a stack and remove that ticket to another geographic position nearby. Stacking from one tray to another is desirable, but it is not absolutely necessary that the tickets be maintained in a neat stack as they are removed. The person who delivers the tickets would be able to stack them in the tray or other device for holding the tickets in some specified position as needed by the pick-up device. Since the quadriplegic will certainly be marginal in performing even this kind of task, the cost of implementing any solution to this problem must not be so high as to make employment of a quadriplegic in this task unfeasible from an economic standpoint. A cost of $200 or less would not be considered prohibitive in this application.

A paper-transporting device (Figure 7) that could be actuated by depression of a single pushbutton was developed by Mr. George M. Dudley of the Langley Research Center. Mr. Dudley developed the unit in response to circulation of the problem statement in the Langley Research newspaper by Mr. John Samos, Technology Utilization Officer at the Langley Research Center. The solution of this problem involves a vacuum pick-up with a transport mechanism operated by an electric motor. As pointed out in the description of the problem, this machine is necessary to permit the vocational rehabilitation of home-bound quadriplegics who have the capability to use a key-type machine.

The paper-transporting unit has been evaluated by the problem originator and personnel of the Evaluation Department of the Woodrow Wilson Rehabilitation Center. As a result of these tests, it has been determined that the paper-transporting device can be effectively used by quadriplegics. Figure 8 shows quadriplegics at the Woodrow Wilson Rehabilitation Center in the process of using the paper transport device. Possession of this unit now permits the Evaluation Department at Woodrow Wilson Rehabilitation Center to proceed with plans for vocational rehabilitation of homebound handicapped persons who are otherwise qualified to carry on a key-machine operation. Such planning could not be undertaken until the feasibility of developing a paper transport device had been proven since it is a vital and indispensable component.

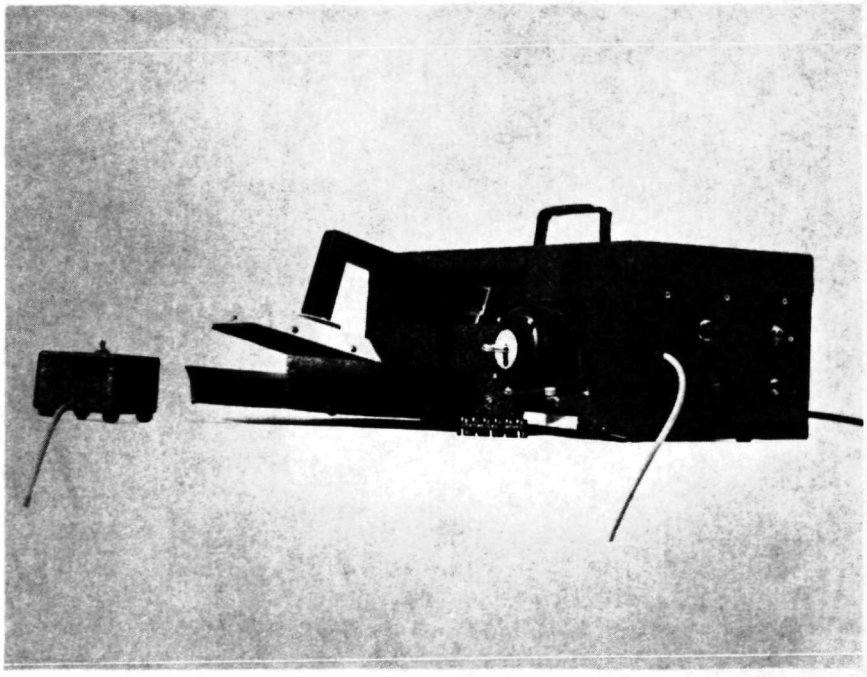

Figure 7. Paper Transport Device.

Figure 8. Paper Transport Device in Use by Paraplegic.

PROBLEM WF-56 *A Fluid Pressure Calibration System*

An aerospace system designed to calibrate pressure transducers will be employed by researchers and clinicians in their investigative and diagnostic procedures.

At many medical facilities such as the Bowman Gray School of Medicine, a large number of pressure tranducers of various manufacturers and designs are employed by investigators in their research program and by clinical personnel in the diagnosis and treatment of patients. A significant question that recurs with great frequency is, "Has my pressure transducer maintained calibration or is it now inaccurate?" Many of these transducers are inherently fragile; nonetheless they receive severe handling and are exposed to harsh environments. Consequently, the accuracy of a transducer is usually uncertain unless it is calibrated before each use. Since a calibration facility is not available at the Bowman Gray School of Medicine, no doubt many transducers are used whose accuracy is no longer within specification.

To alleviate this situation, the researcher desires to establish a calibration facility where the staff and faculty members of the Bowman Gray School of Medicine can determine the accuracy of the pressure transducers that are employed to obtain measurements in research and clinical practice.

Basically, the calibration unit would consist of a pressure wave generator, an accurate standard transducer, a pressure chamber, and appropriate manifolding. The fluid within the pressure chamber can be distilled water. Means of eliminating air bubbles in the chamber is necessary, because air bubbles seriously affect the pressure generated by the pressure transducer. The pressure generator must be capable of generating fluid pressures in the pressure chamber from near zero to approximately 1 atmosphere of pressure (760 mm Hg gage). Frequency response of the pressure generator with a given pressure output should be constant (±5 percent) over the frequency range of 1/10 to 150 Hz.

Commercial function generators that have the desired frequency response are available for use in this system. If these are used, a driver with characteristics tailored to the response of the selected pressure generator would be required.

If the output frequency response of the pressure generator cannot be held to a ±5 percent over the frequency range from 1/10 to 150 Hz, then a calibration curve for the pressure generator is acceptable. This, of course, is not as desirable as a constant frequency response.

A fluid pressure calibration system designed and fabricated at the U.S. Air Force School of Aerospace Medicine, Brooks Air Force Base, Texas, was evaluated as a potential solution to this problem and found to be an acceptable solution. A calibration system based upon this design has been fabricated by the Biomedical Engineering Department of the University of Virginia under NASA sponsorship as a solution to this problem. Basically,

the unit consists of three components: (1) an electromagnetic driver/ aqueous chamber assembly, (2) a reference transducer, and (3) an electronics package housing the driver and reference transducer amplifiers, power supplies, etc. The unit generates hydrodynamic/hydrostatic pressure in a closed liquid system that can be used for calibration of blood pressure transducers and similar liquid pressure transducers. Characteristics of the unit are as follows:

Frequency range - 0 to about 350 Hz (flat to within 3 db, with or without a catheter up to 100 cm in length)

Hydrostatic range - 0 to +50 mm of mercury pressure

Hydrodynamic range - 0 up to the hydrostatic pressure level selected.

Basically, a reference signal generator is used to supply a signal to driver amplifiers that power the electromagnetic driver. The electromagnetic driver, in turn, creates the desired pressure in the aqueous solution. The aqueous chamber system is a closed, water-filled volume, the bottom wall of which includes a bellows driven by a loud speaker voice coil. This method of transmitting energy to the chamber has two desirable characteristics: (1) it eliminates problems associated with sealing the cone of the loud speaker, and (2) from a performance viewpoint, it provides a method of transforming the force-generating characteristics of the driver efficiently into chamber pressure through a stroke-cross sectional area trade-off. The top of the aqueous chamber is a Lexan cone with three manifolds. At the apex of the cone is a fill-vent manifold provided with a Becton-Dickinson one-way stopcock. On one side a fitting is provided for the reference pressure transducer, and on the other side is a Touhy-Borst adapter and a Luer-lok female-to-tubing connector, which either can be capped or can be used to provide coupling through a catheter to a transducer. The amplitude vs. frequency response of the system with no catheter is shown in Figure 9. The amplitude vs. the frequency response of the system with a 100-cm catheter is shown in Figure 10. Figure 11 shows the calibration system in use in the laboratory, while Figure 12 shows a close-up of the aqueous chamber and driver assembly.

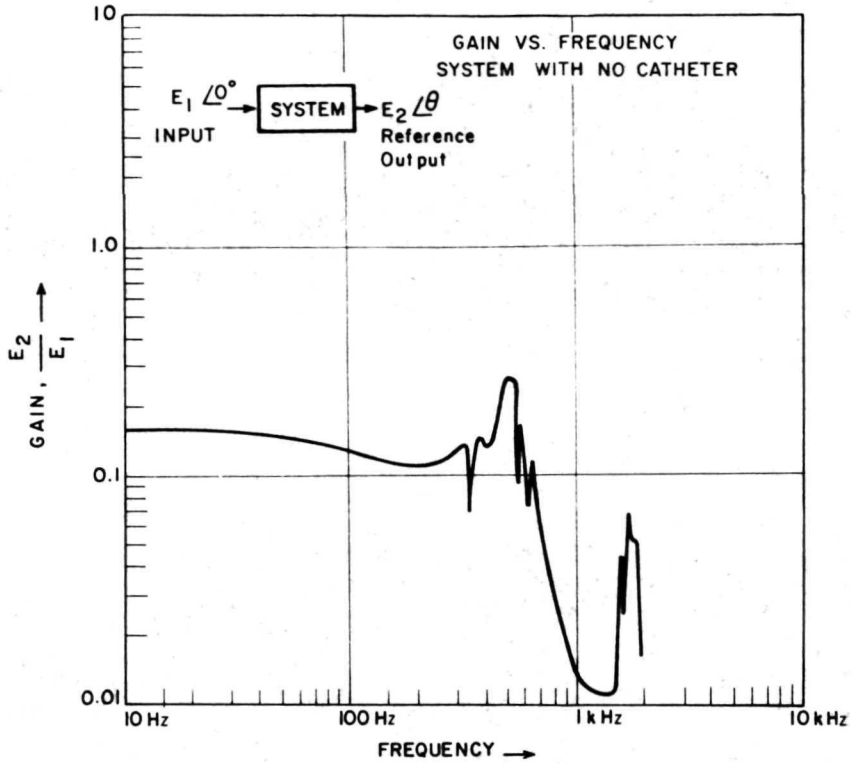

Figure 9. System Frequency Response --No Catheter.

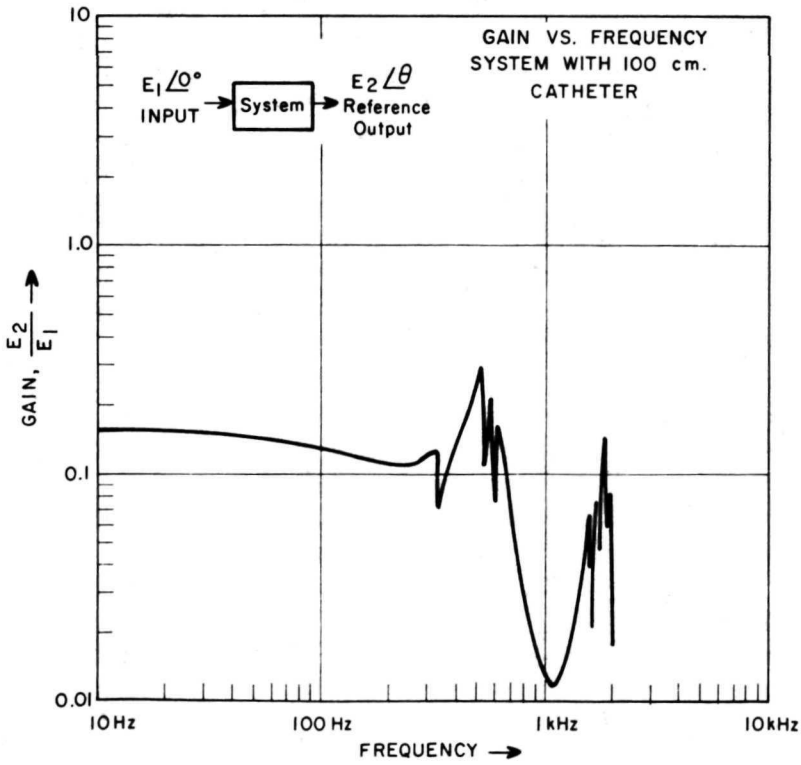

Figure 10. System Frequency Response--/100-cm Catheter.

Figure 11. Calibration System.

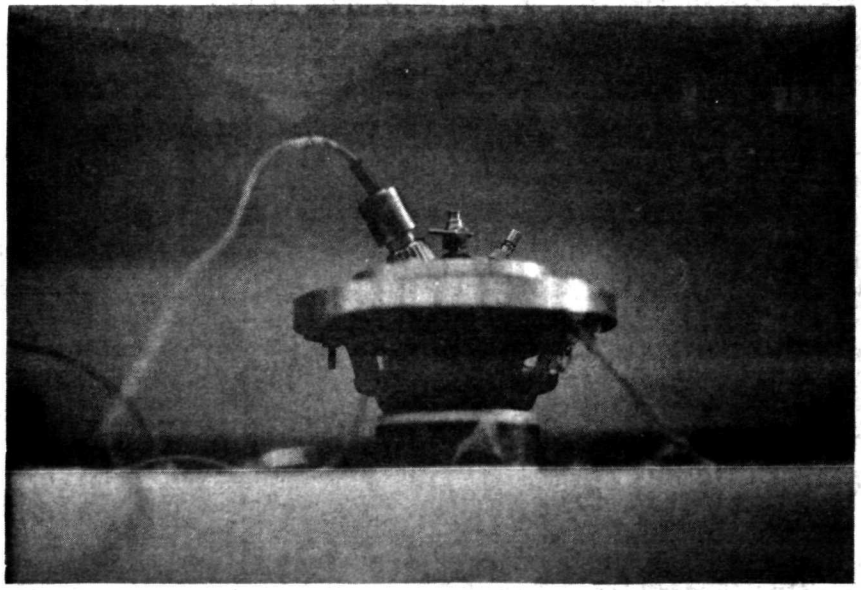

Figure 12. Aqueous Chamber and Driver Assembly.

PROBLEM WF-113 *Digital Clock*

Aerospace analytical procedures have proved valuable in basic heart research. Digital computers are becoming an increasingly important tool in the acquisition and analysis of cardiovascular data. Analog data such as blood pressure, flow rate, ECG, etc., must be sampled at a rate that depends upon their frequency content. If the sampling rate is too low, not enough data is taken to reconstruct the analog signal. If the rate is too high, more data is taken than is needed, resulting in both wasted storage and computation time. Thus, a means of varying the sampling rate depending upon the nature of the analog signal is essential. It is possible to obtain the desired sampling rate through programming techniques; however, this method requires an experienced programmer and makes inefficient use of computer memory. In addition, software techniques for controlling the sampling rate do not permit the degree of operational flexibility that is possible through the use of an external hardware clock.

It is necessary to be able to sample analog pressure and flow signals in the cardiovascular laboratory at a fairly well-defined and precise frequency. The intercycle time must be fairly precise. The way in which the intersample delay is accomplished without a programmable clock is (knowing the execution time of each part of the program) to build a series of execution loops lasting about a millisecond and then to multiply these loops by integer numbers to achieve the variable delays required. This can become fairly complicated because it takes a large number of samples in the program just to build-in the timer (as much as 25 percent of the available computer memory could be required, which is prohibitive). A millisecond is the basic time base and, if it is desired to go under a millisecond, the entire sequence, that is, the entire program, must be rewritten. If, for example, a 1/2-millisecond delay were needed, it is just not possible to run half way through an execution loop. Consequently, a programmable periodic pulse is a more ideal situation. The pulse could provide a signal on an external logic line, which could, in turn, provide the program interrupt to the computer and initiate the sampling of the analog signals.

Mr. Edward Huff at Ames Research Center has designed a digital clock for use with a research program at Ames involving the study of operant conditioning of behavior in animals. The Ames unit is more versatile than that required for the solution of this problem, but the basic techniques are identical. Therefore, the medical researcher obtained sufficient design information from Mr. Huff and constructed a digital clock for use with his computer system at Bowman Gray School of Medicine.

The researcher is performing Fourier analysis and time-series (auto- and cross-correlation) analysis of cardiovascular data. For Fourier analysis, required sampling times are 1, 2, or 3 milliseconds, and the time-series analysis requires sampling times of 1/2 and 1/4 millisecond. The clock design has provided a computer-compatible pulse that actually triggers the machine to branch on the appearance of this pulse and to sample the basic analog data that comes from the transducers. All of these frequency spectral analytical routines now make use of the clock. The digital clock is shown in Figure 13 and Figure 14.

Another important application of the clock involves the fact that the intercycle time between cardiac cycles is not constant. Fluctuations occur in the heart cycle in response to respiratory fluctuations such as increase and decrease of pressure, which, in turn, increase and decrease reflex drive of receptors that happen to be located in this area. There is some slow variation that roughly corresponds to respiration. With the clock, it is possible to look at 10 or any number of cycles, average those, and perform analysis on the average of the 10 consecutive cycles, which represents an average over, say, one respiratory cycle as opposed to 10 isolated samples at some arbitrary position on the respiratory cycle. For example, if one were to sample the cardiac cycle at the peak of the respiratory cycle and then sample at the bottom of the respiratory cycle, it would be an unfair comparison. To analyze any frequency cycle and compare it with another arbitrarily chosen frequency cycle is invalid because of the intercycle and intracycle variation. It is, indeed, possible, with the variations caused by respiration rate, for the signals to have significantly different frequency spectra.

Since one of the objectives of this research is to determine the extent to which contour of the cardiac pulse can be used as an indication of disease or the type or quality of disease, then the analytical process used in identifying that particular waveform is extremely important. The basic need in this problem was fundamentally a programmable timing signal that would not encroach on the relatively small computer memory, but its consequence relates to the quality of the signals derived from the research program, which in turn relates to the identification of wave shapes that have significance with respect to waveform analysis for disease.

Finally, another potential application is the possibility of using the clock pulse as a trigger to stimulate the heart of the experimental animals. This, of course, would stabilize the intercardiac cycle and would eliminate the intercycle variable time delay. This has not yet been implemented in this research program; however, plans are being made to construct the hardware that will be required for implementation.

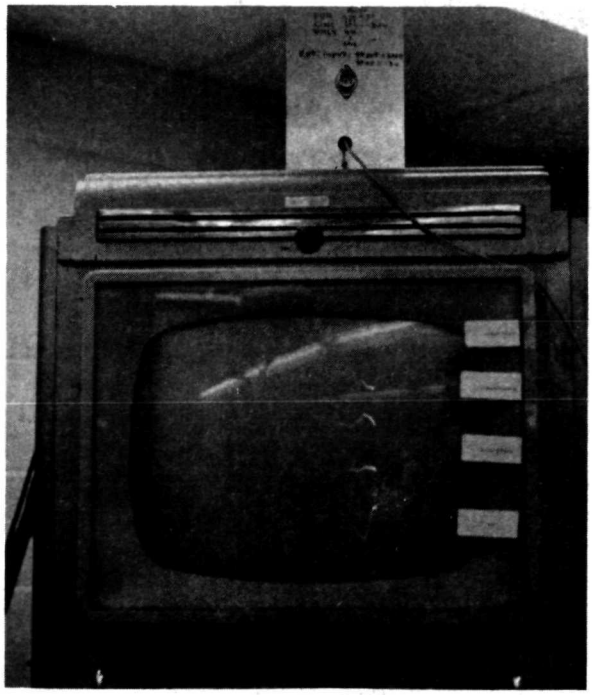

Figure 13. Digital Clock with Physiological Monitor.

Figure 14. Interior of Digital Clock.

2.2 Potential Technology Applications

During the reporting period, eight problems achieved the status of potential technology applications. This status indicates that an adequate solution to the problem has been identified and implementation is in various stages of accomplishment. These eight problems are discussed in the following summaries.

PROBLEM EU-5 *Sensors to Define the Position of Specific Parts of the Human Anatomy in Space During Normal Locomotion*

A suit developed for NASA may prove to be a key factor in the diagnosis of various disorders of locomotion.

Many studies involving gait, locomotion, spinal damage, etc. require time-spatial measurement of various bones with respect to each other or some external reference. These studies are important for the diagnosis of gait abnormalities and for the evaluation of the effectiveness of therapeutic procedures and prosthetic attachments in improving treatment of disabilities associated with locomotion. In the past, photographic

and TV techniques against one or more reference grids have been employed to obtain this information in a more or less fragmentary and hard to measure fashion. These techniques require that the measurements be taken in a laboratory or other prescribed environment in order to maintain proximity to the optical recording apparatus and the reference grids. It is desired to obtain a method of measuring the position of bones of the legs and hips with respect either to an external reference point or to a movable reference point on the body. For preliminary applications the attachment of mobility limiting devices such as cables will be permitted to prove feasibility of the measurement techniques. The eventual goal of these studies, however, is to obtain such measurements when the subject is free-ranging in his normal environment. This will require telemetric transmission of these data to a remote point. Essentially, sensors that can provide quantitative data on their positions with respect to each other or some external reference are desired.

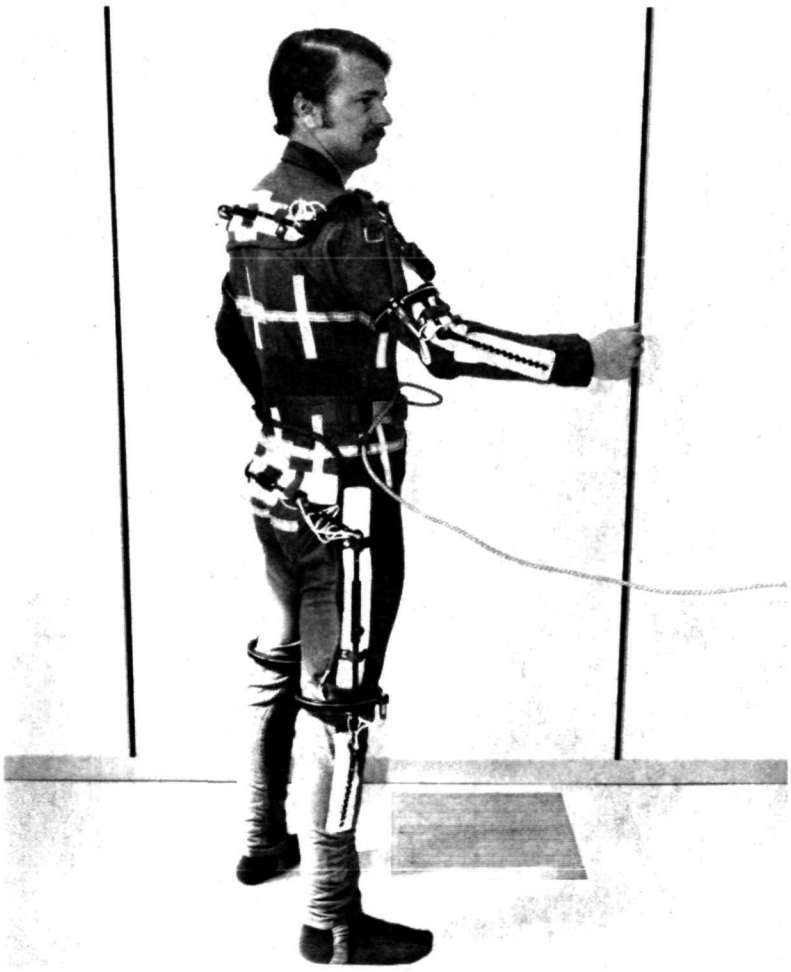

Figure 15. NASA Exoskeleton Suit.

The potential solution to this problem was discovered as a result of personal communications with personnel at the Langley Research Center (LRC). (See Figure 15). A specially instrumented suit for the Crew Vehicle Disturbances Study in the 1973 Skylab Mission was developed at the Langley Research Center. The suit consists essentially of a partial exoskeleton which is fitted to the individual by means of a suit. Potentiometers are used at the various joints and also on rings located on the arms and legs to provide information on the angular relationships between the joints. The rings on the arms and legs provide information on rotation of the arms and legs. This unit is lightweight and compatible with the overall requirements of the problem. The results at LRC indicate that precision of measurement of rotation of one member with respect to the other using this technique approaches $\pm$ 1 percent. It is anticipated that some difficulty may be encountered in affixing the exoskeleton to the patient. However, this difficulty may be overcome by the light weight and relatively small size of the exoskeleton. For these preliminary studies it is anticipated that only the lower half of the exoskeleton unit will be required since the studies are primarily concerned with gait analysis. The present suit developed at LRC uses an umbilical cable to transmit data from the potentiometers on the exoskeleton to the data processing equipment.

The unit was evaluated at Emory University. It was determined that the range of adjustment of the exoskeleton was not adequate for clinical use. Some of the ideas in the exoskeleton suit may be incorporated into existing instrumentation at Emory. Other approaches to this problem are now being investigated.

PROBLEM WWRC-7 *A Signalling (Nurse-Call) System for Multiple Sclerosis Patients*

A NASA engineer has designed a call system for multiple sclerosis patients which is being evaluated in a major rehabilitation center.

The Woodrow Wilson Rehabilitation Center (WWRC) of the Virginia Department of Vocational Rehabilitation is planning a new building for the Medical Services Division. Among those who will be housed in the new building are a number of multiple sclerosis patients with severe disabilities. Such patients have little or no use of hands or feet. Consequently, they must depend on the services of nurses for practically all of their needs. Their disabilities are often so severe that they cannot accomplish the relatively simple task (for a person without disability) of operating the call button used in most hospitals to initiate a signaling system.

The patients requiring such a signaling system generally have voluntary control of one or all of the following functions that could conceivably be used for control:

(1) Breath (respiration)

(2) Eye movement and blink

(3) Head motion--the head can generally be raised 2 inches and can be turned from side to side.

