NASA

APPLICATION TEAM PROGRAM

Applications of Aerospace Technology in Biology and Medicine

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RESEARCH TRIANGLE INSTITUTE
RESEARCH TRIANGLE PARK, NORTH CAROLINA

PREFACE

This report covers the activities of the NASA Application Team Program at the Research Triangle Institute between October 1, 1970, and March 31, 1971. The activities were performed in accomplishing Tasks A through F, Statement of Work, NASA Contract No. NASW-1950. Accomplishment of Task G, Supplementary Efforts, is reported separately. This work was performed in the Engineering and Environmental Sciences Division of the Research Triangle Institute under the technical direction of Dr. J. N. Brown, Manager, Systems Engineering Department, and Dr. F. T. Wooten, Director, Application Team. Full-time members of the Team and other RTI staff members who participated in the project are Mr. Ernest Harrison, Jr., Mr. E. W. Page, and Mrs. Mary Carpenter. 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. G. S. Malindzak, Jr., Bowman Gray School of Medicine, Wake Forest University, Winston-Salem, North Carolina; Mr. William Z. Penland, National Cancer Institute, Bethesda, Maryland; Professor Hal Becker, Tulane University School of Medicine, New Orleans, Louisiana; and Mr. Myron Youdin, Institute of Rehabilitation Medicine, New York, New York.

ABSTRACT

This report presents the results of the 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-1950 for the reporting period October 1, 1970, to March 31, 1971. 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; and Mrs. Mary Carpenter, 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 52 new problems for investigation, has accomplished 4 technology applications and 13 potential technology applications, has closed 49 old problems, has reactivated 2 old problems, and on March 31, 1971, had a total of 86 problems under active investigation.

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LIST OF ABBREVIATIONS

AAMI	*Association for Advancement of Medical Instrumentation*
ARC	*Ames Research Center*
Team	*Application Team*
COSMIC	*Computer Software Management and Information Center*
FRC	*Flight Research Center*
GSFC	*Goddard Space Flight Center*
Hdqtrs	*NASA Headquarters*
IAA	*International Aerospace Abstracts*
KSC	*Kennedy Space Center*
LeRC	*Lewis Research Center*
LRC	*Langley Research Center*
MSC	*Manned Spacecraft Center*
MSFC	*Marshall Space Flight Center*
NCSTRC	*North Carolina Science and Technology Research Center*
RDC	*Regional Dissemination Center*
RTI	*Research Triangle Institute*
STAR	*Scientific and Technical Aerospace Reports*
TUO	*Technology Utilization Officer*
ZPN	*Impedance Pneumograph*

1.0 INTRODUCTION

1.1 Introductory Comments

The National Aeronautics and Space Administration (NASA) has been a leader and innovator in the establishment, study, 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 R & D to an impressive number of nonaerospace applications.

More recently NASA has established a program which uses an active and directed methodology. In this program, Application Teams have been 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 crime 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

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

Southwest Research Institute
8500 Culebra Road
San Antonio, Texas 78228

In addition, a new Team which will specialize in the area of cardiovascular medicine is being established at the Stanford University School of Medicine.

This report covers the accomplishments and activities of the Team located at the Research Triangle Institute for the period October 1, 1970, to March 31, 1971. In the remainder of Section 1.0, Team objectives and methodology are presented.

1.2 Application Team Program

The specific objectives of NASA's Application Team Program in biomedicine are as follows:

(a) The transfer of a maximum number of specific items of aerospace technology to medicine in order to partially or fully solve problems in biology and medicine;

(b) The transfer of aerospace technology to medicine in order to enhance the understanding of active processes of technology transfer; and

(c) The motivation of potential adopters of aerospace technology in medicine, organizations involved in generating advanced technology, and individuals who can influence technology transfer programs to become actively involved in more comprehensive technology utilization programs.

A summary representation of the Application Team Program can be facilitated by referring to Figure 1. Basically, the Team represents an interface between medical investigators and clinicians and the body of scientific and technological knowledge that has resulted from the national aerospace R & D effort.

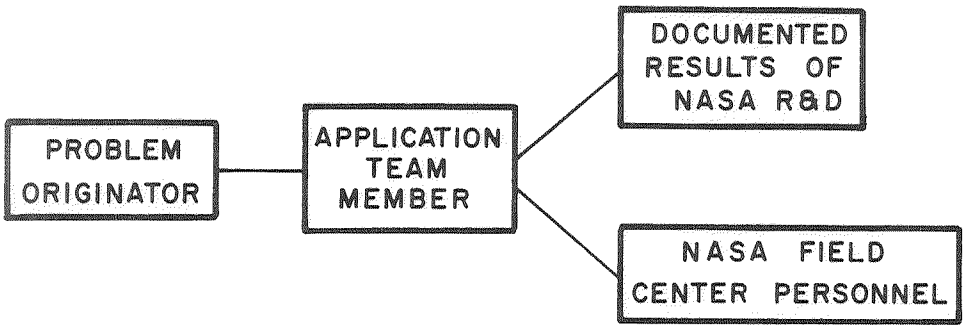


Figure 1. Possible Mechanisms for Transfer of Technology

The Team attempts to couple the technological problems and requirements in medicine with relevant aerospace technology and, in particular, NASA-generated technology. The problems and requirements are those being encountered in medical research programs attempting to improve general medical practice. The Team actively engages in identifying these problems through direct contact with medical staffs or problem originators. The identification and specification of medical problems is followed by a search for technology which may be relevant to solutions to these problems.

Generally, technology relevant to specific problems is identified through two approaches: (1) manual and computer searching of the aerospace information bank created by NASA as part of its R & D effort, and (2) direct contact with the engineering and scientific staff at NASA Field Centers. 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 less frequently, 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 a reengineering or adaptive engineering program in the School of Engineering and Applied Science of the University of Virginia which is assisting in this program by adapting NASA technology to the needs of a limited number of problem originators. This process of adaptive engineering is directed by Dr. M. L. McCartney of the Division of Biomedical Engineering. The Teams are responsible for identifying the NASA technology which is potentially a solution to a specific problem and for specifying the changes required in this technology. This 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 work which 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. Technology transfer 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 four basic steps: problem definition, identification of relevant technology, evaluation of relevant technology, and documentation. This methodology can be better

understood, however, if it is separated into the steps shown in Figure 2. These steps are described in the following paragraphs.

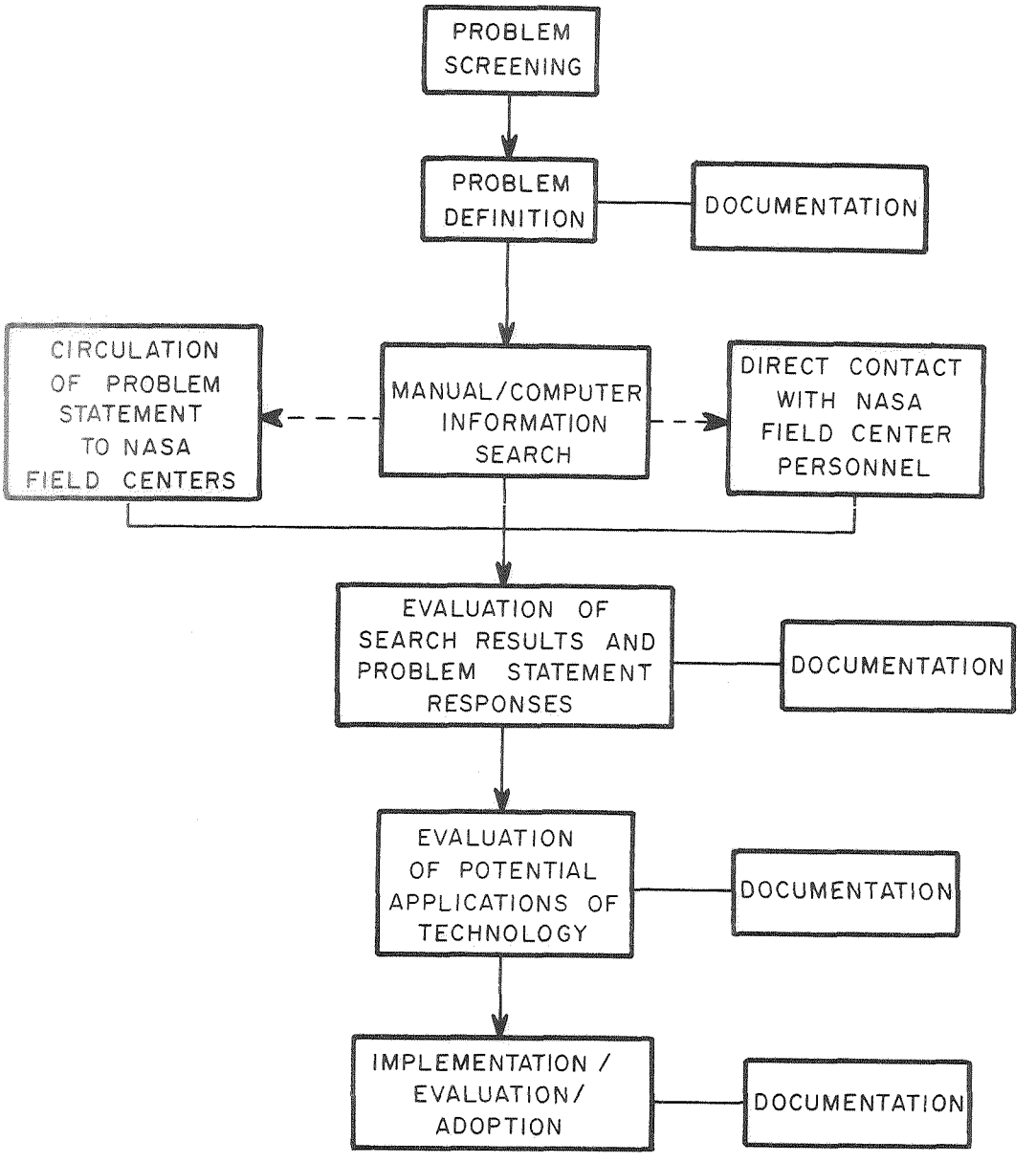


Figure 2. Flow Chart of Application Team Transfer Methodology

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 2. Analysis of the RTI Team's accomplishments in the early days of the program indicates clearly that a very significant fraction of the problems which 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:

(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 mission-oriented group efforts.)

Problems which 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 which 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. The information which can be assessed through the RDC's bank consists of approximately 700,000 documents, articles, and translations which 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 which 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 which 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 experimental evaluation of potential solutions. The Team is available for assistance in this step when required. Hopefully, when a potential solution is shown to be a valid solution to a problem, this solution is adopted and implemented by the problem originator and the transfer is completed.

Documentation - Documentation is an integral part of the Team methodology; it is involved at most steps in the process, as indicated in Figure 2. 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 industrial, educational,

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
Mrs. Mary Carpenter	Research Assistant	Documentation

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

At present, fourteen 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 3 shows the geographical distribution of the RTI Application Team user institutions as well as the location of the major NASA resources.

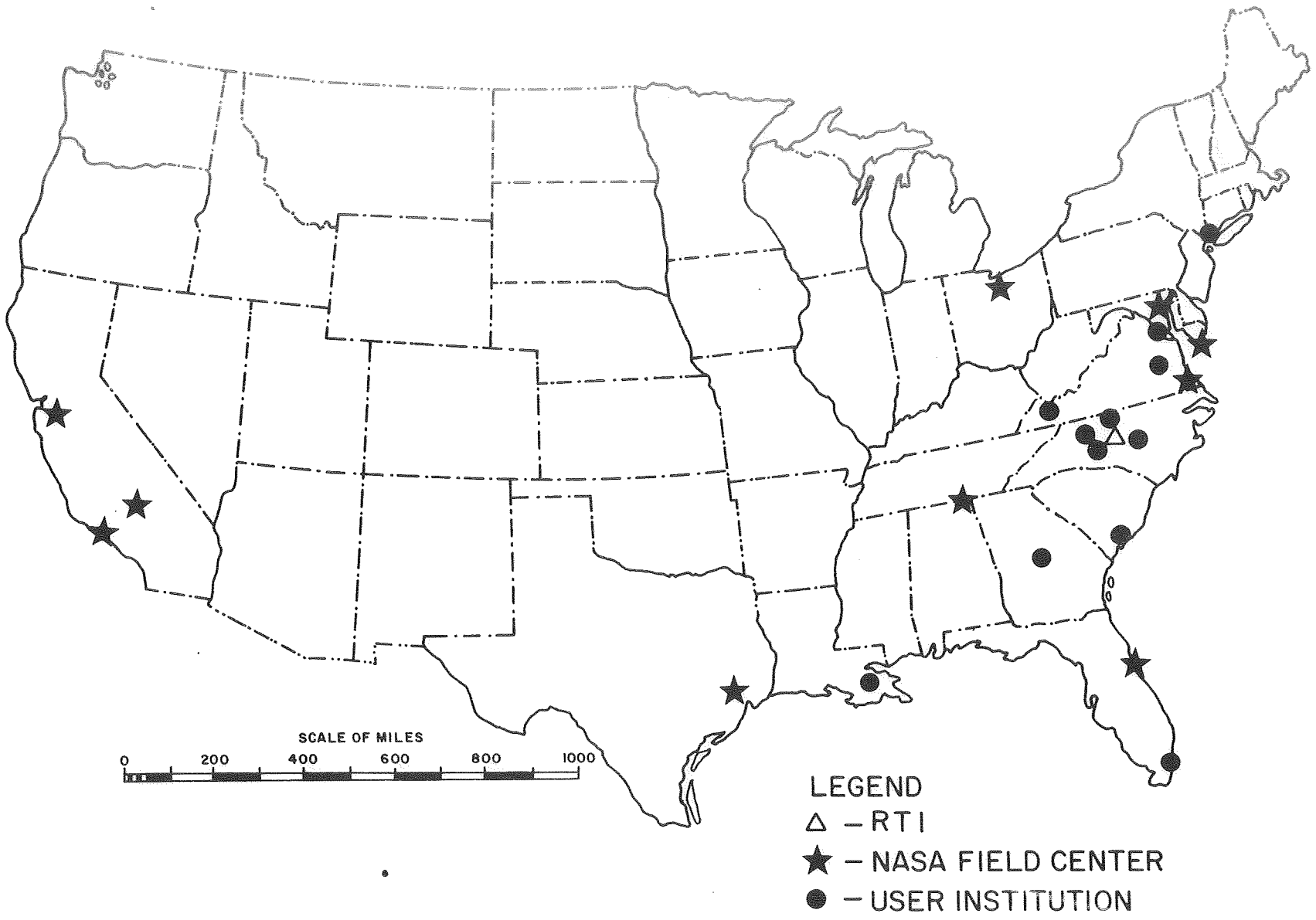


Figure 3. Team Activity Centers in the United States

The RTI Team is assisted at various stages of the technology application process by consultants who are on the medical staff 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
Mr. Myron Youdin Institute of Rehabilitation Medicine, New York University	Engineering

In addition, Dr. T. C. Pilkington, Chairman, Biomedical Engineering Department, Duke University, is assisting the RTI Team in investigating the potential for transferring NASA digital computer applications programs to applications in medicine.

Individuals at the following seven institutions have participated on certain special problems:

Jefferson Medical College, Philadelphia, Pennsylvania;
Medical College of Virginia, Richmond, Virginia;
National Communicable Diseases Center, Atlanta, Georgia;
National Institute of Mental Health, Washington, D. C.;
North Carolina Department of Vocational Rehabilitation,
Winston-Salem, North Carolina;
North Carolina State University, Raleigh, North Carolina; and
University of Mississippi Medical School, Jackson, Mississippi.

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

BH - Brookdale Hospital Center
CP - Computer software-type problem
DU - Duke University Medical Center
EU - Emory University School of Medicine
IRM - Institute of Rehabilitation Medicine, New York University

MCV - Medical College of Virginia
MISC - Miscellaneous
MUSC - Medical University of South Carolina
NCI - National Cancer Institute
NCSU - North Carolina State University
NCVR - North Carolina Department of Vocational Rehabilitation
NEHSC - National Environmental Health Sciences Center
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 - Veterans' Administration Hospital - Miami
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 which 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 easy and quick 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 which is impeding progress toward that objective.

Participating Institution - A medically oriented educational institution, hospital, medical center, or government agency having as one of its organizational 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 time and effort to assist the Team in identifying and coordinating visits with 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 biology and medicine with the specific objectives of effecting the transfer of aerospace technology to solve or aid in solving problems in medicine and of understanding and optimizing the methodology for effecting such transfers of technology. 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 with commercially available equipment or through the application of information or knowledge available to the problem originator through routinely used information channels.

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

Problem Statement - This is a concise, written statement of a problem which is 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 scientist 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 which 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.

2.0 TECHNOLOGY APPLICATIONS, POTENTIAL TECHNOLOGY APPLICATIONS, AND IMPACTS

2.1 Technology Applications

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

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-perpetuating proliferation of white blood cell forming tissue.

The National Cancer Institute of the National Institutes of Health is conducting a vigorous program directed toward finding the causes and cures 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 sphygmomanometer which is a cuff placed around the upper arm. The microphone of a stethoscope is placed under the cuff and over the brachial artery near the fold of the arm. The cuff is inflated to a pressure which is higher than maximum blood pressure and is then slowly reduced. When the cuff pressure reaches the systolic or maximum pressure, a pulse is heard in the stethoscope. When the cuff pressure is reduced still further to the diastolic pressure, the pulse sounds drop sharply.

The cuff method is undesirable for continuous monitoring of blood pressure because the repeated inflation of the cuff disturbs the patient.

A method of 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 which 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 4, 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.

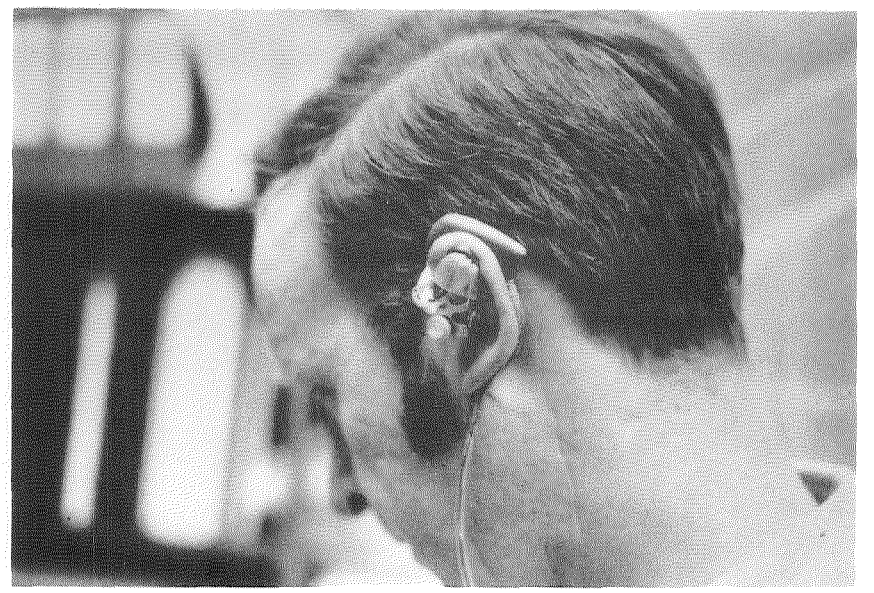


Figure 4. NASA Ear Oximeter

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.

Arrangements were made to loan the oximeter to the National Cancer Institute (NCI) for tests. At the present time, tests are underway to determine a number of characteristics of the ear oximeter in this particular problem area. Long-term stability tests on the output of the oximeter are being made as well as calibration tests to determine the sensitivity of the unit for changes in blood pressure. Although some preliminary information was available on these matters from NASA, the problem originator naturally wants to perform his own tests. Following the outcome of these tests, the output circuit of the oximeter will be modified by installing a small alarm circuit which will be triggered by changes in blood pressure. The basic idea is to have an alarm which will be triggered when the mean blood pressure drops below a particular point. This threshold level will be adjusted for each individual patient. The Team plans to work closely with the problem originator to make certain that any impediments in the utilization of this equipment are quickly solved.

Successful conclusion of the tests at NCI will provide a valuable tool in monitoring critically ill patients. Although the major emphasis at this point is on the measurement of shock in leukemia patients, it is clear that this type of monitoring would also be useful in almost any type of intensive care unit where shock is a significant hazard. Publication of favorable results from the ongoing tests will provide excellent visibility for the use of this equipment in general critical monitoring situations.

PROBLEM TU-2 *Respiratory Rate Measurement*

A device designed to measure respiration of astronauts is being used in the diagnosis of respiratory diseases in children. Respiratory diseases are the major cause of illness in children from infancy through adolescence. Some of the more serious respiratory diseases are asthma, cystic fibrosis, and bronchitis. Much research is presently being conducted in causes, diagnoses, and cures of respiratory diseases.

One valuable index for diagnosing lung disease is the respiratory rate of children engaged in quiet play. If this rate is studied for the same patient over a period of months, much information can be gained about the condition and changes in condition of the patient's lungs. Respiration rate is important because it is directly related to lung compliance or stiffness. For example, if disease stiffens the lungs, the body will adjust to the disease by breathing more shallowly and more rapidly. In the case of asthma, which restricts the air flow, the patient will breathe more slowly and more deeply. Thus, respiratory rate is an important parameter in the diagnosis of lung disease.