Most patients cannot change their positions except for the head so that they remain essentially stationary unless moved by attendants. It is desirable that the signaling system be capable of activation by a patient sitting in a wheelchair beside the bed. Generally, complicated electronic and optical systems of high sensitivity that require frequent adjustment or maintenance are undesirable because of the lack of skilled technicians. On the other hand, if an electronic or optical system of great ruggedness and high reliability could be achieved, it would certainly be given consideration. In summary, a system capable of operation by one of the three control mechanisms available to the patient is required, but ease of maintenance and high reliability cannot be ignored as constraints on this problem.

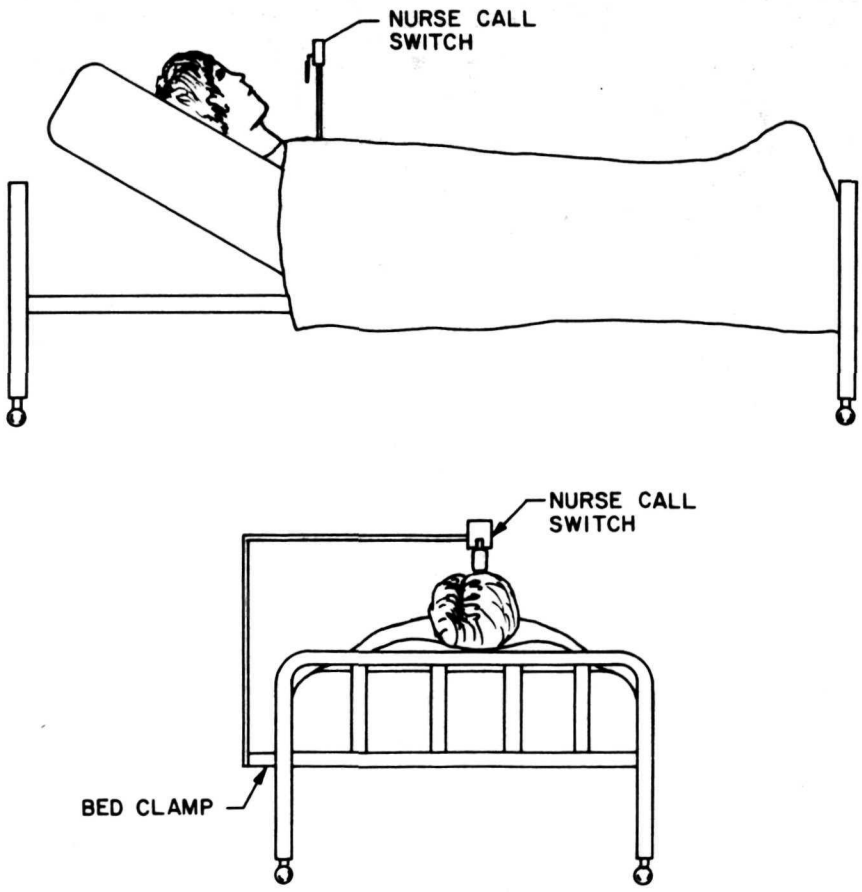

Figure 16. Breath-actuated Switch.

The Southwest Research Institute (SwRI) Team has been working for some time with the Marshall Space Flight Center and the Langley Research Center on a device to permit paraplegics to perform a number of functions from their beds. The system that is being developed employs a breath-actuated switch suggested by personnel at the Langley Research Center along with a logic circuit that permits the patient to control a number of electrically operable devices from his bed. The system being developed for the application identified by the SwRI Team is more complex than that required by the problem at WWRC. The problem at WWRC is merely to call the nurse and, essentially, a substitute for the hand-activated nurse-call button is required. (See Figure 16). At WWRC a commerically available unit is used to permit communication between the nurse station and the patient by means of an intercom system. The system is activated by a call button. Although the problem at WWRC does not require the complexity of that required at SwRI, the breath-operated microswitch suggested by LRC as the control element for the more complex system can be used in conjunction with the commerically available system at WWRC. The Langley breath-actuated switch appears to be completely compatible with the current installation at WWRC. This, of course, is a very significant advantage. One of the breath-actuated switches has been obtained for evaluation at WWRC. Should the evaluation prove that the breath-actuated switch is a viable solution to the problem, it is anticipated that WWRC will convert all multiple sclerosis and paraplegic call stations to the use of the breath-actuated microswitch.

PROBLEM WF-88 *Accurate Determination of Arterial Pressure Pulse Transit Time*

Aerospace research has resulted in an instrument that may be useful in careful analysis of the cardiovascular system.

The volume elasticity of blood vessels is an important parameter in the evaluation of total cardiovascular function. Knowledge of this parameter is necessary in formulating a meaningful model of the behavior of the cardiovascular system under a variety of states of health and disease. For example, atherosclerotic disease is known to change arterial elasticity or distensibility by changing the composition of the arterial wall. The velocity of the arterial pressure pulse wave is roughly proportional to the inverse of arterial distensibility; therefore, changes in arterial distensibility will produce changes in arterial pulse wave velocity.

The researcher is involved in a project to establish a relationship between the extent of atherosclerotic disease as determined by conventional histopathological grading and changes in pulse wave propagation velocity that is potentially a noninvasive technique. Conventional methods of determining arterial blood vessel elasticity yield only approximate results. In addition, conventional techniques require that a small section of the blood vessel be removed in order to subject the vessel to pressure changes. The volume elasticity is computed from the rate at which the pressure changes in response to a change in vascular volume. Because of the relationship between arterial elasticity and arterial pulse wave

velocity, it is felt that accurate measurement of pulse wave propagation velocity in arteries will provide information related to the arterial blood vessel elasticity, which is, in turn, related to the amount of atherosclerotic disease present.

Conventional methods for determining arterial pulse wave transmission have been shown to be unsatisfactory[1] for reasons related to distortion of the pulse wave as it travels from the heart to the extremities. Distortion may occur (1) along the artery where a significant change in vessel wall composition occurs (such as severe aortic atherosclerosis), (2) at vessel bifurcations, or (3) at terminal arteriolar vascular beds where reflection of the pulse wave occurs. The process of wave reflection accounts for a major part of wave distortion and occurs when part of the energy imparted to the blood by the heart is actually reflected (bounced back) toward the heart. When this occurs, the reflected wave adds to the actual wave transmitted by the heart and forms a third wave. Neither the reflected wave nor the actual pulse wave transmitted by the heart can be measured directly; what is measured appears to be a combination of the two. Generally, the closer to the reflection site that blood pressure is measured, the greater the amount of reflection and distortion. Reflection of pulse waves appears to provide one explanation for the observation that systolic blood pressure is greater in the peripheral vessels than in the aorta because the peripheral area is nearer the sites of reflections.

Basically, this problem seeks a noninvasive means of detecting atherosclerotic disease. Since conventional techniques employ histopathological examination, which requires surgical excision and opening of the artery, it is desired to investigate means of indirectly sensing the presence of atherosclerotic disease as it affects the mechanical properties of the arterial walls. As a result, noninvasive techniques of measuring volume elasticity of the arterial vessel or of measuring arterial pulse wave transmission velocity, which is related to the volume elasticity of the arterial wall, are desired.

Dr. Max Anliker has developed a unique pressure generator system at the NASA Ames Research Center and Stanford University. This pressure generator system eliminates the distortion present in conventional methods of measuring pulse wave velocity.[2] The system, developed by Dr. Anliker, consists of two fundamental components: (1) a pressure wave generator, and (2) a thin catheter on which is mounted two pressure transducers separated by a fixed distance (about 10-15 cm.). The pressure wave generator operates to produce a burst of sine waves that superimpose on the naturally occurring

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[1] G. S. Malindzak, Jr. and J. H. Meredith, "Comparative Study of the Arterial Transmission Velocity," Journal of Biomechanics, Vol. III, No. 3 (May 1970), pp. 337-350

[2] Max Anliker, M. B. Histand, and Eric Ogden, "Dispersion and Attenuation of Small Artificial Pressure Pulse Waves in the Canine Aorta," Circulation Research, Vol. XXIII (October 1968), pp. 539-551.

pressure pulse. The superimposed sine waves are higher in frequency than the naturally occurring pressure pulse (usually 40 to 100 Hz; the natural pulse is 1 to 3 Hz) and travel along with the pressure pulse. Little difficulty is encountered in detecting the superimposed pulses. Because they are higher in frequency, their energy is dissipated in a much shorter distance. Consequently, little or no energy is available for reflections, thus eliminating the distortion problems associated with measuring the natural pulse. The time relationship of a train of sine waves measured simultaneously at two sites provides information related to the pulse wave velocity within the vessel segment under examination. The method of superimposing a high frequency, sinusoidal pressure oscillation on the naturally occurring arterial pressure pulse for the purpose of examining quantitatively the elastic behavior of the cardiovascular system in health and disease appears unique. No such system is available commercially. The technique has been proved to be useful in characterizing the elastic behavior of blood vessels in healthy dogs and should be even more important in the same capacity for evaluating diseased subhuman primates. The application of the technique for identifying the extensiveness of atherosclerotic disease in humans noninvasively appears also to be practical and scientifically sound. The pressure generator system was developed by Dr. Anliker at the NASA Ames Research Center under NASA grant NGR05-020-223.

Contact has been established with Mr. Horace Emerson of the TU Office, NASA Ames Research Center to explore implementation possibilities.

PROBLEM VAM-12 *Heart Rate Tachometer*

A heart rate measuring device developed for the Skylab program may have uses in clinical medicine. The problem originator is concerned with the problem of assessing the extent of the loss of mental function by persons having experienced brain damage. Patients having suffered brain damage (e.g., a stroke victim) will be subjected to tests in which they are given information at varying rates and are expected to make simple decisions. For example, the patient may be shown a movie of a series of automobiles passing a certain point and will be required to press a button each time a particular sequence of cars is encountered (e.g., two red cars immediately followed by one blue car). The frame speed of the movie will be increased until the patient experiences difficulty in making decisions. The problem is to find a quantitative measure of the level of difficulty that is experienced by the patient. The error rate is, of course, important but provides insufficient information to adequately determine the point at which decision making becomes particularly stressful. One of the parameters that will provide additional information is heart rate. Heart rate will provide an indication of mental stress and should be responsive to subtle changes in levels of stress. While heart rate can be determined by a number of methods, it is necessary to have a noninvasive technique that will not arouse the awareness of the patient. This research should lead to a clinical method that will be useful in determining the extent of impaired mental function.

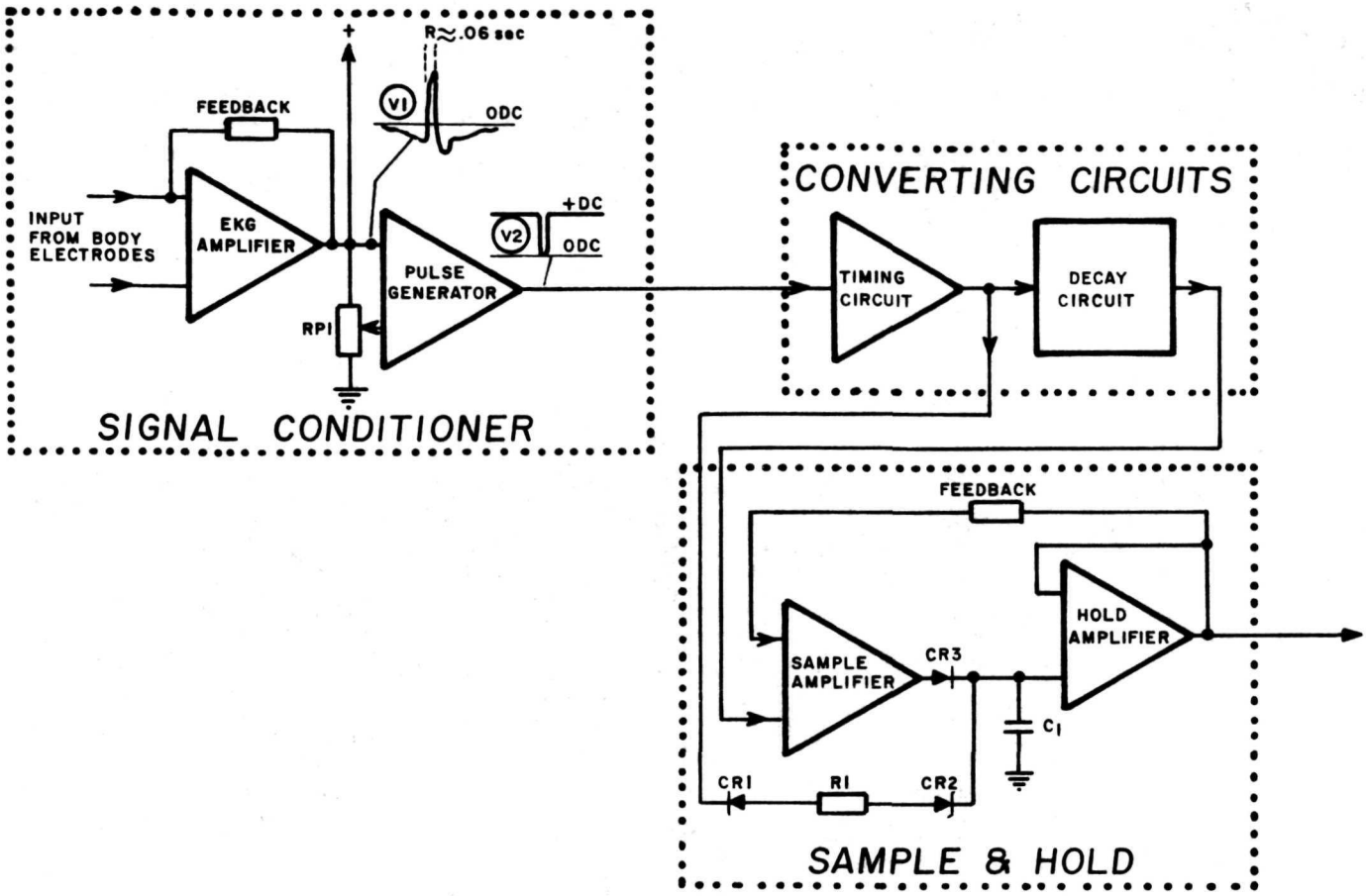

Figure 17. NASA Tachometer.

A heart rate tachometer that was developed as a possible candidate for monitoring the astronauts' heart rates during the Skylab mission has provided a potential solution to this problem. The proposed system, which was suggested by a Marshall Space Flight Center employee, consists of an ear plethysmograph together with associated tachometer circuitry. The plethysmograph employs a light source that transmits light energy through the ear to a photocell. As the heart beats, the quantity of blood in the ear changes, thus modulating the intensity of the light energy received at the photocell. The tachometer circuitry averages over several heart cycles and produces a voltage output that is proportional to the heart rate in beats per minute. A digital or analog voltmeter is then used for displaying the heart rate. The expected accuracy of the system is $\pm$ 1 beat per minute.

The MSFC Technology Utilization Office has arranged for a unit (shown in Figure 17) to be lent to the problem originator.

PROBLEM VAM-6 *Negative Pressure Chamber*

Respiratory distress syndrome (also called hyaline membrane disease) is the major cause of death in the newborn. It is estimated that more than 20,000 babies succumb to this disease in the United States each year. Respiratory distress syndrome is a condition of the newborn in which the lungs are collapsed; it is thought to be due to the absence, because of immaturity, of an alveoloar substance that decreases the surface tension and permits lung reexpansion after each expiration.

Recently, researchers at several medical centers in the United States and Canada have produced encouraging results with the use of continuous positive airway pressure (CPAP) and continuous negative pressure (CNP) therapeutic techniques. The CPAP method makes use of an endotrachael tube which continuously forces oxygen-rich air into the lungs while the CNP method keeps the infant's lungs expanded by subjecting the chest to continuous negative pressure. The negative pressure around the chest helps the infant to expand his lungs and to maintain the proper residual volume of air. If life can be sustained for 4 days by either method of treatment, the missing surfactant will become present in a sufficient quantity for normal breathing to occur.

The CNP method has been employed by specialists at the University of Miami School of Medicine who were among the first to make use of the technique. A commercially available respirator was modified to produce a constant negative pressure and has proven successful in saving the lives of several infants. The University of Miami researchers, Dr. Akram Tamer and Dr. Eduardo Bancalari, recognized several shortcomings in their present system and requested assistance from the RTI Biomedical Application Team. The disadvantages of the present system are:

(1) High cost because it is equipped with an electronic cycling system (for controlled breathing), which is not necessary in the continuous negative pressure technique.

(2) The negative pressure is applied to the entire body except the head, thus interferring with the infant's cardiovascular function and producing an increase of air in the gastrointestinal tract.

(3) The nursing care of the infant is very difficult and cannot be given without discontinuing the negative pressure.

To overcome these disadvantages, the University of Miami medical team wished to fabricate a CNP chamber that would cover only the infant's thorax, arms, and upper abdomen. Such a system would offer the following advantages over the use of continuous positive pressure in the airway:

(1) It avoids tracheal intubation and leaves the face free for nursing care. This point is of great importance since, in addition to feeding the infant, it is normally necessary to suck mucus from the infant's trachea at frequent intervals. The CPAP must be discontinued during such nursing care.

(2) Its interference with venous return to the right heart will be minimal.

(3) It avoids the increase of air in the gastrointestinal tract.

The technology employed in the construction of the Lower Body Negative Pressure system (Figure 18) for NASA's 1973 Skylab mission has direct application in providing therapeutic treatment for respiratory distress syndrome. A Marshall Space Flight Center engineer, Mr. Ted Knowling, visited the University of Miami medical team to consider the applicability of the NASA Lower Body Negative Pressure system to this problem. The major problem to be encountered in the design of the needed CNP system is the air seal that will be required at the waist. (The neck seal that is used on commercially available respirators is thought to be adequate.) The waist seal that was designed for NASA's Lower Body Negative Pressure system appears to provide an excellent solution to the problem of sealing the CNP unit at the infant's waist. Additionally, the NASA seal is adjustable, which will allow the CNP chamber to accommodate infants of various sizes.

A mechanical designer from the University of Miami visited Mr. Ted Knowling at MSFC during August 1972. A preliminary design for the CNP system was worked out at that time. The Department of Biomedical Engineering at the University of Miami plans to fabricate the CNP unit; the problem originator is presently seeking funds for the project.

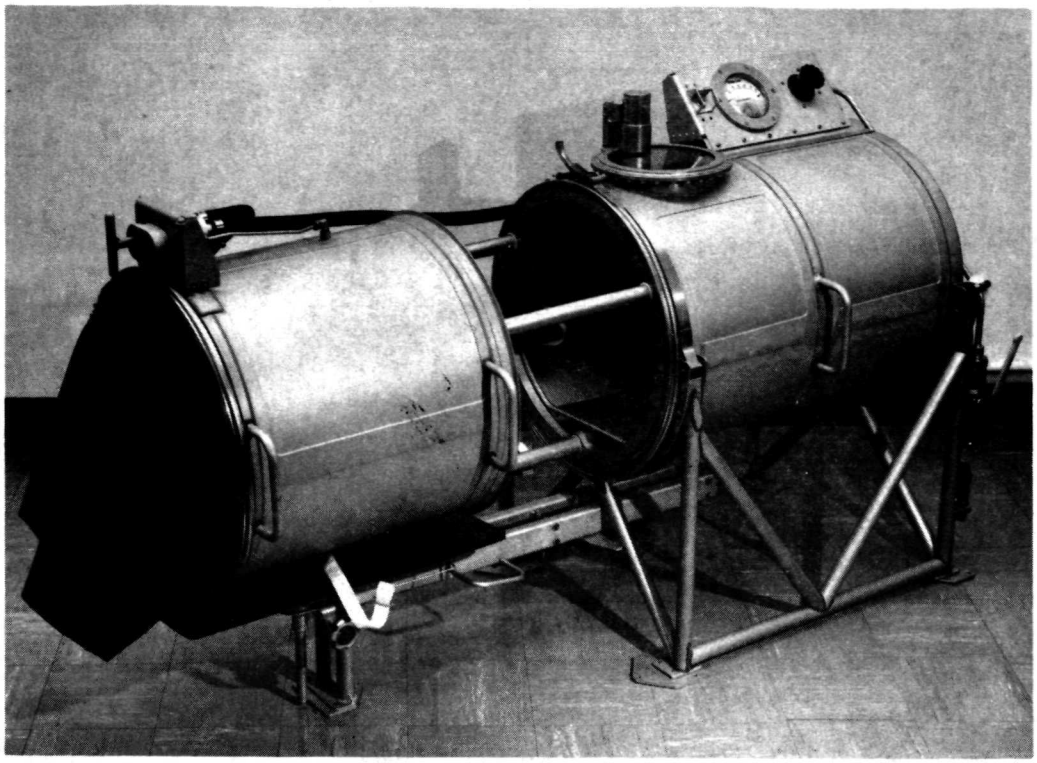

Figure 18a. NASA Lower Body Negative Pressure Chamber.

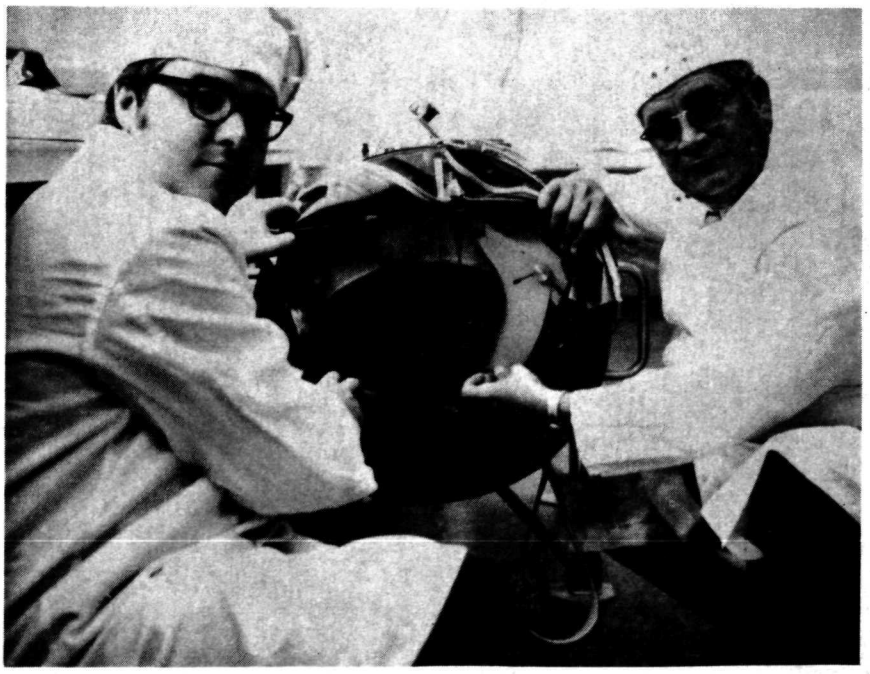

Figure 18b. NASA Lower Body Negative Pressure Chamber.

PROBLEM VAM-2 *Diagnosing Gait Abnormalities*

A suit developed for NASA's 1973 Skylab flights may prove to be a key factor in the diagnosis of gait abnormalities.

Thousands of Americans suffer loss or impairment of their limb functions. Artificial limbs and therapeutic treatment offer a degree of rehabilitation for many of these persons who are then able to resume many of their normal activities. Presently, gait abnormalities are diagnosed and progress is followed by a physician's visual observation of the patient while walking. The physician has little trouble in determining the type of affliction (e.g., Parkinson's disease, cerebral palsy) by his observation of the patient during walking; however, it is difficult to determine the degree of impairment of gait function. It is perhaps more difficult to quantitate progress made by the patient. This is an important task of the physician since therapeutic treatment must be tailored to a particular individual's needs. More rapid and more complete recovery might be expected if the gait abnormalities could be analyzed in more than a subjective manner.

An equally important need for quantitating gait abnormalities exists in the design and fitting of prosthetic limbs. Here quantitative gait information might be used to design better prostheses. In addition, the prosthesis adjustments could be refined to yield a more normal pattern of walking.

Preliminary experiments employing triaxial accelerometers attached to various points on a patient's leg indicate that a knowledge of the acceleration of the limb segments while walking might be used to detect and quantitate gait abnormalities. It is desired to find a method of determining the acceleration of the body's lower limb segments.

The problem was posed to Mr. John Samos, Technology Utilization Officer at Langley Research Center (LRC), who contacted an LRC engineer experienced in accelerometer instrumentation. Discussions with this engineer revealed that there were several problems involved in instrumenting a patient with accelerometers and that an alternate approach should be considered. He suggested that we contact the LRC staff concerned with the Crew Vehicle Disturbances study, which is scheduled for NASA's 1973 Skylab mission. This experiment was designed to assess the effects of crew motion on the attitude stability of a manned spacecraft. To conduct the study, a device for determining the position of an astronaut's limb segments relative to the torso was developed. This system is actually a type of exoskeleton incorporated into a pair of coveralls that measures joint rotations in real time. (see Figure 15).

Team members discussed the applicability of this system to the study of pathologic gait and concluded that the system provides an excellent method of determining acceleration of the body's limb segments. In addition, the system yields the actual position of the limb segments in space, which

will be of even greater benefit than the acceleration data alone. The Team has made arrangements with the principal investigator for the Skylab Crew Vehicle Disturbances experiment to obtain the limb position sensing system on loan to assess its potential in rehabilitation of patients with gait abnormalities.

PROBLEM TU-29 *Damage to Blood from Microwave Heaters*

A blood analysis technique developed for the space program may be useful in the study of warming techniques for blood used in transfusions.