The patients range in age from infancy to adolescence, and the monitoring will occur in a hospital clinic. The rate measurement method should not encumber the child, but should let him be free to engage in quiet play.

The impedance pneumograph (ZPN) used by NASA on the Gemini space flights was applied to this problem. The impedance pneumograph was designed by

NASA to measure respiration rate and respiratory volume during a manned space flight. Although the unit had been slightly modified for the Apollo missions, the Gemini equipment appeared capable of solving this problem. The Team performed a search of the commercial literature and determined that, although certain commercial impedance pneumography equipment was available, none of the equipment was as small as the NASA equipment.

This approach was discussed with the problem originator, and it was determined that the NASA ZPN would be a useful approach to the problem. The first step in this effort was to obtain the Gemini hardware to test the suitability of the equipment. When these tests proved satisfactory, it was decided to implement the telemetry portion of the problem with a piece of commercial telemetry equipment. During the preliminary tests at the Tulane University School of Medicine, it was determined that not only was respiration rate information available, but the clean waveforms produced by the impedance pneumograph allowed both inspiratory and expiratory times to be determined.

At the present time, the impedance pneumograph has been mated with a commercial telemetry system. Initial tests on this system allow the subject to range up to 40 feet from the antenna, and a multiple antenna system has been installed which will allow the children to roam freely throughout the clinic area. The unit has been packaged into a small final unit, shown in Figure 5, that will enable clinical use to start immediately.

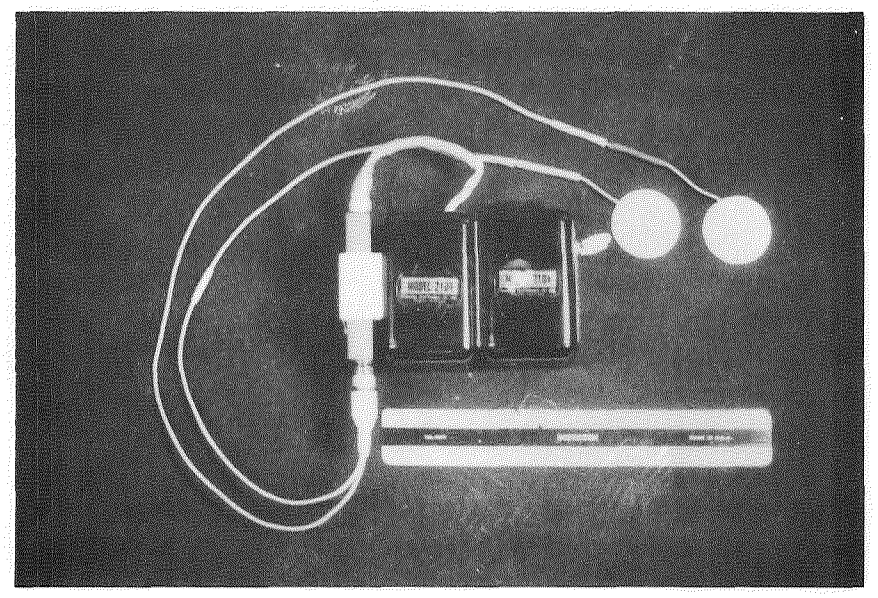


Figure 5. Impedance Pneumograph with Telemetry and Battery Package

This transfer will enable the problem originator to obtain valuable clinical information on the respiratory rates of children who are moving freely and unimpaired in a quiet play environment. This information can be used both for diagnostic purposes and for obtaining baseline information on respiratory rates of small children. It is believed that baseline information at the present time is inaccurate because of the fact that the act of taking the respiratory rate modifies the voluntary control of the respiration. Thus, both general clinical information and specific diagnostic information can be obtained because of this transfer.

PROBLEM IRM-23 *A Respiration Alarm*

NASA expertise in monitoring air flows has been applied to monitor flow in respirators at the Goldwater Memorial Hospital of the New York University Medical Center, one of the largest respiratory centers in the United States. Users of these respirators are permanently disabled--e.g., stroke victims, paralysis victims, and others permanently unable to respire themselves as a result of accident or disease. This means that the respirators must be used on the patients continuously. The respirators have battery-operated alarms connected to their mechanisms which function when the respirator becomes disabled. The alarms are not foolproof, however, because the alarm system itself is subject to failure; circuit failures can and do occur. In addition, the batteries that power the alarm system can become depleted without the knowledge of the nurse, and maintenance personnel must be relied on to insure that the batteries are always adequate. Consequently, the nurses do not fully trust the alarm system. This results in closer surveillance by the nurses and, correspondingly, requires more of their time. There have been reported cases in which patients have died when respirators with faulty alarms became inoperative before medical personnel became aware of the situation. As a result, a separate alarm system is desired, independent of the respirator alarm, which can sense when a patient is not being respired. It is desired that the alarm be attached to the patient and monitor some parameter that is a direct index of whether the patient is being respired or not. Detection of a mechanical parameter, such as change in volume of the chest with respiration, would be acceptable.

The alarm must be reliable. It must be sensitive enough to detect loss of respiration, but not so sensitive as to give frequent false alarms. If frequent false alarms occur, the unit will be turned off or ignored and will serve no useful purpose. Attachments to the patient must not be so bulky as to cause patient discomfort. In summary, simplicity, reliability, and low false alarm rate are primary requirements.

NASA's Ames Research Center has developed a thermistor alarm system for determining respirator failure or for monitoring breathing rate. This technique depends upon the rise in temperature of the inspired air when it is passed into the lungs and held there. The temperature rise is sensed by means of a thermistor placed in the expired airstream from the lungs. The NASA technology, as originally developed, employed telemetric techniques permitting remote location of alarms. In this particular application, remote alarms were not required; therefore,the system could be simplified considerably by removing the telemetric portion of the system. Mr. Jack Pope designed and fabricated a hard-wire system with

an audible alarm which could be used on the respirators available at the Goldwater Memorial Hospital. The system, shown in Figure 6, consists of a thermistor placed in the exhaust tube.

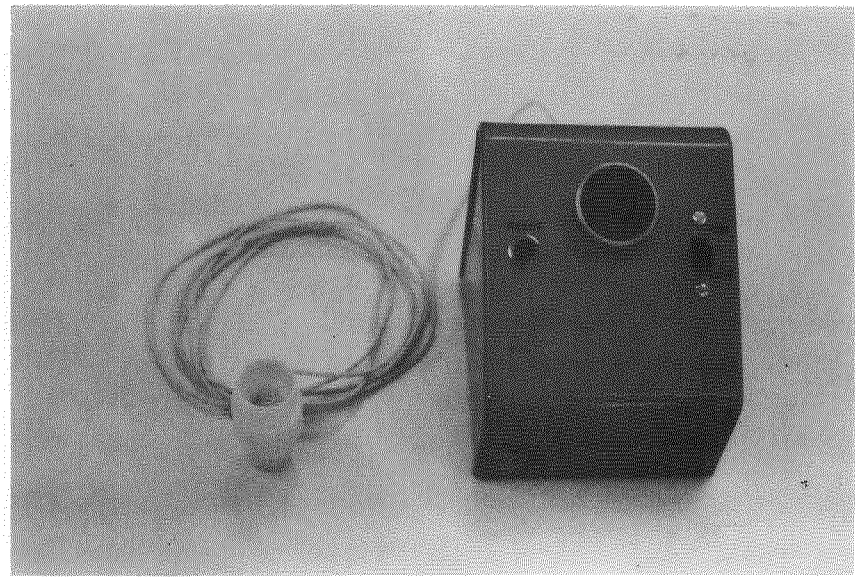


Figure 6. Respiration Alarm

The thermistor detects the thermal fluctuation of the air as the patient is respired. This thermistor is hard-wired to a signal processor and alarm circuit. Adjustments are provided for depth of respiration, and a delay is incorporated into the circuit which can be adjusted for individual requirements. When a failure is detected, an audible alarm is actuated.

This unit will permit one of the more seriously ill patients to be monitored for respiration failure on a long-term basis with significant confidence. This will eliminate much of the monitoring which is presently done by the nurse and will free her for other duties for which she is badly needed in the hospital. Favorable final evaluation is likely to result in a number of the units being constructed for use at the Goldwater Memorial Hospital on those patients who are critically ill and who must be maintained on respirators for long periods of time. If final evaluation of this technology is favorable, it is recommended that information on these techniques be disseminated to some of the major hospitals which maintain large numbers of patients on respirators; for example, an effective alarm system might find application in many of the VA hospitals across the United States.

PROBLEM WF-98 *An Improved Technique to Yield Precise Information on Surface Morphology of Kidney Stones*

Research techniques at NASA's Marshall Space Flight Center have been used to extract information on the structure of kidney stones. A researcher

at Bowman Gray School of Medicine has been engaged in a long-term study of kidney stones, their occurrence, causes, and related surgical techniques. The overall objective of his research is, of course, to prevent the formation of kidney stones in patients. Specifically, he is seeking to understand the mechanisms which cause kidney stones to form in some people and not in others. To this end, he has undertaken a number of research programs and techniques which have yielded much useful information. However, a precise theory for why kidney stones form in certain people and not in others has not yet been clearly established. For example, it appears that concentration of the chemical components in the urine may not be the critical factor because stones form in certain people who have lower concentrations of the chemicals which seem to be the basic ingredients from which urinary calculi are formed. Tiny crystals are formed in the tubules of the kidneys in many people. However, in certain people these tiny crystals grow and form kidney stones. As a result of the researcher's work in this area, he suspects that there may be a difference in the surface structure or in the surface energy between those crystals which grow and form urinary calculi and those which remain in the tubules and do not grow.

A significant portion of the population is affected by kidney stones. Passing kidney stones is an extremely painful process, and those which are not passed can frequently cause severe problems and even necessitate surgical intervention. The researcher is seeking to determine those factors which control the formation of kidney stones in human beings. In this particular problem, he is seeking a means to examine the surface morphology of renal calculi which will yield more useful information on the surface structure than that presently obtained from light microscope techniques. Basically, a means of examining the surface structure of various kidney stones is desired so as to be able to determine whether or not surface morphology is a factor in kidney stone formation.

As a result of a visit to the Marshall Space Flight Center (MSFC) by one of the RTI Team members, the existence of a very excellent scanning electron microscope facility at MSFC was already known to the Team. The potential usefulness of the scanning electron microscope in performing the surface structure studies which were needed was discussed with Dr. Boyce. Discussions revealed that this technique appeared capable of providing the exact information he required.

Mr. Juan Pizarro of the Technology Utilization Office at MSFC made arrangements to use the facility and four samples of representative kidney stones with identification numbers were sent to the scanning electron microscope facility at MSFC. Electron micrographs were desired of the surfaces of the kidney stones and of the cross-sections obtained when the crystals were fractured. This was accomplished by the scanning electron microscope facility at MSFC, and a total of forty scanning electron micrographs were made (one of these is shown in Figure 7).

The immediate benefit of this transfer is that the analytical techniques necessary for the researcher to determine the applicability of a theoretical hypothesis which he had formulated regarding the formation of kidney stones in human beings has been made available. The researcher did not

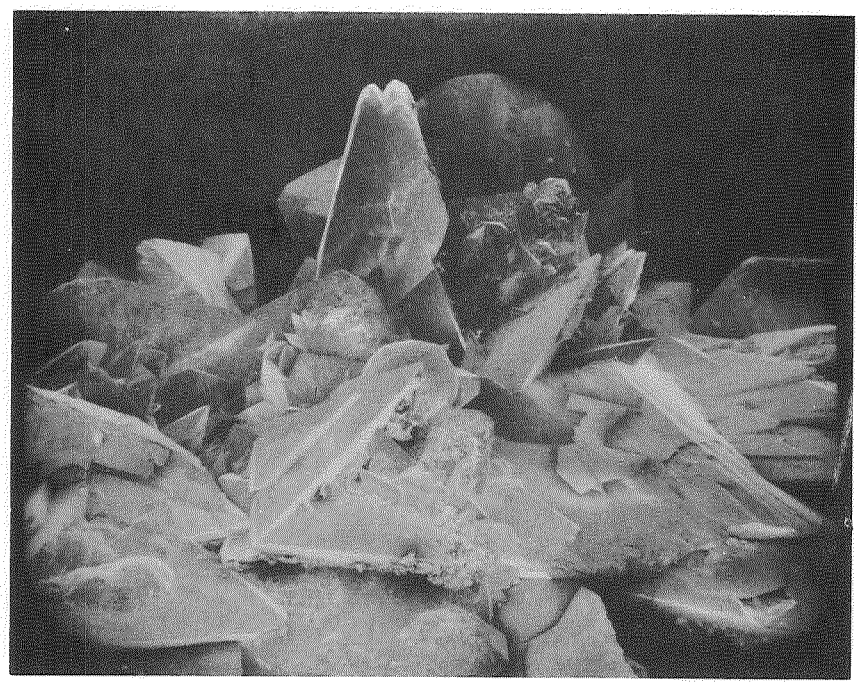


Figure 7. Electron Micrograph of a Kidney Stone

have available within the School of Medicine the analytical techniques and the instrumentation which were required for the solution of this problem. The long-range benefits of this transfer, of course, depend upon whether the hypothesis concerning the relationship between surface morphology and kidney stone formation is proved or disproved. If the relationship is indeed established, then significant strides will have been made in the understanding of the formation of kidney stones in human beings. One can foresee that once a fundamental understanding of the mechanisms involved has been delineated, methods to prevent the formation of kidney stones would soon follow.

2.2 Potential Technology Applications

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

PROBLEM CP-3 *Automated Measurement from Coronary Angiograms*

Techniques used to extract information from pictures of Mars are being 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 loss of muscle function and as a means of determining effectiveness of surgical procedures designed to improve cardiac function by improving the blood 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 which 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 twenty 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.

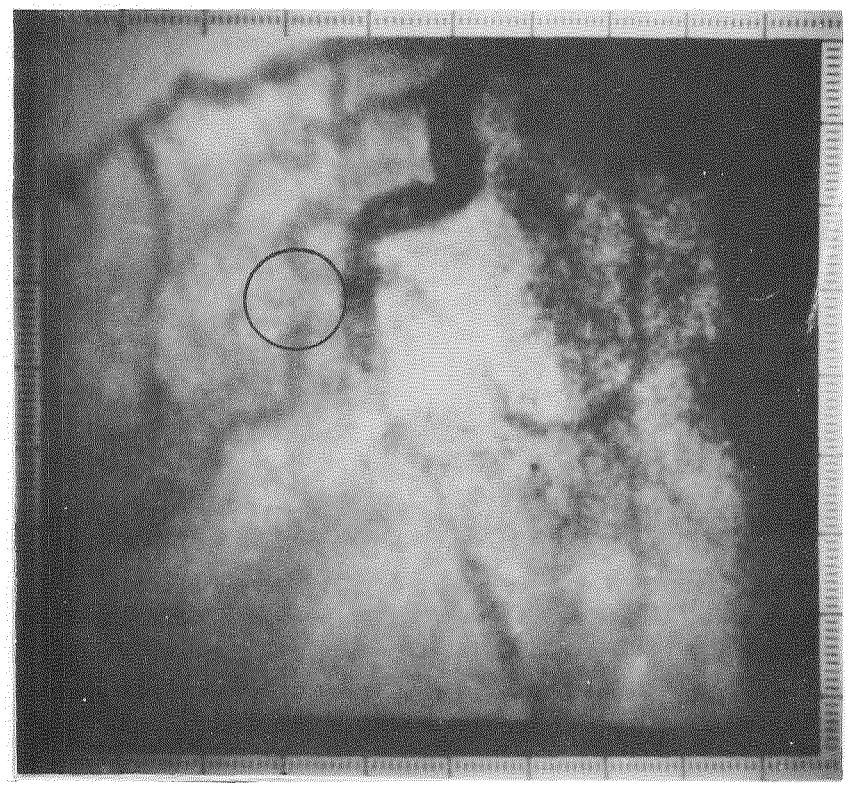


Figure 8. X-Ray of Human Heart Enhanced by Computer Techniques

This significant medical problem will be solved using a modification of the JPL image processing procedures. The equipment is operational, but the size of this effort will prevent the actual bifurcation identification from being accomplished for about one year. Figure 8 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.

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 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-fill catheters which are commonly used cause significant overshoot 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.

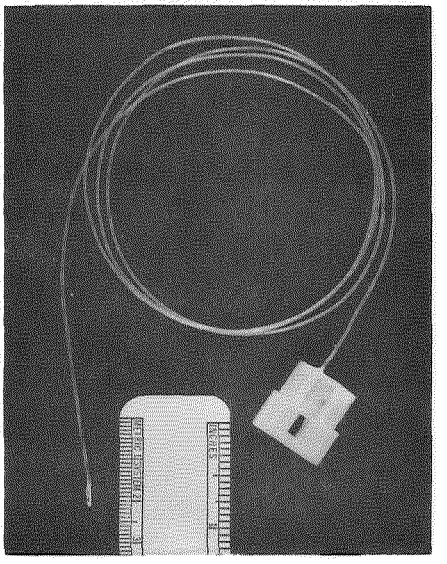


Figure 9. Tunnel Diode Pressure Transducer

The TD-1 pressure transducer, shown in Figure 9, is presently undergoing tests at Duke University Medical Center to determine its characteristics in animal experiments.

PROBLEM DU-74 *Testing of Neuropathic Patients*

A system designed to measure pilot performance has been adapted for the study of neuromuscular disorders.

Many people suffer neuromuscular disorders which result in the loss or impairment of muscular control. The cause of these disorders is damage to the nervous system which controls the musculature. One symptom of this disorder is uncontrollable onset 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, to 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 which 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 which 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 which was employed at LRC. In this case, aircraft pilots were required to track a random disturbance by positioning a joystick in a manner which maintains an oscilloscope trace in the zero position. With this configuration, it was possible to record both pilot response and instantaneous error in tracking random disturbance. Included in the task were model stick and aircraft dynamics. This configuration is illustrated in Figure 10 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 neuromuscular patients. The LRC tracking task with the suggested modifications as shown in Figure 11 was implemented, and the problem originator is evaluating the technique.

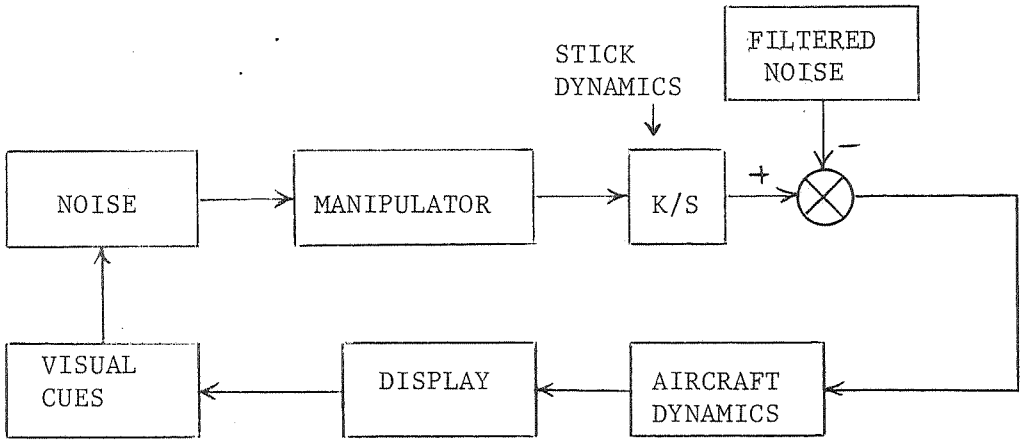


Figure 10. Single Axis LRC Tracking Task Block Diagram

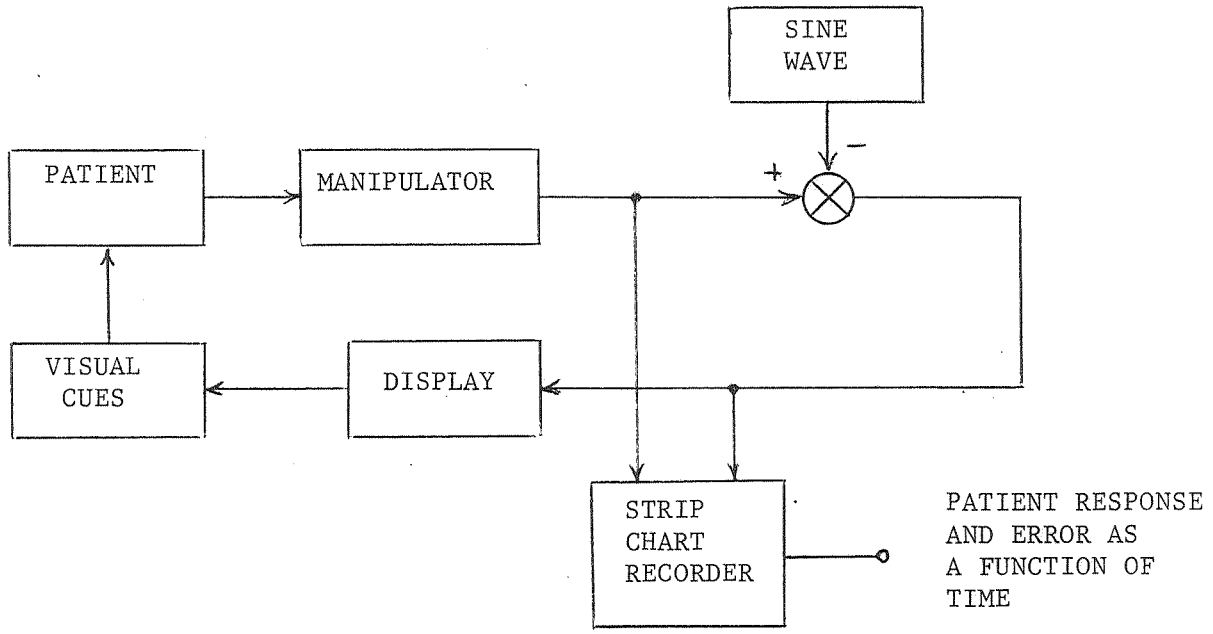


Figure 11. Block Diagram of Single Axis Track Task
for Testing Neuropathic Patients

PROBLEM DU-75 *Epicardial Electrodes*

A material designed for spacecraft antennas is being considered for use as epicardial electrodes in the study of heart disease.