Warming of refrigerated bank blood (4° to 6°C) has become a common clinical practice because of the difficulties encountered with transfusing cold blood. Clinical studies have left little doubt that rapid transfusion of large quantities of blood at refrigerator temperatures may be a dangerous practice resulting in cardiac or general body hypothermia. Warming of the blood before infusion reduces the morbidity and mortality of the recipients. To avoid the effects of cardiac and general hypothermia during massive hemorrhage, cold bank blood should be warmed to body temperature when rapidly administered in large amounts.

Until very recently, the basic method of warming refrigerated blood involved the use of some form of water bath heat exchanger. Because human blood at 4°C is a highly viscous fluid, coil-type heating systems cannot attain sufficient flow since they must force cold blood through a filter before warming. The method is relatively inexpensive, but the apparatus requires considerable warmup time as well as some blood for priming. In addition, the precise temperature control is difficult to achieve, and the unit must be placed close to the patient, thus adding to the equipment clutter in an already crowded operating room. Recently, the use of microwave blood warming has eliminated these problems by warming the blood in the bag before filtering, which offers speed, economy, and ease of use. The refrigerated blood can be heated to a desired temperature in 1 minute. Blood is heated only when needed and there is no wasted blood.

Microwave heating is unique in that it does not involve a hot object with the transfer of heat through conduction, radiation, or convection. Instead, electromagnetic energy is generated at a very high frequency (2.5 GHz) by a special oscillator tube. This sets up an alternating electromagnetic field that causes the molecules within the blood to constantly try to realign themselves electrically with each field reversal. The friction between these moving molecules generates heat, thus converting electromagnetic energy into thermal energy.

Although initial tests on the use of microwave-heated blood indicate that the method is basically safe, the rapidly increasing use of microwave warming demands that a more subtle test of blood damage be used to determine whether the method is safe in all circumstances. The basic problem is to find a method of determining subtle damage to blood from the microwave heating.

The potential solution to this problem was discovered as a result of a problem statement circulation in regard to problem TU-25, "Measurement of Blood Damage from Heart Lung Pumps." In response to that problem statement, Dr. Stanley Ellis of Ames Research Center suggested the use of an enzymatic technique. The technique is used at Ames for measuring the effect of high oxygen pressures on blood cells. In particular, the technique uses a proteolytic enzyme that can be monitored in a simple manner and with very high sensitivity using a specific substrate. The enzyme is dipeptidyl aminopeptidase III, which was first purified and characterized from the pituitary gland and which can be specifically determined by means of the fluorogenic substrate, arg-arg-beta-naphthylamide.

The problem originator discussed the basic technique with Dr. Ellis who then agreed to process some initial samples of microwave-warmed blood. Dr. Delili sent 12 units of blood to Ames Research Center for analysis using the Ames enzymatic technique. The initial tests revealed that some of the microwave-warmed blood did, in fact, have a high reading using the enzymatic technique. However, not all microwave-warmed blood gave the same response, which indicated that other factors may be obscuring the basic phenomenon. Therefore, the problem originator plans to send additional samples to Ames for evaluation. In addition, arrangements are being made to duplicate the Ames technique at the Tulane School of Medicine so that more complete studies can be instituted.

PROBLEM EU-18 *Display Panel for Testing Acuity*

The researcher is performing fundamental studies of the visual system and its functioning. In a particularly significant experiment, it is desired to determine the visual acuity of a trained laboratory animal (a rat). After the animal enters a T-shaped passageway, it will be trained to turn left or right in order to obtain a food pellet, depending on whether the lines in a display are horizontal or vertical. It is desired to vary the width of the dark and light strips. Starting with large strips, the width will be incrementally reduced until the animal can no longer determine the orientation of the strips and thus does not know which passageway contains the food.

The overall display size can be in the range of 2 to 5 inches square, with a 2-inch square being preferred. The width of the dark and light strips must be incrementally variable from 1/4 inch down to 1/32 inch or even 1/64 inch. It would be desirable to vary the strip width in 1/16-inch increments down to a strip width of 1/16 inch with additional increments to achieve strip widths of 1/32 inch and 1/64 inch. For any given strip width, the size of the light and dark strips must be equal so that the total illumination presented to the animal does not change with strip width. It is also necessary to be able to rotate the display 90° between trials in order to present horizontal or vertical orientations to the laboratory animal.

As a result of discussion of this problem with Mr. John Samos at the Langley Research Center, Mr. Richard Morris and Mr. William M. Kahlbaum, Jr., of the simulator development section, were identified as NASA researchers who might be in a position to contribute to the solution of this problem. A meeting was arranged in which the overall problem was discussed, and two approaches to the solution of the problem were suggested by Messrs. Morris and Kahlbaum.

Following discussion of these potential approaches with the medical researcher, the suggestions were considered by the medical investigator to be sufficiently applicable for further discussions. As a result, Dr. K. V. Anderson, the problem originator, visited the Langley Research Center and discussed the biomedical problem with Mr. Kahlbaum. At this time, Mr. Kahlbaum had arranged two breadboard demonstrations on an optical bench to show the manner in which his suggestions could be implemented to provide a solution to the problem. Dr. Anderson was impressed with the simplicity of both techniques and the applicability of the techniques to the particular experimental problem that he faces in his research. Both approaches were deemed capable of providing a solution to the problem. As a result, Dr. Anderson plans to construct preliminary models of both systems for evaluation purposes.

In the basic configuration of the optical system suggested as the first solution (Figure 19), a point light source is required. Light from the point source is passed through an optical lens that generates parallel light rays. The optical material (transparency) to be projected is placed on the other side of the lens in the parallel light. The parallel light, having passed through the transparency, is focused by means of an additional lens. By changing the positions of the front lens, the overall size of the projected image can be changed.

In the second solution (Figure 20), the basic technique is that the transparency is illuminated by a diffuse light source. An optical lens is used to obtain parallel light rays in the region between the two lenses. Two optical wedges are interposed between the lenses in the region in which the light rays are parallel. The projected image size can be changed by rotating the two optical wedges about their vertical axes.

The problem of changing the orientation of displayed information from vertical to horizontal or from horizontal to vertical can, of course, be accomplished by rotating the transparency itself by 90°. This can be accomplished by providing a mechanically rotatable transparency carriage that can be automatically controlled or by rotating the display optically. Mr. Kahlbaum suggested an approach to the rotation of the image using an optical technique employing a Dove prism. This prism has the characteristic that an image transmitted through the prism is rotated as the prism is rotated. The angular rotation of the image is twice the angular rotation of the prism, so that it would be possible to construct a system using a Dove prism in which no motion of the transparency or of the transparency carriage would be required. An objection to mechanical manipulation of the slide carrier is that this may generate noise, thus providing cues to the animal under test. The relative ease of rotating the negative carriage or a Dove prism will be evaluated additionally during the test program.

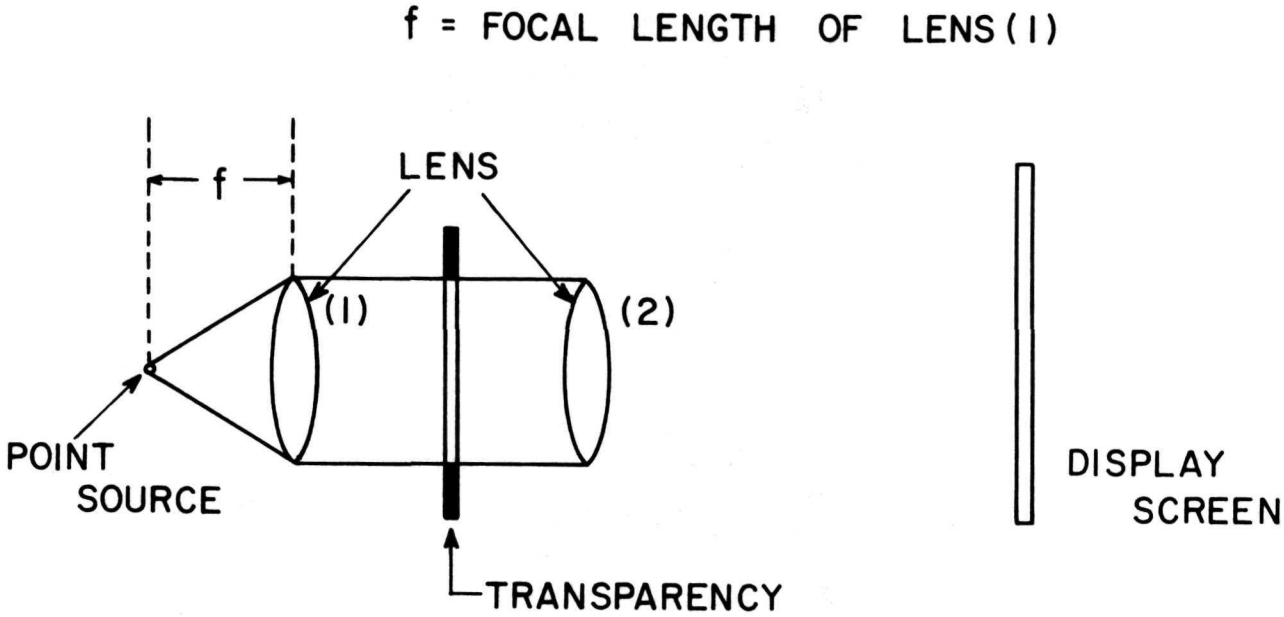

Figure 19. First Proposed Solution.

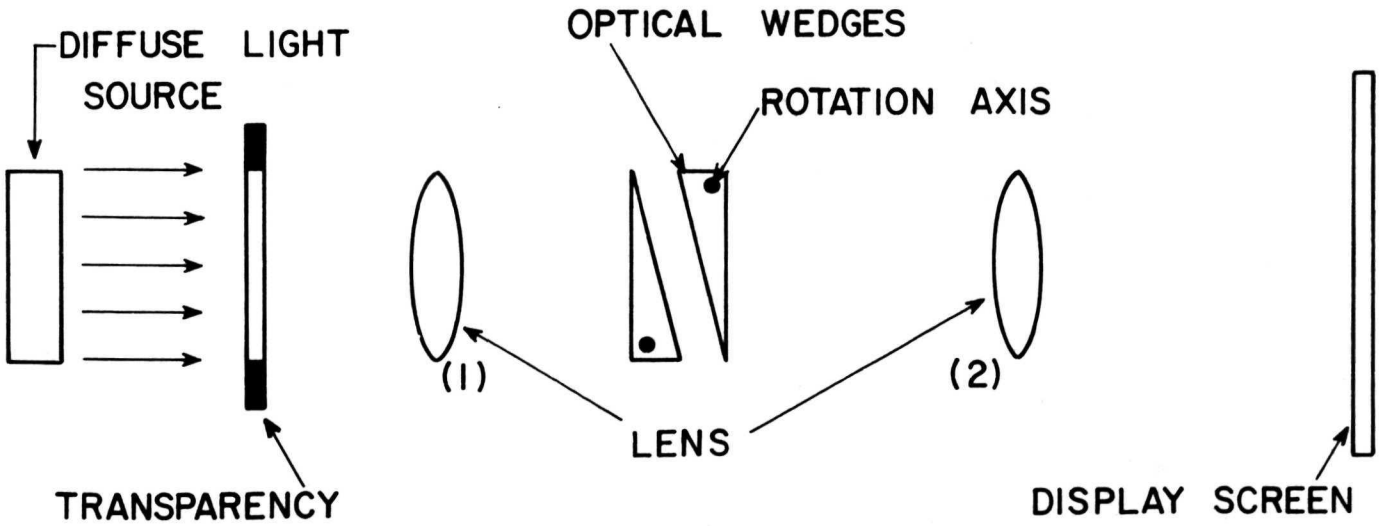

Figure 20. Second Proposed Solution.

2.3 Impacts

The Application Team's efforts often provide a significant benefit to the researcher even though no technology application has been accomplished. During this reporting period, Team activities had a significant impact on the researcher's activities in two such problems that are discussed in the following summaries.

PROBLEM EU-8 *A Simple, Reliable Means of Attaching Instrumentation to the Skin*

Studies in human gait and locomotion frequently require the attachment of instrumentation to human limbs to measure various parameters, such as angular relationships between bones, rate of movement, and displacement. Standard techniques of attaching such instrumentation consist of various kinds of straps or adhesive tapes. Unfortunately, because of perspiration, vibration, and shock encountered during walking, these techniques are very unreliable.

Basically, improved methods or techniques are required for attaching sensors to human limbs so that a fixed relationship is maintained between the sensor and the limb to which it is attached. The attachment method must withstand the shock and variation associated with human locomotion while maintaining the fixed attachment relationship desired. Any material placed in contact with the skin must be nontoxic and nonirritating and must not be affected by perspiration. Finally, attachment and removal must be easily accomplished.

Shortly after this problem was accepted, a Team member suggested that the medical adhesives used on colostomy and ileostomy bags might be useful in the solution of this problem. As a result of the workload at the institution, this problem assumed a low priority for several months. When the problem assumed a high priority, the researcher contacted the manufacturers of colostomy cement and obtained several different kinds. These adhesives, after careful evaluation by the researcher for the past 4 or 5 months, have been proved to be very effective solutions to the problem. Two types of adhesives, Skin Bond, marketed by United Surgical Corporation, and Marlen Ileo Cement, marketed by Marlen Manufacturing and Development Company, have both proved to be acceptable solutions. The researchers are extremely enthusiastic over the success of the adhesive in this application since it replaces straps, masking tape, adhesive tape, and a number of other cumbersome and ineffective techniques that had been used in the past. Patient acceptance is also very high because, with the elimination of straps, the patient no longer feels as encumbered as previously. The adhesive had been used to attach various kinds of electrogoniometers to human limbs. In this application, it has withstood the vibration and shock encountered while walking, and the normal perspiration of the patient. Attachment using the cement is extremely easy, and removal can be accomplished by means of a nonirritating adhesive remover supplied by the manufacturer. Acetone has also been discovered to be very effective in removing the cement.

PROBLEM WWRC-5 *An Improved Connector for Polyvinyl Tubing*

Many males with urinary incontinence wear a leg bag urinal, which is supported on the inside of the leg by straps around the leg. Whenever urine is emitted by the patient, it is conducted by gravity through a sheath and 1/4-inch polyvinyl tubing to the legbag which functions as a collector and temporary storage for the urine. When the patient retires at night, the leg bag can no longer be used, and a night bag which is attached to the patient's bed at a level lower than the patient is used. This means that the tubing must be removed from the leg bag and attached to the night bag. Presently, the connection to the leg bag consists of a sleeve slightly larger than the tubing, over which the tubing must be forced to complete the connection. This requires considerable grip and strength in the hands. Removal of the tubing from the leg bag is much more difficult and can be quite hard for a person of normal hand strength to accomplish. Many of these patients have reduced strength and partial loss of function in their hands, so it is even more difficult for them. Upon arising in the morning, the tubing must be removed from the night bag and connection again made to the leg bag. It is extremely important that these patients be made as self-sufficient as possible, not only from a practical standpoint, but also to lower their sense of dependence and thus improve their mental outlook.

Because of the difficulty presented by the connectors now in use, many of these patients require assistance both in the evening upon retiring and in the morning. This is extremely undesirable both from the patient's and the therapist's viewpoints. A new type of connector that requires less strength to connect and disconnect but provides a leak-proof connection is desired. It is also desirable that use of the connector not require highly coordinated motions or great skill.

The month following acceptance of this problem, Mr. Bob Zimmerman of George Washington University suggested that a commercially available connector from the Cole-Parmer Instrument Company might prove to be a solution to this problem. Information on the connector was obtained from the manufacturer and forwarded to the medical investigator who then ordered one of the connectors to determine its applicability to this problem. The connector has been evaluated in the clinical environment and has been found to be completely acceptable as a solution to the problem.

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3.0 SUMMARY OF TEAM ACTIVITY DURING REPORTING PERIOD

3.1 Problem Activity Summary

The following is a summary of project activity undertaken by the RTI Team during the period August 23, 1971, to August 31, 1972.

New Problems Accepted	*44*
Problems Rejected	*6*
Problems Inactivated	*88*
Problems Reactivated	*3*
Total Problems Currently Active	*57*
Preliminary Problem Statements Prepared	*44*
Problem Statements Disseminated	*4*
Responses to Problem Statements	*23*
RDC Computer Searches Initiated	*31*
Impacts	*2*
Potential Technology Applications	*8*
Technology Applications	*8*

A description of currently active problems categorized by health area is attached as Appendix B.

Table I lists the currently active problems by impact area.

3.2 Presentations by Team Members at Conferences, Meetings, and Symposia

On September 14, 1971, Dr. F. T. Wooten and Mr. Ed Page presented the Biomedical Application Team to the Executive Committee of the University of Miami School of Medicine.

On October 6, 1971, Dr. F. T. Wooten presented, by invitation, a paper entitled, "Future Needs for Biomedical Transducers," at the Transducer Conference in Washington sponsored by the Institute of Electrical and Electronic Engineers.

PROBABLE SOLUTION REQUIREMENT

TABLE I

IMPACT AREAS OF ACTIVE PROBLEMS

HEALTH CARE IMPACT CATEGORIES	ANALYTICAL INSTRUMENT SYSTEMS	SYSTEM COMPONENTS (EQUIPMENT)	COMPUTER PROGRAMS	PROSTHETIC DEVICES	MATERIALS, CHEMICALS	THERAPEUTIC EQUIPMENT	OTHER	TOTAL
OTHER, MISCELLANEOUS	3	2		1	2		2	10
BASIC MEDICAL RESEARCH PROBLEMS	9	2						11
DETECTION AND TREATMENT OF DENTAL AND ORAL DISORDERS	1							1
IMPROVED SURGICAL PROCEDURES	2				1			3
RESPIRATORY DISEASE DETECTION AND TREATMENT	2	1						3
REDUCTION OF INFANT MORTALITY								
KIDNEY DISEASE DETECTION AND TREATMENT		1		1			1	3
PROVISION OF MORE/BETTER MEDICAL/PARAMEDICAL PERSONNEL								
REMOTE HEALTH CARE SERVICES								
HEALTH CARE COST REDUCTION								
ECOLOGY	1							1
DETECTION AND TREATMENT OF CANCER	5	2						7
DETECTION AND TREATMENT OF HEART DISEASE	4	4	1					9
MENTAL HEALTH	1							1
ORGAN ASSIST DEVICES								
ARTIFICIAL ORGANS					1			1
REHABILITATION MEDICINE	3	1						4
MULTIPHASIC HEALTH SCREENING, CLINICAL DIAGNOSIS	1		1		2			4
COMMUNICABLE DISEASE DETECTION AND PREVENTION								
TOTAL	32	13	2	2	6		3	58

On October 14, 1971, Mr. Ernest Harrison presented the keynote address at the Regional Physical Therapist Association Meeting in Asheville, North Carolina. This presentation included a discussion of the Biomedical Application Team Program as well as a movie of the Apollo XV flight.

On November 1, 1971, Mr. Ernest Harrison presented the keynote address at the American Occupational Therapy Association Meeting in Cleveland, Ohio.

During the week of November 1, 1971, Dr. F. T. Wooten attended the Annual Conference on Engineering in Medicine and Biology held in Las Vegas, Nevada.

On November 17, 1971, Mr. Edward Page presented Dr. Wooten's paper entitled, "Advancements in Medicine from Aerospace Research," at the National Space Conference in Huntsville, Alabama.

On February 18, 1972, Mr. Ed Page attended the Conference on Aerospace Technology and Radiology sponsored jointly by the American College of Radiology and the National Aeronautics and Space Administration.

On February 23, 1972, Dr. F. T. Wooten presented a paper describing the Application Team Program at the invitation of the Detroit Engineering Society.

On March 21, 1972, Dr. F. T. Wooten presented a paper entitled, "An Ear Oximeter for Shock Detection," at the IEEE INTERCON Conference in New York.

On March 27 & 28, 1972, Dr. F. T. Wooten participated in a panel discussion at the National Conference on Electronics in Medicine held in Chicago. The panel discussion subject was "Aerospace Technology in Medicine."

On April 17, 1972, Mr. Ernest Harrison presented a paper co-authored with Dr. J. L. Lubkur and Dr. G. D. Allen of the University of North Carolina entitled, "Electrodes for Use in Speech Neurology," at the American Accoustical Society Meeting in Buffalo.

During the week of April 24, 1972, Dr. F. T. Wooten attended the Annual Conference of the Association for the Advancement of Medical Instrumentation and presented a paper entitled, "Evaluation of a New Catheter Pressure Transducer."

On June 7, 1972, Mr. Ernest Harrison presented a discussion of the Biomedical Application Team Program at the invitation of the Department of Vocational Rehabilitation of the State of North Carolina. This presentation was made to a meeting of about forty rehabilitation counselors.

3.3 Visits to NASA Field Centers

In order to continually increase Team knowledge of NASA research, members make frequent visits to field centers for technical discussions. During this reporting period, visits were made to Ames Research Center, Goddard Space Flight Center, Jet Propulsion Laboratory, Langley Research Center, Lewis Research Center, Marshall Space Flight Center, and Michoud Assembly Facility

3.4 Association for the Advancement of Medical Instrumentation

3.4.1 Committee on Aerospace Technology

In order to enhance the impact on the medical community of technology applications resulting from the NASA program, the team is actively seeking industrial manufacture of marketable devices. One approach being used is a committee within the Association for the Advancement of Medical Instrumentation (AAMI), which is considering ways to advise and interest the industrial community in applications of technology. This committee, called the Aerospace Technology Committee, met twice during the year in association with national meetings. One meeting of the committee was held on November 3, 1971, in association with the Conference on Engineering in Medicine and Biology in Las Vegas, Nevada. The other meeting of the committee was held on April 24, 1972, in association with the Annual Meeting of the Association for the Advancement of Medical Instrumentation.

During the meetings that were held this year, a number of significant problem areas were discussed. During both meetings, specific examples of NASA technology were considered and during the second meeting actual pieces of hardware were exhibited including a vital signs monitor, a light monitor for the blind, a sound-level meter for the deaf, a radiation detector, and a signaling system for paraplegic patients. One important conclusion drawn from these discussions is that a personal interaction between a NASA or Biomedical Application Team member and the industrial representative is required. In general, it was felt that it would be very difficult to interest any company in a specific device by general mailings but that direct contacts would be necessary. This methodology would be consistent with the overall Biomedical Application Team methodology, which relies heavily on personal interaction between team members and medical community as well as between team members and the NASA community.

Another conclusion of the committee is that it is unexpectedly difficult to interest companies in devices for which they have little input during the research and development phase. Superficially, it would seem likely that a company would find it advantageous to accept a

particular device for manufacture for which the research and development cost has already been borne by the Federal Government. However, this does not appear to be the case; in fact, it appears to be of major importance to have a company involved in the project at the earliest possible stage.

This committee, which is composed of physicians, NASA personnel, and industrial representatives, has provided some insight into the difficulties inherent in attempting to interest manufacturers in specific technology applications. It is hoped that continued efforts by this committee will help to solve the problems surrounding this important aspect of the technology utilization program.

3.4.2 Conference Session on NASA Technology

At the invitation of Mr. Michael Miller, Executive Director of AAMI, the Research Triangle Institute Biomedical Application Team organized a program session on NASA technology at the Annual Meeting of the Association for the Advancement of Medical Instrumentation held in Las Vegas April 23-26, 1972. The program for the session was as follows:

Lessons from Support of Man in Space Applied to Medical Support on Earth	David L. Winter, M.D. NASA
New Concepts in Trace Chemical Analysis	S.A. Rositano NASA
Advanced Concepts in Graphic Techniques for Studying Heart Function	Harold Sandler, M.D. NASA
Recent Developments in Ultrasonic Technology for Use in Measuring Physiological States in Man	S.A. Rositano NASA
Biomedical Engineering at the Jet Propulsion Laboratory	Benn D. Martin NASA
Evaluation of a New Catheter Pressure Transducer	F. Thomas Wooten, Ph.D. Research Triangle Institute M. M. Jarmakani, M.D. Duke University Medical School

This session was attended by approximately 75 people and was followed by an active question and answer session. Because of the success of this presentation, Mr. Miller has requested that a similar session be presented at the 1973 Conference.

4.0 SUMMARY OF BIOMEDICAL APPLICATION TEAM STATUS AT USER INSTITUTIONS

4.1 Introduction

In Section 1.4 of this report, the 14 medical institutions participating in the RTI Application Team Program were listed. In order to put into perspective the relative activity and history of the activity at each school, the following brief summaries are presented.

4.2 Summary Status for User Institutions Participating in the Program on August 31, 1972.

Duke University Medical Center - This institution has been active in the Application Team Program for 5 years, and a total of 84 problems have been considered at this school. During the past 2 years, there has been a noticeable slackening of activity because of the reduction in Federal funds at this school, but an increase in activity is expected during the coming year.

Bowman Gray School of Medicine of the Wake Forest University - This school has been active in the Application Team Program for 5 years during which time a total of 112 problems have been considered. Activity has slowed noticeably in recent months and this lower level of activity is expected to continue at this school over the next year.

University of North Carolina Medical School and Dental School - A total of 95 problems have been defined at the schools of medicine and dentistry during the past 5 years. Activity at the present time is low but an increase in activity is already underway.

Tulane University School of Medicine - Team activity started at Tulane in December 1969, making this school one of the more recent additions to the Application Team Program. The cooperation and enthusiasm of the Tulane staff have contributed to a very successful program. Thus far, a total of 34 problems have been considered and activity is expected to continue at a very satisfactory level.

Institute of Rehabilitation Medicine of the New York University - Since activity started in this school in April 1969, a total of 26 problems have been considered. This institution is a small group within a large university and most of the acceptable problems have already been considered. No further activity is anticipated with this institution.