Early diagnosis of heart disease is an important factor in reducing the mortality from the major cause of death in this country. At the present time, the electrocardiograph is the principal tool in diagnosing heart disease. The electrocardiogram is a measure of the electrical activity at the surface of the chest which is generated by heart action and is determined as a function of time. One of the most significant advances in electrocardiography is the recent development of body surface mapping or isopotentials surface maps. This technique involves measuring the progress of isopotentials on the chest surface as a function of time. Rather than a time relation of a fixed point, the interrelation of a large number of points and, in particular, the phase relationships between these points is studied.

One of the basic difficulties in this type of study is determining how much information is actually required in order to map the potential distributions. This study attempts to determine whether or not the presently used 150 electrodes are actually required in order to determine the isopotential. Obviously, from a financial point of view, it is desirable to find the smallest possible number of electrodes which will provide a given amount of information. In order to obtain this information, the potentials generated at the surface of the heart and chest must be determined so that a correlation can be made between the two. This information is then fed into a PDP-12 computer for analysis on the amount of redundant information.

Although the major interest in the past has been in ventricular potentials, researchers at Duke University Medical Center have recently shown that the information at the atrial surface is of major importance--in particular, it is interesting that small transient relations on the atrial surface may be of major importance.

The present study involves attaching forty electrodes to the atrial surface. These forty electrodes provide detailed information concerning changes on the atrial surface. The electrodes will be attached during open chest surgery and must occupy an area not greater than 1 mm. The basic problem is to develop a method of quickly attaching these electrodes which will be implanted for a period of several weeks. The existing method of attaching the electrodes requires an inordinate amount of time; rapid attachment would not only save surgical time but would also reduce trauma.

NASA has developed a method for opening antennas in space by using a material with a mechanical memory. This material, called Nitinol, is annealed in a particular shape as shown in Figure 12c. When cooled to room temperature, the material can be deformed as shown in Figure 12a; then when it is reheated above the critical transition temperature, the material will return to its annealed form. This critical transition temperature can be adjusted to body temperature. Thus if electrodes made of Nitinol are annealed into a hooked configuration at body temperature and then lowered to room temperature, the hook shape can be

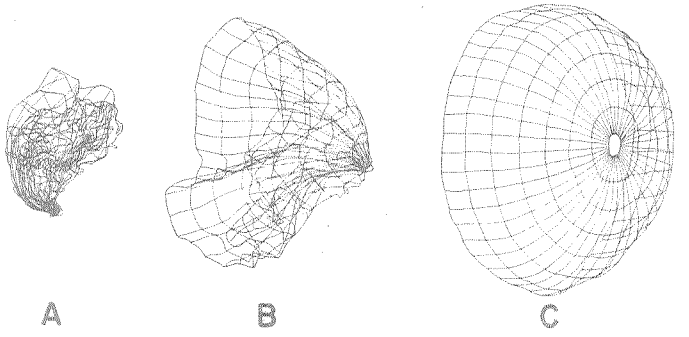


Figure 12. Antenna Formation Using NITINOL Wire

straightened. Then when the straightened electrode is stuck into the atrial surface, the hook will immediately form and attach the electrode.

This method has been discussed with the researcher, and he is extremely interested in pursuing it. Samples of the material have been provided to the researcher and biocompatibility studies are underway.

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 was quite knowledgeable in this field. Dr. Trombka had experimented with several

types of specially prepared noncommercially available emulsions which will reduce the required exposure time. A Team member met with Dr. Trombka and he discussed these techniques at length. Dr. Trombka agreed to prepare such an emulsion for testing at NCI. These new emulsions offer the promise of improved information about cancerous cells.

PROBLEM OF-1 *Blood Embolism Detection*

Ultrasonic flow detectors developed by NASA may prove useful in detecting embolisms occurring during 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 arteriosus, and tetralogy of Fallot can be corrected by open heart surgery. If the heart is opened, a heart-lung machine is 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 embolisms which can stop blood circulation if lodged in a small artery. In addition, surgery can break loose small particles which can stop blood circulation. It is estimated that 20% of open heart surgery cases at present result in a neurological deficiency (reduction of blood flow to the brain); thus a means of detecting the embolisms as they occur is vital for successful open heart surgery.

Because the embolisms occur during open chest surgery, attachment of electrodes is easily accomplished. Particle sizes as small as 1 micron should be detected in the output of the heart-lung machine. The particles can be either gas or solid.

The Team contacted Mr. Sal Rositano of Ames Research Center who has had experience in the measurement of blood flow. Mr. Rositano advised that the ultrasonic blood flow units developed for NASA by L & M Electronics would detect embolisms of the type of interest to the problem originator. The problem originator was advised of this fact, and he is now obtaining a quotation on a device similar to the NASA-developed units.

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 which leaches calcium from the bone. This can produce lethal hypercalcemia. For example, 20% of lung cancer victims and 40% 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 which 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. A method which does not involve X-rays would be desirable.

Although the technique will be used evenuually on humans, initially it will be used on rat tibia (3 x 0.5 cm). Changes in bone density as high as 50% are expected, and the accuracy of detection should be ±5%. Preferably, the rat will not be sacrificed so that repeated measurements can be made over a fourteen-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 13) measured the ultrasonic velocity through the bone which could be correlated with bone density.

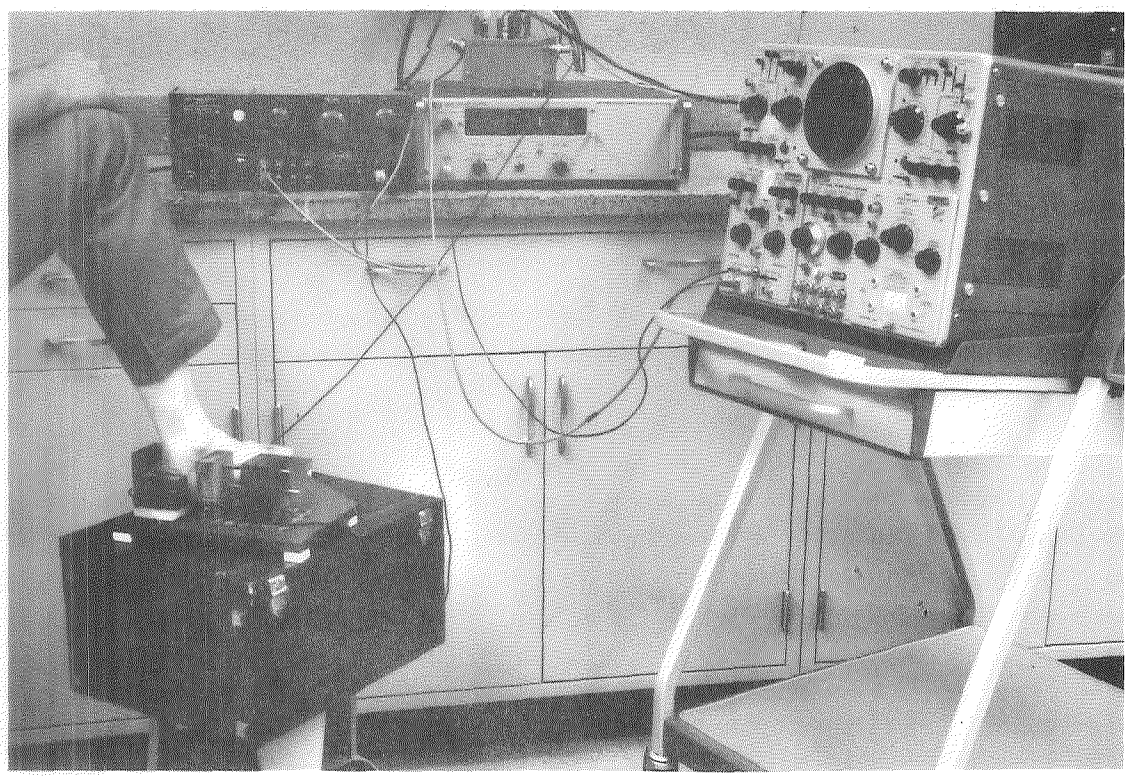


Figure 13. NASA Bone Densitometer

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. Efforts are now being made to obtain the loan of the MSFC bone densitometer for the Ochsner researcher.

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 adolescence is respiratory disease of which the serious forms include asthma, cystic fibrosis, and bronchitis. Significant research is being conducted both in the causes and cures of respiratory diseases and in better methods of diagnosis of the diseases. This problem statement is devoted to finding a method of improved diagnosis which will improve the treatment of respiratory diseases.

The respiratory system consists of the lungs and the system of tubes or ducts which 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 bronchus, 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 and simple method to determine whether a portion of the lung is performing properly is to listen to the sounds made by air flow. 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 the 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 50-15,000 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 was 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 14, composed of a microphone, amplifier, and envelope detector which could be fed to a dual-channel strip chart recorder. This dual-channel system would allow time delay measurement for

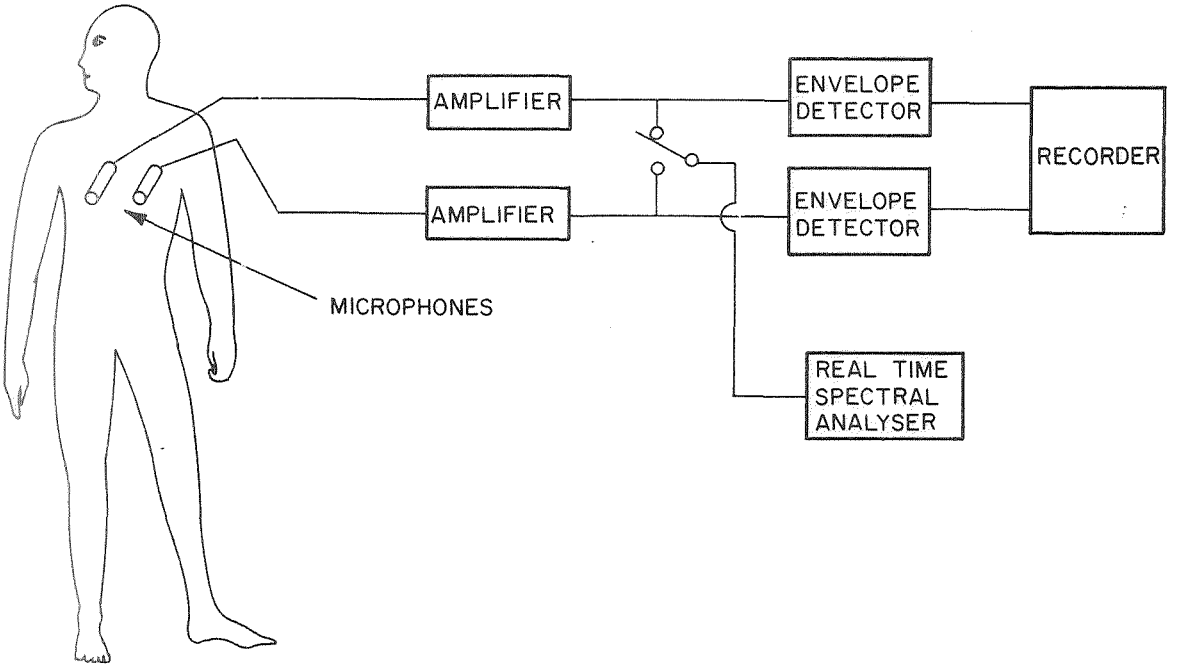


Figure 14. Block Diagram of Lung Sound Analysis System

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 NASA contractor who supplies the spectral analysis equipment is presently discussing a joint investigation with the physician on a spectral analyzer specifically for respiratory analysis. The contractor has agreed to furnish the equipment at a fraction of the normal cost; in return, the physician will provide the medical consultation necessary to develop this new product.

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.

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% 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 which 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 cps 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.

A computer search of the NASA document file was conducted and 136 citations were noted. Among this large number, several documents appeared to be of particular significance in that they discussed speech analysis and, in particular, fast Fourier transform as applied to speech analysis.

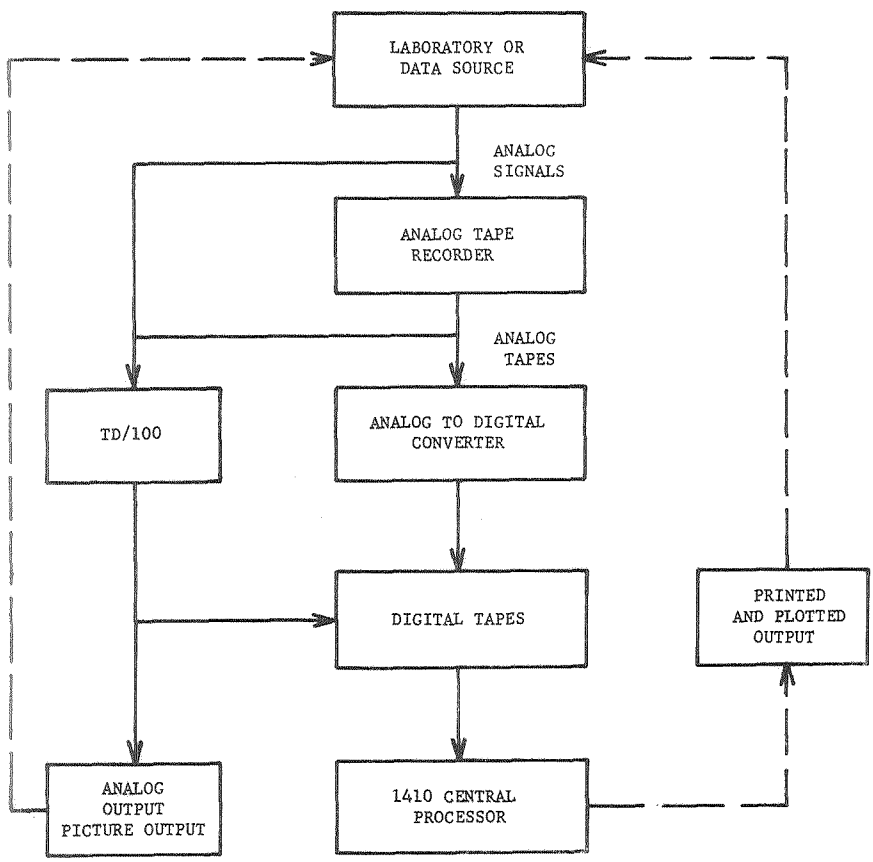


Figure 15. Block Diagram of Voice Analysis System

These documents were concerned with determining the spectral differences between several languages and in voice detection from a noisy environment (for example, spacecraft). The techniques discussed in the documents appeared to be directly relevant to the problem of speech therapy, and the problem originator expressed strong interest in pursuing this approach. The use of the fast Fourier transform and a digital computer for analysis was of exceptional interest because of the availability of a computer capable of handling the fast Fourier transform analysis at the Tulane University School of Medicine. This computer was in the Neurology Department, but arrangements were made for its use by the Otolaryngology Department. At the present time, the fast Fourier transform techniques, outlined in Figure 15, are being implemented on the digital computer for analysis of tape-recorded speech, and comparisons are being made before and after therapy. The initial portion of the study is to establish a baseline of information from which changes can be documented. The physician has indicated that the initial results are favorable, and it is anticipated that an advance in speech therapy will result.

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 in some cases, a peculiar softening of the heart tissue can be seen in 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 studied 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 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.

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 which 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 (shown in Figure 16) which had been modified for his purposes by Mr. Schell;

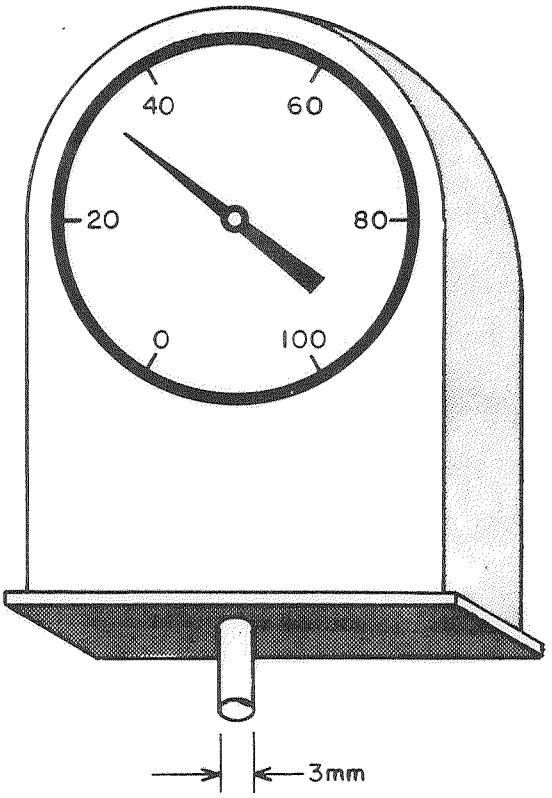


Figure 16. Hardness Tester for Human Tissue

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 great medical significance.

PROBLEM TU-22 *X-Ray Microplanigraph*

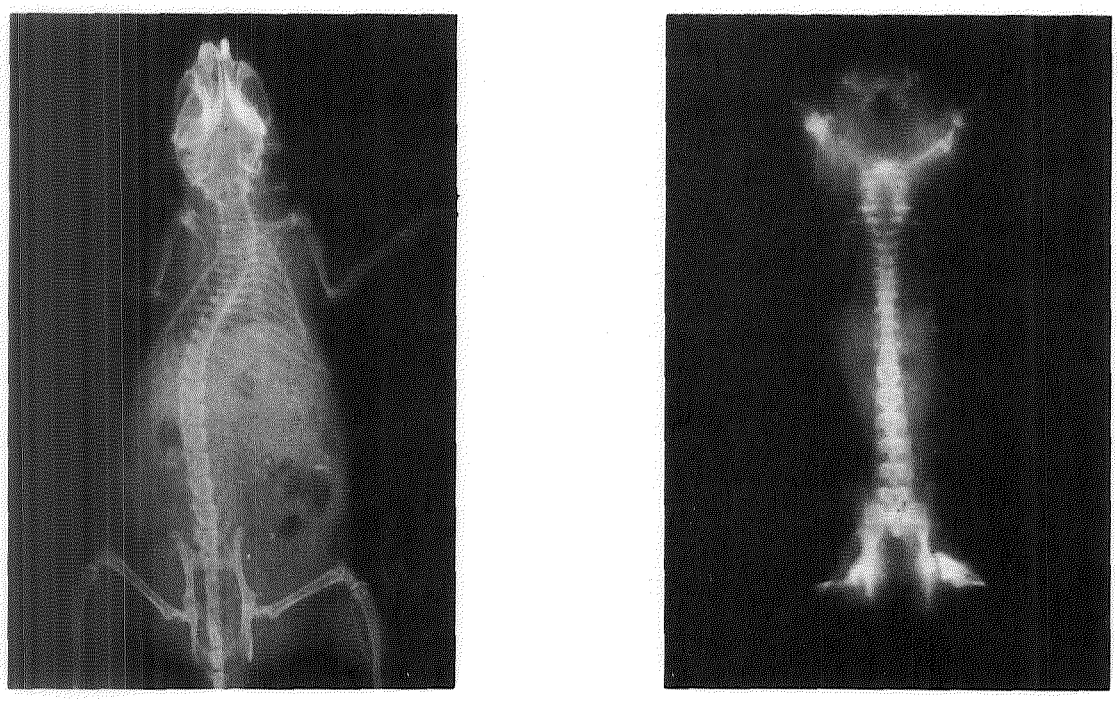
An aerospace method used for analysis of printed circuit boards is being applied to obtain improved X-ray techniques of cancer detection.

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 which 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. Thus, the X-rays could be made of thin laminae and 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 IIT 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 17.



A. Conventional X-Ray Image of a Mouse

B. X-Ray Planigraphic Image of a Mouse

Figure 17

The problem originator has submitted a proposal to the National Institutes of Health for development of this device. It is highly significant that the entire proposal is based on NASA work. In addition to the NASA work at IIT, the problem originator has referenced a significant portion of the documents disclosed in the computer search. He has also acknowledged the assistance of the Team in the proposal. The Team feels that if this technique can be implemented, a major diagnostic tool for cancer will be developed.

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 which 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 which 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 which are useful in locating tumors in humans 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 which 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 involves the use of lithium-drifted germanium detectors to analyze the gamma radiation emitted during the decay of Gallium-67. The excellent resolution of these detectors should lead to easy identification of the primary radiation and will greatly simplify the collimation procedure since scattered radiation will normally be degraded in energy and therefore easily separated from the primary radiation of interest. Investigators at SREL are preparing a three-dimensional computer-controlled scanning mechanism for use in radiobiological experiments. Dr. Siegel suggested that this scanning mechanism might be used to control two lithium-drifted germanium detectors (operating at right angles to each other) to scan a tumorous source in three dimensions. A data acquisition system developed at SREL would move a small animal relative to the two radiation detectors and record the position of the animal at all times during the scanning procedure. The SREL system would then produce a map of the activity of the animal.

It appears that SREL is remarkably suited to solve the problem of scanning small animals. Dr. Siegel has agreed to demonstrate this system in the near future. Tumorous mice will be supplied to SREL by the National Cancer Institute.

PROBLEM WF-99 *A Means of Subjecting an Excised Heart to Physiological Pressure Pulses*

A control system developed by NASA may prove useful in the study of myocardial infarction.

The medical researcher is presently planning a research program in which methods for determining the infarcted area of human hearts will be evaluated. The overall objective of the program is to develop a means whereby the presence of infarcted areas on the heart can be detected and the exact location of the infarcted area delineated. During Phase I of this project, excised hearts having infarcted areas will be placed in a fluid-filled chamber simulating the chest cavity. Various techniques will then be evaluated for their effectiveness in detecting and locating the infarcted area. In order for this simulation to be realistic, it is necessary that the heart itself be subjected to pressure pulses of the magnitude and duration of the normal heart by means of an external pump. The researcher is seeking a pump which can simulate the volume and flow rates along with the pressure and waveshape characteristics of the normal human heart.

A manual search revealed a NASA document, TND-6171, "Pneumatic Artificial Heart Driving System Providing Quasi-Steady-State Regulation and Pressure Waveform Control", by John A. Webb, Jr., Michael J. Crosby, and Miles O. Dustin of the Lewis Research Center, Cleveland, Ohio. This document discusses the design of an artificial heart control system for reproducing the pumping and flow-regulating functions of the natural heart. The quasi-steady-state characteristics of the natural heart are reproduced in an artificial heart by means of feedback control. The system uses a specially designed servo-valve to provide adjustable pressure waveforms. This element of the artificial heart control system (the specially designed servo-valve) plus its control circuitry is directly applicable to this problem. Since the function of the artificial heart driving system as outlined in TND-6171 is to provide pressure waveforms simulating those of the natural heart, this element of the system is directly applicable to simulating the pressure pulse magnitude and duration of the normal heart which is required in the excised hearts which will be tested during Phase I of this project. The researcher has incorporated this unit into the planning for his research program as well as in a proposal to the National Heart and Lung Institute. Funds in the amount of $186,000 are being sought in support of this program. At the same time, the researcher has begun a research program to gather the preliminary data for Phase I. This work will no doubt be accomplished by the researcher even if funding cannot be obtained. The experimental apparatus necessary to perform Phase I are being gathered. In addition information concerning the servo-valve and its control circuitry is being sought from the Lewis Research Center for inclusion in the Phase I work.

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 four such problems which are discussed in the following summaries:

PROBLEM WF-79 *Computer Processing of Chromosome Data*

The researcher, a geneticist, is engaged in a research program to permit the detection of mongolism in unborn fetuses sufficiently early to permit therapeutic abortion. Techniques for accomplishing this determination are available; indeed, they are no more difficult than determining the sex of the fetus. However, they require the sampling of large numbers of blood cells, so that the process is not amenable to mass screening.

The greatest benefits can be derived from this technique only if it can be applied to the entire pregnant female population. For example, there are 150 mongoloids born in North Carolina each year. The cost during the mongoloid's lifetime to the State is between $50,000 and $100,000. If this test could be applied to the entire pregnant female population of the State of North Carolina, there would accrue a saving of approximately $11,000,000 each year. Mongolian idiocy is the major single cause of severe mental deficiency, and the elimination of mongolism would result in a 10 percent reduction in the number of people in State mental institutions. The national saving could be extrapolated by considering that approximately 6,000 mongoloids are born in this country annually.

As presently accomplished, a technician examines blood cells from the maternal blood. In order to obtain enough fetal blood cells to be statistically significant, the technician must examine approximately 1200 cells First, the white cells are examined and the positions of those that are dividing are noted, using a projection attachment to the microscope. The total number is obtained. Then it is necessary to go back and look at each cell in detail under higher magnification. Under high magnification, the chromosomes of each cell are classified. Some of the chromosome types are abnormal, and the presence of specific abnormal types permits correlation with particular disease anomalies. There is a particular chromosomal aberration associated with mongolism. A normal person has 46 chromosomes which consist of two each of 22 types plus X and Y sex chromosomes. Mongoloids have an extra type 21 or type 22 chromosome or part of a chromosome. There are two types (note in the following examples, 21 can be read as either type 21 or type 22 chromosomes), as follows:

(1) Triplo-21, in which the individual has 47 chromosomes with three, instead of two, type 21 chromosomes.
(2) Translocation mongolism, in which the extra type 21 chromosome has become attached to one of the chromosomes not associated with the sex of the individual. Generally, the extra type 21 becomes attached to one of the type 15 chromosomes, so that the individual has 46 chromosomes. In this case there are two normal type 21 chromosomes, but only one normal type 15 chromosome. The abnormal chromosome is the joined 15-21 chromosome.

Another important factor in mongolism is that the incidence of mongolism increases with the age of the mother. For example, a woman of 20 has one

chance in 3,000 of producing a mongoloid, while a woman of 45 has one chance in 40.

This karotyping (chromosome classification) must be done on the fetal blood cells. Fetal blood cells are present in very small concentrations in the maternal blood. Blood samples are taken from the mother, hence the majority of blood cells thus obtained are maternal cells.

Two approaches can be taken to reduce the time required in karotyping blood for detecting mongolism. First, a means of processing the blood sample so as to enrich the number of fetal cells with respect to maternal cells would significantly reduce the screening time. One phase of the researcher's program is aimed at this aspect of the problem.

Second, data processing techniques can be applied to the problem to speed up the screening process. There are two levels at which computer processing could be used to advantage:

(1) The computer can be used to store the data, to note the position of the individual cells, and to access the cells on the microscope slide for karotyping with visual discrimination and classification being performed by the technician.
(2) By employing digital image processing and pattern recognition techniques, the computer can be made to perform the karotyping as well as the data processing.

If the karotyping is performed by means of a computer, a scanner of some type is required. In addition, a more sophisticated computer is required than the computer that would be needed to perform the first option. Because of the equipment cost and complexity, it is expected that the first option will be exercised with potential expansion of the system to permit automatic computer karotyping for mongolian idiocy.

A computer search of the aerospace literature, "Chromosomal Image Processing," #1851 and a manual search were made and delivered to the researcher. Of particular interest was Tech Brief B69-10088 and a number of documents on the digital image processing techniques developed by Dr. Robert Nathan at the NASA Jet Propulsion Laboratories. In addition, because of previous discussions by the Team with researchers at the Goddard Space Flight Center in the field of optical data processing, the application of optical data processing was suggested to the researcher. Consultation between optical data processing personnel at RTI and the medical researcher were arranged. The information resulting from these documents and consultations has resulted in the preparation of a proposal to the National Institutes of Health in the amount of $70,000. Information furnished by the Team and consultation by RTI scientists were directly applicable to the preparation of this grant. In fact, the Research Triangle Institute is a subcontractor in this proposal to the researcher for the purpose of performing the equipment design and optical data processing involved in this proposal.

PROBLEM WF-89 *Animal Restraints for Primates*

Arteriosclerosis is one of the significant contributors to coronary disease. The buildup of extraneous material within the arterial system

causes a reduction in the size (diameter) of the arteries which carry life-giving oxygenated blood to the body tissues. This narrowing of the arteries can occur systemically or locally. When the arteries are narrowed, the blood flow to the tissues is reduced. If the blood flow is reduced sufficiently, the tissue being supplied by the artery dies. If the coronary arterial system, which supplies blood to the heart, is thus affected, the part of the heart tissue being supplied by that artery dies. This is called an infarct.

Narrowing of the arteries also increases the impedance of the arterial system. In an attempt to maintain blood supply to the tissue, the heart must work harder, thus imposing an additional workload on the heart. When constriction of the arteries occurs, there is an autoregulatory feedback mechanism which causes dilation of the arteries (vasodilation) in an attempt to compensate for reduction in blood supply to the tissue. In addition, this vasodilation can be accomplished by the administration of certain drugs (vasodilators). These drugs are frequently employed in treatment of arterial disease and associated problems where the objective is to improve the blood supply to the tissues. However, much is not understood about the mechanisms and effects of these drugs. This research program is designed to obtain this information on various vasodilators to permit their more effective use.

The investigator has accomplished extensive research to determine the effects of vasodilators on dogs using open chest methods. The next phase of the research program requires the use of rhesus monkeys using closed chest methods. The monkeys will be instrumented to measure blood flow, blood pressure, temperature, and ECG. The sensors will be implanted by open chest surgery, and the animal will then be sewn up. The monkeys will be monitored for three to six months during the course of the study. During this period the monkeys must be restrained from activities which would potentially impair or damage the instrumentation. As a result of the Biosatellite Program and NASA research involving monkeys, it was felt by the researcher that animal restraint apparatus may have been built by NASA which would be potentially useful in this program.

Suitable animal restraint apparatus which can be employed on rhesus monkeys to prevent impairment or damage to instrumentation is required. The apparatus must permit maintenance of the monkeys for periods of three to six months.

Useful information resulted from contact with the Biosatellite Project Office at the Ames Research Center. Mr. Louis Polaski, as a result of a telephone contact the the Team, furnished complete information on the primate restraint system which has been developed at ARC for the Biosatellite Program. Specifically, complete engineering drawings of the primate restraint system were furnished to the researcher, and one of the animal restraint suits was mailed to the researcher by Mr. Charles A. Wilson, Biosatellite Project Manager, for inspection. This information and the cooperation from ARC, has been extremely useful to the researcher and has been applied as background and supporting information in the preparation of a grant request to the National Heart and Lung Institute for the establishment of an atherosclerosis research center at the Bowman Gray School of Medicine. This grant request covers a seven-year program

in the amount of 3.8 million dollars. The particular portion of the program to which this information was applied is one facet of the experimental program comprising $238,000 of the total grant request. It should be noted in assessing the impact reports for this reporting period that this particular grant, because of its size, has involved the use of information which has been supplied on two other problems (WF-90 and WF-91) as well. Therefore, the grant discussed in the impact reports on these problems is the same grant as the one referred to on this problem.

In addition, the primate restraint system information has been used in the preparation of a three-year grant request to the American Heart Association in the amount of $42,000. This program involves the study of atherosclerosis and coronary adrenergic response. The experimental animals to be used in this particular research program are similar in size and weight to the animals used on the Biosatellite Program so that the Biosatellite restraint units can be easily modified for this research program.

PROBLEM WF-91 *Blood Flow Measurement in Primates*

Arteriosclerosis is one of the significant contributors to coronary disease. The buildup of extraneous material within the arterial system causes a reduction in the size (diameter) of the arteries which carry life-giving oxygenated blood to the body tissues. This narrowing of the arteries can occur systemically or locally. When the arteries are narrowed, the blood flow to the tissues is reduced. If the blood flow is reduced sufficiently, the tissue being supplied by the artery dies. If the coronary arterial system, which supplies blood to the heart, is thus affected, the part of the heart tissue being supplied by that artery dies. This is called an infarct.

Narrowing of the arteries also increases the impedance of the arterial system. In an attempt to maintain blood supply to the tissue, the heart must work harder, thus imposing an additional workload on the heart. When constriction of the arteries occurs, there is an autoregulatory feedback mechanism which causes dilation of the arteries (vasodilation) in an attempt to compensate for reduction in blood supply to the tissue. In addition, this vasodilation can be accomplished by the administration of certain drugs (vasodilators). These drugs are frequently employed in treatment of arterial disease and associated problems where the objective is to improve the blood supply to the tissues. However, much is not understood about the mechanisms and effects of these drugs. This research program is designed to obtain this information on various vasodilators to permit their more effective use.

The investigator has accomplished extensive research to determine the effects of vasodilators on dogs using open chest methods. The next phase of the research program requires the use of rhesus monkeys using closed chest methods. The monkeys will be instrumented to measure blood flow, blood pressure, temperature, and ECG. The sensors will be implanted by open chest surgery, and the animal will be sewn up.

The monkeys will be monitored for three to six months during the course of the study. During this period, it is required that the blood flow in

the coronary artery be monitored for approximately one hour during each experimental period which may last up to four hours. Although continuous monitoring is desired during each of these periods, repetitive flow measurement at intervals not exceeding one second is acceptable. The flow rate to be measured is in the range of 5-500 cc/minute and an accuracy of ±5 percent is desired. The coronary artery of the rhesus monkey is approximately 3-5 mm in circumference.

In previous experiments, blood flow has been measured with a noncannulating electromagnetic blood flow probe and a Carolina Medical Electronics Model 301 single-channel, square-wave electromagnetic blood flowmeter. Zero flow was obtained as a reference by briefly occluding the coronary artery distal to the probe using a ligature.

It is desired to ascertain if improved blood flow measurement techniques applicable to animal implementation have been developed. Desirable characteristics sought are smaller size, easier implantation, greater accuracy, compatibility with long-term implantation, and elimination of external connections. It is thus apparent that the ideal solution would be a permanently implantable blood flow meter-telemetry package small enough to fit easily within the chest cavity of a rhesus monkey. The available volume for all instrumentation in the chest cavity is approximately 12 cubic inches. Only one-half this volume could be allotted to the blood flow instrumentation.

A computer search of the aerospace literature, "Blood Flow and Blood Pressure Measurement in Primates," #2137 and a manual search were made and delivered to the researcher. A number of documents were found which were pertinent to this particular problem. Of particular interest were documents N70-21292, AD-70136, and N69-31632. The information contained in these documents was used as background and supporting information in a $425,000 proposal to the National Heart and Lung Institute. Information in these documents was useful to the researcher in formulating an approach to certain aspects of the research program to which the proposal was directed.

In addition to the above grant request, the information on ultrasonic Doppler techniques resulting from the documents listed above was extremely helpful in the preparation of a proposal in the amount of $186,000 to the National Heart and Lung Institute and in the formulation of the approach to be employed in attacking this research area.

PROBLEM WF-90 *Blood Pressure Measurements in Primates*

Arteriosclerosis is one of the significant contributors to coronary disease. The buildup of extraneous material within the arterial system causes a reduction in the size (diameter) of the arteries which carry life-giving oxygenated blood to the body tissues. This narrowing of the arteries can occur systemically or locally. When the arteries are narrowed, the blood flow to the tissues is reduced. If the blood flow is reduced sufficiently, the tissue being supplied by the artery dies. If the coronary arterial system, which supplies blood to the heart, is thus affected, the part of the heart tissue being supplied by that artery dies. This is called an infarct.

Narrowing of the arteries also increases the impedance of the arterial system. In an attempt to maintain blood supply to the tissue, the heart must work harder, thus imposing an additional workload on the heart. When constriction of the arteries occurs, there is an autoregulatory feedback mechanism which causes dilation of the arteries (vasodilation) in an attempt to compensate for reduction in blood supply to the tissue. In addition, this vasodilation can be accomplished by the administration of certain drugs (vasodilators). These drugs are frequently employed in treatment of arterial disease and associated problems where the objective is to improve the blood supply to the tissues. However, much is not understood about the mechanisms and effects of these drugs. This research program is designed to obtain this information on various vasodilators to permit their more effective use.

The investigator has accomplished extensive research to determine the effects of vasodilators on dogs using open chest methods. The next phase of the research program requires the use of rhesus monkeys using closed chest methods. The monkeys will be instrumented to measure blood flow, blood pressure, temperature, and ECG. The sensors will be implanted by open chest surgery, and the animal will then be sewn up.

The monkeys will be monitored for three to six months during the course of the study. During this period, it is required that the pulsatile, systemic arterial blood pressure as measured in the aorta be monitored for approximately one hour during the various experimental periods which may last up to four hours. Pressure measurement during the experimental periods must be either continuous or repetitive at no less than one measurement per second. The pressure range to be measured is 50 to 250 mm Hg, and an accuracy of ±1 percent is desired.

A computer search of the aerospace literature, "Blood Flow and Blood Pressure Measurements in Primates," #2137 and a manual search were made and delivered to the researcher. Several documents were of significant interest to the researcher. In particular, information on the ERC tunnel diode pressure transducer was extremely useful. In addition to the NASA publications concerning the ERC pressure transducer, information was obtained from Device Research Incorporated which is presently marketing the ERC tunnel diode pressure transducer commercially. The detailed information about pressure resolution, dynamic range, temperature compensation, and cost and delivery were of significant value. Additional information considered to be very relevant to this problem was that concerning the Mark IV ultrasonic Doppler instrument for indirect blood pressure measurement which was developed at the Southwest Research Institute. Detailed information including an instruction manual and a demonstration unit were borrowed from SwRI. Using the demonstration unit, the researcher was able to determine the applicability of this technique to the specific measurements required in his research program. This combined information has been used as background and supporting data in a grant request to the National Heart and Lung Institute for the establishment of an atherosclerosis research center at the Bowman Gray School of Medicine. This is a seven-year program in the amount of 3.8 million dollars. The particular portion of the program to which this information was applied was one facet of the experimental program comprising $231,000. It should be noted in assessing the impact reports for this reporting period that

this particular grant, because of its size, has involved the use of information which has been supplied on two other problems as well. They are WF-89 and WF-91. The grant discussed in the impact reports on these problems is the same grant as the one referred to in this problem.

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 October 1, 1970, to March 31, 1971.

New Problems Accepted	*52*
Problems Rejected	*9*
Problems Inactivated	*49*
Problems Reactivated	*2*
Total Problems Currently Active	*86*
Preliminary Problem Statements Prepared	*52*
Problem Statements Disseminated	*1*
Responses to Problem Statements	*26*
RDC Computer Searches Initiated	*29*
Impacts	*4*
Potential Technology Applications	*13*
Technology Applications	*4*

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 October 27, 1970, Dr. F. T. Wooten presented a paper entitled "Application of Aerospace Technology to Medicine" at the First Western Space Congress in Santa Maria, California. The paper is attached as Appendix C of this report.

On December 9, 1970, Dr. F. T. Wooten presented the paper in Appendix C to the New Orleans Group on Biomedical Engineering of the Institute of Electrical and Electronic Engineers.

TABLE I

IMPACT AREAS OF ACTIVE PROBLEMS

Health Area Impact Categories	Analytic Instrument Systems	System Components (Equipment)	Prosthetic Devices	Materials/ Chemicals	Other	Total
Communicable Disease						
Multiphasic Health Screening						
Rehabilitation Medicine	2	7	4		8	21
Artificial Organs				2		2
Organ Assist Devices				1		1
Mental Health						
Heart Disease Treatment	1	1			2	4
Cancer Detection	2					2
Ecology						
Health Care Cost Reduction				1		1
Remote Health Services						
Medical Personnel						
Kidney Disease					1	1
Infant Mortality					1	1
Respiratory Disease	3					3
Surgical Procedures						
Dental Medicine						
Basic Medical Research	7	1			2	10
Other	2	3			1	6

On January 18, 1971, Mr. Ernest Harrison presented a paper on the Application Team Program at the Splinting Workshop at the University of North Carolina Hand Rehabilitation Center.

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, Langley Research Center, Jet Propulsion Laboratory, and Marshall Space Flight Center.

3.4 Association for Advancement of Medical Instrumentation (AAMI)

In order to enhance the impact on the medical community of Team transfers, the Team is actively seeking industrial manufacture of marketable technology applications. The approach conceived recently was the formation of a committee within the Association for Advancement of Medical Instrumentation (AAMI) which will consider ways to advise and interest the industrial community in applications of technology. An organizational meeting was held at the annual meeting of AAMI in Los Angeles on March 19, 1971. It is anticipated that this committee, chaired by Dr. F. T. Wooten, will be a useful force in seeking industrial participation in the Application Team Program.

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, as well as seven institutions that have participated on certain special problems. The major thrust of the activity of the Team has been at the primary institutions. 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 March 31, 1971

Duke University Medical Center - This institution has been active in the Application Team Program for four years, and a total of 82 problems have been considered at this school. During the past year, there has been a noticeable slackening of activity because of the reduction in Federal funds, but the Team expects to see an increase of activity at this school 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 four years during which time a total of 99 problems have been considered. Activity has slowed noticeably in recent months, and a general reduction in activity is anticipated at this school over the next year.

University of North Carolina Medical School and Dental School - A total of 89 problems have been defined at the schools of medicine and dentistry during the past four years, but activity at the present time is at a virtual standstill. The primary reason for this is the lack of a suitable consultant at this school making it very difficult for the Team to reach the potential users of the program. No change in the low activity status at this school is anticipated in the near future.

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 23 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. This relatively low level of activity was designed to allow the NCI personnel to evaluate the program. NCI personnel have expressed satisfaction with the success of the program, and continued activity is anticipated 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 a high probability of solution.