National Cancer Institute - Activities at the National Cancer Institute (NCI) started in August 1969, and a total of 12 problems have been considered. NCI personnel have expressed satisfaction with the success of the program and activity is anticipated to be continued at the existing level during the coming months.

Ochsner Clinic and Foundation - The Ochsner Foundation is a small research group associated with a private clinic in New Orleans. Only two problems have been defined at this institution but both problems have been solved using aerospace technology.

Virginia Department of Vocational Rehabilitation - This department operates the Woodrow Wilson Rehabilitation Center. An unsolicited request for Team assistance was received and problem definition started in November 1970. A total of 16 problems have been considered at this institution. Activity during the past year has emphasized the implementation of existing potential solutions, and no significant new problem activity is expected over the next year.

National Heart and Lung Institute - Activities started within the Medical Devices Application Branch of NHLI in September 1970. A total of seven problems have been defined and continued interaction is anticipated with NHLI.

National Institute of Environmental Health Sciences - This is the smallest institute of the National Institutes of Health and Team activities began at NIEHS in October 1970. A total of three problems have been accepted and a low level of problem activity is anticipated at this institution.

Emory University School of Medicine - Activities at this school started in January 1971, and a total of 18 problems have been considered. Continuing substantial activity is anticipated at this school.

University of Miami School of Medicine - In answer to an unsolicited request, the Team initiated activities in December 1970 at this institution. In September 1971 a presentation was made to the Dean of Medicine, and a substantial problem activity level resulted. A significant level of activity is expected over the next year.

Medical University of South Carolina - In answer to an unsolicited request, the Team initiated activities at this school in March 1971. Activities were concentrated in one group of individuals in the Department of Surgery. A low level of activity is expected for this institution during the coming year.

5.0 APPLICATIONS ENGINEERING PROGRAM

Selected problems have been accepted for implementation of technology under the Applications Engineering Program. In the program, the technology is actually implemented by NASA. Activities for these nine problems are presented in the following summaries.

PROBLEM DU-31 *Catheter-Mounted Pressure Transducer*

A pressure transducer developed for use in the aerospace program has been modified for measurement of pressure in human hearts.

Heart disease is the major cause of death among the American people. The disease affects every age group, and it is extremely interesting that the youngest age group, infants, demonstrates nearly all varieties of abnormal cardiac condition. Thus,the study of pediatric heart disease is of major importance. Many types of abnormal heart conditions in children can be surgically corrected, but proper diagnosis becomes of paramount importance. The correct diagnosis of heart disease in children requires very careful measurements of pressure and volume of the heart. The arteries and heart chambers are very small and require an unusually small catheter for making various measurements. One of the measurements of great importance is pressure in the aorta and in all four chambers of the heart. This pressure measurement is more difficult in small children because heart rates can range as high as 300 beats per minute. Thus, the pressure transducers must be able to measure rapid changes in pressure and very small gradients in pressure in order to detect the abnormalities in heart condition.

A major research effort at Duke University Medical Center is devoted to understanding the heart diseases in children. In particular, the research is devoted to determining a correlation between pressure changes in all four chambers of the heart with motions of the chest wall. The motions of the chest wall can be detected by an apex cardiogram. Thus, a correlation will be made between a measurement technique requiring penetration of the heart and a measurement technique entirely external to the body. It is necessary to measure pressure, but the existing methods of measuring pressure do not have sufficient sensitivity, frequency response, or size capability. Also, fluid-filled catheters, which are commonly used, cause significant over-shoot in the contraction pressure waveform. Thus, a new pressure-measuring device is required.

A pressure transducer with size #5 French (1.5 mm) or smaller is required. The pressure range is -30 mm to +300 mm Hg. The maximum frequency of response is undetermined but frequencies as high as 100 Hz may be encountered. Pressure resolution of 1 mm Hg is required, and temperature compensation from 35°-40°C is required. The transducer should be mounted on the side of a catheter to prevent erroneous readings due to motion of the catheter against the heart wall.

The solution to this problem appears to be the tunnel diode transducer developed by Dr. W. Rindner at Electronics Research Center. Dr. Rindner has formed his own company, Device Research, Incorporated, and is presently offering the NASA-developed transducer. The Duke researcher has examined the specifications of the Rindner TD-1 Transducer and believes that this will solve his problem.

Figure 21. Tunnel Diode Pressure Transducer.

The TD-1 pressure transducer, shown in Figure 21, is presently undergoing tests at Duke University Medical Center to determine its characteristics in animal experiments. Initial tests indicated excellent sensitivity

but some problems in thermal drift. Dr. Rindner has modified the transducer to solve this problem, and further tests are underway.

PROBLEM NCI-3 *Automatic Blood Pressure Measurement of Critically Ill Patients*

Equipment designed to monitor astronauts during ground training is being used in the monitoring of leukemia patients. Leukemia, a major form of cancer, is a disease characterized by a self-penetrating proliferation of white blood cell forming tissue.

The National Cancer Institute (NCI) is conducting a vigorous program directed toward finding the causes and cure for this disease. In the clinical phase of this program, a problem exists in the early detection of shock, which is defined as a sudden reduction in the volume of circulating blood. Shock often occurs as the result of hemorrhage, infection, or a combination of the two; but if not recognized early, shock becomes irreversible and rapidly fatal. Thus, a need exists for an accurate indicator of the onset of shock so that corrective measures can be taken.

One important measure of the onset of shock is a reduction in blood pressure. Blood pressure is defined as the pressure exerted by the blood within the arteries. The two pressures of interest, systolic and diastolic, are the maximum and minimum pressures exerted on the walls of the arteries by the pulsatile pumping of the heart.

The primary method for measuring blood pressure is the sphygamomanometer, which is a cuff placed around the upper arm. The cuff method is undesirable for continuous monitoring of blood pressure because the repeated inflation of the cuff disturbs the patient.

A method for monitoring blood pressure on a continuous basis is needed for bed patients. The method should not significantly disturb the patient. The pressure range of interest is 0-200 mm Hg and a sensitivity of 5-10 mm Hg is required. An invasive technique (i.e., one that punctures the skin) is considered undesirable.

A computer search of the NASA document file was made as the first step toward finding a solution to this problem. Although the search revealed a number of interesting documents, no adequate solution was found. However, the search revealed that Ames Research Center had conducted much of NASA's research in blood pressure measurement. During a trip to Ames Research Center, the Team discussed the problem with Mr. Joseph R. Smith who suggested that an alternate approach would be to use the oximeter

developed by ARC for measuring blood oxygen content. This device was designed to clip onto the upper part of the ear and measure the oxygen content of the peripheral blood during various ground testing operations such as centrifuging. This approach was discussed with the problem originator, and it was agreed that the approach was a useful one.

The oximeter, shown in Figure 22 , operates by measuring the infrared absorption through the upper part of the ear by placing an infrared source and a detector on opposite sides of the ear.

The output of the meter is a measure of the oxygen in the blood of the ear. Since the constantly changing blood volume of the ear is caused by the blood pressure changes, the output of the oximeter is affected by changes in the blood pressure. Thus, the unit can be used to obtain a relative measure of blood pressure but not an absolute measure. The problem originator stated that the relative change in blood pressure was of major interest because it is this relative measure that is of importance in detecting the onset of shock. The problem originator also stated that tests needed to be conducted to determine whether the peripheral blood pressure could be used as an adequate measure of the onset of shock.

The NASA ear oximeter is presently on loan for clinical trials at NCI. Present efforts are devoted to achieving maximum stability during *in vitro* testing.

Figure 22. NASA Ear Oximeter.

PROBLEM NCI-4 *Controlled Rate of Freezing a Liquid*

Leukemia, a disease that kills about 15,000 Americans annually, is characterized by a proliferation of the tissue that forms white blood cells. Although the white cells in the blood can either increase, decrease, or remain constant in number, the bone marrow where the cells are formed will proliferate.

Treatment of leukemia involves killing the cancerous white blood cells in the blood and in the bone marrow using drugs or radiation. This process can cause loss of all bone marrow so that normal white cell production cannot occur.

When this loss of bone marrow occurs, white cells must be resupplied to the patient. For this purpose a bank or storage facility of white cells is required. This is impossible at present because adequate storage procedures are unavailable. Although red cells can be preserved by freezing, white cells are now destroyed by the existing freezing and thawing procedures. One important parameter in freezing white blood cells is believed to be the rate of freezing. Rate of freezing cannot at present be controlled because of the plateau in cooling rate when the latent heat is released at the freezing point.

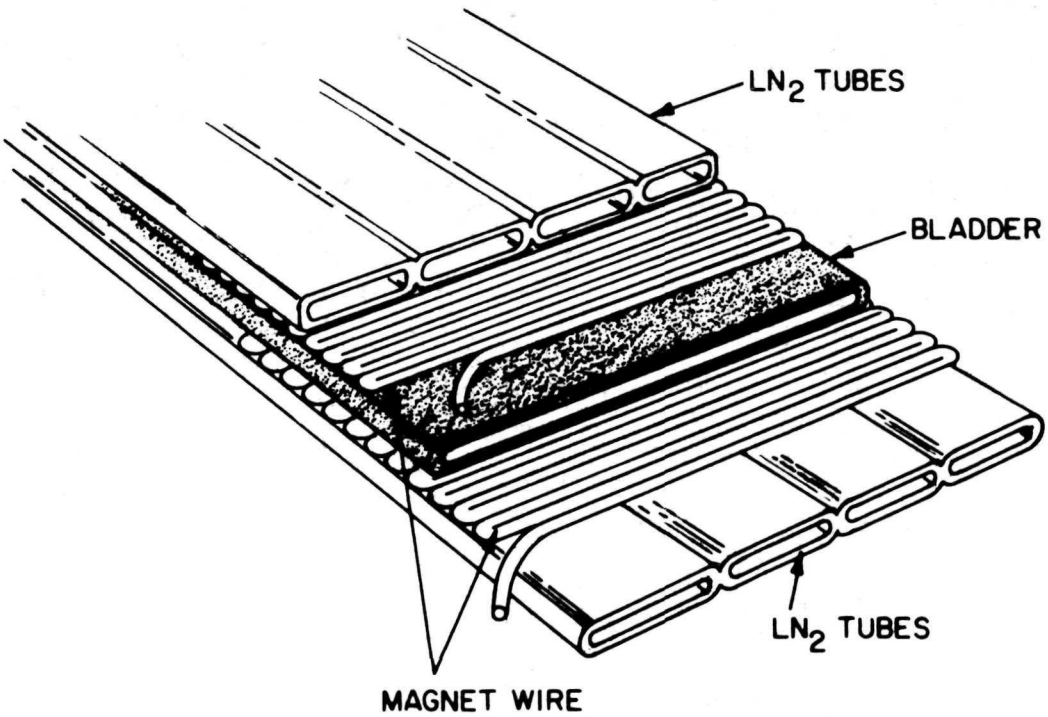

Figure 23. Controlled Freezing Unit.

The present method for freezing is a liquid nitrogen system, which cools a secondary liquid, which in turn cools the cells contained in a flat Teflon bag. To prevent contamination of the cells, it is desirable that any new technique utilize a Teflon container.

The basic requirement is to have a method of detecting the onset of freezing and then increasing the heat transfer rate during the release of latent heat so that a nearly constant rate of freezing can be maintained from room temperature to -50°C.

This problem was forwarded to the Jet Propulsion Laboratory (JPL) where Mr. L. S. Doubt and Mr. W. Tener suggested the configuration shown in Figure 23. The cells are held in a Teflon bladder, which is surrounded by a copper heating element and liquid nitrogen tubes. During the cooling cycle from room temperature to the freezing point, the heating coils control the cooling rate. At the freezing point, the heat is turned off and the latent heat of the cells is rapidly removed. Then the heat is turned on again to control the rate until -50°C is reached.

Although the proposed solution originated at JPL, implementation of this idea is being pursued by the Goddard Space Flight Center (GSFC) because of the geographic proximity of NCI and GSFC. GSFC personnel are now using computer aided design to optimize the basic configuration before hardware construction begins. The computer analysis utilizes the same techniques that NASA uses in space applications such as thermal balance in spacecraft. Coordination between NCI and GSFC research staff members will be closely maintained to insure that the final device will meet all medical and engineering requirements.

Initial studies have shown that a modification of the initial concept will be required. A computer simulation model has been developed that will allow design modifications to be quickly evaluated.

PROBLEM OF-2 *Bone Density Measurement*

A technique developed for measuring calcium loss in astronaut bones may prove useful in measuring calcium loss of cancer patients.

One of the many effects of a cancer is the secretion of a hormone that leaches calcium from the bone. This can produce lethal hypercalcemia. For example, 20 percent of lung cancer victims and 40 percent of breast cancer victims have hypercalcemia during the course of their diseases. Although some forms of hypercalcemia can be treated medically, the fundamental cause of its occurrence is unknown. In studies of experimental, tumor-bearing animals that secrete a hypercalcemia-producing substance, measurements of bone density would be useful in order to follow the progress of demineralization. Thus, a method of measuring bone density in experimental animals to be used in basic research on cancer is required.

At present, bone density is measured using the radiographic method in which an X-ray is made of the bone and the density of the X-ray film is

used as a measure of the bone density. This method is unsuitable for repeated measurements because of the high doses of X-rays required. For complete safety, dose levels should not exceed 5 rads per year for continual exposure. A method that does not involve X-rays would be desirable.

Although the technique will be used eventually on human beings, initially it will be used on rat tibia (3 x 0.5 cm). Changes in bone density as high as 50 percent are expected and the accuracy of detection should be ±5 percent. Preferably, the rat will not be sacrificed so that repeated measurements can be made over a 14-week period. Large numbers of animals bearing tumors can be utilized, allowing for destructive measurement comparisons to be made.

A technique developed to measure astronaut bone density on the Skylab flights has been identified as applicable to this problem. Basically, this device (shown in Figure 24) measures the ultrasonic velocity through the bone, which could be correlated with bone density.

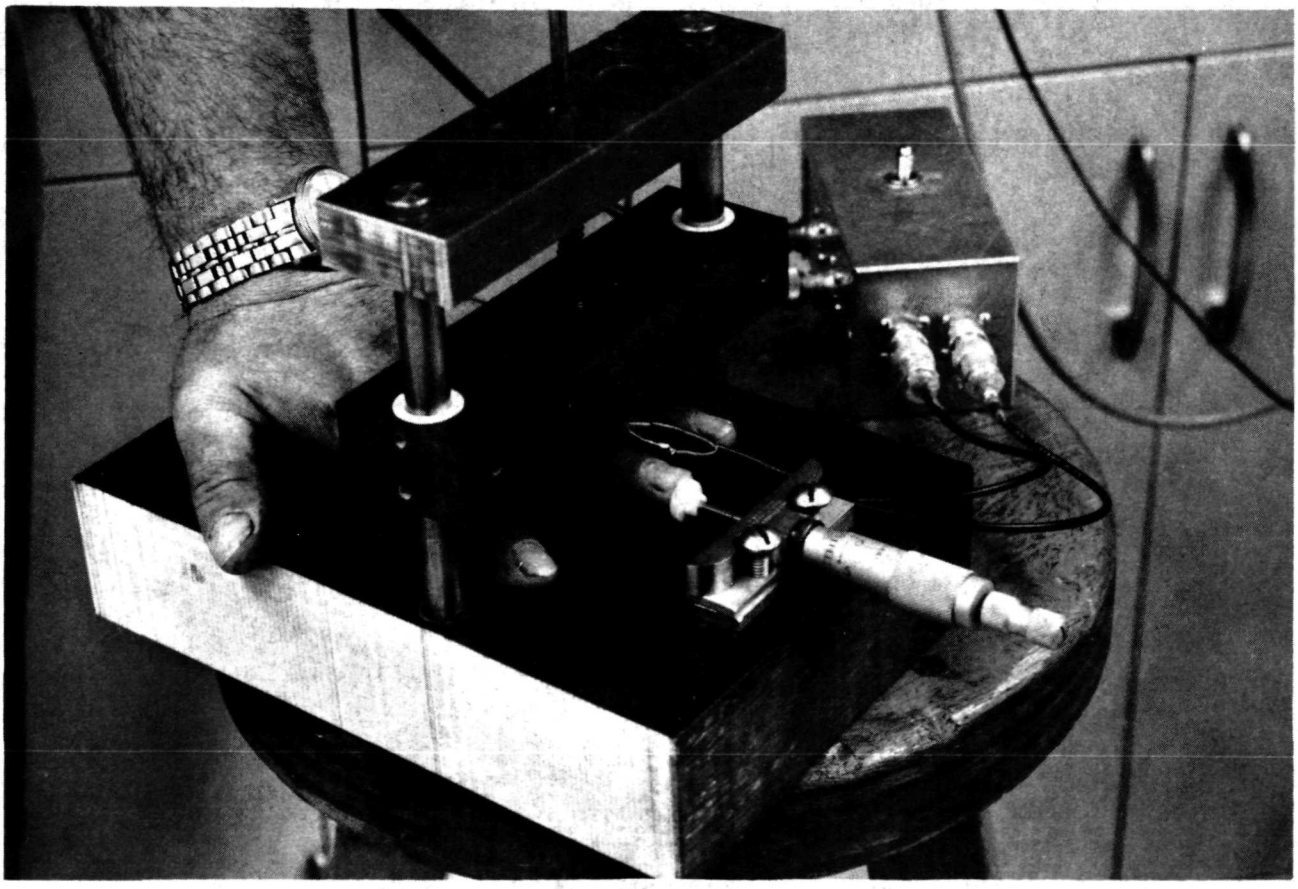

Figure 24. NASA Bone Densitometer.

Discussions with Dr. Ray Gause and Mr. Jim Hoop of MSFC revealed that this instrument was directly applicable to this particular problem. A complete description of the instrument was given to the problem originator, who has stated that he would like to obtain such a unit for his experimental studies. Plans are now being made to lend the MSFC bone densitometer to the Ochsner research group. Initial tests on the denitometer at the Baptist Hospital in Memphis have indicated that the device will be an excellent solution to this problem. Mr. Jim Hoop has designed and built a modification of the transducer in order to fit the experimental animals.

PROBLEM DU-74 *Testing of Neuropathic Patients*

A system designed to measure pilot performance will be adapted for the study of neuromuscular disorders.

Many people suffer neuromuscular disorders that result in the loss or impairment of muscular control. The cause of these disorders is damage to the nervous system that controls the musculature. One symptom of this disorder is uncontollable contraction and relaxation of muscles.

Modern therapeutic treatment allows many thousands of patients to improve the degree to which they can exercise voluntary control over their muscles and, therefore, assume a more active and useful role in society. Therapeutic treatment, however, is presently hampered by the difficulty of measuring the improvement that individual patients make during the course of therapy. As an example of a currently employed technique for measuring a patient's progress, the patient is presented with a drawing of a thin-lined geometrical pattern and is asked to trace the pattern with a pencil. From this experiment, one can make a subjective judgment regarding the degree to which a patient is able to control the movement of his hand. A more quantitative measurement of a patient's progress would lead to refined therapeutic techniques, which, in turn, should bring about more rapid and more complete recovery for the many patients suffering from neuromuscular disorders.

In the design of highly reliable aircraft and space systems that are to be operated under direct manual control, the problem of the man-machine interface becomes critical. Scientists at NASA's Langley Research Center have been working for several years on the problems of designing flight vehicles that are well suited for control by a human operator. Of major importance is the understanding of the motor and perceptual characteristics of the human pilot. To measure pilot characteristics such as limb controllability, response time, rate of movement, etc., LRC researchers developed a variety of tests and testing apparatuses. This research resulted in a mathematical model of the human pilot.

The Team learned of this research at Langley and arranged a visit to talk with two of the pioneers in pilot modeling. Upon discussing this problem with the Langley researchers, it became evident that the tests they had devised to determine pilot characteristics had much in common with the requirements for testing patients with motor disorders. The Team was given a demonstration of a tracking task that was employed at LRC. In this case, aircraft pilots were required to track an oscilloscope trace of a noisy signal using a joystick manipulator. With this configuration, it was possible to record both pilot response and instantaneous error in tracking random disturbance. Included in the LRC tasks were control stick and aircraft dynamics. This configuration is illustrated in Figure 25 for a single-axis tracking task. The Langley researchers suggested that the stick and aircraft dynamics be removed from the tasks in order to acquire a better measurement of the motor performance of neuropathic patients. The LRC tracking unit with the suggested modifications as shown in Figure 26 has been evaluated by the problem originator.

The LRC system will provide much quantitative information on human motor performance; however, a modified version of the manipulator will be required to make the test results less sensitive to the patient's perceptual performance. Engineers at LRC have agreed to give assistance in the design of a unit for administering and analyzing the results of tracking tasks. This system is expected to be employed in a clinical environment at Duke.

PROBLEM WF-3 *Prosthetic Valve for Urinary Tract*

A number of different injuries and diseases can result in loss of control of urinary function. Victims of congenital defects, neurogenic bladder diseases, stroke, and multiple sclerosis, as well as war and automobile accident casualties, frequently experience bladder and urethral malfunctions. These malfunctions usually involve an inability to contract the muscles in the bladder wall or an inability to relax muscles that close the urethra; i.e., the passage through which the bladder is emptied. This condition generally results in gradual deterioration of the bladder, infections of the urinary tract, and, in some cases, damage to the kidneys and subsequent death. This condition is the most frequent cause of death of paraplegics. In treating patients who cannot control urinary function, it is important that the bladder be allowed to fill and then be emptied rapidly every 3 to 4 hours. This periodic functioning allows the muscles of the bladder to be exercised and, as a result, to remain healthy. One approach that has been taken is to attach electrodes to the bladder muscles so that contraction of the bladder can be electrically induced by the patient. This electrical stimulation unfortunately also induces contraction of muscle groups--i.e., sphincters--that close the urethra. As a result, fluid pressure inside the bladder becomes dangerously and painfully high.

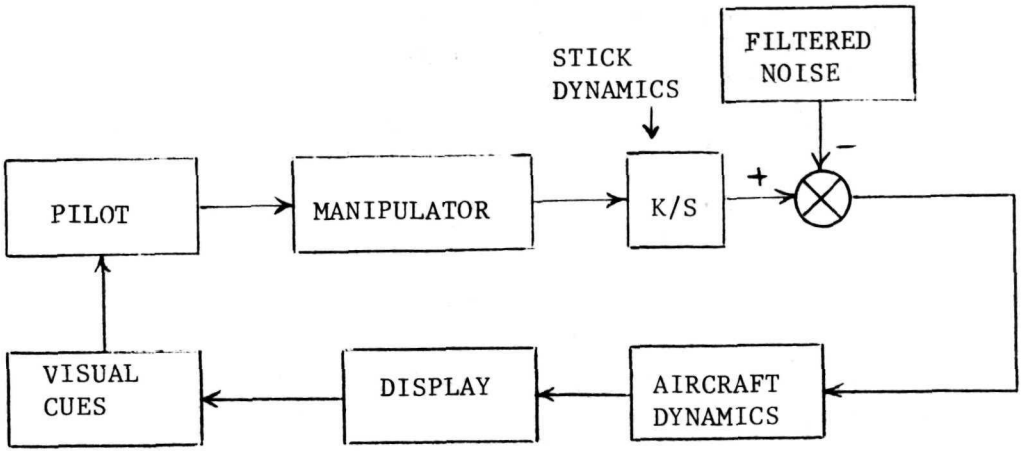

Figure 25. Single Axis LRC Tracking Task Block Diagram.

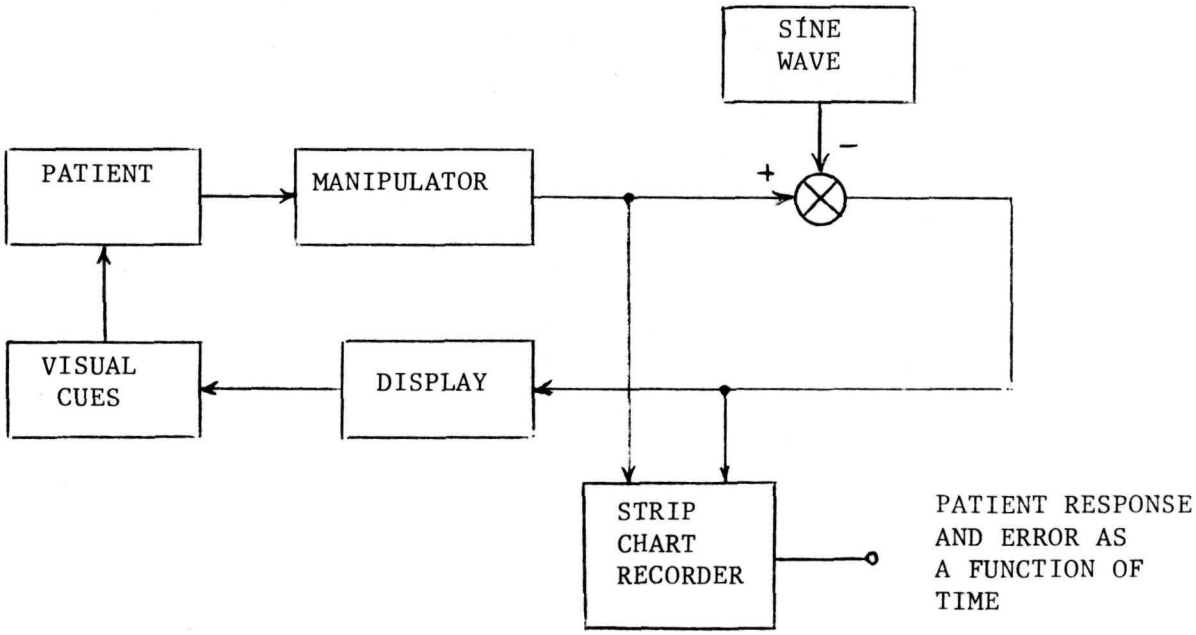

Figure 26. Block Diagram of Single Axis Track Task for Testing Neuropathic Patients.

A valve that can be implanted in the urethra and can be controlled by the patient is needed to successfully treat the loss of urinary function. In cases where bladder muscle is healthy when the valve is implanted, the bladder would contract when the valve is opened without stimulation due to the inherent elasticity of healthy muscle tissue. If bladder muscle deterioration has occurred, electrical stimulation can be used simultaneously with opening of the valve without causing excessive internal pressure.

Functional requirements and constraints on the configuration of the prosthetic urethral valve are as follows:

(1) It is desirable that the valve be cylindrical with a maximum length of 2 cm and a maximum diameter of 2.5 cm. (Small rigid tubes will pass through the physiological valves--sphincter vesicle and external sphincter--shown in the figure so that fluid is held in the bladder only by the prosthetic valve.)

(2) The patient must have manual control of the valve.

(3) The valve must remain closed when exposed to a maximum differential pressure of 150 cm of H_2O.

(4) The valve cannot be controlled through the use of wires or tubes passing through the skin.

(5) All surfaces of the valve that are exposed to tissue must be physiologically inert material, such as silicone rubber.

(6) Functional reliability is an absolute necessity.

The solution to the requirement for a prosthetic urethral valve (Figure 27) is a completely implanted and closed hydraulic system with two stable states. One state corresponds to the valve being closed; in the other state, the valve is open. The open and closed states of the prothesis are selected by the patient. This is done simply by pressing with the hand on one of two positions of his body. A more detailed description of the operation and construction of the valve is presented in the following paragraphs.

The valve essentially consists of three elements: the urinary valve, a check valve, and a pressure bulb, connected by flexible tubing. The urinary valve consists of an inflatable, rubber diaphragm fitted into a polystyrene tube. The polystyrene tube restrains the diaphragm, so that, when the diaphragm is inflated, the tube is completely sealed. In addition, the polystyrene tube is configured to allow the urethral valve to be securely attached in place.

The check valve, which lies between the urinary valve and the pressure bulb, serves two functions. First, it is a one-way check valve

placed so that, when the urethral valve diaphragm is inflated, the check valve is closed, pressurizing the diaphragm and keeping the urethral valve closed. Second, the check valve is specially designed so that slight deformation of the check valve, achieved by applying a small force to the body of the valve, causes the check valve to open. This releases pressure in the diaphragm opening the urethral valve. The body of the check valve is constructed from silicone rubber with a rigid ball preloaded on the seat. Slight pressure applied to the body of the check valve deforms the valve seat so that, instead of having a circular cross section, which can be sealed by a ball, it becomes an essentially eliptical cross section through which fluid can leak around the ball, releasing pressure on the urethral valve.

The pressure bulb is used to apply pressure to the diaphragm of the urethral valve, thus closing it. Both the check valve and the pressure bulb can be implanted beneath and operated through the skin on the patient's side. The two are separated by a flexible tube approximately 4 inches long to achieve unambiguous separation of function.

This system fulfills all of the requirements of the desired prosthetic urethral valve, yet retains a simplicity which should lead to reliable operation. Several features of the valve are particularly important: (1) The entire system can be easily coated with silicone rubber and rendered physiologically inert. (2) No external connections are required to actuate the valve. The simplicity of the check valve permits voiding using only the pressure of one finger on the skin at the appropriate point. Reinflation of the diaphragm, when voiding is complete, is easily accomplished by pressing with the palm of the hand over the bulb, which is implanted underneath the skin. (3) Because of the simplicity of the system, it should be a highly reliable device. Should the system fail, resulting in loss of pressure to the prosthetic urethral valve, the urinary track would remain open. Thus an immediate emergency operation would not be required, as would be the case if the valve could fail in a closed position. (4) Inflation and deflation of the diaphragm in the urinary valve will result in flexing of the exterior surfaces of the valve that come in contact with the urine. This flexing action will tend to break off any incrustation that might occur, keeping the closing surfaces of the valve clean.

The prosthetic urethral valve has been fabricated under NASA contract by the Biomedical Engineering Department of the University of Virginia. A total of five units were completed. Arrangements have been completed with members of the University of Virginia Medical School for *in vivo* testing of the valves in experimental animals.

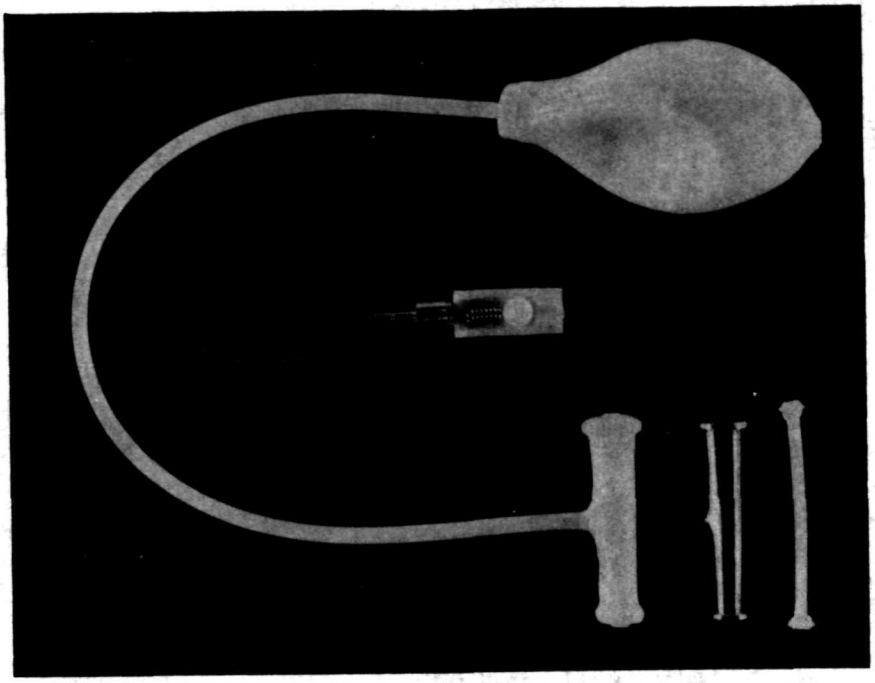

Figure 27. Prosthetic Urethral Valve.

PROBLEM VAM-6 *Negative Pressure Chamber*

Activities for this problem are discussed in the Potential Technology Application Report in Section 2.2.

PROBLEM WWRC-7 *A Signalling (Nurse-Call) System for Multiple Sclerosis Patients*

Activities for this problem are discussed in the Potential Technology Application Report in Section 2.2.

PROBLEM WWRC-11 *A Remotely Controlled Device to Pick Up and Transfer Single Sheets of Paper*

Activities for this problem are discussed in the Technology Application Report in Section 2.1.

6.0 CONCLUSIONS AND RECOMMENDATIONS

During this reporting period, the Team has accomplished a total of eight applications and eight potential applications of aerospace technology to medicine. The major source of solutions for these problems continues to be direct contact with NASA Field Centers by Team personnel. During this reporting period, 81 percent of the applications and potential applications of technology were solved by direct contact with the Field Centers and only 6 percent were solved by information searching. This continues a trend that the Team has noted for several years although the percentage of solutions from direct contact with the Field Centers is the highest ever noted during a reporting period. For example, during the reporting period March 1970 through March 1971, direct contact with the Field Centers resulted in 68 percent of the solutions. It is clear that the primary source of information for the Team is still direct contact with the Field Centers, which conclusively demonstrates the need for continual close contact by the Team with all NASA Field Centers.

Over the past several years, the team philosophy on problem solving has been directed towards accepting fewer problems in order that more attention can be given to each individual problem. Experience has shown that an adequate base of technology is available for solution of most problems. The NASA system, however, is so large and so diverse that a significant effort must be devoted to each individual problem in order to develop the innovative uses of aerospace technology. The basic philosophy is thus directed toward accepting fewer but higher quality problems with an attempt to devote significant effort to each problem.

The Team has analyzed its activities at each of the medical institutions and has concluded that a more efficient team operation would result from significantly reducing the activities at some institutions and concentrating activity on those institutions that are more productive. In addition, this will allow the Team to expand its activities further with the National Institutes of Health. The Team experience with three of the National Institutes of Health has shown that the broad scope of activities at NIH and the availability of special resources are of significant benefit to Team activities.

The continued availability of reengineering resources at NASA Field Centers has become a significant factor in Team activities. The availability of these resources considerably increases the probability of solution implementation and has the potential for greatly increasing the impact of the program. Many problems have been solved that would have been solved without the availability of reengineering resources. This new direction in the Application Team Program has added significant impact in the medical community.

As noted above, a major source of problem solution is the direct interaction with NASA Field Centers. The enthusiastic support of the team program by Technology Utilization Officers in most of the Field

Centers has enabled the Team to develop quick access to individuals knowledgeable in unique aerospace technology. This resource is of major value to the Team and significant credit must be given to the efforts of the Technology Utilization Officers.

One problem in interaction with NASA Field Centers has developed during this reporting period and concerns the responses to problem statements. During the past year, the number of responses to Biomedical Problem Statements has dramatically decreased and this has significantly hampered the ability of the Team to solve problems using the circulated problem statement. This has placed even more emphasis on the direct contact with the Field Center and makes the cooperation of the Technology Utilization Officers of even greater importance.

The Team has made increasing utilization of direct personal interaction between physicians and the NASA personnel. The Team has found that a personal visit by a physician to a NASA Field Center is a very productive method for solving intricate medical problems. The Team normally accompanies a physician and, by arranging the visits through the Technology Utilization Officers, effective interactions have resulted. The Team recommends continued emphasis on this valuable tool for problem solving.

The Team has begun to investigate the problem of commercialization of the technology applications. Commercialization is accomplished when products result from technology applications in the medical community. As a result of the formation of a committee of the Association by the Advancement of Medical Instrumentation, new insight has been gained into the problems associated with the commercialization of specific technology applications. The problem has many facets but the Team believes that many of the problems associated with this area can be overcome by direct contact between Team personnel or NASA personnel and the industrial community. The mode of personal contact has been a cornerstone of the entire Application Team Program and should provide a valuable tool in solving this new aspect of the Technology Application Program. The Team recommends direct contact whenever possible in order to interest the industrial community in new biomedical products.

Finally, the Team notes that one indication of the growing importance of the Application Team Program in the medical community is the increase in requests for solutions to problems by physicians who have learned of the program through their colleagues. The growth in these unsolicited requests demonstrates that the Application Team Program has grown significantly in maturity over the past several years and now shows great promise in achieving the true potential of the unique concept of technology utilization.

APPENDIX A

PROJECT ACTIVITY SUMMARY

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TECHNOLOGY APPLICATIONS ACCOMPLISHED

MISC-11	*Electrodes for Emergency Coronary Care*
NCI-8	*Elliptical Lens*
OF-1	*Blood Embolism Detection*
WF-56	*A Fluid Pressure Calibration System*
WF-103	*Liquid Crystal Sterilization*
WF-113	*Digital Clock*
WWRC-13	*A Remotely Controlled Device to Pick Up and Transfer Single Sheets of Paper*
WWRC-14	*An Improved Axillary Strap*

POTENTIAL TECHNOLOGY APPLICATIONS IDENTIFIED

EU-5	*Sensors to Define the Position of Specific Parts of the Human Anatomy in Space During Normal Locomotion*
EU-18	*Display Panel for Testing Acuity*
TU-29	*Damage to Blood from Microwave Heaters*
VAM-2	*Diagnosing Gait Abnormalities*
VAM-6	*Negative Pressure Chamber*
VAM-12	*Heart Rate Tachometer*
WF-88	*Accurate Determination of Arterial Pressure Pulse Transit Time*
WWRC-7	*A Signalling (Nurse-Call) System for Multiple Sclerosis Patients*

IMPACTS

EU-8	*A Simple, Reliable Means of Attaching Instrumentation to the Skin*
WWRC-5	*An Improved Connector for Polyvinyl Tubing*

CURRENTLY ACTIVE PROBLEMS AS OF 31 AUGUST 1972

Problem Number	Status Code*	Problem Title
CP-3	E	*Automated Measurements from Coronary Angiograms*
DU-31	E	*Catheter-Mounted Pressure Transducer*
DU-48	E	*Urine Flowmeter*
DU-74	E	*Testing of Neuropathic Patients*
EU-9	B	*A Means of Uniquely Numbering Events Using One Channel of a Hard Copy Recorder*
EU-12	E	*A Rapid Method of Applying EEG Electrodes*
EU-17	B	*A Scanning Optical Display That Can Be Rotated About a Central Axis*
EU-18	B	*Display Panel for Testing Visual Acuity*
MISC-6	E	*Motor for Powering Prosthetic Unit*
MISC-9	B	*pO_2 Telemetry Capsule*
MISC-11	F	*Electrodes for Emergency Coronary Unit*
MISC-19	D	*Exercise EKG Analysis*
MISC-20	B	*Visual Field Mapping*
MISC-23	B	*Pattern Recognition of Ultrasonograms*
MISC-24	B	*Metal pH Electrode*
MUSC-13	B	*A Technique of Presenting Hot and/or Cold Stimuli to the Skin*
NCI-3	F	*Blood Pressure Measurement*
NCI-4	E	*Controlled Rate of Freezing a Liquid*
NCI-9	E	*Improved Emulsion for Autoradiography*
NCI-10	C	*Scanning Tumors in Small Animals with Gallium-67*
NCI-12	B	*New or Improved Methods of Detecting Breast Cancer*
NHLI-1	E	*Intramyocardial Stress Measurement*
NHLI-2	D	*Enhancement of the Efficiency of Transfer of Oxygen through the Boundary Layer in Flowing Blood*
OF-2	E	*Bone Density Measurement*
TU-3	E	*Lung Sound Detection*

*See explanation of status codes at end of listing.

Problem Number	Status Code	Problem Title
TU-9	E	*Human Voice Analysis*
TU-10	E	*Quantization of Heart Tissue Hardness*
TU-20	D	*Cell Area Measurement*
TU-22	E	*X-Ray Microplanigraph*
TU-25	D	*Blood Damage Measurement*
TU-27	C	*Blood Volume Measurement in the Lung*
TU-29	E	*Damage to Blood from Microwave Heaters*
TU-32	B	*Calcium Microelectrode*
TU-33	B	*Silica Measurement in Microgram Quantities*
UNC-60	D	*Counting Exposed Points on Autoradiographs*
UNC-61	D	*Pen Force Measurement*
UNC-63	D	*EKG Processor*
UNC-65	B	*Ultrasonic Image Enhancement*
UNC-66	B	*Determining Tissue Perfusion Adequacy*
USDA-1	C	*Separation of Foods with Carcinogenic Agent by Density*
VAM-1	D	*Passive Stress Measurement*
VAM-2	E	*Diagnosing Gait Abnormalities*
VAM-4	D	*Microanalysis of Hormone Levels in Blood*
VAM-5	D	*Safety Mechanism for Patients' Medicine*
VAM-6	D	*Negative Pressure Chamber*
VAM-7	B	*Bacteria Detection Using Fluorescent Labelling*
VAM-8	D	*Impedance Cardiographic System for Infants*
VAM-12	E	*Blood Pulse Rate Indicator*
VAM-13	B	*Corrosion and Fracture of Orthopedic Implants*
VAM-14	B	*Gas Concentration System*
VAM-15	B	*Cooling of Metals Under Electron Bombardment*
WF-3	E	*Prosthetic Valve for Urinary Tract*
WF-88	E	*Accurate Determination of Arterial Pressure Pulse Transit Time*
WF-107	D	*An Inexpensive Method of Monitoring Respiration in Anesthetized Primates Being Ventilated by Mechanical Respirators*

Problem Number	Status Code	Problem Title
WF-112	B	*Method of Correlating Composition with Differences in Surface Morphology of Kidney Stones*
WF-113	F	*Digital Clock*
WWRC-7	E	*A Signalling (Nurse-Call) System for Multiple Sclerosis Patients*

STATUS CODE DEFINITIONS

A. Problem Definition

Problem definition includes the identification of specific technology-related problems through discussions with biomedical investigators and the preparation of functional descriptions of problems using non-disciplinary terminology.

B. Information Searching

Information relevant to a solution is being sought by computer and/or manual information searching.

C. Problem Abstract Dissemination

An information search has revealed no potential solutions, and a problem abstract is being circulated to individual scientists and engineers at NASA Centers and contractor facilities to solicit suggestions.

D. Evaluation

Potentially useful information or technology has been identified and is being evaluated by the Team and/or the problem originator.

E. Potential Technology Application

Information or technology has been evaluated and found to be of potential value but has not been applied.

F. Followup Activity

A technology application has been accomplished, but further activity (e.g., documentation, obtaining experimental validation of utility, continuing modification, etc.) is required.

APPENDIX B

DESCRIPTION OF CURRENTLY ACTIVE PROBLEMS (CATEGORIZED BY HEALTH AREAS)

(This description does not include those active problems previously discussed in Section 2 as technology applications, potential technology applications, and impacts.)

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HEALTH AREAS

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MULTIPHASIC HEALTH SCREENING, CLINICAL DIAGNOSIS

PROBLEM MISC-20 *Visual Field Mapping*

The National Institute of Occupational Safety and Health (NIOSH) is concerned with assessing visual requirements and visual degradation associated with various occupational groups. One of the most important factors is the determination of the visual field: the part of the external world that is seen by the eye when its gaze is fixed. The visual field (for white light) of the normal eye subtends an angle of about 160° in the horizontal and 145° in the vertical meridian. Obviously, potential safety hazards exist if one's visual field is not compatible with his occupational environment. While the visual field narrows with age, it is suspected that certain occupational groups may experience more rapid degradation in their visual field because of their working environment.

Perimetry is the term applied to the procedure of mapping out the visual field. The instrument employed is called a perimeter. Perimeters currently in use are capable of determining major limitations of the visual field, but are not suitable for mass screening in order to assess the occupational factors that contribute to changes in the visual field.

The problem originator is presently reviewing specifications on a vision tester developed for NASA under the IMBLMS program.

PROBLEM UNC-65 *Ultrasonic Image Enhancement*

Ultrasound is becoming an increasingly important tool in diagnostic medicine. Defective heart valves, for example, can be detected and the degree of impairment can be assessed via ultrasonic techniques. Ultrasonic imaging holds much promise as a means of replacing some of the functions that can now be accomplished only through nuclear techniques. Indeed, some of the simpler problems such as the determination of the size of the fetus head (which gives an indication of age) and the diagnosis of cystic tissue can now be solved by ultrasonic imaging. Because of the specular nature of the ultrasonic echos, and the finite beam width of the signal energy, the scanning geometry plays an important role in ultrasonic imaging. The echo from a point does not appear as a point and the echo energy from a given object is a function of the angle of incident energy. As a result, a great deal of experience is required in interpreting the image. Researchers at the University of North Carolina are studying the feasibility of enhancing the image through the use of a digital computer. Effort is presently being devoted to the study of heuristic algorithms for edge enhancement in order to better outline the image of internal organs.

A literature search is underway. Detailed information on JPL's image enhancement work was given to the problem originator.

PROBLEM VAM-14 *Gas Concentration System*

The Department of Nuclear Medicine at the University of Miami is presently installing a cyclotron. One of the benefits to be derived from the cyclotron is the production of various radioactive gases. In particular, they will produce radioactive O_2, CO_2, CO, and N_2. Such radioactive gases have very short half-lives--often on the order of 20 seconds. This permits radiographic studies to be done while incurring a minimum radiation hazard. These gases will be piped to various locations within the hospital. It will be necessary to dispose of the unused gas. While it is possible to allow the unused gas to escape into the atmosphere, the Department of Nuclear Medicine feels that the best approach is to convert the gaseous waste into a liquid waste through a gas concentration system.

A search of the aerospace literature has resulted in some potentially useful information which is under evaluation by the problem originator.

PROBLEM VAM-15 *Cooling of Metals Under Positron and Deuteron Bombardment*

Improved techniques are needed for cooling metals that are bombarded by high intensity positron or deuteron beams during the process of generating radioactive materials. A cyclotron is presently being installed at the Mount Sinai Hospital of Greater Miami. The cyclotron will produce a variety of radioactive materials which will be employed to conduct radiographic studies as well as to provide radiation therapy for patients. Materials are made radioactive by bombarding them with a positron or deuteron beam. A given metal produces a specific radioactive element. The bombardments cause very high temperatures to exist in the metal in the vicinity of the beam. It is necessary to find a means of dissipating this heat. Contact with a metallurgist at Langley Research Center has been established.

REHABILITATION MEDICINE

PROBLEM EU-9 *A Means of Uniquely Numbering Events Using One Channel of a Hard Copy Recorder*

At the Rehabilitation Research and Training Center, most research projects and studies in neurophysiology employ computerized data processing techniques. In many of the clinical tests, however, the data is recorded on hard copy using a multichannel recorder because relatively small amounts of data are involved. During these tests, EMG signals are recorded as the patient follows a specified protocol of movements. The EMG signals are thus recorded sequentially. In order to analyze these signals, it is absolutely necessary that any given signal be uniquely identified with the precise motion of the individual. Extraneous signals are produced by the patient between steps in the protocol; not infrequently,

patients do not perform the movement properly and it must be repeated. This leads to confusion and difficulty in correctly identifying the EMG signal with the particular step in the protocol that produced it. A simple means of uniquely indicating, on one channel of a hard copy recorder, the number of the step in the protocol being accomplished by the patient, as well as the beginning and ending of the step, is desired. Entry of the data into the recorder should be easily accomplished by the researcher or clinician--preferably by depressing a pushbutton. Up to 100 steps may be required in the protocol, although most procedures are considerably shorter in length. A potential commercial solution has been identified and is being evaluated by the researcher.

PROBLEM VAM-1 *Passive Stress Measurement*

Thousands of Americans suffer loss or impairment of their limb functions. Artificial limbs offer a degree of rehabilitation for many of these persons who are then able to resume some of their normal activities. A problem that is impeding the development of improved limbs is the lack of knowledge as to why certain designs lead to more complete rehabilitation than others. To resolve this problem and, therefore, to establish better design criteria for artificial limbs, a researcher wishes to implant a stress sensor within certain muscle and fatty tissue of the knee. The information derived by this approach should define those stress conditions that are brought about by various artificial limb configurations and identify those stress conditions that are compatible with more complete rehabilitation.

An implantable, passive stress measurement system, i.e., one that accepts power from a remote location and reradiates it with a modulation determined by the applied stress, would provide a means of extracting stress parameters from patients without interfering with their limb movements. Of primary concern is that the device be completely implantable and capable of periodic use over a 3- to 5-year period.

No solution to this problem has been found. Hewlett-Packard plans to market a passive stress measuring system within a year but the applicability of this device is questionable. The Team is searching for an alternate solution to the problem.

ARTIFICIAL ORGANS

PROBLEM NHLI-2 *Enhancement of the Efficiency of Transfer of Organ Through the Boundary Layer in Flowing Blood*

Heart disease is the major cause of death in the United States. Although much advancement has been made in the treatment of diseased hearts, it is unlikely that complete rehabilitation will be possible unless the patient's heart is returned to full health. Artificial heart systems are being

developed as one of the possible future therapeutic methods of restoring circulation. One of the critical technology areas in the artificial heart program is concerned with the power sources to be used to operate the various devices that are necessary to perform the heart function. A totally implanted biological fuel cell operating on reactants (chiefly oxygen) derived from the blood stream, if feasible, would be a nearly ideal power source for operating an implanted artificial heart. Basically, the biological fuel cell will employ membrane-coated electrodes over which arterial blood will flow, transferring oxygen from the blood to the electrode by diffusion. The efficiency of the transfer of oxygen through the boundary layer in flowing blood must be high in order to generate sufficient power to carry out the function of the heart. A method of increasing the rate of diffusion of oxygen through the boundary layer of the blood adjacent to the membrane-coated electrode is needed.

A literature search failed to produce a solution to this problem. A problem statement was circulated to the NASA field centers and several suggestions were received. The suggestions are under evaluation by the National Heart and Lung Institute.

DETECTION AND TREATMENT OF HEART DISEASE

PROBLEM CP-3 *Automated Measurement from Coronary Angiograms*

Techniques used to extract information from pictures of Mars will be used to obtain automated information on the performance of the human heart. Medical researchers at Duke University Medical Center developed a technique to determine myocardial contractility or functional character of the cardiac muscle. This technique should be particularly useful in determining the location and extent of muscle function and in determining effectiveness of surgical procedures designed to improve cardiac function by improving supply to the heart. The technique is thus suitable both pre- and post-operatively to determine coronary revascularization following treatment. The most appropriate surgical procedure or treatment to improve cardiac blood flow, and, in turn, cardiac function, can be determined by this technique that is based upon measurements taken from sequential coronary angiograms.

A coronary Angiogram is an X-ray image of the heart taken after injection of a radiopaque dye into the coronary artery; this procedure makes the coronary artery and the arterial bifurcations (branching points) visible. The analysis technique above relies on measurements of dimensional changes of various portions of cardiac muscle during a cardiac cycle. These linear dimensional changes can be related directly to cardiac muscle function. The measurement of these dimensional changes is accomplished by measurement of position of specific arterial bifurcations recorded in coronary angiograms. Two separate angiograms are needed, a front-back view and a side view, to determine the location in three-dimensional

space of a specified bifurcation. The distance between two bifurcations is a measure of the dimension of the intervening muscle at that instant of time.