Virginia Department of Vocational Rehabilitation - This department operates the Woodrow Wilson Rehabilitation Center. An unsolicited request for Team assistance was received during the reporting period, and problem definition started in November 1970. A total of 14 problems have been considered at this institution. Activity is anticipated to continue at about the same level.

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

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

Emory University School of Medicine - Activities at this school started in January 1971, and a total of twelve 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. An increasing level of problem activity is anticipated from this school during the coming year.

Medical University of South Carolina - In answer to an unsolicited request, the Team initiated activities at this school during March 1971. Although activities are concentrated in one group of individuals in the Department of Surgery, a substantial level of activity is anticipated at this institution during the coming year. The response at this school has been highly enthusiastic, and significant efforts will be devoted to this school.

5.0 APPLICATIONS ENGINEERING PROGRAM

Selected problems have been accepted for implementation of technology under the Applications Engineering Program. In this program, the technology is actually complemented by a NASA facility. Activities for these seven problems are presented in the following summaries:

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, urogenic bladder diseases, stroke, and multiple sclerosis, as well as war and automobile casualties, experience bladder and urethral malfunctions. These malfunctions frequently involve an inability to control the muscles which open and close the urethra, i.e., the passage through which the bladder is emptied. This condition 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 among paraplegics. In addition, inability to control urinary function in even ambulatory patients is a serious inconvenience. In treating patients who cannot control urinary function, it is important that the bladder be allowed to fill and then be emptied rapidly every three to four hours. This periodic functioning allows the muscles in the bladder to be exercised and, as a result, to remain healthy. A valve which can be implanted in the urethra and controlled by the patient is needed to successfully treat the loss of urinary functions.

A suggestion was received from the NASA Lewis Research Center which was relevant to this problem. It involved a valving technique which was used at the Lewis Research Center involving hazardous fluids. This problem was submitted as an applications engineering candidate to the Technology Utilization Division and was subsequently approved for reengineering. The Biomedical Engineering Department of the University of Virginia has been involved in reengineering this technology to the medical application for some time. A preliminary unit, shown in Figure 18, has been constructed, and finished units are expected to be completed within a very short time. These units will be used by the researcher in an animal experimentation program to test the feasibility of these valves as a solution to this problem.

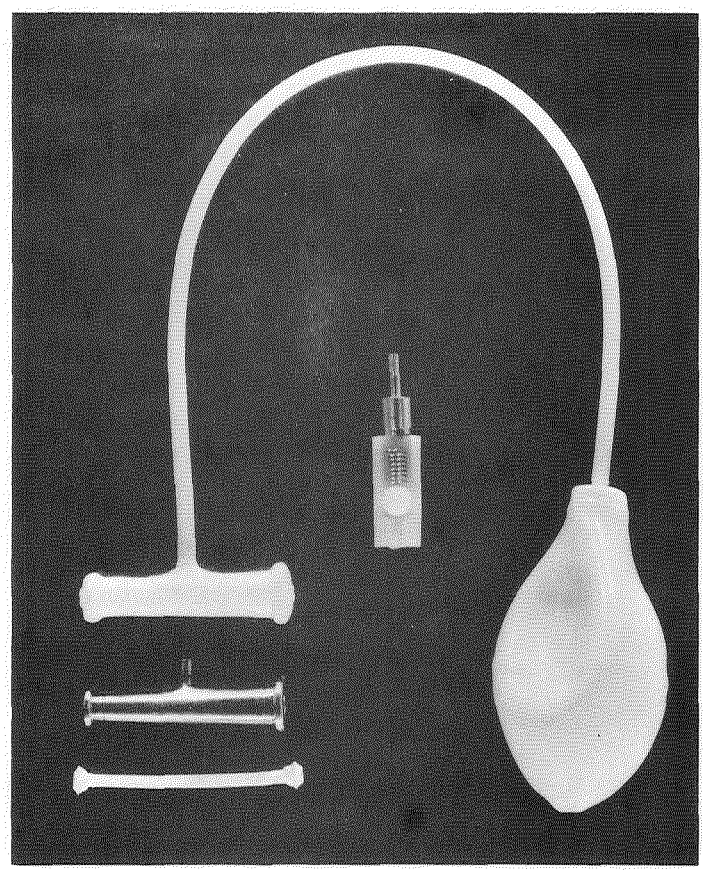


Figure 18. Prosthetic Urethral Valve

PROBLEM DU-31 *Catheter-Mounted Pressure Transducer*

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

PROBLEM IRM-23 *A Respiration Alarm*

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

PROBLEM NCI-3 *Blood Pressure Measurement*

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

PROBLEM NCI-9 *Improved Emulsion for Autoradiography*

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

PROBLEM OF-2 *Bone Density Measurement*

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

PROBLEM WF-89 *Animal Restraints for Primates*

Activities for this problem are discussed in the Impact Report in Section 2.3.

6.0 CONCLUSIONS AND RECOMMENDATIONS

During the past six months, the Team has accomplished a total of four applications and thirteen potential applications of aerospace technology to medicine. The major source of solution for these problems has been the direct contact with the NASA Field Centers by Team personnel. During this reporting period, 70% of the applications and potential applications of technology were solved by direct contact with the field centers and 30% were solved by information searching. In the reporting period for March through September 1970, direct contact with the field centers resulted in more than 60% of the solutions while information searches resulted in only 9% of the solutions. Thus, it can be seen that the primary source of information is still direct contact with the field centers although a significant improvement in information searching results has occurred during the past six months. The reason for the improvement in information searching may be related to the efforts of Dr. W. Clingman of Dallas, Texas, in his study of the information searching procedures.

It is no surprise that personal interaction with NASA researchers has been a major source of information for the Team. Personal interaction has been proven repeatedly to be a keystone of the Application Team Program. In fact, the concept of a small, multidisciplinary group working between two diverse disciplines is based upon the concept that personal interaction is a vital force in bringing remote disciplines closer together. The personal interactions that are important occur at every level of Team action. They are important with the problem originator in adequately understanding his problem; they are important in understanding the vast amount of research performed by NASA; and they are extremely important in assuring that once an adequate solution has been found the solution will be implemented by the researcher. Thus, the personal interaction used by the Team will continue to be a keystone in the success of any application of technology.

During the past six months, there has been a significant increase in the number of new institutions being served by the Team. The Team has received numerous unsolicited requests for assistance at new user institutions. The Team has found that in new institutions it is much easier to obtain good problems for solution study than at some institutions that have been served for several years by the Team.

The Team has noted in past reports that a key individual in defining new problems is the consultant at each user institution. The source of problems is usually within the circle of the consultant's colleagues, and because this is a finite number, the number of problems coming to the Team shows a decrease with time. Thus in some institutions there may well be significant problems of which the Team is unaware. Consequently, it may

prove useful to change consultants at certain schools after a number of years of interaction. Careful selection of a new consultant could significantly broaden the base of interaction.

The Team has developed considerable experience in problems at rehabilitation centers. This experience has shown that, as compared with problems from other sections of the medical community, the problems originated at rehabilitation centers tend to be a requirement for a relatively simple or unsophisticated type of technology. There is also a considerable need for inexpensive technology. This requirement reflects not only the nature of the problems within rehabilitation but also the philosophy of rehabilitation personnel. The medical problem is no less significant because of its unsophisticated requirements; but in many cases, the requirement for highly advanced technology is reduced. Thus increased problem selection criteria must be applied in the rehabilitation area to assure that the problems require NASA technology.

Another factor affecting Team operation is related to the other extreme of sophistication of technology. In highly sophisticated technology (for example, computer solutions), the interaction of medical and NASA personnel for a short time may not be sufficient to transfer the technology. In these highly sophisticated problem areas, it becomes necessary for the medical researcher and the aerospace scientist to work together for a longer period. Thus, it is recommended that a format such as the summer fellowship program be established to allow these more lengthy interactions to occur. This action would increase the number of problems with very high impact in the program.

For some time the major obstacle to the transfer of technology to medicine has been the implementation area. Although significant efforts in the implementation of technology by NASA have occurred, continued emphasis will have to be placed on this area to overcome this major obstacle. The researchers are continuing to press for implementation within their own avenues, as evidenced by the large numbers of outstanding proposals associated with technology applications at this time; however, continued careful selection of problems for applications engineering needs to be made.

Finally, the Team notes with pride the increasing number of unsolicited requests for assistance from both individuals and medical schools. The Team believes that this increase is a result of increased awareness of the medical community of the past successes of the program. However, an additional type of publicity is required if the program is to continue to receive Congressional support. The Team recommends that publicity be sought of the Team's activities on a local and national level in the general public area. This will assist in the continuing support by the Congress of this important program.

APPENDIX A

PROJECT ACTIVITY SUMMARY

TECHNOLOGY APPLICATIONS ACCOMPLISHED

IRM-23	*A Respiration Alarm*
NCI-3	*Blood Pressure Measurement*
TU-2	*Respiratory Rate Measurement*
WF-98	*An Improved Technique to Yield Precise Information on Surface Morphology of Kidney Stones*

POTENTIAL TECHNOLOGY APPLICATIONS IDENTIFIED

CP-3	*Automated Measurement from Coronary Angiograms*
DU-31	*Catheter-Mounted Pressure Transducer*
DU-74	*Testing of Neuropathic Patients*
DU-75	*Epicardial Electrodes*
NCI-9	*Improved Emulsion for Autoradiography*
NCI-10	*Scanning Tumors in Small Animals with Gallium-67*
OF-1	*Blood Embolism Detection*
OF-2	*Bone Density Measurement*
TU-3	*Lung Sound Detection*
TU-9	*Human Voice Analysis*
TU-10	*Quantization of Heart Tissue Hardness*
TU-22	*X-Ray Microplanigraph*
WF-99	*A Means of Subjecting an Excised Heart to Physiological Pressure Pulse*

IMPACTS

WF-79	*Computer Processing of Chromosome Data*
WF-89	*Animal Restraints for Primates*
WF-90	*Blood Pressure Measurements in Primates*
WF-91	*Blood Flow Measurement in Primates*

CURRENTLY ACTIVE PROBLEMS AS OF 31 MARCH 1971

Problem Number	Status Code*	Problem Title
CP-3	E	*Automated Measurements from Coronary Angiograms*
CP-6	D	*Utilization of Hodgkin-Huxley Equation for Determining the Propagation of Cardiac Action Potentials*
DU-31	E	*Catheter-Mounted Pressure Transducer*
DU-48	E	*Urine Flowmeter*
DU-68	D	*Grooves in Glass for Cell Growing*
DU-72	D	*Shadow Coating in Electron Microscopy*
DU-74	E	*Testing of Neuropathic Patients*
DU-75	E	*Epicardial Electrodes*
DU-80	B	*Measurement of Pleural Pressure*
DU-81	B	*Detection of Blood Vessels in Bronchus*
DU-82	B	*Maintaining Position of Telemetry Capsule in Digestive Tract*
EU-1	B	*A Means of Stripping Insulation from Fine Wire*
EU-2	B	*A Means of Maintaining Two 25-Micron Wires in Fixed Relationship to Each Other*
EU-3	B	*Prevention of Electrode Migration in Tissue*
EU-4	D	*A Simple Method of Obtaining Electrical Connection to 25-Micron Wire*
EU-5	B	*Sensors to Define the Position of Specific Parts of the Human Anatomy in Space during Normal Locomotion*
EU-6	B	*Method of Controlling Temperature in Open Body Cavities of Experimental Animals*
EU-7	B	*Precise, Remote Micromanipulator Control*
EU-8	B	*A Simple, Reliable Means of Attaching Instrumentation to the Skin*
EU-9	B	*A Means of Uniquely Numbering Events Using One Channel of a Hard Copy Recorder*
EU-10	D	*An Implantable, Four-Channel Telemetry System*
EU-12	B	*A Rapid Method of Applying EEG Electrodes*
IRM-22	E	*A Means of Tracking Eye Movements While Viewing Printed Matter, Geometric Forms, and Pictures*

*See explanation of status codes at end of listing.

Problem Number	Status Code	Problem Title
IRM-23	F	*A Respiration Alarm*
MISC-9	B	*pO_2 Telemetry Capsule*
NCI-1	D	*Noise Reduction in Laminar Flow Rooms*
NCI-2	D	*Lactate/Pyruvate Measurement in Blood*
NCI-3	F	*Blood Pressure Measurement*
NCI-4	E	*Controlled Rate of Freezing a Liquid*
NCI-6	C	*Separation of White Cells*
NCI-7	D	*Method of Fast Warming of a Frozen Liquid*
NCI-8	E	*Elliptical Lens*
NCI-9	E	*Improved Emulsion for Autoradiography*
NCI-10	E	*Scanning Tumors in Small Animals with Gallium-67*
NCI-12	B	*New or Improved Methods of Detecting Breast Cancer*
NCSU-9	D	*Analysis Techniques for Physiological Data*
NEHSC-1	B	*Miniature Telemetry*
NEHSC-2	B	*A Means of Characterizing Seizures in Laboratory Animals*
NEHSC-3	B	*A Means of Determining the Quantity and Size of Cell Colonies in a Transparent Gel*
NHLI-1	D	*Intramyocardial Stress Measurement*
NHLI-2	B	*Enhancement of the Efficiency of Transfer of Oxygen through the Boundary Layer in Flowing Blood*
NHLI-3	B	*Security System for Computer Data*
NHLI-5	D	*Bonding of Metal to Ceramic*
NHLI-6	B	*Techniques for Sterilization with Plasmas*
NIMH-1	E	*Urination Detection*
OF-1	E	*Blood Embolism Detection*
OF-2	E	*Bone Density Measurement*
TU-2	F	*Respiratory Rate Measurement*
TU-3	E	*Lung Sound Detection*
TU-5	D	*Measurement of Change in Heart Wall Dimensions*
TU-6	D	*Measurement of pCO_2, pO_2, and pH in Blood*
TU-8	F	*Telemetry System for Impedance Pneumography*
TU-9	E	*Human Voice Analysis*
TU-10	E	*Quantization of Heart Tissue Hardness*
TU-14	C	*Left Ventricular Volume Measurement*

Problem Number	Status Code	Problem Title
TU-20	B	*Cell Area Measurement*
TU-22	E	*X-Ray Microplanigraph*
TU-23	B	*Oxygen Measurement in Microgram Tissue Samples*
UNC-56	B	*Tissue Preservation*
UNC-57	B	*A Displacement Monitor*
UNC-58	B	*Microfocused X-Ray Beams*
UNC-60	B	*Counting Exposed Points on Autoradiographs*
VAM-1	D	*Passive Stress Measurement*
VAM-2	B	*Diagnosing Gait Abnormalities*
WF-56	E	*An Improved Fluid Pressure Calibration System*
WF-79	E	*Computer Processing of Chromosome Data*
WF-88	E	*Accurate Determination of Arterial Pressure Pulse Transit Time*
WF-89	E	*Animal Restraints for Primates*
WF-90	B	*Blood Pressure in Primates*
WF-91	B	*Blood Flow in Primates*
WF-94	D	*A Means of Detecting Arterial Pressure Pulse Wave Shape and Evaluating Differences in Wave Shape between Various Points in the Arterial System*
WF-96	D	*Method of Determining the Time of Transit of a Time-Varying Waveform between Two Points in Space*
WF-97	B	*An Ergometer for Paraplegics*
WF-98	F	*An Improved Technique to Yield Precise Information on Surface Morphology of Kidney Stones*
WF-99	B	*A Means of Subjecting an Excised Heart to Physiological Pressure Pulses*
WWRC-1	D	*Marking of Identification Method for Tools*
WWRC-2	B	*A Method to Eliminate Slipping of Total Contact Lower Extremity Prostheses*
WWRC-3	B	*Lightweight Powered Wheelchairs*
WWRC-4	B	*A Multi-Purpose, Remotely Controlled Linear Motion Activator*
WWRC-5	D	*An Improved Connector for Polyvinyl Tubing*
WWRC-7	B	*A Signalling (Nurse-call) System for Multiple Sclerosis Patients*
WWRC-8	D	*A Waterproof Sealant for Rubber-Coated Nylon Stretcher Pads*
WWRC-10	B	*A Means of Reducing Friction in Upper Extremity Prostheses Control Mechanisms*

Problem Number	Status Code	Problem Title
WWRC-11	B	*A Valve to Permit Easy Emptying of Leg-Bag Urinals by Handicapped Patients*
WWRC-13	B	*A Remotely Controlled Device to Pick Up and Transport Single Sheets of Paper*
WWRC-14	B	*An Improved Axillary Strap*

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 nondisciplinary 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. Follow-up Activity

A technology application has been accomplished, but further activity (i.e.,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.)

REHABILITATION MEDICINE

PROBLEM EU-1 *A Means of Stripping Insulation from Fine Wire*

In EMG studies of the spinal musculature, subcutaneous electrodes are employed. The electrodes consist of fine wire which is placed in the desired muscle by means of a hypodermic needle. The wire is 25-micron "Karma" metal with a 10- to 15-micron thick insulating coating of either nylon or polyurethane. In fabricating these electrodes, it is necessary to strip the insulation from both ends of the wire, from the exterior end to permit connection to a preamplifier and from the interior end to provide the electrode pick-up surface. A reliable means of removing the insulation from the wire is desired. A commercial solvent used at Langley Research Center has been suggested as a potential solution to this problem. The manufacturer of the commercial solvent has been contacted, and samples have been obtained for evaluation. At the present time, the researcher is evaluating the use of these materials in actual clinical trials.

PROBLEM EU-2 *A Means of Maintaining Two 25-Micron Wires in Fixed Relation to Each Other*

Subcutaneous electrodes formed by stripping the insulation from 25-micron wires are employed to pick up EMG signals from subsurface musculature. Two electrodes are inserted simultaneously with a hypodermic needle. Movement of one electrode with respect to the other causes signal artifacts, movement from the desired site, high impedance, or even shorting of the two electrodes--depending on the direction of relative movement. The wires are 25-micron "Karma" metal with a 10- to 15-micron thick nylon or polyurethane insulation. A means of attaching the two wires together so that they lie parallel to each other is desired. This would prevent the relative movement which is causing difficulty at the present time. Any material used to accomplish this must be nonconducting with resistivities in excess of 10^8 ohms per square. The difficulty of working with wire in this small size must be appreciated, and it must be possible to prevent the material from covering the bare ends of the wire which are employed as the electrode surfaces. Since the electrodes are injected into tissue, any material used to attach the two wires together must be nonirritating to human tissue. In addition, it must be easy to apply and must be able to withstand body fluids without electrical degradation for up to an eight-hour period. Finally, the overall diameter should not be increased by more than 20-30 microns. Manual searching is now being accomplished.

PROBLEM EU-3 *Prevention of Electrode Migration in Tissue*

In EMG studies of the spinal musculature, fine wire subcutaneous electrodes are hypodermically injected through the skin and directly into the muscle whose EMG signals it is desired to monitor. The electrode wires pass through

the skin, subdermal fatty tissue, and directly into the muscle which is contracting and relaxing. Relative motion in these tissues occurs as a result of contraction and elongation of the monitored muscle movements of the patient. This relative motion seems to cause the electrodes to migrate (not infrequently, they withdraw completely from the muscle under study) so that the precise region being monitored by the electrodes is no longer known. A technique or method to stabilize the position of subcutaneous electrodes in active muscles for prolonged periods of time (at least one month) is desired. The technique must be amenable to hypodermic injection of the electrodes with no further incisions being permitted. Manual searching is presently being accomplished. One material of potential application to this problem is the Nitinol alloy with its memory properties. Specifications and properties of the Nitinol alloys are presently being evaluated with respect to the requirements of this problem.

PROBLEM EU-4 *A Simple Method of Obtaining Electrical Connection to 25-Micron Wire*

Wires having a 25-micron diameter are as fine as human hair. They are fragile, difficult to see, and even more difficult to handle. EMG studies are presently being made of the spinal musculature using these fine wires as subcutaneous electrodes. The wires are stripped of insulation on one end and hypodermically injected into the muscle whose signal it is desired to monitor. The end of the electrode wire not in the muscle protrudes through the skin approximately 1 to 1½ inch. This end of the wire has approximately ½ inch of the insulation material removed. The external end of the electrode wire must be electrically connected to an integrated circuit preamplifier strapped or taped nearby on the patient. Soldering, welding, or other bonding techniques which pose a real or psychological danger to the patient cannot be employed. The present method of making this connection uses a coiled spring as the input terminal to the preamplifier. Connection is made by pulling the spring apart, inserting the bare electrode wire, and allowing the spring to compress back down on the wire. This results essentially in a pair of point contacts which yield unreliable contact with large variability in the resistance of the contact. Use of the NASA-developed spray-on electrode composition has been suggested to the researcher as an adhesive which can provide electrical contact and connection for the wires. Initial trials have indicated that the dry electrode material is very easy to apply--requiring only the use of an artist's small, camel-hair paint brush (or even a matchstick for that matter), and reliable contacts have been made with a number of electrodes on patients. The researcher is evaluating this technique in a series of trials to determine its applicability.

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

Many studies involving gait, locomotion, spinal damage, etc., require the measurement with time of the positions and orientations of various bones with respect to each other or some external reference. Photographic and TV techniques against one or more reference grids have been employed to obtain this information in a more or less fragmentary and difficult-to-quantitate 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.