At present this procedure is implemented manually. About 20 specific bifurcation points are recorded on the two X-ray views, and the positions of these points are then recorded over several complete cardiac cycles by angiograms exposed every 1/60 second. At 60 frames per second, two projections, 20 specified bifurcations and a total of several seconds of cineangiograms, the required determination of position changes and their time course is an exceedingly difficult and lengthy task. A reasonable method of automating this analysis of the angiograms is clearly needed if this technique of cardiac function analysis is to achieve clinical importance.

The automated reading of the 35-mm X-ray film strips should provide rapid and accurate information on the positions of specified arterial bifurcations. Accuracy should be compatible with image resolution on the order of 500 x 500 image resolution elements. It would be acceptable and probably desirable to manually identify (possibly by a light pen or similar technique) on the first film frame the specific bifurcation points to be used, and have the film reading system automatically follow the location of these points in the subsequent frames.

One approach would be to digitize each entire film frame and apply pattern recognition techniques. This is difficult and probably very inefficient for this problem, however, because at each frame the positions of the 20 or so desired points are already fairly well known from the analysis of the preceding frame. What is needed is a method of identifying and locating these points whose neighborhood values are already known.

The Team determined that the information of interest was at the Jet Propulsion Laboratory. Details of the JPL VICAR software program were given to the researcher and he decided that the enormity of this project required that he work directly at JPL for a short period. Thus, he applied for and received a summer fellowship at JPL for 1970. During this period, he learned the JPL image processing procedures, worked out his own algorithm, and determined that this approach could solve his problem. He then designed a modified system of image scanning and processing, which was contracted by Dicomed Corporation. This equipment has been delivered and is operational.

This significant medical problem will be solved using a modification of the JPL image processing procedures. The equipment is operational, and the actual bifurcation identification has been accomplished over about 10 frames of film. Figure B-1 shows the result of using this technique to identify a region of reduced flow (the circled area in the figure). Additional use of this technique will enable the researcher to automatically record dimensional changes in the heart during a cardiac cycle.

Figure B-1. X-ray of Human Heart Enhanced by Computer Techniques.

PROBLEM MISC-19 *Exercise ECG Analysis*

The Environmental Protection Agency (EPA) is presently conducting a study of the effects of carbon monoxide on the cardiovascular system. Recent research has indicated that angina patients may be in danger when exposed to low levels of carbon monoxide such as that found in heavy automobile traffic. (The results of this preliminary study were discussed in the Journal of the American Medical Association, Volume 221, No. 5 (1972), p. 456. Subjects with proven ischemic heart disease were exposed to carbon monoxide levels of 50 to 100 ppm. These subjects when exposed to exercise testing had a significantly shorter time of exercise before the onset of anginal pain as compared with subjects exposed to pure air. Carboxyhemoglobin levels are well known to impair tissue oxygenation and it appears that the hypoxic effect on carbon monoxide may act in a synergistic manner with other factors operative in ischemic heart disease.

These early studies have resulted in an expanded study of this phenomenon. In this study, which is already underway, improved methods for automatic

analysis of ECG signals are required to detect subtle changes that occur. Although existing automatic analysis techniques can detect some changes in the ECG signals, the EPA research team desires to detect far more subtle changes than can now be detected.

Following a computer information search of the NASA document file, direct contact was made with members of the medical research team at the Manned Spacecraft Center. Conversations between the NASA personnel and the EPA personnel indicated that some of the techniques for automatic ECG analysis developed for the Apollo program may be applicable in this case. The EPA personnel are now evaluating the NASA techniques in order to determine whether they should be incorporated in the ongoing research study.

PROBLEM NHLI-1 *Intramyocardial Stress Measurement*

A pressure transducer designed by NASA for aerospace use is proving useful in basic heart research.

Myocardial infarction is a process resulting in the death of an area of the heart muscle following a reduction in the blood supply to that area. Acute myocardial infarction is the main cause of premature death in the population of the developed countries. Myocardial infarction can usually be diagnosed by electrocardiography; however, no method is available for determining the precise location of the affected tissue, which is necessary to assure the success of surgical procedures for repairing the injured muscle.

Since the damaged or dead tissue (whose size and location is dependent on degree of compromised blood supply) results in a "weak area" of the heart muscle, it is expected that a measurement of the forces sustained during the successive contraction and relaxation of the heart will differ from similar measurements made in unaffected areas. The myocardium cannot be treated as though it were a fluid since the heart develops tension in its muscle fibers while exerting pressure on its contents. If the heart is treated as a solid, stresses upon any one element can be resolved into three purely compressive or tensile stresses mutually perpendicular to each other. A probe that could be used to make stress measurements within a small region of muscle tissue would lead to a refined location of the region that needs to be removed by surgery. It would also improve our understanding of hemodynamic performance and several other pertinent physiological problems. This should in turn lead to improved surgical procedures and, therefore, to a higher probability of successful recovery for thousands of persons who must undergo surgery for this disorder each year. The physiological assessment might also provide rationale for other therapeutic interventions.

A search of the aerospace literature uncovered many interesting types of pressure and stress transducers; however, none was well suited for the application in question. The Team was aware of two NASA-developed pressure

transducers that are significantly smaller than commercially available devices: one developed by Mr. Grant Coon at Ames Research Center, the other by Dr. Wilhelm Rindner, formerly at Electronics Research Center (ERC). The Ames Transducer is potentially applicable to this problem; however, more developmental work is necessary. The ERC transducer appears to offer a possible solution to the problem.

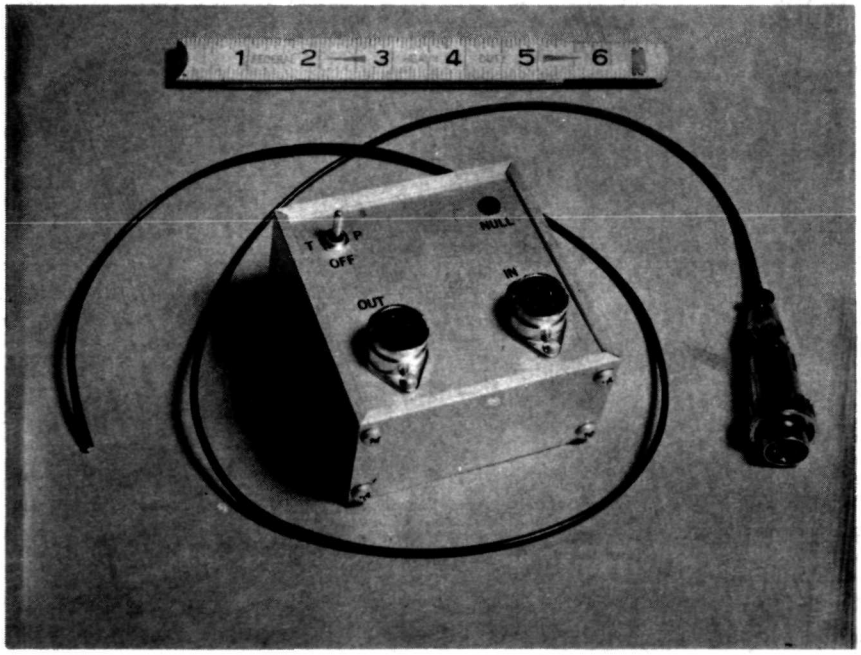


Figure B-2. NASA Pressure Transducer (ERC).

The Team lent an ERC transducer to the problem originator, Dr. Karl Weber, of the National Heart and Lung Institute (NHLI) and assisted in a preliminary experiment with a live animal. Although the preliminary experimental results are not yet fully understood, it is evident that mechanical stress in the heart muscle does undergo changes as the region surrounding the transducer becomes ischemic. Additionally, Dr. Weber has detected changes in the myocardial stress characteristics as the hemodynamic properties of the heart are altered by the administration of certain drugs. Dr. Rindner has provided the transducer in the form of a needle in order to make it somewhat more suitable for probing the heart; evaluation tests are underway (See Figure B-2).

PROBLEM UNC-63 *ECG Processor*

An EKG processor is needed to recognize a specific point of the ECG signal to be used as a gate to record ultrasonic echoes during a preselected interval of the ECG.

Ultrasonic techniques are finding increasing use in the medical field. Perhaps one of the most important uses of ultrasound in medicine has been cardiology. By making modifications to an existing ultrasonic system, the Department of Nuclear Medicine at the University of North Carolina will employ ultrasound to detect cardiac tumors, to study valve anatomy, and to diagnose pericardial infusion with more accuracy than is presently possible.

Commercially available ultrasound systems are designed to produce echo images by displaying on a storage CRT the echoes from pulses transmitted at a constant rate. If the object being imaged moves, then the image on the CRT is blurred. Thus, the problem of imaging a moving heart is complicated. The problem originator wishes to employ a stroboscopic technique when imaging the heart by recording images during only a preselected interval of the patient ECG. This will insure that the heart is in virtually the same position each time the echoes are recorded. Since the ECG is to be employed as a gating signal, it is necessary to process the ECG in order to recognize the beginning of each heart cycle. A processor that will recognize a specific point on the ECG signal (e.g., the peak of the R wave) is needed. The processor should be relatively immune to baseline shifts in the ECG as well as artifacts. A NASA R-wave detector is under evaluation.

PROBLEM VAM-8 *Impedance Cardiographic System for Infants*

In order to better diagnose and treat infants with congenital heart defects, researchers at the University of Miami are experimenting with a NASA-developed impedance cardiographic system. This system was developed to provide a simple, bloodless method of monitoring various parameters of cardiac function of adults without penetrating the skin. The

system employs four circular, flexible, metallic electrodes, which are attached to the patient: two around the neck and two around the upper abdomen. University of Miami investigators wish to be able to use this system to measure cardiac parameters of infants; however, the neck electrodes that were designed for this system are inadequate for infants. It is necessary to find a means of employing the existing system with infants. If this system can be used with infants, the next step will be to determine whether useful measurements can be made on children with congenital heart defects.

PROBLEM WF-107 *An Inexpensive Method of Monitoring Respiration in Anesthetized Primates Being Ventilated by Mechanical Respirators*

As part of a long-term study program into atherosclerosis, the Bowman Gray School of Medicine is involved in a project using primates as experimental animals. Some animals will be fed normal diets while others will be fed atherogenic diets. During these studies it will be necessary to surgically implant a number of devices for monitoring various physiological parameters. During the surgical procedures, the primate will be anesthetized and respired using a positive displacement animal respirator. A trachial tube inserted into the animal's throat is used to connect the animal to the respirator. It is important, of course, that the animal be properly respired during these surgical procedures. Any interruption of the air flow supply to the animal will result in its death. These animals are specially prepared and represent a significant investment of funds and researcher time so that the loss of even one animal as a result of improper respiration is significant. In order to eliminate this possibility, a technique or method of monitoring the respiration of the animal is desired. A visual indication of the normal respiration of the animal is desired. For example, a meter could be used to provide a varying amplitude indication proportional to the respiration of the animal. For example, inspiration could represent a zero reading, an expiration a positive reading, so that the meter would fluctuate between zero and some positive reading during a normal inspiration/expiration cycle.

The respirator-alarm system using telemetry techniques developed at the Ames Research Center appears useful in this application. The requirements in this problem, however, are significantly simpler so that complicated telemetric equipment is not necessary. In addition, the requirements for an alarm are not necessary. The fundamental requirement is for a meter reading to indicate inspiration and expiration. It is felt that a modification of the Ames circuitry can be accomplished to provide the required monitor at a very low cost. The Biomedical Engineering Department at Bowman Gray School of Medicine is evaluating the Ames circuitry and modifying the system to this application.

DETECTION AND TREATMENT OF CANCER

PROBLEM MISC-23 *Pattern Recognition of Ultrasonograms*

Tumor detection at an early stage is a critical factor in the successful treatment of the disease. In general, the chances for cure are dramatically improved if the cancer is detected at a very early stage. Conversely, if the tumor is significantly advanced at the time of detection, little chance for cure exists. One new method being explored for tumor detection in the eye is the ultrasonogram. Basically, this consists of a scan of the eye using ultrasonic energy and a display on an X-ray tube. Although visual observation of an ultrasonogram allows one to distinguish a tumorous eye from a normal eye, a more precise method of pattern recognition is required in order to detect smaller tumors. The basic problem is to determine the subtle differences in ultrasonogram patterns of a normal eye and a tumorous eye using some scanning process and automatic pattern recognition technique. The normal eye has a diameter of about 24 millimeters and tumors as small as 3 millimeters must be detected.

The National Aeronautics and Space Administration has broad experience in the area of pattern recognition, and it is felt that this problem is amenable to solution using advanced pattern recognition techniques. The NASA document files are now being carefully studied to determine whether applicable techniques exist.

PROBLEM NCI-9 *Improved Emulsion for Autoradiography*

Knowledge of photographic emulsions by a NASA researcher may improve the emulsions used in the autoradiographic study of cancer.

The study of cancer in experimental animals can be facilitated by labeling the cells with radioactive tritium. The tritium attaches itself to the DNA molecule, and the division of the tumor cell produces new labeled cells. A process called autoradiography detects a radioactive cell by placing a film of photographic emulsion over the cell and exposing the emulsion by the radioactivity. Existing emulsions require an exposure time on the order of months. If a much faster film can be developed, then this technique can be used clinically in following the progress of human cancers. This will provide a valuable new technique in the fight against human cancer.

A computer search of the literature on nuclear emulsions revealed that scientists at Goddard Space Flight Center had employed sounding rockets carrying nuclear emulsions to study the composition and energy spectra of low energy cosmic rays. The TUO at GSFC was presented with this problem and suggested that the Team contact Dr. Jacob Trombka who is quite knowledgeable in this field. Dr. Trombka has experimented with several types of specifically prepared noncommercially available

emulsions that will reduce the required exposure time. A Team member met with Dr. Trombka and he discussed these techniques at length. The National Cancer Institute subsequently contracted with a research team at Duke University to undertake a study to develop improved emulsions. Dr. Trombka has been in frequent contact with the Duke team and his ideas will be implemented and evaluated.

PROBLEM NCI-10 *Scanning Tumors in Small Animals with Gallium-67*

An analytic technique developed for aerospace radiation detection is being considered for scanning tumors in animals.

Gallium-67, a radioactive isotope, possesses the special property of concentrating in various types of tumors when administered orally or intravenously to a patient. The mechanism of gallium uptake is not well understood; it is not known whether there is a direct binding of gallium in the tumor tissue or binding to some other agent that, in turn, is concentrated by the tumor. Whichever is the case, Gallium-67 appears mainly in viable rather than necrotic tumors. In addition, studies indicate that Gallium-67 is superior to other commonly employed tumor-scanning agents in absolute tumor concentration and in ratio of tumor to normal tissue concentration. These observations are possibly the most significant recent developments in nuclear medicine.

By administering Gallium-67 to a patient and scanning the body with an instrument that will detect the presence of radioactive substances, the location as well as the size of a tumor can be determined. Radiologists currently employ a variety of camera and scanning systems that are useful in locating tumors in human beings but are relatively ineffective in studying the response of the tumor to therapy. In order to follow tumor growth on a day-to-day basis, a high resolution scanning system that is sensitive to Gallium-67 is needed. In particular, the scanning system should be suitable for scanning the entire bodies of small experimental animals. Such a system would offer a unique opportunity to study methods of inhibiting or retarding tumor growth.

A solution to this problem was proposed by Dr. R. T. Siegel, Director of the Space Radiation Effects Laboratory (SREL), which is operated by the College of William and Mary under support from Langley Research Center. Dr. Siegel's suggestion was experimentally evaluated but found to have inadequate sensitivity. A problem statement has now been circulated to the NASA field centers.

PROBLEM NCI-12 *New or Improved Methods of Detecting Breast Cancer*

Breast cancer is common: 5-6 percent of all women will at some time in their lives develop breast cancer. If cancers are discovered when they are still localized, the majority of them can be cured by surgery and

radiotherapy. Provisions for earlier and more comprehensive treatment of patients with breast cancer require improved techniques for detecting malignant tissue during the initial stages of growth. Four techniques for detecting breast cancer are in use at present: physical examination, thermography, xerography, and mammography.

None of these techniques is sufficiently reliable. A combination of these methods provides an improved probability of detecting breast cancer; however, none of the methods provides conclusive results. Each of the methods has shortcomings. New or improved methods, techniques, or approaches for detecting breast cancer at an early stage are needed.

A problem statement was circulated to the NASA field centers and the Team received two suggestions that warranted additional investigation: (1) the use of liquid crystal thermography to obtain visualization of the temperature patterns of the breast with minimum effort and cost, and (2) vibrational methods for detecting tumors deep under the skin surface.

These suggestions were evaluated by a member of the National Cancer Institute's Detection and Diagnosis Subcommittee. While there was some merit in both suggestions, there was no reason to believe that these techniques would offer an improvement over methods presently in use. The Team plans to assist on specific problems encountered in improving existing breast cancer detection techniques.

PROBLEM TU-22 *X-Ray Microplanigraph*

An aerospace method used for analysis of printed circuit boards is being applied to obtain improved X-ray techniques of cancer detection.

Cancer is the second largest cause of death in this country and, according to a recent survey, is the disease most feared by the American people. The state of cancer treatment today is such that generally those cancers that are found early can be successfully treated. The easiest cancers to detect are those that are on the surface of the body, and those most difficult to detect are those deep within the body. Thus, cancers arising deep within the body usually result in the death of the patient because detection of the cancer occurs too late.

It is desirable to develop an instrument capable of detecting tumors deep within the body. In addition, it is desirable to be able to determine whether or not the tumor is malignant or benign and the extent to which the tumor has spread. One common method of detecting tumors is by X-ray. Unfortunately, when the entire body is X-rayed, small tumors cannot be detected because the background level of signal of the X-ray is vastly increased by the thickness of the body. It would be highly desirable to develop a technique whereby X-rays could

be made of lamina regions only. If X-rays could be made of thin laminae, smaller tumors could be detected. The basic problem then is to develop a method whereby X-rays of thin laminae can be made of a patient instead of the conventional X-ray technique.

The technique of making X-rays of thin laminae with high resolution is called X-ray microplanigraphy. This technique has been theoretically possible for many years. Recently, a development in NASA has significantly increased the possibility of developing such a technique. NASA developed such a technique for inspecting multilayer printed circuit boards layer by layer with a resolution of 0.001 inch. This technique has been well developed by a NASA contractor at Illinois Institute of Technology. Basically, it involves moving the X-ray source and detector in a particular geometrical arrangement in such a manner that only thin laminae are measured. The work was funded by MSFC, and the Team was apprised of the work through a computer search. The Team then contacted MSFC for additional information and was referred to the ITT investigator. The problem originator has discussed this technique in detail with the NASA contractor and has decided that this work is highly relevant to his investigation. An example of the use of the technique is shown in Figure B-3.

The device has been implemented at the Tulane School of Medicine. The researcher indicates that tests to date indicate a significant improvement in tumor detection capability. A major study is now in progress to develop this device for clinical use.

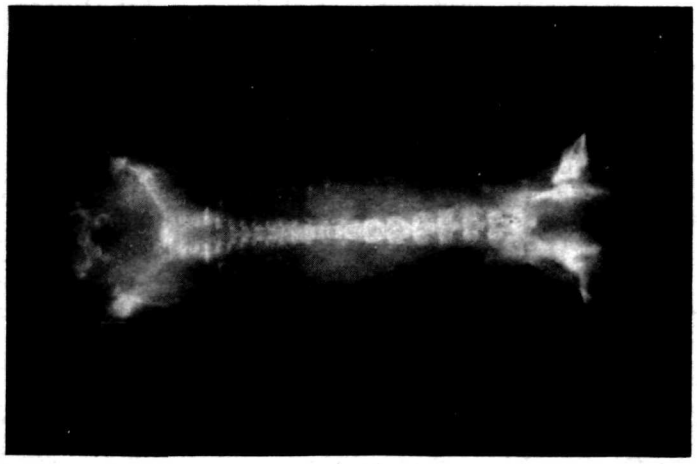


Figure B-3. X-ray Microplanigraph of a Mouse.

ECOLOGY

PROBLEM TU-9 *Human Voice Analysis*

An aerospace technique for improving speech transmission from aircraft is being applied in analyzing speech defects.

Approximately 6-7 percent of the population is considered to have either temporary or chronic speech defects. In chronic cases, inadequate understanding of the causes of speech defects hampers treatment. For example, one speech defect is characterized by a pitch that is either too high or too low and can be caused by contact ulcers, polyps, polypoid degeneration, or chronic laryngitis.

A technological impediment exists in the analysis of speech defects because of the inability to precisely quantize characteristics of the human voice. This is further complicated by the fact that many changes in the human voice are easily detected by the ear but are often quite subtle in their spectral density or frequency changes. A number of techniques have been employed in an attempt to quantize the human voice, but to date no technique has been found that permits the therapist to measure changes in the human voice before and after therapy.

Speech consists of a broad fundamental frequency and many harmonics. Small shifts in fundamental frequency and amplitude cause large changes in the human voice. Frequency spectrum analysis must be able to detect fundamental frequencies that range from as low as 50 Hz for low-pitched male voices to more than 400 Hz for high-pitched children's voices. The technique must measure fundamental frequencies to a precision of 1 Hz and amplitude to a precision of 1 db. The analysis technique must take into account both fundamental frequency and harmonics and their relation to the fundamental frequency. Although not required, real-time analysis is desirable.

Spectral analysis techniques developed by the NASA Michoud Assembly Facility may be applicable to this problem. The problem originator is now discussing the applicability of these techniques with the cognizant NASA personnel.

KIDNEY DISEASE DETECTION AND TREATMENT

PROBLEM DU-48 *Urine Flowmeter*

Diseases of the urinary system are a significant problem in medicine. One of the problem areas concerns the ureters, i.e., the tubes that connect each kidney to the bladder. Urine-flow measurements in the ureter are being used in a research study to gain knowledge of ureteral physiology. Improved flow-measurement techniques also could be used

in clinical studies of kidney, ureteral, and bladder diseases. All existing techniques for measuring flow in the ureter involve collecting samples of urine over definite intervals of time and calculating average flow rates. These average flow measurements are not satisfactory when the pulsatile nature of flow in the ureter is being studied. This pulsatile flow of urine is felt to be a very important factor in obtaining a better understanding of ureteral physiology.

The requirement here is for a technique that employs a transducer for measuring instantaneous rates of urine flow in the ureter. The transducer can be used either internally or externally. If an external transducer is used, the flow of urine can be diverted to a point outside the body using a catheter.

The flowmeter should measure transient urine flows of from 1 to 100 cc/min with an accuracy of ±1 percent. Size of the flowmeter is not important because it can be outside the body. A flowmeter using the principle of thermal distribution developed for the Skylab flight program is being evaluated as a potential solution to this problem. The NASA contractor and the problem originator are discussing the possibilities of a joint effort.

PROBLEM WF-112 *Method of Correlating Composition with Differences in Surface Morphology of Kidney Stones*

This problem is related to and, indeed, has been identified as a result of previous work on biomedical problem WF-98, "An Improved Technique to Yield Precise Information on Surface Morphology of Kidney Stones." Under this previous biomedical problem, a number of kidney stones were analyzed by means of scanning electron microscopy at the NASA Marshall Space Flight Center. In this study it was desired to identify the micromorphology of kidney stones of various types and to attempt to correlate the morphologic characteristics of kidney stones with various crystalline types. It was specifically desired to determine whether or not surface morphology is a factor in kidney stone formation.

Information obtained as a result of the cooperation of NASA personnel at the Marshall Space Flight Center is providing for Dr. Boyce a number of scanning electron micrographs of various characteristic kidney stone types has been extremely useful in Dr. Boyce's studies. The scanning electron microscope studies, however, indicated that there are certain lamellar characteristics on the kidney stone surfaces observed. These surface characteristics showed up in many of the scanning electron micrographs as striations on the surface. In order to probe further into the mysteries of kidney stone formation, Dr. Boyce has considered it extremely important to determine whether or not these striations or lamellar-appearing variations on the scanning electron micrographs are related to compositional changes of the kidney stone itself. Consequently, Dr. Boyce wishes to compare certain kidney stones using scanning electron micrographic techniques on the same kidney stones to determine,

using the best available techniques the microcomposition of the kidney stone surface. Essentially, a method of obtaining the microcomposition (the composition of portions of the kidney stone surface 1 or 2 micrometers in diameter) of kidney stones is desired to permit comparison of the surface morphology with composition. The possession of this information will provide an answer to the question of whether the lamellar-like structures, shown on many of the kidney stones, are actually associated with compositional differences in the kidney stones.

The scanning electron microscope laboratory at the NASA Marshall Space Flight Center is being fitted with an electron microprobe. This unit will permit measurement of certain elements of the kidney stones. Measurements of composition of areas down to 1-2 micrometers in diameter can be made. Sampling of such small areas of the stone's surface will permit correlation of compositional data with morphologic data as obtained with the scanning electron microscope. A request has been made to Mr. Juan Pizarro, Technology Utilization Office, Marshall Space Flight Center, for assistance on this problem with positive results. Dr. Boyce is presently preparing the kidney stones for processing at Marshall Space Flight Center.

RESPIRATORY DISEASE DETECTION AND TREATMENT

PROBLEM TU-3 *Lung Sound Detection*

A technique developed to analyze sounds of aircraft engines is being applied to study respiratory diseases in children.

The major cause of illness in children from infancy through adolesence is respiratory disease of which the serious forms include asthma, cystic fibrosis, and bronchitis. Significant research is being conducted both into the causes and cures of respiratory diseases and into better methods of diagnosis of the diseases. This problem statement is devoted to finding a method of improved diagnosis that will improve the treatment of respiratory diseases.

The respiratory system consists of the lungs and the system of tubes or ducts that feed air into the lungs. Air proceeds from the nose and mouth through the trachea, which is the central air duct. From this central tube, two branches diverge that eventually feed air into the two lungs. These two branches, called the left and right bronchi, eventually subdivide still further into smaller tubes called bronchial tubes. Each bronchial tube feeds air into and out of a section of the lung, and each tube has a symmetrical counterpart in the other lung.

One useful, simple method to determine whether a portion of the lung is performing properly is to listen to the sounds made by airflow. Usually, this is done with a stethoscope, but only one section of the

lung can be heard at a time. To compare sections of the lung, it would be useful to be able to compare the sounds generated by a section of one lung with the sounds generated by the symmetrical counterpart in the other lung.

The basic problem is to detect the sounds from two sections of the chest wall by microphones and display the sounds graphically. Comparison will be made on the amplitude, frequency, and time interval between appearance of the two sounds.

The frequencies of interest will be 20-10,000 Hz. Breathing rates normally will be 25 breaths/minute although a range of 12 to 80 may occur. The amplitude of the sounds of interest is not known. Measurements will be made on children from infancy to adolescence in a hospital clinic.

In the basic description of the problem, the researcher desired simply a strip-chart recorder and microphone combination. However, the Team advised him that far more information could be gained by going to spectral analysis such as had been used in analyzing aircraft engines. A difficulty arises in spectral analysis in that real-time spectral analysis is required because of the rapidly changing information in lung sound. Thus, a simple scanning-filter spectral-analysis technique is insufficient because of the time response required. A computer search of the NASA document file revealed that NASA had done considerable work in spectral analysis--particularly as pertains to aircraft engines and vibration for vibration testing of spacecraft. The Team proposed to the physician a system, shown in Figure B-4, composed of a microphone, amplifier, and envelope detector that could be fed to a dual-channel strip-chart recorder. This dual-channel system, which is now operational, will allow time-delay measurement for respiratory sounds between similar lobes. In addition, the output of the amplifier could be fed into a spectral analyzer similar to that used in aerospace applications.

The spectral analyzer is now operational and clinical trials are underway. Initial results indicate that useful information is being obtained.

The Team feels that this highly significant potential technology application will result in a new diagnostic tool of particular importance in the pediatric field for detection of asthma, cystic fibrosis, and bronchitis.

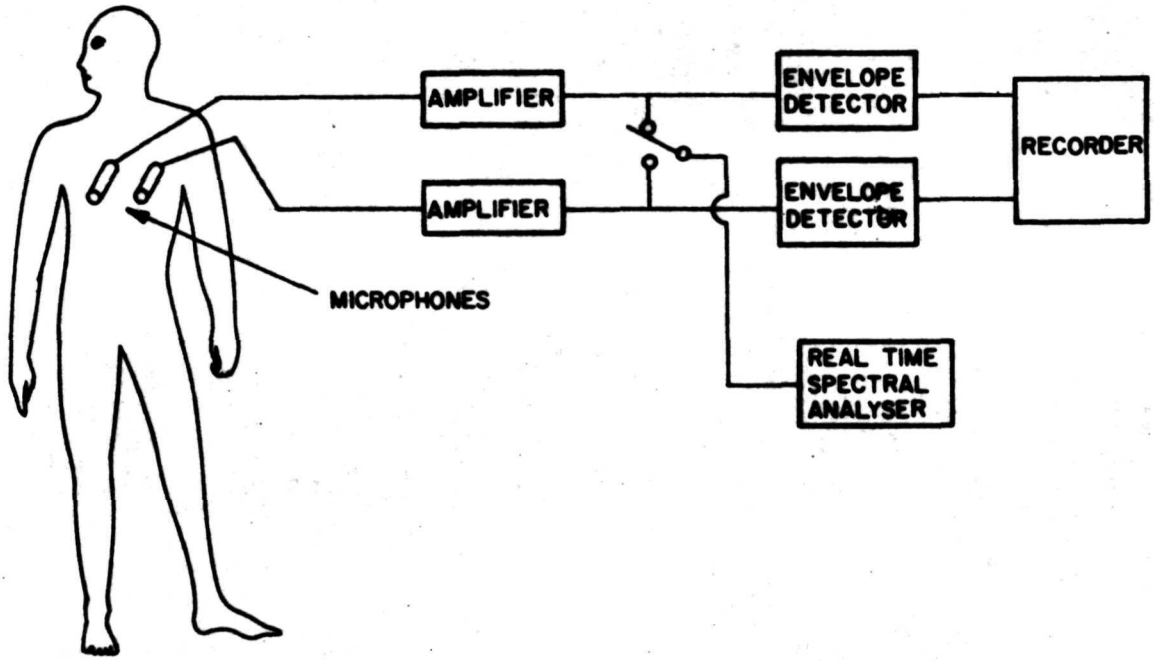


Figure B-4. Block Diagram of Lung Sound Analysis System.

PROBLEM TU-33 *Silica Measurements in Microgram Quantities*

Silicosis is a disease caused by inhalation of silicon dioxide dust particles less than 10 micrometers in diameter. The result of this inhalation is fibrosis of the lungs, which severely reduces the vital capacity of the lungs. Although silicosis has been studied for many years, a new form of the disease has recently appeared. This disease, called accelerated silicosis, can result in death after 3 years exposure as compared to a more typical period of 40 years of exposure for miners and foundry workers. Accelerated silicosis is often found among workers using sand blasting equipment. The Tulane School of Medicine clinicians rarely saw a case of silicosis until sand blasting became common on the drilling platforms in the Gulf of Mexico.

A study is under way to characterize the environment of the workers susceptible to this disease. A method exists for sampling the air

around the workers but only microgram quantities of the dust is obtained. A method for the analysis of the silica content of these samples is required. Since a computer search of the NASA document file did not reveal an acceptable solution to this problem, a solution is now being sought by direct contact with the NASA field centers.

IMPROVED SURGICAL PROCEDURES

PROBLEM TU-25 *Blood Damage Measurement*

Recent medical developments in oxygenators have improved the probability of patient support in cases where temporary assistance in lung function is required. Examples of such use include infants with certain diseases and adults with crushed chests due to accidents. Some damage to the blood results from oxygenators, and a new means of measuring blood damage is required. Existing tests usually consist of hemolysis analysis.

Possible measurement techniques include partial pressure O_2 and CO_2, cell mass, lactate/pyruvate, plasma hemoglobin, protoglandin, serotonin, and platelet damage.

A useful enzymatic technique was disclosed by a problem statement circulation. The technique, developed for use on the Skylab mission, will be implemented when a current grant request of the problem originator is funded.

PROBLEM VAM-13 *Corrosion and Fracture of Orthopedic Implants*

Metal alloys are currently used in a number of bioassists such as pacemakers and heart valves. The most widespread use of metallic implants is found in a multitude of orthopedic devices. One of the most common examples of an orthopedic implant is the fracture brace, which consists of a stainless steel shaft (called a nail) and screws for attaching the nail to the bone. The nail serves to hold the bone in place while the fracture mends, as well as to give added support to the fractured region. In healthy persons the nail will usually be removed after the fracture has healed. However, in many instances, the nail will fail prior to the healing of the fracture.

A recent study indicates that the incidence of fracture failure is in the order of 9 percent. Although much is already known about the mechanism of failure in orthopedic implants, additional analysis is necessary to arrive at improved surgical procedures and improved implant design. This combination of improvements will circumvent the problems of failure that are now being experienced.

The problem originator visited NASA's Langley Research Center and discussed the problem with structural and materials engineers. Studies of two fractured implants were carried out using Langley's scanning electron microscope and X-ray spectrometer. Continued interaction between Langley engineers and the problem originator is expected.

DETECTION AND TREATMENT OF DENTAL AND ORAL DISORDERS

PROBLEM VAM-7 *Bacteria Detection Using Fluorescent Labelling*

Researchers at the University of Miami have discovered an unusual type of bacteria that causes tooth decay in laboratory animals. This bacteria has now been found in human beings and is possibly a major cause of tooth decay in man. Fluorescent techniques are employed to discover the presence of this bacteria in human beings. This is possible because of the development of a vaccine that makes laboratory animals produce antibodies to attack the bacteria. These antibodies are labeled with a substance (fluorexcin thiocyanate) that makes them fluoresce when excited with ultraviolet light. When the labeled antibodies are applied to a culture having these bacteria, they become bound to the cell wall of the bacteria. The culture is then washed and only those antibodies that are bound to the bacteria remain. Therefore, when the culture is viewed under a microscope using ultraviolet illumination, the antibodies can be spotted, thus signifying the presence of the bacteria that cause tooth decay.

To find out how many of these bacteria are present, all bacteria in the culture are allowed to grow. It was discovered that a second type of bacteria that normally resides in the mouths of human beings exhibits a natural fluorescence. The autofluorescence of the second bacteria complicates the detection of the labeled antibodies. It should be emphasized that the autofluorescence presents a problem only when all bacteria are allowed to grow (i.e., it is only when the autofluorescing bacteria are in colonies that the autofluorescence is of sufficient intensity to be observable). A means of suppressing the radiation due to autofluorescence is needed.

Mr. Larry Dunkleman of Goddard Space Flight Center visited the problem originator and conducted a preliminary investigation of the problem during March of 1972. Mr. Dunkleman has arranged to conduct additional studies that are expected to lead to a solution to the problem.

PROBLEM EU-17 *A Scanning Optical Display That Can Be Rotated About a Central Axis*

A variety of visual difficulties are encountered in human beings, about which little quantitative information is known. Basic research on the functioning of the visual system is required in order to understand many of these visual difficulties. Understanding the nature of these difficulties is, of course, the first step toward their solution. One such area involves the manner in which relative motion is sensed. In the monkey, there appears to be a specific part of the brain that performs this detection of relative motion. If that part of the brain (the superior colliculus) is removed, the monkey is no longer able to detect relative motion. The fundamental question is, "how do neurons in this part of the brain respond to relative motion, i.e., what is the mechanism of relative motion detection?" It appears that some neurons sense direction and perhaps others respond to certain velocities or velocity ranges. In order to study this part of the visual system, it is necessary to provide the monkey with the proper stimuli and then monitor the neuronal responses in the brain. A programmable display is needed to display a moving spot of light. The velocity of movement must be variable, and the scan axis must be capable of 360° rotation.

An optical system is required that can project a geometric figure (a circle, rectangle, etc.) on a 6-foot-square screen. The projected image, however, will be constrained to a 3-foot-diameter circle concentric about the centerpoint of the screen. The size of the projected image should be variable from 0.25 inch up to 2-3 inches in diameter. The animal will be placed at a distance from the screen such that 1 inch on the screen will correspond to 1 degree of retinal angle. The speed at which the projected image is scanned on the screen should be variable from 3 inches per second to 150 inches per second. The scan axis must be capable of 360° rotation about the centerpoint of the display.

Results of a meeting between the researcher and personnel at the Langley Research Center are being evaluated for potential application to this problem.

PROBLEM MISC-9 *pO_2 Telemetry Capsule*

Diarrhea may be due to various causes ranging from acute infection to psychogenic factors. Current research indicates that bacteria that normally reside in the mouth can, under certain conditions, give rise to diarrheal states. There are two types of such bacteria: one that must have oxygen to live and another that cannot thrive in the presence

of oxygen. Oxygen exists in the gaseous state throughout the digestive tract and must remain relatively constant to provide for the proper balance of bacteria.

In order to learn more about the conditions that give rise to diarrhea and to evaluate the use of antibiotics in altering the oxygen content of the digestive tract, this researcher would like to measure the partial pressure of oxygen in the lumen of the gut at various points. This problem has baffled researchers for several years.

The researcher feels that the best solution would be a swallowable capsule for measuring and telemetering the partial pressure of oxygen as it passes through the gut.

A search of the aerospace literature failed to uncover a solution to this problem. The Team's efforts led to the discovery of an industrial research group that had developed a pO_2 telemetry capsule for marketing purposes. It was decided that, because of its limited market potential, the pO_2 telemetry capsule would be pursued no longer by the industrial concern. The developers of the pO_2 telemetry capsule made available to the Team the schematic diagram of the device as well as test results that will allow the problem originator to begin a developmental program in this area.

PROBLEM MUSC-13 *A Technique of Presenting Hot and/or Cold Stimuli to the Skin*

The researcher is directing a basic research program on neural conditions in the spinal cord. In this program, stimuli are applied to various points on the skin surface, and the neural responses to the stimuli are recorded. It is desired to use hot and/or cold stimuli and direct application to the skin surface.

Heat pulses of 0.1 millisecond to 1.0 millisecond duration are desired. The pulses should be capable of repetition at 1 second or longer intervals. Square wave pulses would be ideal; however, such pulses are not easily attained in this application because of the heat sink effects. The neural response to such signals is very small; therefore, the stimuli will be repeated 128 times and fed through a signal averager to obtain a good signal. The area of the skin to which the stimulus is applied should be approximately 1 to 2 inches in diameter.

Suggestions made by the Applications Team member are being evaluated by the researcher. If the suggestions are valid, the problem will be greatly simplified.

PROBLEM TU-10 *Quantization of Heart Tissue Hardness*

Techniques developed to study aerospace materials have been used to study the human heart during pathological examination.

Examination of the various organs of the human body following death can reveal not only the cause of death, but other conditions affecting the person at the time of death. Research at the Tulane University School of Medicine has shown that a peculiar softening of the heart tissue can be seen in some patients that did not die of heart disease. The cause of this unusual softening is not known, but a number of factors are believed to be important. For example, there appears to be an infarction and a definite softness in the heart tissue. The reasons for this are being sought in experimental work using rats in which the blood is cut off temporarily from portions of the heart in order to discover the changes in the heart tissue. Simultaneously, studies are being conducted on human hearts in autopsy examinations to determine whether this soft region can be attributed to any known condition of the human being prior to death. In order to carefully characterize these soft regions, a means of measuring softness of the heart tissue is required. The researcher has attempted to use a conventional eye tonometer for this purpose but the results have not been reproducible.

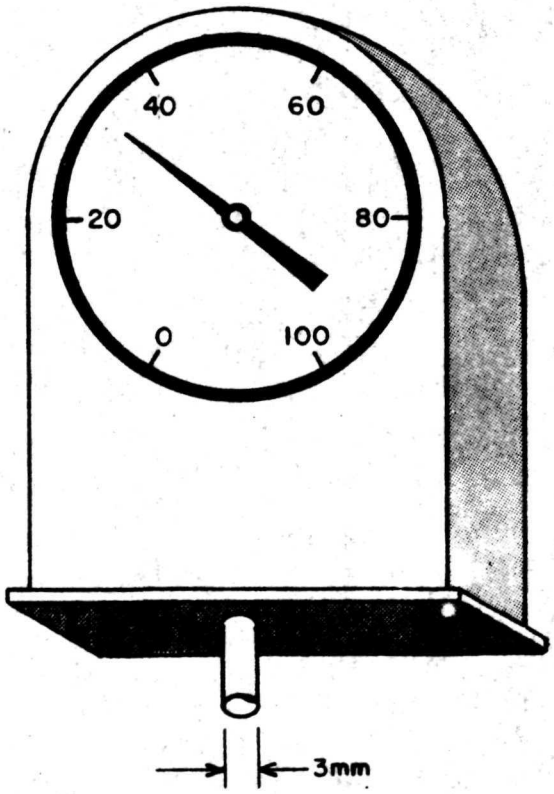


Figure B-5. Hardness Tester.

The Team performed a computer search of the NASA document file on measuring hardness of soft materials such as sponge rubbers and plastics. This search revealed that Mr. John Schell of Marshall Space Flight Center had conducted experiments on a variety of hardness testing techniques that appeared to be applicable to this problem. The Team visited MSFC for discussions with Mr. Schell and discovered that a number of techniques in current use at MSFC were applicable to this problem. Mr. Schell not only indicated the type of instrument required for this purpose, but also, of more importance, indicated the procedures necessary to obtain reproducible results. This information was then relayed to the physician at Tulane University School of Medicine who purchased a special instrument that had been modified for his purposes by Mr. Schell; the physician also incorporated Mr. Schell's suggestions in his testing procedures. The experiments by the physician are currently underway utilizing the NASA techniques, and the results to date have been successful. It is anticipated that the results of this experiment will have notable medical significance.

PROBLEM TU-20 *Cell Area Measurement*

The problems of aging are being attacked in order to better understand the processes of aging. One area of interest is glandular change, particularly the testes, pituitary gland, and adrenal glands. This research concerns the relationship between biochemical changes and morphological changes in certain tissue.

The cells will be examined under a microscope that can be projected so that the areas can be drawn on a paper sized 8 x 10 inches. The cell area and the interstitial area need to be measured to an accuracy of ±1 percent.

A problem statement was circulated to the NASA field center and several applicable suggestions were received. The problem originator is now attempting to obtain funding to implement one of the suggestions.

PROBLEM TU-27 *Blood Volume Measurement in the Lung*

Because of the prevalence of heart disease, considerable research is being conducted into the effects of various agents, or drugs, on the cardiovascular system. Although the cardiac and peripheral vascular responses to these various agents have been extensively studied, the effect on the pulmonary vascular system of many of these agents has received little attention. Since the pulmonary veins are a distensible reservoir between the pulmonary capillaries and the left atrium of the heart, and may account for 25 to 50 percent of the total pressure gradient between the pulmonary artery and the left atrium, changes in pulmonary venous tone may effect pulmonary hemodynamics and may contribute to the clinically observed responses following administration of these agents. Unfortunately, the pulmonary vascular responses

are extremely difficult to measure because of the difficulty in isolating the various components of the pulmonary vascular system.

In studies now underway, it is important to determine the compliance of a particular lobar vascular region. Compliance is defined as the ratio of a change of volume to a change of pressure. Pressure measurements are easily accomplished but changes in the volume of a particular region are difficult to measure. At the present time, the investigator is determining volume by measuring (1) the flow through a particular region, and (2) the transit time through the region. The product of these two numbers is a measure of the volume of a particular region. The difficulty arises because of the methods required to measure flow-transit time in a region of complicated circulatory pattern.

The blood volume of the left lower lobe of a dog needs to be measured with a closed chest. Required electrodes can be surgically implanted or a catheter can be inserted. Accuracy of ±10 percent is required. A problem statement has been circulated to the NASA field centers.

PROBLEM UNC-60 *Counting Exposed Points on Autoradiographs*

A means of counting exposed points on autoradiographs to be used in the study of cellular uptake of various chemicals is needed. Medicine has not yet reached the point where an ailment can be cured or its condition improved by chemical means without some likelihood of harmful side effects. Improving the effectiveness of medicines while minimizing harmful side effects seems possible only if there is a better understanding of what specific chemicals accomplish on the cellular level. One of the means of studying chemical uptake of various portions of the cell is autoradiography. In this process, chemicals of interest are made slightly radioactive and administered either orally or intravenously to a patient (or an experimental animal). After the chemicals have had time to reach their destination, tissue samples are taken and are covered with a film of photographic emulsion. The radioactivity in the tissue then exposes the emulsion and gives an indication of the relative uptake of the chemicals in various portions of the cell.

One of the major problems encountered with this technique is the tedious process of manually counting the exposed silver halide grains of the emulsion. A method of automatically counting the number of exposed grains in the violet, red, and white areas of the autoradiograph is needed so that the cellular effects of specific chemicals can be studied more rapidly and in greater detail.

The Team has identified a commercially available system, only recently marketed, that appears to provide a solution to this problem.

PROBLEM VAM-4 *Microanalysis of Hormone Levels in Blood*

The effects of noise on man are not well understood. The increasing awareness of noise pollution in our environment has prompted several investigations of the physiological effects of noise on man. The problem originator plans to investigate the effects of noise by performing a series of experiments with a Rhesus monkey. The monkey is to be subjected to various types of noise. Researchers intend to monitor the monkey's EKG, EEG, and blood pressure levels during the experiment. It has been demonstrated that certain hormones, in particular cortisol and the growth hormone, are particularly sensitive to physiological stress. If hormone levels in the monkey's blood could be monitored, it would be possible to learn more about the relationship between hormone levels and physiological stress. More importantly, it would provide an answer to the question, "Can man adapt to stress caused by noise?" This question can be answered only if it can be determined whether or not long-term shifts in blood hormone levels exist as a result of the noise stimulus.

At present, a rather large sample of blood is required to determine the hormone levels, which prohibits frequent determination of the hormone levels. A technique is needed that will allow the determination of the levels of cortisol and the growth hormone in blood from only a few drops of blood.

NASA scientists have had to cope with a similar problem in planning for the 1973 SKYLAB mission. In order to keep a close check on the state of health of the astronauts, a technique for microanalysis of blood constituents was developed by AEC under NASA sponsorship. The technique is currently under evaluation by the problem originator.

OTHER, MISCELLANEOUS

PROBLEM EU-12 *A Rapid Method of Applying EEG Electrodes*

A special helmet developed by NASA may prove useful in measuring neurological disorders.

People with neurologic dysfunction represent a significant portion of the patients undergoing rehabilitation in the United States. Neurologic dysfunction can occur as a result of birth defects, disease, or traumatic injury. Emory University Regional Rehabilitation Research and Training Center is active in the rehabilitation of such patients. One of the first things to be determined about such a person is the degree of neurologic dysfunction. One program objective at Emory University Regional Rehabilitation Research and Training Center is to develop techniques to measure the degree of neurologic dysfunction. This information is required at the beginning of treatment because, if the patient cannot process sensory information, there is little hope for rehabilitation.

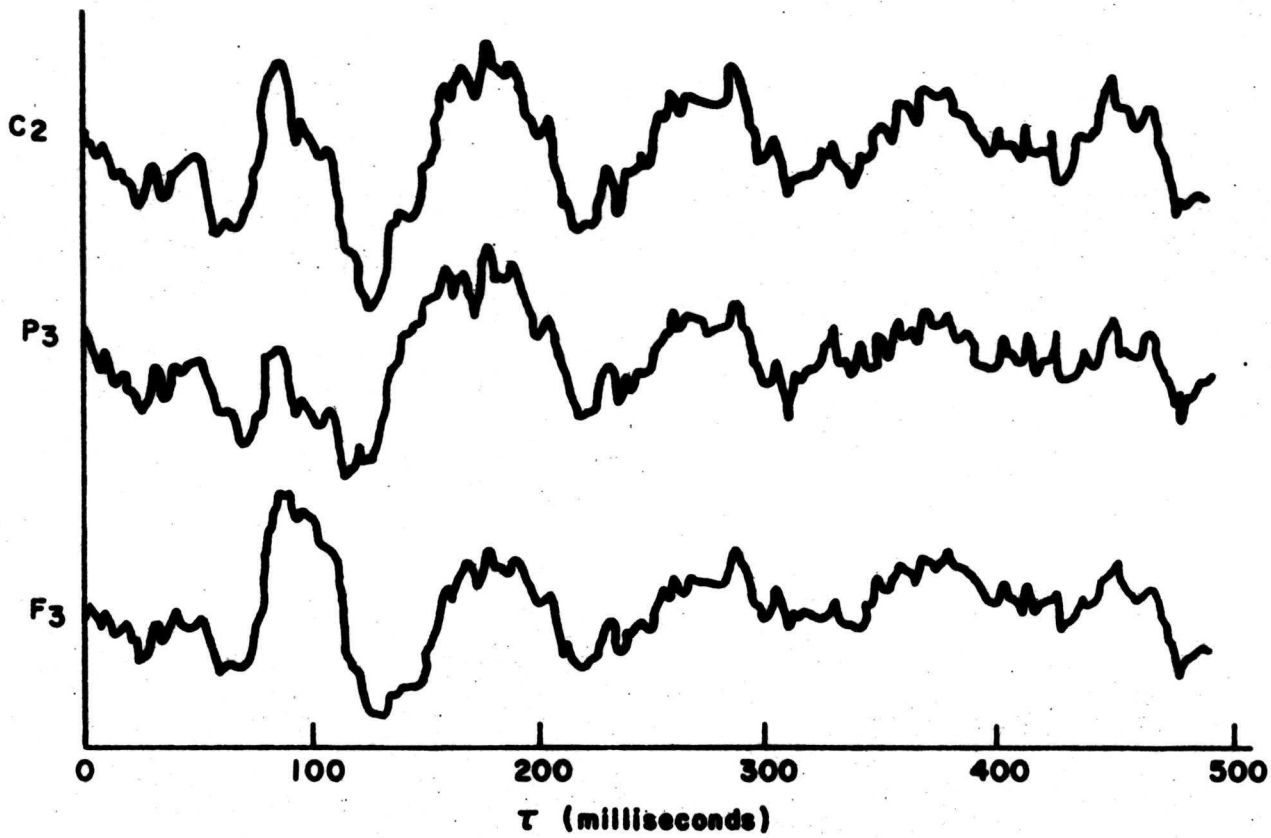
At the present time, evoked responses as measured by electroencephalograms (EEG) are used as an index of dysfunction. In this technique, stimuli of various kinds (auditory, visual, tactile, etc.) are presented to the patient, and the EEG is recorded from electrodes attached to the patient's skull at points appropriate to the type of stimulus. Multiple electrodes are required, varying from 3 to 16, depending on the various circumstances. Attachment of these electrodes by conventional techniques (e.g., collodion) is very time-comsuming and frustrating to the patient. It can also be quite alarming to the patient, particularly to one who has received shock therapy.