Attachable sensors to indicate coordinates or relative motion of the body parts are desired in this problem. The researcher wishes to study subjects free-ranging in their normal environment. As a result, TV and optical techniques requiring external reference frames on which the subject must be superimposed are not usable. Basically, a sensor or sensors which can detect the position in three dimensions (either relative or absolute) to a precision of at least 5 mm in each dimension is desired. A search of the aerospace literature has been conducted, and further searching activities at NASA Research Centers is anticipated.

PROBLEM EU-6 *Method of Controlling Temperature in Open Body Cavities of Experimental Animals*

In neurological studies of the spine, experimental animals are surgically opened in the abdominal or chest cavity to expose the spine, and at the same time, the neck is surgically opened to expose the spine in that region. Electrical potentials are recorded using precisely positioned microelectrodes. These measurements are sensitive to small changes in temperature. To reduce these thermal effects, the cavities are filled with a liquid which does not interfere with the measurements being made. Unfortunately, this does not provide sufficient thermal control. During the process of the experiment, the temperature of the liquid drops as a result of cooling of the room atmosphere. Basically, a means of controlling the temperature of the fluid in these open cavities to within 0.1°F. is desired. The introduction of additional wires or other electrical apparatus into the body cavities is undesirable. Alternating current fields must be specifically excluded from the vicinity of the animal since they are likely to interfere with the measurements being taken. A search of the aerospace literature has been accomplished, and the researcher is presently evaluating the documents produced by this search.

PROBLEM EU-7 *Precise, Remote Micromanipulator Control*

Field mapping of potentials using microelectrodes is a technique employed in neurophysiological research. In this technique a micromanipulator is used to position microelectrodes in X, Y, and Z directions. Positioning must be accurate to ±5 microns in the X and Y directions and ±1 micron in the Z direction. Manual positioning of the micromanipulator is thus a time-consuming and laborious process in order to provide the field mapping required. A means of automatically positioning the micromanipulator in X and Y directions and then stepping in the Z direction in steps of one micron under remote control is desired. Such control of the micromanipulator would greatly facilitate the gathering of these data. Basically, X-Y control with a micromanipulator may be accomplished separately from the Z control. Once the X-Y position is achieved, the Z direction must then be stepped in one-micron increments. The micromanipulator employs three orthogonal lead screws to control X, Y, and Z movement. One complete revolution of the lead screw produces a linear motion of 500 microns. A search of the NASA literature failed to retrieve any direct solutions to this problem. A search of NASA tech briefs revealed two tech briefs which are peripherally related to this application. These tech briefs have been supplied to the researcher. If, in the researcher's evaluation, the techniques described

in the tech briefs are applicable to this problem, then contact will be made with researchers at the NASA Research Center from which the tech briefs originated for further information.

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

Studies in human gait and locomotion frequently require instrumentation to be attached to human limbs to measure various parameters, such as angular relationships between bones, rate of movement, and displacement. Standard techniques of attaching the sensors, etc., have employed various kinds of straps or wrappings. Unfortunately, because of perspiration, vibration, and shock encountered during walking, these techniques are very unreliable. Basically, improved methods or techniques are desired for attaching sensors to human limbs so that a fixed relationship between the sensor and the limb to which it is attached is maintained throughout the locomotion studies. The attachment method must withstand the shock and vibration associated with human locomotion while maintaining the fixed attachment relationship desired. Any materials placed in contact with the skin must be nontoxic and nonirritating and must not be affected by perspiration. Ease of attachment and removal are also necessary. A search of the NASA literature has failed to yield a direct solution to this problem. Additional manual searching by the Team is continuing.

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 which 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 push-button. Up to 100 steps may be required in the protocol, although most procedures are considerably shorter in length. A computer search of the aerospace literature has been conducted, and the researcher is presently evaluating the material contained in this search.

PROBLEM EU-10 *An Implantable, Four-Channel Telemetry System*

As part of a continuing research program in neurophysiology at the Rehabilitation Research and Training Center, a number of large primates (apes) are to instrumented so as to obtain records of the EMG signals from specific muscles during

free-ranging activities in a pen. No restriction on the motion of the apes, other than the geographic bounds of the pen, are desired; therefore, a telemetry system is required. Implantable units are desired although some compromise may be possible in this area. Four data channels are required, and the signals to be transmitted vary from 50 microvolts to 2 millivolts within a frequency spectrum of 10-200 Hz. Linear output from the telemeter is desirable. A total battery life of 24 hours is adequate. Remote activation and deactivation of the transmitter is desired so that data can be collected for one or two hours a day over a nominal ten-day period. It is expected that the receiver and remote control unit can be placed 10-15 feet from the animals so that a range of 15 feet is required. Information on multichannel implantable telemetry systems developed at the Ames Research Center has been forwarded to the researcher. It is felt that these units meet all the specifications of this problem. The researcher is currently evaluating the Ames-developed telemetry systems to determine the feasibility of fabricating units for use in this research program.

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

The researcher is currently conducting an experimental program that has as its fundamental objective a better understanding of how people process information at the cortical level. One aspect of the research at the present time involves sensory-motor unit training (this represents the smallest control function that can be obtained) of individuals. In this program, audio and visual clues or stimuli are given to the subject, and the ability of the subject to control sensory-motor units is evaluated. Also underway is a program of modeling the processes of sensory-motor information of individuals. It is desired to extend these programs to severely mentally retarded children. The objective is to obtain a quantitative measure of the neurological dysfunction of the child. This is extremely important information to obtain because, if a child can process sensory information, he can be rehabilitated. On the other hand, if he cannot process sensory information, there is little hope for rehabilitation. As a result, a quantitative measurement of neurological dysfunction in the child is extremely important to rehabilitation of the child. Electroencephalograms are useful in making this determination. Unfortunately, severely mentally retarded children present a significant problem with respect to handling so that conventional techniques of applying EEG electrodes and taking the EEG data are virtually useless (the child simply will not tolerate the procedures involved in attaching the electrodes). For these children, a means of quickly applying and removing the EEG electrodes is required. The NASA-developed EEG helmet is thought to be a potential solution to this problem. Data on the EEG helmet has been furnished to the researcher, and efforts are being made through NASA's Technology Utilization Division to obtain one of the units for evaluation at the researcher's facility.

PROBLEM IRM-22 *A Means of Tracking Eye Movements While Viewing Printed Matter, Geometric Forms, and Pictures*

Visual scanning difficulties in one side of the visual field are often encountered in the hemiplegic patient. These scanning difficulties interfere in the processing of visual information. They prevent the hemiplegic from singling out pertinent cues that are involved in visual-perception tasks. Some tend to ignore visual stimuli located on their impaired side; others render false information on the impaired side, and as a result, spoil the information on their intact side;

while still others compensate by turning their heads. These difficulties affect the cognitive functioning of the hemiplegic and have consequences for activities in his daily life--such as reading, dressing, and manipulation of his wheelchair. There is also a relationship between scanning difficulties and accidents in the hemiplegic population. The researcher wishes to explore the movements of the eye while the patient is viewing printed matter, geometric forms, and pictures. This information will permit comparison of hemiplegic patients with normals and hopefully will permit the characterization of eye movements. This information could then be employed in appropriate individual programs of retraining to eliminate or reduce the visual difficulties of the hemiplegic.

An oculometer developed at the NASA Electronics Research Center has all the technical capability required to solve this problem. Unfortunately, its cost is quite high, and efforts to obtain a unit on a trial basis have been unsuccessful. Efforts are continuing to be made, however, to obtain such a unit for the researcher's use. Another unit has been identified which potentially could be of value to the solution of this problem. This unit is an automated visual sensitivity tester developed at the NASA Ames Research Center. Detailed information on the automated sensitivity tester has been obtained from the Ames Research Center and is being evaluated by the medical 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 which 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 which 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.

A literature search failed to uncover a solution to this problem. The Team was able to identify an engineer at NASA's Ames Research Center who had built a passive stress measuring device. Technical information on this device was given to the problem originator and is presently under evaluation.

PROBLEM VAM-2 *Diagnosing 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 some of their normal activities.

In order to correct gait abnormalities, it is desirable to have some means of quantitating the abnormality. Preliminary experiments employing triaxial accelerometers attached to various points on a patient's leg indicate that this technique might be used to detect and quantitate gait abnormalities. In addition, this technique would provide a means of measuring a patient's improvement after having suitable prostheses and therapy. It is planned to attach triaxial accelerometers to four positions on the leg. Manual analysis of the records is too cumbersome and time consuming for the full potential of this technique to be realized. An automatic means of analyzing the accelerometer data is necessary to make this information useful for diagnostic purposes.

A problem statement is being prepared for dissemination to the NASA Field Centers.

PROBLEM WWRC-2 *A Method to Eliminate Slipping of Total Contact Lower Extremity Prostheses*

Total contact lower extremity prostheses (artificial legs) have been developed for both below- and above-knee applications. Difficulties have been experienced with the above-the-knee prostheses, however, in that they tend to slip off. The objective of total contact prostheses is to eliminate straps and other external means of keeping the prostheses in place. The prostheses are made to fit the individual stump. A hole is left in the bottom of the prosthesis socket, and the user inserts the stump into the prosthesis and seats it firmly into the prosthesis socket. A valve is then placed in the opening at the base of the stump thus providing a seal. It is generally thought that the suction generated when the prosthesis begins to slip from the stump is actually what holds the prosthesis to the stump. There is no means to dissipate the heat and water vapor from the stump so that even in mild weather, perspiration freely bathes the stump and the socket of the prosthesis. When this occurs, the prosthesis begins to slip and eventually loosens or comes off as the user raises the prosthesis in the process of walking. The fundamental problem is to prevent the prosthesis from slipping off the stump. The most obvious solution to this problem is to eliminate the perspiration. Indeed, to this end antiperspirants, powders, and cotton socks to absorb the perspiration have already been tried with little or no success. Indeed, insufficient studies have been made to determine whether it is even desirable to prevent perspiration unless the stump is cooled sufficiently to reduce perspiration. Most wearers of prostheses have heat balance problems already as a result of their reduced surface area, so to reduce heat loss by eliminating perspiration from an additional part of the body might interfere with the heat balance of the body. In addition, the prostheses as presently manufactured are unnecessarily heavy because of the manner in which they are fabricated and the materials which are used in the fabrication process. Several other fundamental engineering aspects in the general philosophy of total contact prosthesis design are involved in the solution to this problem. At the present time, information is being gathered on these aspects of the problem, and evaluation is in process.

PROBLEM WWRC-3 *Lightweight Powered Wheelchairs*

The development of powered wheelchairs has significantly increased the mobility of the handicapped who are unable to walk. Around the home, at work, or in any other level area, the powered wheelchair has made a significant contribution to

the rehabilitation of such handicapped persons. A problem, which exists for regular wheelchairs as well, is that they do not interface well with other means of transportation. The problem has been alleviated somewhat with conventional wheelchairs by the design of lightweight folding units which can be stored in the trunk of an automobile or placed upright on the floor behind the front seat. The handicapped person himself is frequently able to fold the chair and place it behind the front seat. This increases his mobility and self-confidence, both important factors in the rehabilitation of the individual. With most powered wheelchairs, it is a difficult and time-consuming job to fold the chair, and it is sufficiently heavy that it is a difficult job to load even for a normal adult. Further, the problem is complicated by the fact that lead-acid storage batteries are used which, if turned over, will result in spillage of acid. The problem originator is interested in advanced design techniques which can be employed to reduce the weight of powered wheelchairs. The most likely candidates for weight and size reduction are, of course, the drive mechanism and the storage battery.

As a result of searching the aerospace literature, a number of publications on high energy density batteries and lightweight high-efficiency electric motors which have potential for reducing the size and weight of powered wheelchairs has been furnished to the problem originator. The problem originator plans to use this information to contact one of the commercial manufacturers of powered wheelchairs to determine if reduction in size and weight could be incorporated into commercial designs.

PROBLEM WWRC-4 *A Multipurpose, Remotely Controlled Linear Motion Activator*

In training the handicapped for gainful employment, the control of machines is frequently a significant problem. Vocational training to permit the handicapped to operate industrial sewing machines and thus find gainful employment is one of the areas of activity at the Woodrow Wilson Rehabilitation Center of the Virginia Department of Vocational Rehabilitation. A particular problem arises when the handicapped has lost the function of both legs. Industrial sewing machines differ in a number of ways from their home counterparts. First, they operate at a much higher stitch speed so that rather precise speed control and virtually instantaneous stopping is required. Second, the sewing machine motors run continuously at a constant speed. The stitching speed is controlled by a clutch and brake combination and is activated through a lever arm and mechanical linkage by foot treadle. When the foot treadle is depressed, the brake on the sewing machine drive is released and the clutch is engaged by means of a conical drive mechanism. The speed at which the sewing head is driven is proportional to the amount the foot treadle is depressed. When the foot treadle is released, the brake is activated to stop the sewing head almost immediately. It is very important that this almost immediate deactivation be retained since it is absolutely necessary for the operator to sew as rapidly as possible up to the last moment before he has to stop the machine to turn or remove the material. This high sewing speed must be maintained in order for the handicapped to remain competitive with the normal operator and thus be employable. Finally, in the industrial environment, most machines are operated on a two- or three-shift basis. Consequently, no permanent modifications to the machines can be tolerated. Any auxillary mechanisms required by the handicapped must be removable so that

the machine can be converted to normal operation quite rapidly and without tools. A search of the aerospace literature has been made, and no directly applicable technology has been found. Searching is continuing on this problem.

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 leg-bag 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 connected 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. It is 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 very undesirable both from the patient's and the therapist's viewpoints. A new type connector which requires less strength to connect and disconnect but which provides a leak-proof connection is desired.

A suggestion from the George Washington University Biological Sciences Communication Project was received which indicated that a commercially available connector might have application to this problem. This information was relayed to the problem originator who plans to order several of these connectors and test their applicability to this problem.

PROBLEM WWRC-10 *A Means of Reducing Friction in Upper Extremity Prostheses Control Mechanisms*

Many currently used upper extremity prostheses rely upon cables to perform the actual control function. Generally speaking, a cable harness arrangement is used to permit operation of the hook so as to obtain pinch. One of the difficulties encountered with these types of prostheses is the fact that a significant amount of effort is required to operate them. In examining the causes of this effort which is required to operate the unit, it has been determined that as much as 40 percent of the energy is consumed as friction loss in the cabling mechanism. An effective means of reducing this friction loss to as low a value as possible is desired. The Team is continuing to investigate this problem and search for solutions.

PROBLEM WWRC-11 *A Valve to Permit Easy Emptying of Leg-Bag Urinals by Handicapped Patients*

Many handicapped people do not have control of their urinary functions. These people must wear a polyethylene bag strapped to their leg which collects the urine. The present leg-bag urinals have a tube coming out the bottom end of the bag which is used to empty the urinal. The tube is closed by a clamp which clamps across the tube and prevents the flow of urine except when the patient wishes to empty the bag. The present clamp must exert a significant amount of pressure on the tube in order to eliminate all leakage. Unfortunately, the clamp is very difficult to operate in that it requires a great amount of force and significant manual dexterity to either open or close. The people who wear these leg-bags generally have severe disabilities and experience great difficulty in operating these clamps. Another means of draining the leg-bag urinal is desired. Easy operation is of paramount importance.

A flexible ball check valve employed as one component of a prosthetic urethral valve was identified as having potential application to this problem. This check valve can be operated merely by pressing on the side of the valve's body. When the valve body does not experience mechanical distortion, it provides a leakproof seal. Such an approach appears ideal to the solution of this problem. Efforts are currently underway to fabricate a control valve for use in this application.

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

The number of vocations open to severely disabled quadriplegics is extremely limited. Many such patients maintain little control of their musculature, and the only basic proficiency which they can acquire is to punch pegs or to press keys on a keyboard. The training Division of the Woodrow Wilson Rehabilitation Center is constantly seeking vocations for which these patients can be trained. A commercially available bookkeeping machine permits the bookkeeping function to be accomplished by merely entering data into the proper categories on a machine keyboard. Quadriplegics can operate the machines as far as entering the data is concerned. In most businesses, however, the data is not in a form which is readily visible to them. For example, in most instances businesses which 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 top ticket from the stack. Consequently, since he cannot gain access to the tickets underneath the top ticket, he cannot use the machine unless someone is present to transport the top ticket off the pile and into another pile as he enters the data. A simple device which can be remotely controlled by means of a single button to pick up the top ticket on a stack of papers and then to remove that ticket to another geographic position nearby is needed. Since the quadriplegic is certainly marginal in performing even this kind of an operation, the cost of implementing any solution to this problem must be sufficiently low so that the use of a quadriplegic in this operation would not be completely unfeasible from an economic standpoint. A cost of $200 or less would not be considered prohibitive. Initial searching of the aerospace literature has begun on this problem.

PROBLEM WWRC-14 *An Improved Axillary Strap*

Commonly used upper extremity prostheses employ a cabling arrangement to operate the hook so as to obtain pinch, thus permitting items to be grasped and transported. In operation, the cable is passed across the back of the patient and 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 curl up until it actually resembles a rope, causing concentration of all the force being exerted by the shoulder and arm on a very small area. This frequently results in sore spots caused by the excessive 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 which 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. The strap must be capable of use by a large number of people. Primary constraint on the solution of this problem is low cost. Implementation of any solution should not require the expenditure of more than $15-25 for each axillary strap. Initial searching has begun on this problem.

MENTAL HEALTH

PROBLEM NIMH-1 *Urination Detection*

One of the significant problems facing the National Institute of Mental Health is concerned with geriatric patients (patients over the age of 65). A frequent problem with these patients is incontinence of urine (the inability to control urination) and the lack of realization by the patient that urination has occurred. As an example of the extent of this problem, in one Veterans' Administration hospital over 200 of the 2000 patients were incontinent, and the staff time and effort required to keep the patients dry significantly reduces the staff time available for activities such as group therapy or occupational therapy.

It is believed that if the nursing staff could be made aware of the onset of urination by patients, the patients can be trained to respond to the sensation of a full-bladder by promptly being taken to the bathroom; this procedure has been effective with children who wet the bed.

A transducer is required for detecting the onset of urination. If an appropriate transducer can be found, the output of the transducer will be telemetered to a central nursing station.

The patients wear cotton work pants with no underclothing, and it will be possible to measure moisture in the pants without requiring a direct attachment to the

genitals. The transducer must be small and lightweight because the patients are generally confused and might not tolerate bulky equipment strapped to them. Total weight of the transducer must be on the order of ounces.

This problem can be solved using miniature telemetry systems developed at Ames Research Center. Because of lack of resources, this proposed solution cannot be implemented at this time.

DETECTION AND TREATMENT OF HEART DISEASE

PROBLEM CP-6 *Utilization of the Hodgkin-Huxley Equations for Determining the Propagation of Cardiac Action Potentials*

The present understanding and capabilities for the diagnosis of cardiac diseases such as myocardial infarction are limited by the lack of a precise quantitative description of the propagation of cardiac action potentials. This quantitative description requires the solution of a nonlinear partial differential equation developed by Hodgkin and Huxley.

In 1952, Hodgkin and Huxley developed and tested a set of differential equations which describe the electrical properties of the excitable membrane of the squid nerve fiber. Since then the range of application has been extended in two ways. First, the original equations have been applied to a wider variety of phenomena in squid nerve, including the effects of temperature on the propagated action potential, the repetitive firing observed in low calcium concentrations, the prolonged action potentials produced by tetraethylammonium ions, and the hyperpolarizing responses observed in high potassium solutions. Second, the equations have been applied to other excitable tissues including myelinated nerve and cardiac muscle.

The work described in this problem statement is concerned with incorporating recent cardiac muscle data for the dependence of potassium conductivity into the Hodgkin-Huxley equations to study the propagation of cardiac action potentials. A solution to this basic research problem in cardiac physiology would have important clinical and diagnostic consequences.

Computer programs are needed to solve numerically the Hodgkin-Huxley equation for the case in which the sodium and potassium conductivities vary with position, time, and potential, to be used in basic research on the heart.

A computer program used for aerospace thermal problem solution is being evaluated as a potential solution to this problem. The program was obtained from NASA and evaluation on the problem originator's computer is underway.

PROBLEM DU-68 *Grooves in Glass for Cell Growing*

A proposed method of growing oriented cardiac muscle cells requires troughs or grooves, 10 microns wide and deep with a length of several centimeters, in a glass surface. A simple method for producing the grooves is needed.

The grooves are to be produced on a special type of microscope slide cover glass. The cover glass is a disc 45 mm diameter and 0.16 mm thick. The bottom of the

groove should be optically clear if at all possible because the researchers employ an inverted microscope looking upward through the glass at the cells growing in the groove. Also there is the possibility of a two-layer structure as indicated. Instead of removing glass in forming the groove, possibly some material could be added. The question of what material is difficult because of the cellular responses to different materials. That is why a single material (glass) with grooves might be better. A layer of cellulose acetate with grooves cut through to glass might work.

A number of parallel grooves could be desirable for the initial work establishing the conditions for growing the desired linear chains of cardiac cells. The spacing between parallel grooves would not be critical, possibly 100 microns or so would do. Once the growth rules are established, the researchers eventually will want branching or "Y-shaped" grooves. The method of producing grooves should work for this shape too, if possible. Simplicity, reliability, and relatively low cost (tens of dollars per glass disc instead of hundreds) are important constraints, and the researchers would prefer something which could be implemented at their university rather than require outside facilities.

This problem can probably be solved using advanced photolithography techniques which are being evaluated by the researcher. A computer search of NASA developments in photolithography is being evaluated by the researcher.

PROBLEM NHLI-1 *Intramyocardial Stress Measurement*

Myocardial infarction is a damaged or dead area of the heart muscle resulting from a reduction in the blood supply reaching that area. Acute myocardial infarction is the main cause of premature death in the population of the developed countries. This condition can usually be diagnosed by electrocardiography; however, the precise location of the affected tissue 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 contraction and successive relaxation of the heart will differ with similar measurements made in unaffected areas. A probe which could be used to make stress measurements within a small region of muscle tissue would lead to a refined location of the region which needs to be removed by surgery. This would lead to improved surgical procedures and, therefore, to a higher probability of successful recovery for the thousands of persons who must undergo surgery for this disorder each year.

A search of the aerospace literature failed to produce a solution to this problem. The Team contacted an engineer at NASA's Ames Research Center who had fabricated a miniature pressure transducer and discussed this problem in detail. He suggested a technique for constructing the needed probe for making stress measurements. The suggested technique employs the Ames miniature pressure transducer and appears to offer an excellent solution to the problem. The suggestion is currently under evaluation.

PROBLEM TU-5 *Measurement of Change in Heart Wall Dimensions*

Heart disease is the focus of a major research effort in this country and recent dramatic advances have been made in this effort using the artificial heart. One function of the artificial heart is to provide partial assistance to a failing heart, but during the period of assistance some measure of the output of the human heart is required. This measurement is necessary in order to determine the output or work required from the artificial heart.

The usual method of determining the output of the human heart is to measure the volume of the left ventricle, the chamber of the heart that pumps blood to the body after the blood has returned from the lungs. The left ventricular volume can be measured by two techniques called dye indicator, and biplaner angiography, but neither method produces an instantaneous output. An instantaneous measurement is necessary so that rapid changes can be made in the artificial heart output.

Recently a new technique for measuring left ventricular volume has been developed which does allow the desired instantaneous measurement. This method involves measuring the stretch or dilation of a small section of the heart wall and this stretch or dilation can be correlated with left ventricular volume which, in turn, can determine the work required for a cardiac assist device. A method is required for measuring the change in dilation of a small section of heart wall during a complete pumping cycle.

The distance covered by the measurement must be less than 20 millimeters. A 25-50% change in dimension is expected and the accuracy of measurement must be better than 5%. The accuracy of interest is the relative change and not the absolute change in dimension.

A computer search of the NASA document bank revealed that this problem can be solved with commercial ultrasonic equipment and the problem originator is seeking funds to implement the recommended approach.

PROBLEM TU-14 *Left Ventricular Volume Measurement*

Diagnosis of heart trouble is hampered by the lack of information available on the pumping characteristics of the heart. The widely used EKG is a secondary measurement, and primary information would be more valuable. Existing methods for measuring left ventricular volume are too slow or too inaccurate. A new approach to the problem is required. The problem originator is a leading cardiac authority, and he estimates that a useful technique would have more impact than the discovery of the EKG.

The typical maximum left ventricular volume is 200 cc and the volume change is about 70 cc. A noninvasive technique would be best although a small catheter would be acceptable.

A computer search, a manual search, and a problem statement distribution revealed no new approaches to this problem.

PROBLEM UNC-57 *A Displacement Monitor*

The Clinical Research Unit at the University of North Carolina Memorial Hospital is examining patients on a routine basis. One of the screening procedures in the detection of cardiac difficulties involves the simultaneous gathering of a number of parameters indicative of the state of the cardiovascular system. At the present time, patients who are being screened undergo electrocardiograms, two audiocardiograms placed at different points on the chest wall, a carotid pulse, and displacement measurements of the chest wall at two different points. This information is simultaneously recorded on multichannel paper tape recorders. This is basic data input to the patient's file. On the basis of these data and other special data which may be required, the condition of the patient's cardiac system is evaluated. Some of the data as now taken is considered to be misleading because it does not represent the actual measurement which is desired. The specific measurement in question is chest wall displacement. Present units have the capability of measuring a maximum excursion of 1/16 inch or less while the actual displacement of the chest wall is as high as 1/4 inch. Consequently, it is apparent that the transducers currently being employed are not capable of measuring the entire chest wall displacement. What is actually being measured is a highly damped representation of the chest wall displacement in which the transducer measures the outward movement of the chest wall to the limit of its maximum excursion. Beyond that point, the unit can no longer measure displacement. Therefore, since the displacement of the chest wall is beyond the maximum capabilities of the displacement measuring units, the resulting waveform is obviously not indicative of chest wall movement throughout the entire cardiac cycle. A new method or new instrumentation techniques for measuring chest wall displacement which can accurately reflect the movement of the chest wall without loading the chest wall is desired. A search of the aerospace literature on displacement measuring techniques employed by NASA has been delivered to the researcher for his evaluation.

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

In the arterial system, the arterial pressure is a function of distance and time; hence, it has wave properties. The wave speed of the pressure pulse is related to the elastic modulus of the arterial wall. In addition, wave reflections that occur in the arterial system perturb the pressure function. It is known that the elastic properties of the arterial wall change in human beings with age and arterial disease. The biological problem is basically to detect changes in the material properties of the arterial vessel nondestructively early in the process of arterial disease. Change of the properties of the arterial wall are thought to be related to wave speed or transit time of the arterial pressure pulse. To validate the accuracy of this hypothesis, it is necessary to establish the relationship, if any, between arterial disease and wave speed or transit time of the arterial pulse. An accurate means of determining wave speed or transit time will aid in the determination of this relationship. If the relationship between arterial wall properties and transit time or wave speed measurements of the arterial pulse could be established using improved instrumentation or improved analysis techniques, it would be an important contribution to the diagnosis of arterial disease.

A Mark IV ultrasonic Doppler instrument for indirect blood pressure measurement designed by the Southwest Research Institute for NASA and the Air Force has

potential application in the solution of this problem. A single-channel unit was obtained from SwRI for evaluation by the researcher. Results of this evaluation were that the unit appears to have the characteristics necessary for the gathering of the information required in the solution of this problem. The unit as designed would not provide all the desired information, however; therefore, it will be necessary to modify the existing unit. Quotations for the design modification and fabrication of a new unit have been obtained from the Southwest Research Institute, and the researcher is seeking funds from his contracting resources to permit fabrication of the unit.

PROBLEM WF-94 *A Means of Detecting Arterial Pressure Pulse Wave Shape and Evaluating Differences in Wave Shape between Various Points in the Arterial System*

This problem which is related to WF-88 involves the detection of the arterial pressure pulse wave shape at different points in the arterial system. A series of arterial pressure pulse wave shapes taken at different points in the arterial system could then be compared to determine if significant information is contained in the variation of arterial pressure pulse wave shape which is related to arterial occlusive disease. Arterial occlusive disease is a significant health problem in the United States affecting large segments of the population. It can be alleviated or corrected by various techniques. The major difficulty is that it is extremely difficult to detect in its early stages when little damage has been done. Often the disease reaches crippling or catastrophic proportions before it is detected. The consequences of advanced arterial disease are numerous and severe, not infrequently leading to death with little advance warning. A means to detect the presence of arterial occlusive disease earlier in its development is desired. It is felt that the presence of arterial disease will affect the dynamic elastic properties of the arterial wall. In addition, localized damage may lead to relative arterial constriction at the point of damage. The arterial pressure pulse is propagated down the arteries. Any change in dynamic elastic properties or changes in diameter of the arteries will affect the shape of the arterial pressure pulse and its transit time. Consequently, a means of accurately determining the arterial pressure pulse wave shape may yield information which can be correlated with the progress of arterial occlusive disease.

An ultrasonic Doppler blood pressure measuring instrument developed by the Southwest Research Institute for NASA and the Air Force has some capability for producing the arterial pressure pulse waveshape. The application of this NASA and Air Force developed unit to this problem is being evaluated by the researcher.

PROBLEM WF-96 *Method of Determining the Time of Transit of a Time-Varying Waveform between Two Points in Space*

A parameter of significant interest in dye dilution techniques for determining blood volume in cardiac output is mean blood transit time. Using the dye dilution technique, dye is injected as a pulse into the blood vessel. Fairly sharp pulses are obtained; however, there is some delay in actually getting the dye into the flowing blood. In addition, it is known that the trailing edge of the pulse decays slowly because of dye leakage from the injector and inadequate mixing. Nevertheless, a mean departure time for the pulse is assigned on the basis of when the dye is injected. The dye pulse is allowed to traverse a

distance and is then monitored by detector. The detected dye peak is very diffuse with a long, slowly decaying trailing edge so that it is very difficult to estimate the mean departure time from the detector. Using these techniques, mean transit times two to three times greater than the theoretical mean transit time are obtained in current practice. A method of analyzing these pulses in order to more accurately assign a mean departure time from the injector and a mean departure time from the detector is desired.

A search of the aerospace literature has been conducted. Certain specialized signal analysis techniques developed at the NASA Marshall Space Flight Center appear to have application to this problem. In addition, research in fluid mechanics at North Carolina State University appropriate to this problem has been identified by the Team. Both the NASA signal analysis techniques and the approaches underway at the North Carolina State University are being evaluated for application to this problem.

ARTIFICIAL ORGANS

PROBLEM NHLI-2 *Enhancement of the Efficiency of Transfer of Oxygen 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 adjancent to the membrane coated electrode is needed.

A literature search failed to produce a solution to this problem. A problem statement is being prepared for dissemination to the NASA field centers.

PROBLEM NHLI-5 *Bonding of Metal to Ceramic*

In attempting to achieve an artificial heart system for man, the guiding objective is not only to prolong life per se but also to provide full rehabilitation to the patient. To the extent that this goal can be realized, the patient should experience a minimum of discomfort and encumbrance. Ideally, the prosthetic heart system should be totally implantable; i.e., all its parts should be contained within the body. In addition to the many physical and physiological requirements that must be met to realize a compatible, safe, and reliable system

for long-term use, the artificial heart must satisfy many stringent design and functional requirements demanded of high performance aerospace systems.

An unanswered problem is that of the type of energy conversion system which will be used to carry out the pumping function of the heart. A stack of piezoelectric disks with interspaced electrodes is a leading candidate for this task. Upon the application of an electric field across the stack, each disk lengthens axially, and the net result is an additive linear movement in the axial direction of the stack. It is this force that will power the blood pump. Various methods of bonding the electrodes to the piezoelectric crystal exist; however, a reliable bonding technique which leads to a high-operating efficiency of the pumping mechanism is necessary.

This problem was discussed with investigators at NASA's Langley Research Center. An engineer at Langley had constructed several piezoelectric stacks like the configuration under study at the National Heart and Lung Institute. The bonding techniques in use at Langley appear to provide an excellent solution to this problem and are presently under evaluation.

DETECTION AND TREATMENT OF CANCER

PROBLEM NCI-1 *Noise Reduction in Laminar Flow Rooms*

The National Cancer Institute is conducting a vigorous program to find the causes and cure for cancer, a major cause of death in this country. One of the approaches used us chemotherapy, or the use of drugs to cause remission of existing cancers. Patients requiring this treatment are usually weak and more susceptible to other diseases than normal patients. A sterile environment would help to combat this problem as well as to increase the patient tolerance to antitumor drugs with regard to incidence of infection. A sterile environment can be produced by a laminar flow room which is equipped with sterilizing agents in the filter system.

The existing laminar flow rooms were designed to be installed inside standard hospital rooms, which allows maximum flexibility in the use of these rooms. This design, however, requires that the blower fans be inside the patient's room, which creates a noise problem. A heating and air conditioning consulting engineering firm has added conventional noise abatement procedures such as foam padding in ducts, a discharge muffler, and vibration isolators on the motors. However, even with these additions, the resulting noise level is intolerable.

Noise abatement procedures are desired which will reduce the noise level from the existing Noise Criterion 50 to Noise Criterion 30. Noise Criterion 30 is defined as approximately 50 db at 100 Hz and 26 db at 10,000 Hz. The decibels are relative to 0.0002 dynes/cm^2. The air velocity output varies between 30 and 90 ft/min. and the blower capacity is 2,000 cu. ft. per min. at a static head of one inch of water. A centrifugal fan is used, and a fan which produces lower noise levels is desired.

A computer search revealed that a technique exists for changing the fan geometry to reduce noise from centrifugal fans. This technique is being considered by the problem originator.

PROBLEM NCI-2 *Lactate/Pyruvate Measurement in Blood*

Leukemia, a major cause of death, is a disease which is characterized by an unusually high number of white blood cells. Many forms of the disease exist, but nearly all forms have a rapid onset of symptoms.

The National Cancer Institute is conducting a vigorous program to find the causes and cures for this disease. In the clinical phase of this program, a problem exists in the prevention of shock. If not detected early enough, shock can cause serious infection which is a major problem in leukemia patients. Thus, a need exists for an accurate indicator of the onset of shock so that corrective measures can be taken.

One measure of the onset of shock is the pyruvate or the lactate concentration in the blood. Both lactate and pyruvate are intermediate products in the metabolism of carbohydrates and proteins. The concentration of lactate and pyruvate in the blood is a measure of the oxygen availability to the tissue.

Existing methods for measurement of these organic compounds are inadequate because of the long analysis times required. The usual wet chemistry method has been replaced in the last few years by an enzymatic method but a time of 45 minutes is still required which is inadequate.

A method is required which allows measurement within 5-10 minutes. Normal procedures involve taking 5 ml. blood with lactate levels of 9-15 mg.% and pyruvate levels of 0.39-0.86 mg.%.

A computer search revealed a method which is being considered by the problem originator.

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

Leukemia, a disease which kills about 15,000 Americans annually, is characterized by a proliferation of the tissue which 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 cells is believed to be the rate of freezing. Rate of freezing

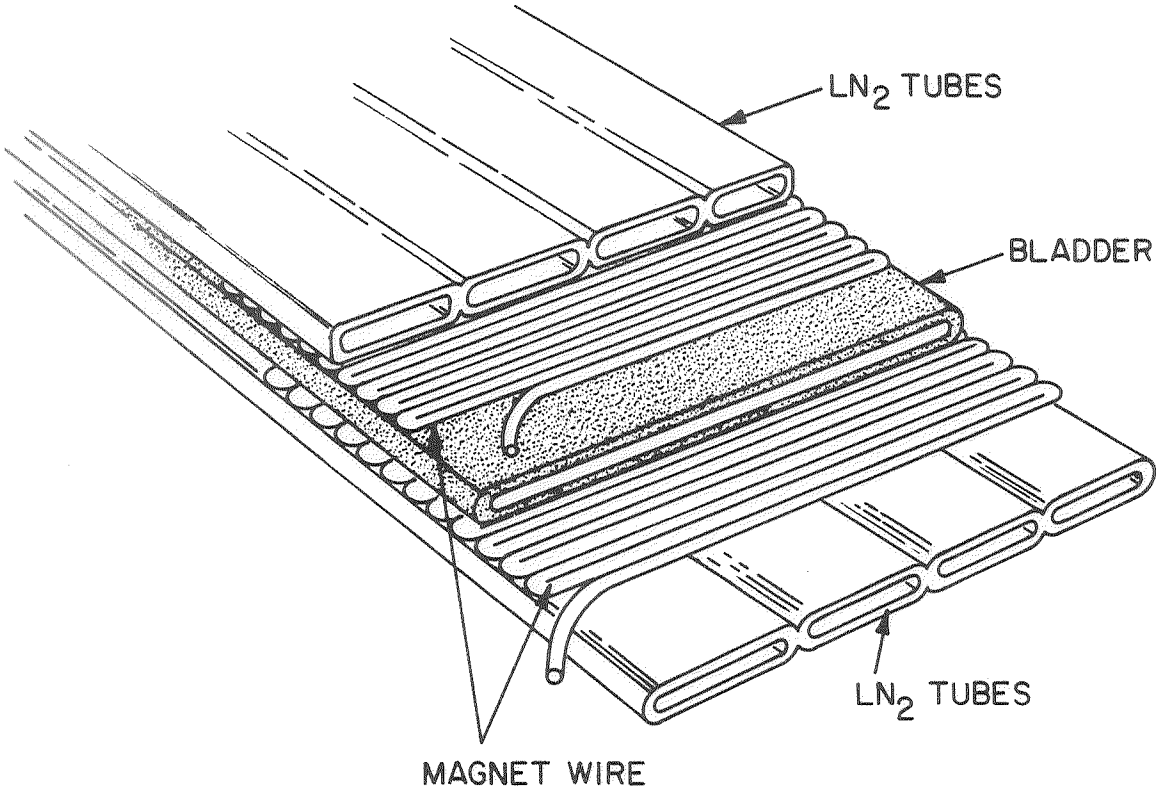


Figure 19. Controlled Freezing Unit

cannot at present be controlled because of the plateau in cooling rate when the latent heat is released at the freezing point.

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 $-50^{\circ}C$.

This problem was forwarded to the Jet Propulsion Laboratory where Mr. L. S. Doubt and Mr. W. Tener suggested the configuration shown in Fig. 19. 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 $-50^{\circ}C$ is reached.

The problem originator is seeking ways to implement this clever approach to this problem.

PROBLEM NCI-6 *Separation of White Cells*

Leukemia, a disease which kills about 15,000 Americans annually, is characterized by a proliferation of white blood cell forming tissue. Efforts to find the cause and cure of this disease are important, not only because of the disease death rate, but because the disease is the only form of cancer that can be continuously studied (i.e., repeated blood samples can be taken but repeated samples of solid tumors cannot be taken). Thus, understanding leukemia will provide a vital key to understanding cancer.

Part of the difficulty in understanding leukemia is the fact that a poor understanding exists of the role of the various blood constituents as well as the constituents of the blood forming organs. These constituents are cells which can be considered to be spheres having a diameter of about 10-20 microns. The cells are all very similar in specific gravity (1.06 to 1.08).

A method is required of separating the cells according to size or density such that an undamaged quantity of each category of cells is retained. The existing methods for this separation include sedimentation and centrifuging. Sedimentation consists of allowing the cells to settle in a viscous medium contained in a one-foot deep tank. This technique produces an insufficient number of cells. Centrifuging methods now used do not allow sufficiently fine separation of cells.

A new separation method or an improved centrifuging method is required.

A computer search, a manual search, and a problem statement distribution have been conducted on this problem but no useful technology has been uncovered.

PROBLEM NCI-7 *Method for Fast Warming a Frozen Liquid*

Leukemia, a disease which kills about 15,000 Americans annually, is characterized by a proliferation of the tissue which forms white blood cells. Treatment of leukemia involves killing the cancerous white blood cells in the blood and in the 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 from a bank or storage facility of white cells. This is impossible at present because adequate storage procedures are unavailable. One part of the storage problem is a controlled freezing method which is the subject of problem number RTI/NCI-4, "Methods of Controlled Rate of Cooling in Liquids." The second part of the storage problem is the warming or thawing of the frozen white blood cells which is the subject of this problem statement.

One important parameter in the successful warming of cells is believed to be the rate of temperature change. Researchers believe this because experiments with spleen cells have indicated that very fast warming rates can significantly increase the yield or survival rate of frozen cells.

The present method for warming cells is an infrared heating system for the cells contained in a flat Teflon bag. This infrared system is unsuitable because the cells are not warmed uniformly nor fast enough.

The Team recommended microwave heating as an approach to this problem and the problem originator is considering several commercial microwave heaters as a solution.

PROBLEM NCI-8 *Elliptical Lens*

In many advanced medical research studies (e.g., cancer studies), the basic unit 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 Institutes of Health 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 monochromator 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 elliptical lens between the monochromator 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 monochromator to a more circular shape and thus more of the monochromator 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 lens can be obtained.

A NASA-developed computer program was found which is used for designing complex optical systems. This program has not been used for an elliptical lens but NASA personnel believe that the program can perform the desired design. The Fortran language program was obtained from NASA and shipped to the researcher. He is implementing this program on his computer. This potential solution resulted from direct Team contact with Marshall Space Flight Center and Jet Propulsion Laboratory. The program was called to the Team's attention by Mr. Juan Pizarro of MSFC. The availability of an elliptical lens will improve the ability of the NIH research staff to extract detailed histochemical data from human cells.

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

Breast cancer is common: 5-6% 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 are sufficiently reliable. A combination of the methods provides an improved probability of detecting breast cancer; however, none of the methods provide 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 is being prepared for dissemination to NASA field centers.

HEALTH CARE COST REDUCTION

PROBLEM WWRC-8 *A Waterproof Sealant for Rubber-Coated Nylon Stretcher Pads*

The Medical Services Division of the Woodrow Wilson Rehabilitation Center receives patients having spinal cord injuries. These injuries result in varying degrees of lower extremity paralysis and loss of function. Not infrequently these patients lose muscular control to the extent that they can no longer control their bowel movements. Stretchers have been modified by cutting out a square portion of the stretcher underneath the buttocks so that the patients can be given enemas while lying on the stretcher. Modification consists merely of cutting an appropriately sized square out of the stretcher and stretcher pad, and covering the edges thus exposed by sewing a rubberized nylon cloth in place. Unfortunately, this leaves a seam and needle-puncture holes. Because of these seams and punctures, the stretcher pad traps and absorbs urine, feces, etc., and it is very difficult to keep clean and odor-free. The result is that the pads must be discarded frequently, thus contributing to operating costs. A means of sealing the seams and needle punctures is desired in order to achieve a waterproof, easily cleanable surface. An alternative might be a flexible, waterproof adhesive which could entirely eliminate the sewing now used to attach the

covering over the exposed edges. As a result of searching procedures, the Team was able to recommend an aerospace silicon rubber adhesive which has potential application to the solution of this problem.