Severely mentally retarded children present a particular problem. It is desired to employ these techniques to determine neurologic dysfunction in these children, but conventional EEG techniques are impossible with these children. They present very significant problems in handling. They are very difficult to engage in any long-term activity; e.g., it is virtually impossible to persuade such a child to remain seated for the 10 or 15 minutes required to attach the EEG electrodes. In addition, hostile reactions are not infrequent in which the child will reach up and rip an electrode off while another is being applied. As a result, a simpler means of obtaining EEG data is required--specifically, a technique that will permit the installation of electrodes in a very rapid fashion.

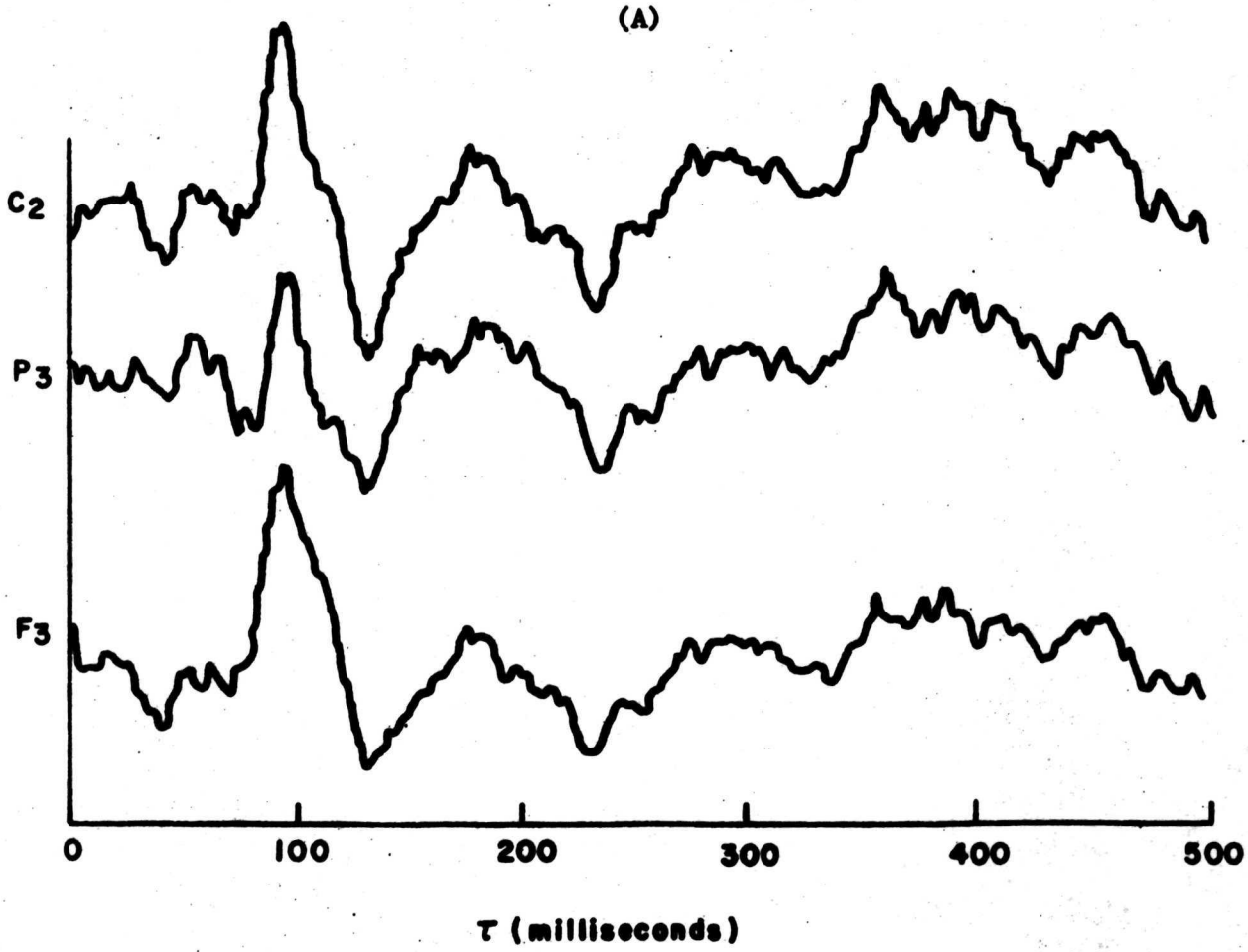
An EEG helmet developed by NASA in the astronaut program was identified as potentially useful in this application. One of the EEG helmets, a three-electrode design, was borrowed from the NASA biomedical applications team at SwRI, which has been modifying the helmet design for civilian biomedical applications. The researcher tested the helmet at Emory University Regional Rehabilitation Research and Training Center using the following procedure.

First, a subject was fitted using EKG solution and conventional silver dish electrodes mounted with collodion. Three electrodes were employed, one each at the C_2, P_3, and F_3 positions, with all signals referred to the left ear. Visually evoked potentials, obtained by using a strobe lamp, were recorded for 200 stimuli. The data were averaged by computer and the average evoked potential for each lead was plotted (See Figure B-6A). The test was repeated using the same electrodes in order to obtain some idea of the variation to be expected with this subject. These data are plotted in Figure B-6B.

The conventional electrodes were removed, the skull carefully cleaned to remove collodion, and the helmet was fitted. Electrode placement was adjusted to obtain, as nearly as possible, the same locations as in the previous trials. The subject was then stimulated using the strobe for 200 flashes as before, and the averaged EEG curve for each lead was plotted (See Figure B-7A). Since the electrode conductor in the helmet electrode is actually saline solution, it was decided to inject saline (as might accidentally occur occasionally). Saline was

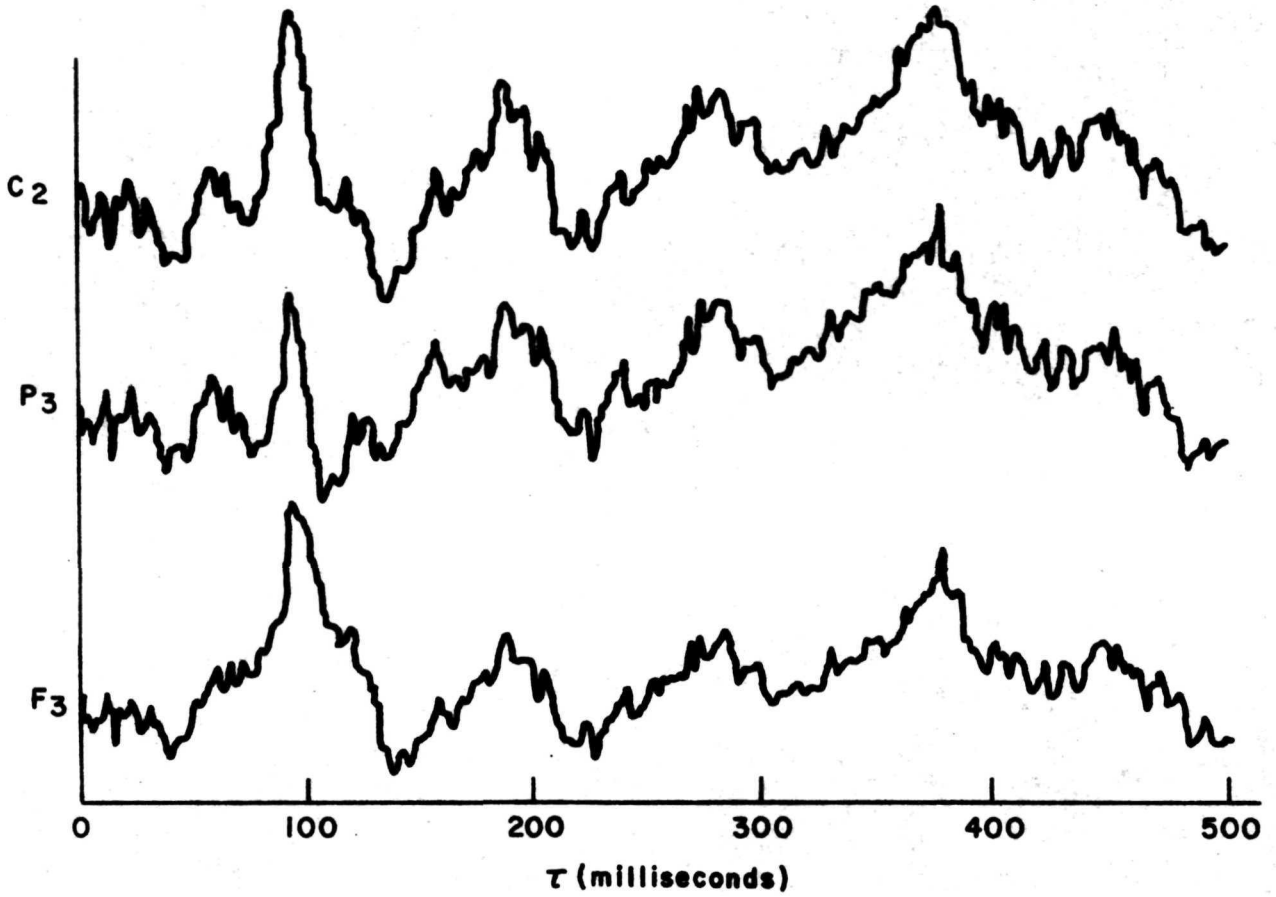


(A)

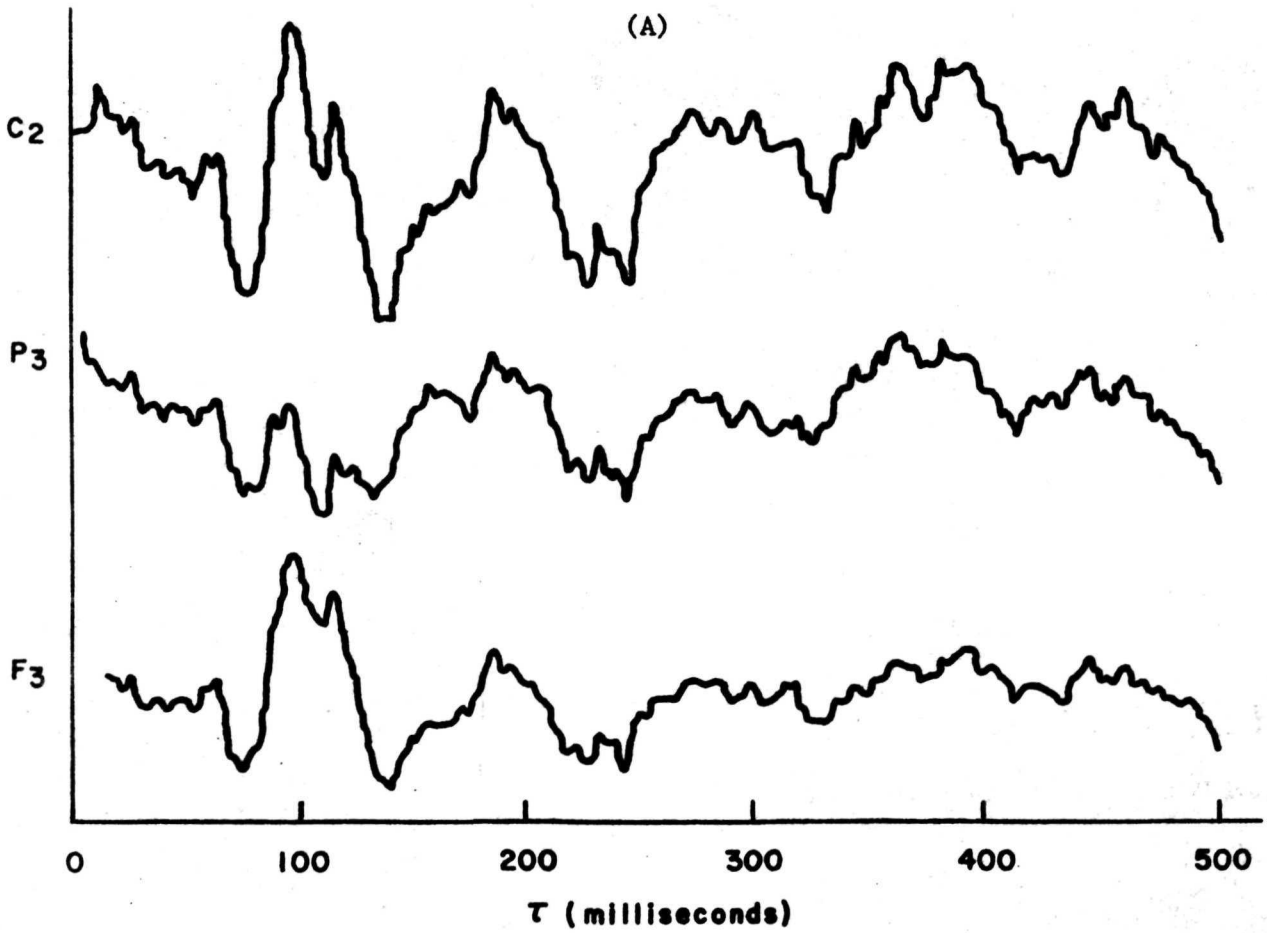


(B)

Figure B-6. Visually Evoked Response with Conventional Electrodes (Average of 200 Trials).



(A)



(B)

Figure B-7. Visually Evoked Response with EEG Helmet (Average of 200 Trials).

injected until it ran down the sides of the patient's head and the tests were repeated. The data from this test is shown in Figure B-7B. It can be clearly seen that excess saline has little observable effect on the records. It was concluded from these tests that (1) the helmet technique provides EEG records that are of comparable quality to those using conventional techniques, and (2) the helmet method is faster and easier than conventional techniques if more than one electrode is involved. Further, it would be significantly faster and easier for the application of seven electrodes on children as is desired by the researcher.

The EEG helmet will definitely solve the researcher's problem; however, during the time period in which the EEG helmet trial was arranged, another technique developed under a NASA contract at UCLA was identified. This unit employs techniques basically similar to those used in the EEG helmet. In the UCLA-developed unit, the cap is made from a stretchable polymer and is donned much like a bathing cap. Because it stretches, electrode adjustment to fit each child's skull is not required. It is significantly lighter in weight than the helmet, which is a distinct advantage with children. One further advantage, at least in a screening program such as that planned by the researcher, is that the electrode positions and spacings remain relatively constant.

The researcher is designing and constructing a soft cap EEG helmet at the present time.

PROBLEM MISC-6 *Motor for Powering Prosthetic Unit*

A small powerful motor developed for space craft may solve a significant problem in a prosthesis for children born without arms and legs.

The researcher is working with a boy 4 years old who was born without arms and legs. With prostheses and intensive training the boy could stand up and walk independently at the age of 19 months. He is now using both legs and arms prostheses. In addition to walking, he can eat, drink, and draw using these prostheses.

The basic problem is to design a prosthetic leg that will permit the boy to go up and down stairs. The researcher has contacted many specialized prosthetics and rehabilitation centers both in Europe and the United States. Unfortunately, little practical experience is available to draw upon in the rehabilitation of one so severely handicapped. The researcher has evolved a design in which the prosthetic legs can be made to telescope by means of a drive motor in the leg. (See Figure B7). Such a telescoping prosthesis would allow one of the legs to be lengthened to the height of the stair tread so that the other foot could be placed on the next step. The boy would then transfer his weight to the upper leg, and the extended leg would be shortened to the proper height to permit him to stand on the level with both feet on the upper stair tread. The process would then be repeated, thus allowing the boy to traverse the stairs.

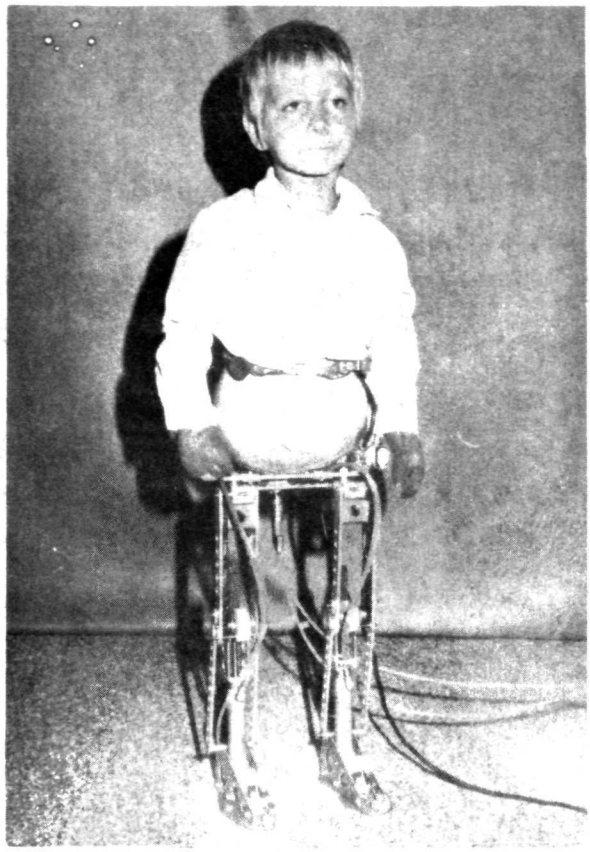


Figure B-8. Hydraulic Version of Prosthesis.

The basic problem in the design is to locate a motor that is small and lightweight enough to fit into the prosthetic leg while at the same time powerful enough to lift the entire weight of the boy. Hard and fast specifications on the motor performance are somewhat difficult to assign. As a result, information on the smallest, most lightweight motors that can be obtained and that can provide the power to lift approximately 50 pounds a distance of 8 to 10 inches within a time span of 5 to 10 seconds is desired.

Size and weight are the primary constraints, provided that the motor can produce sufficient power. Because the final design of the prosthesis will be determined by the motor, we hesitate to assign a minimum size and weight. Rather, the smallest, most lightweight motors with adequate power that can be identified will be considered. When this has been established, studies will be made to determine whether the prosthesis design parameters can be modified sufficiently to permit implementation of a prosthesis that the boy can effectively use.

An authority on small motors at Duke University was consulted. He advised us that brushless DC motors designed under NASA contract by Sperry Marine Systems Division to provide motive power in positioning satellite solar panels and unfurling antennas were the most likely to fit this particular application. Information on the motors was obtained from Sperry and forwarded to the problem originator. After reviewing the motor characteristics with his technical staff, the researcher has decided that these motors are well suited for fulfilling the motive function in the prosthesis for the young boy. At the present time, efforts are being made to obtain the motors.

PROBLEM MISC-24 *Metal pH Electrodes*

Shock, a complex self-compounding process that is often encountered, is initiated by many causes. Regardless of the cause, the progression is similar in all cases. Protective mechanisms are set in action that greatly restrict blood flow through peripheral capillary beds. These beds rapidly become hypoxic (lack of oxygen) with a decrease in pH. If untreated, the changes lead to various stages of progressive deterioration from which recovery becomes increasingly difficult. A stage is reached at which treatment is ineffective and death is inevitable.

Early warning of the onset of shock greatly improves the prognosis. The problem originator believes that monitoring of the peripheral pH change can provide this early warning. Unfortunately, commercially available implantable electrodes do not meet the rigors of patient monitoring.

An antimony microelectrode is commercially available but it is too small and fragile for this application. Use of this metal is not new, but its original applications were troubled by impurities in the antimony. Recent manufacturing techniques have eliminated this problem. Currently, the researcher is developing an antimony electrode for evaluation.

A search of aerospace literature discovered two NASA contractural efforts in implantable electrode development. Both efforts are being investigated for possible application.

PROBLEM TU-32 *Calcium Microelectrode*

The entire class of antibiotic drugs is among the most widely used in modern medicine. Although widely used in the treatment of many diseases such as tuberculosis and urinary infections, dangerous side effects from these drugs can occur. One of these effects is ototoxicity or the loss of hearing due to the drug. Many otherwise useful drugs cannot be used to the extent desired because of the ototoxicity problem. The cause of the ototoxicity is not understood and basic research is underway to determine the origin and cause of the problem. In this research study, the calcium content of individual cells will be analyzed in an attempt

to provide a clue to the origin of the problem. It is felt that a change in the calcium level of individual cells is an important aspect of the overall problem.

A microelectrode with a 10-micrometer diameter capable of measuring concentrations as low as 1 millimolar with an accuracy and precision of ±10 percent is required. The initial study of the NASA literature revealed that a medical investigator at the Ohio State School of Medicine had developed an electrode that may meet the requirements for this problem. The problem originator is planning a visit to the Ohio State School of Medicine to determine the applicability of this new technique to his problem.

PROBLEM UNC-61 *Pen Force Measurement*

Drug abuse in the United States is now one of our major societal problems. In order to combat this problem, research is under way at several institutions to understand more about drug effects on human beings and to find better methods of rehabilitating habitual drug users. Verbal behavior (e.g., coherence and intelligibility of speech and text) may provide a key to understanding more about the effects of drugs as well as the underlying causes of drug abuse in particular individuals. The problem originator plans to study verbal behavior by having a subject write responses to questions that appear before him automatically. The psychologist conducting the test would determine subsequent questions by the subject's response to a presented question. The subject's response comprises not only what he says but how he writes it. For example, hesitancy in response might indicate reluctance to answer the question. A question that arouses feelings of anger (perhaps "Do you like cops?") might result in more force exerted on the writing paper. A means of measuring force exerted by a pen on the paper while writing would provide this auxiliary information, which could aid psychologists in discovering the underlying problems in patients that have turned to drugs. This, in turn, would lead to more appropriate therapy to promote patient rehabilitation.

Several suggestions were received from NASA's Langley Research Center and are under evaluation by the problem originator.

PROBLEM UNC-66 *Determining Tissue Perfusion Adequacy*

Patients suffering from vascular disorders often encounter pain when attempting a routine physical activity, such as walking. These symptoms may result from inadequate tissue perfusion. If uncorrected, the prognosis is usually one of progressive immobilization combined with irreversible damage to the affected tissue.

If the cause is vascular blockage, in most cases it can be accurately located and removed or bypassed. This restores the blood flow but not

necessarily the tissue perfusion. Physiological control systems allow large portions of the blood flow increase to bypass the nutritional capillary beds. In addition, the tissue deterioration could be too extensive to permit perfusion. In either case, additional corrective action is necessary, preferably before the ongoing surgery is terminated. Unfortunately, the physician does not now have a method for quickly evaluating the adequacy of tissue perfusion. Such a method would save the patient the trauma and expense of additional surgery. It would also provide more effective treatment.

Two approaches are being investigated. One combines a radioactive tracer flow indicating method with some form of biochemical assay. The other would consider changes in tissue characteristics resulting from increasing stages of hypoxia.

The problem is currently in the literature search phase.

PROBLEM USDA-1 *Detection and Separation of Food and Feed Commodities Contaminated with Carcinogens*

Recent research has shown that certain carcinogenic compounds can occur in foods. One important example of these types of naturally occurring compounds are metabolites of *Aspergillus flavus* or *parasiticus*, which are fungi that may occur in nearly all seeds, e.g., wheat, corn, peanuts, and cottonseed. Metabolic products of these fungi are aflatoxins, which are known to be carcinogenic.

Although aflatoxins are not present in all seeds, their concentration may rapidly increase when infected seeds are exposed to high ambient temperatures and high relative humidities during either the growing process or storage. In addition to being a potential health hazard when human beings consume the contaminated food, some research indicates that contaminated animal feed can result in transmission of the carcinogenic agent to the human by a secondary path. It is for this reason that a major research effort is underway by the United States Department of Agriculture to improve existing methods of eliminating the contaminated seeds before they are processed for various food or feed products.

One of the difficulties inherent in separating seeds is the large volume of seed that must be processed. Thus, a method is needed for detecting low levels of aflatoxin in large volumes of seed. One useful technique appears to be separation on the basis of specific gravity, because contaminated seeds may have a lower specific gravity than noncontaminated seeds. Aflatoxin can be detected by using thin-layer chromatography with a precision of a few parts per billion. The low density seeds have been analyzed using thin-layer chromatography to show the dangerous levels of aflatoxin. Exploratory methods for separating seeds on the

basis of density or other physical properties consist of air classification or projection of the seeds a distance of 50 or 60 feet. These methods have the disadvantage of lack of precision. Thus, a new method of separating on the basis of density or other physical properties is required.

Separation of seeds by specific gravity (greater than 0.9 and less than 0.9) is required. Large volumes of seed, such as 1,000 tons, can be expected to be received for processing in a single day. A precision of ±5 percent is desired. Each peanut may weigh from 0.5 to 0.8 grams; each cottonseed from 0.04 to 0.17 grams. It should also be noted that the commercial value of most seeds is low (e.g., raw peanuts approximately $0.12 per pound; cottonseed $0.03-0.05 per pound), so that a relatively inexpensive processing cost is required.

A problem statement has been circulated to the NASA field centers.

PROBLEM VAM-5 *Safety Mechanism for Patients' Medicine*

There is a growing concern over the problem of the use of medicine for a longer period of time than prescribed by the physician. Certain antibiotics, for example, if ingested some time after their expiration date, can cause renal failure and, therefore, death. Thus, expired or no longer prescribed medicines present a potential hazard to the patient and his family. The problem becomes even more serious with elderly patients who are not careful about the medication they take and with persons having character disorders who might impulsively begin taking whatever medicine is available in a suicidal attempt.

As a protective measure for the patient and his family, it is desirable to have a warning device that would give an indication when the time for which the medicine was prescribed has passed. In the ideal case, the medicine should no longer be accessible to the patient. Perhaps a coating applied to the medicine or a special container could cause destruction of the medicine after the period of the prescription has elapsed. Medicine is rarely prescribed for longer than 1 month; 1 week or 10 days is typical. The destruction should take place within a few days after the prescription date has passed.

A literature search has produced some potentially useful solutions to this problem.