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 ureter, 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 understand 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 very important in obtaining a better understanding of ureteral physiology.

The requirement here is for a technique 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%. Size of the flowmeter is not important because the flowmeter can be outside the body. A flowmeter using the principle of thermal distribution proposed 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.

RESPIRATORY DISEASE DETECTION AND TREATMENT

PROBLEM DU-80 *Measurement of Pleural Pressure*

The pleura is a membrane which surrounds each lung. A membrane also lines the chest wall. In a healthy person these two membranes are in contact with each other. A thin film of pleural fluid formed by the pleural membrane lubricates the pleural surfaces as they move against each other when the lungs change size during breathing. In respiratory diseases when a lung collapses or when air or fluid collects between the two membranes, a cavity becomes apparent. This cavity is called the pleural cavity. A measurement of the pressure sustained by this cavity can be employed to detect and diagnose respiratory ailments. Pressure measurements at the proper point in the esophagus provide an indirect method of measuring pressure in the pleural cavity. This has been accomplished by placing a balloon-tipped catheter in the esophagus and recording the pressure changes in the balloon. A telemetry capsule to replace the balloon-tipped catheter would be a significant improvement and would provide refined measurement of pleural cavity pressure.

A literature search failed to uncover a solution to this problem. The solution will be pursued by discussing this problem with scientists and engineers at NASA field centers.

PROBLEM DU-81 *Detection of Blood Vessels in Bronchi*

Suspicion of lung diseases, particularly lung cancer, often requires that a sample of lung tissue be taken for laboratory analysis. When taking tissue samples from one of the branches of the trachea, a bronchoscope is employed to allow visual examination of the interior of the bronchi (primary branches of the trachea). This visual examination does not allow the determination of the presence of blood vessels in the bronchi. The taking of tissue samples sometimes severs a blood vessel resulting in bleeding that is difficult to control. This danger could be eliminated if a means of determining the presence of blood vessels in the wall of the trachea were available.

A search of the aerospace literature is in progress.

IMPROVED SURGICAL PROCEDURES

PROBLEM TU-6 *Measurement of pCO_2, pO_2, pH in Blood*

Surgery is a common event in modern medicine, but it still causes significant danger to the patient. To reduce this danger, most hospitals carefully monitor a patient's condition in the most critical period immediately following surgery. Three of the many measurements of value during this period are pCO_2 (partial pressure of carbon dioxide), pO_2 (partial pressure of oxygen, and pH (acid/base relationship) of the blood.

Analyses of blood gases and pH provide insight into the way that the body is utilizing the available oxygen and discharging the waste carbon dioxide. This utilization includes not only lung function but also tissue function. These measurements can tell the physician many things including onset of shock. In addition, the measurements can assist in assessing the patient's general progress.

Existing methods for blood analysis consist primarily of sampling techniques in which blood samples are withdrawn sequentially and tested. An on-line, real time method would provide not only more information but would reduce the effort required of the nursing staff and would free them for other activities. The transducer should allow continuous monitoring of the blood gases (O_2 and CO_2) and blood pH.

A computer search of the NASA document bank revealed that this problem can be solved with a commercial mass spectrometer. The problem originator is seeking funds to implement this approach.

PROBLEM DU-72 *Shadowing Methods for High Resolution Electron Microscopy*

Better methods are needed to obtain very uniform, thin (10-30Å) films of platinum or other heavy metal deposited on cold biological specimens in the freeze-fracture method of electron microscope studies of cellular ultrastructure. Regularity at the level of 5-10Å is desired.

The problem originator is investigating details of cellular membrane structure, and the principal tool in this important fundamental research is the transmission electron microscope. The biological specimen is prepared by the freeze-fracturing process and "shadowed" with platinum to enhance contrast and to reveal three-dimensional detail. While modern electron microscopes have resolution limits of several Angstroms, electron micrographs of cellular ultrastructure are generally limited in resolution to the range 20-100Å, and much of this limitation is due to the shadowing process itself. Improvement in shadowing is the subject of this problem statement.

Shadowing is simply the evaporation in vacuum of a thin layer (10-30Å typically) of a heavy metal (such as platinum) at an oblique angle (often approximately 45°) onto the face of the freeze-fractured specimen. The specimen temperature is 80°K to 150°K when this occurs. The shadowing material must be heavy (relatively high atomic number) to provide adequate electron scattering in the transmission electron microscope. The requirements of geometrical shadow production to emphasize the surface relief features, together with the low specimen temperature, have made vacuum evaporation the only method used thus far for deposition of the shadowing material.

The Team identified a researcher at Langley Research Center who suggested the use of electron bombardment for film evaporation. The researcher is presently attempting to obtain facilities to perform the recommended procedure.

PROBLEM DU-82 *Maintaining the Position of a Telemetry Capsule in the Digestive Tract*

Telemetry from within the human body by means of small sensing and transmitting capsules is becoming an increasingly important method of making physiological measurements that were heretofore impossible. As an example, useful measurements that might be made in the digestive tract are esophagal pressure, stomach pressure, pO_2, pH, etc. Certain measurements require that the sensing capsule remain stationary along the tract even though the natural reaction of the digestive tract is to continuously propagate any matter which enters the system. A means of retaining the sensing capsule at a desired point in the digestive tract would allow needed measurements to be made over a period of time that does not depend on the body's natural reaction. The method for retaining the capsule should not be dangerous nor make the patient uncomfortable.

A problem statement is being prepared for dissemination to the NASA field centers.

PROBLEM MISC-9 *pO_2 Telemetry Capsule*

Diarrhea may be due to various causes from acute infections to psychogenic factors. Current research indicates that bacteria which normally reside in the mouth can, under certain conditions, give rise to diarrheal states. There are two types of such bacteria: one which must have oxygen to live and another which 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 learned of a commercial device (a swallowable telemetry capsule) for measuring the partial pressure of oxygen in the digestive tract which should be available within the next few months. This should offer a solution to the problem.

PROBLEM NEHSC-1 *Miniature Telemetry*

The researcher is studying the effects of several drugs on the immature opossum. The opossum is a particularly well-suited animal for these studies. The gestation period of the opossum is approximately 12½ days. At birth the embryos weigh approximately 100 mg and are approximately 5 mm long. They can be considered embryos at birth, and much of their development occurs during the time they are in the pouch. Consequently, physical access to the embryo in the pouch permits study during this rapid development stage. Most other mammals remain as unborn embryos during this development period. It is, of course, extremely difficult to monitor development of unborn embryos. As a result of the fact that much of the embryonic development occurs while the immature opossum is in the pouch and thus relatively accessible, the opossum is very appropriate for such studies. The basic problem is to telemeter several physiologic signals from the immature opossum in the pouch to a receiver in the same room. A range of 15 feet is considered adequate. If the telemetry unit is to be directly attached to the newborn opossums, the size of the telemetry unit could not exceed 125 mm^3 including battery, and the weight maximum is 100 mg.

A search of the NASA literature has failed to reveal any telemetry equipment of the small size and weight required in this application. No commercial units which approach this range of size and weight have been discovered either. The problem is presently being reviewed and a final search being made for potential solutions. If none are found, it is expected that the problem will be closed since the problem requirements appear to be beyond the present state-of-the-art in telemetry system development.

PROBLEM NEHSC-2 *A Means of Characterizing Seizures in Laboratory Animals*

The researcher is studying the effects of various drugs on laboratory animals. One of the drugs sensitizes the animals so that they are susceptible to seizures. External sensory input is thought to trigger the seizure. It is desired to determine which sensory input is acting as the trigger. There are a number of possibilities including audiogenic induction, photo simulation, tactile stimulation, and stimulation through the vestibula apparatus. A search of the NASA literature has been conducted seeking information on tests and equipment which can be used to provide isolated stimulation to each of the sensory inputs so as to isolate the exact sensory input acting as the trigger. A search has been delivered to the researcher for his evaluation.

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 which can be projected so that the areas can be drawn on a paper sized 8" x 10". The cell area and the interstitial area need to be measured to an accuracy of ± 1%.

A computer search has been delivered to the researcher but no relevant documents have been uncovered.

PROBLEM TU-23 *Oxygen Measurement in Microgram Tissue Samples*

A method for measuring oxygen partial pressure in microgram tissue samples for use in cell kinetics studies is needed.

One method of studying disease is to observe changes at the cellular level. In these studies a correlation between biochemical and morphological changes is important. If smaller volumes of cells can be studied, then more details can be obtained. Specifically, oxygen measurement in tissues is required.

Oxygen partial pressure measurement in 10 micrograms of tissue is required. The measurement can take up to one hour of time. Typical pressure is 50 mm Hg and a 10% accuracy is required. The technique can be destructive.

An information search has been delivered to the researcher with numerous relevant documents.

PROBLEM UNC-56 *Tissue Preservation*

A means of freezing tissue while minimizing freezing damage is needed. Many detailed studies of animal tissue require that a preservation technique be employed to keep the sample as viable as possible over a long period of time. Ideally, structure, membranes, etc., should be preserved so that subsequent

studies can utilize unmutilated tissue. When viables go through a change of state such as freezing, there is a rather sudden release of energy (heat) which ruptures cell walls. In addition, the growth of the ice crystals damages the tissue, resulting in a "swiss cheese" appearance when the tissue is viewed under a microscope. A method of controlled freezing of tissue to minimize freezing damage is needed.

A search of the aerospace literature failed to produce a solution to this problem. The problem originator is preparing to perform some preliminary tests so that a specific approach can be formulated. A problem statement should be prepared for dissemination to the NASA field centers at that time.

PROBLEM UNC-58 *Microfocused X-Ray Beams*

A technique for producing a highly focused X-ray beam is needed. Collagen is the chief constituent of connective tissue, cartilage, and bone. Several types of tissue and bone ailments are a direct result of collagen disorders. In searching for improved methods of combating collagen disorders, X-ray diffraction techniques are employed to better define the molecular structure of collagen. To get better resolution in the diffraction pattern, and hence a refined definition of the molecular structure of a sample under study, a fine X-ray beam is required. Commercially available hardware is not capable of the degree of focusing required. The researcher is seeking technology which will allow him to construct the required focusing device.

A literature search has been completed, and several documents ordered are under study. Also, the Team is in contact with a scientist at NASA's Marshall Space Flight Center who is studying this problem as it related to X-ray telescopes.

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 could be studied more rapidly and in greater detail.

A problem statement is being prepared for dissemination to the NASA field centers.

OTHER, MISCELLANEOUS

PROBLEM NCSU-9 *Analysis Techniques for Physiological Data*

An electroencephalogram (EEG) is simply a time-recording, at the head's surface, of electrical signals generated by the brain. At present, this record can be correlated with certain overall physical states such as sleep, but it is possible that refinement of the mathematical analysis of the EEG would lead to its use in the future for diagnosis of specific and local brain disorders such as small tumors.

There exists a certain amount of electrical noise in the recording process, and the EEG itself would be characterizable as basically stochastic. However, two characteristic rhythms have been identified, the alpha and the beta. The alpha activity has a frequency of 8-13 Hz, relatively high amplitude, and is primarily associated with the resting condition. The beta rhythm has a frequency 18-30 Hz, has lower amplitude, and corresponds to an alert state. Neither the alpha nor the beta rhythms are completely periodic nor are these stationary processes, but the assumptions of stationarity and periodicity have been made in virtually all EEG analyses to date.

These assumptions and their consequences are the main concern of the researchers in the present problem. It may be possible that a different mathematical model and different fundamental assumptions are more appropriate for EEG analysis and that under a different model the amount of useful information derived from EEG analysis could be considerably increased.

The researchers need to know of any developments in the general theory of stochastic processes and particularly those developments related to nonperiodic, nonstationary processes. They are not interested in specific computer programs now available to carry out analyses by auto- or cross-correlation techniques or Fourier transform techniques; it is the basic theory itself which holds their interest.

A computer search has been delivered to the researcher with numerous relevant documents.

PROBLEM NEHSC-3 *A Means of Determining the Quantity and Size of Cell Colonies in a Transparent Gel*

In assessing the effects of the environment on man, one area of interest is the ability of environmental effects to produce mutation of cells. Special cell cultures have been developed at the National Environmental Health Sciences Center to permit study at the cellular level of the mutant capability of various environmental effects. A special cell culture has been developed from mouse lymphoma cells. These cells, when placed in free suspension in a gel medium, do not divide and produce cell colonies under normal circumstances. If, however, a mutation takes place, then the mutant cells divide and produce colonies. The number of colonies and the relative growth rates will provide information on the effectiveness of various environmental mutants to which the cells can be exposed. Basically, a means of quantitating the number of colonies produced and their

sizes (or the size distribution) is desired. The colonies to be detected are contained in flat, plastic bottles which contain the gel medium. It is desired to measure the colonies over a period of time in order to obtain a growth rate for the colonies and distinguish between those colonies that are growing slowly and those that are growing rapidly. Any system to be useful must be capable of detecting colonies as small as 0.1 mm; however, detection of smaller sizes is desirable. Extremely complex and expensive solutions are not acceptable, thus eliminating flying spot scanners and digital image processing. Presently, optical data processing is being evaluated for application to this problem. Contacts have been made at the NASA Goddard Space Flight Center to initiate discussions with NASA scientists in the field of optical data processing.

PROBLEM NHLI-3 *Security System for Computer Data*

Tests and evaluations of medical devices at the National Heart and Lung Institute are becoming largely automated. Since medical devices must undergo analysis before they are cleared for marketing, it is very important to the well-being of the general public that only those devices that are safe and serve well the intended purpose are cleared. Passing an unsafe or ineffective device or rejecting a needed useful device because of a computer-related error must be avoided. The security system should:

(1) Verify test data, i.e., the data recorded must be the actual response of the instrument being tested

(2) Verify the integrity of data after processing.

A literature search resulted in several reports which might be of value. This information is under evaluation.

PROBLEM NHLI-6 *Techniques for Sterilization with Plasmas*

A plasma is a gas which is composed of a nearly equal number of positive ions and electrons. Because it is composed of charged particles, a plasma exhibits many phenomena not encountered in ordinary gases. One such property is its ability to destroy living micro-organisms with which it comes in contact. This important property could provide a greatly improved means of sterilizing medical devices.

Commonly used methods of sterilization are: (1) heat, (2) radiation, and (3) chemical. Material degradation occurs when heat or chemical sterilization techniques are employed while electronic components become less reliable when subjected to high temperatures or radiation.

Sterilization employing plasma techniques would offer a means of more complete sterilization of medical devices without accompanying degradation of device reliability. This method would be of particular importance in sterilizing devices to be implanted in the body where the functional integrity of the implant is critical, e.g., an artificial heart.

A literature search failed to produce a solution to the problem. The Team was aware that much plasma research has been done at NASA's Lewis Research Center

and contacted the Lewis Technology Utilization Office regarding this problem. As a result, the problem originator is currently in direct contact with Lewis personnel involved in plasma research and will work with them in seeking the problem solution.

PROBLEM WF-56 *An Improved Fluid Pressure Calibration System*

A significant problem in hospitals and medical research institutions involves the testing and calibration of equipment used in taking physiologic measurements for research and diagnostic use. Most hospitals and medical research institutions have in their inventory a large number of pressure transducers of varying manufacture and design that are employed by investigators in their research programs and by clinical personnel in the diagnosis and treatment of patients. These devices have real value only when their performance is within specifications. Indeed, when transducers are out of calibration, the indicated results lead to false conclusions. It is extremely desirable that all pressure transducers used for research and clinical purposes alike be within calibration in order not to yield inaccurate and misleading data. A calibration system which could be used to check and verify the accuracy of pressure transducers employed in the hospital and the medical research facility would be a very useful addition. Basically, a calibration unit consisting of a pressure wave generator, an accurate standard transducer, a pressure chamber, and appropriate manifolding is desired. The pressure generator must be capable of generating fluid pressures in the chamber from near zero to approximately one atmosphere of pressure. Frequency response of the pressure generator within a given pressure output should be constant ± 5% over the frequency range 0.1 Hz - 150 Hz.

A potential solution to this problem was discovered in the aerospace literature as a result of a computer search. This problem has been recommended to TUD as an applications engineering project to be carried out at the University of Virginia. Disposition of this problem awaits a decision on the approval or disapproval as a reengineering project.

PROBLEM WF-97 *An Ergometer for Paraplegics*

The researcher has been involved for a number of years in conducting an endurance training program. The effects of various kinds of exercise and endurance training on human subjects have been determined as a result of the programs. The basic areas of study have been the effects on the cardio-vascular and respiratory systems of exercise on a regular periodic basis--in some cases extreme endurance training programs, and in others nothing more strenuous than walking. The researcher wishes to undertake a program involving exercise and endurance training of paraplegics. He is undertaking a program to determine the effects of regular periodic exercise on the respiratory and cardiovascular systems of paraplegics. This will require the implementation of programmed exercise regimens by the exercising paraplegics. Conventional ergometers, in which the subject pedals with his legs to expend a definite amount of energy, cannot be used in this program because the paraplegics cannot use their legs. The exercise must be accomplished with the arms. Because of the construction of conventional ergometers, significant structural modifications will be required to permit these units to be employed with paraplegics. In addition, it would be difficult and

time-consuming to convert the ergometers back to ordinary leg operation. This problem was accepted because it was felt that the exercise requirements for astronauts in space might have resulted in the design of ergometers suitable for use in this particular application.

Discussions with personnel at the NASA Marshall Space Flight Center reveal that an ergometer designed and built there for the Skylab program has application to this problem. Attempts were made to obtain a unit on a loan basis for evaluation by the researcher, but unfortunately both units are committed, and therefore, not available. If funds for construction of a unit could be obtained, the unit would be useful in the researcher's program.

PROBLEM WWRC-1 *Marking or Identification Method for Tools*

The Woodrow Wilson Rehabilitation Center offers training in a number of different areas for handicapped persons so that they can assume fruitful vocations. Many of these classes require the use of hand tools. The necessary hand tools are issued to the student when he begins the course, and he keeps the same tools throughout the course which may last as long as one year. A method of marking these hand tools so that they can be easily identified is desired. The tools may be of wood, plastic, or hardened steel. Various marking methods such as metal stamps, file and center punch marks, paint, enamel, and lacquer, and vibration tools have been used for marking these tools. All of these methods have proven to be unsatisfactory for a variety of reasons ranging from low visibility, poor durability, inability to mark hardened steel, and difficulty of using the marking tools. It is important that the marking method be relatively simple since the students mark their own tools.

A suggestion was received from the Langley Research Center which involved the use of heat shrinkable plastic tubing as a marking method. This type of marking has several desirable features including relatively good durability and extreme ease of application. The problem originator has obtained samples of the heat shrinkable tubing and is currently evaluating their use as a marking method for tools in actual practice.

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

The Woodrow Wilson Rehabilitation Center 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 disability. Such patients have little or no use of hands and 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 a relatively simple task (for a person without disability) of operating the call button used in most hospitals to signal the nursing station that the patient is in need of help. An improved calling system is needed to permit these patients to initiate nurse calls relatively easily. Such patients generally have voluntary control of one or all of the following functions which might conceivably be used for control:

1. Breath (respiration);

2. Eye movement and blink;

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

It is also desirable that the signalling system be capable of activation by a patient sitting in a wheelchair beside the bed. A simple reliable technique is desired.

The Southwest Research Institute has in the past encountered a similar problem. As a result of their searching, they found a NASA tech brief which described an optical system that might be modified for use with MS patients. This technique along with several other potentially useful techniques is being evaluated by the problem originator.

APPENDIX C

APPLICATION OF AEROSPACE TECHNOLOGY TO MEDICINE

(Paper presented at the First Western Space Conference, Santa Maria, California, October 27-29, 1970)

APPLICATION OF AEROSPACE TECHNOLOGY TO MEDICINE

by

F. Thomas Wooten

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October 27-29, 1970

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APPLICATION OF AEROSPACE TECHNOLOGY TO MEDICINE

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Abstract

The National Aeronautics and Space Administration has sponsored a program for several years which is designed to transfer new technology developed in the aerospace field to the field of medicine. Using a multidisciplinary team of engineers and scientists called a Biomedical Application Team, medical research problems are identified by personal interaction between the team and scientists in medical centers throughout the country. In this paper new insights into the process of technology transfer are discussed as well as apecific examples of the success of this program.

1. INTRODUCTION

The dramatic successes of our space program are the result of a broad and carefully developed technological base. The costs involved in establishing and expanding this technological base are of sufficient magnitude to warrant an additional effort to find applications outside the space program. Congress had the foresight to recognize this in the Space Act of 1958 in which the National Aeronautics and Space Administration was directed to search for secondary applications. One part of this effort is described here.

For several years NASA has sponsored a program which has at its core multidisciplinary teams of scientists and engineers called Biomedical Application Teams. Such a team is located at each of three not-for-profit research institutes (Research Triangle Institute of North Carolina, Southwest Research Institute of Texas, and Midwest Research Institute of Missouri). The teams seek to provide an interface between two diverse fields: aerospace and medicine.

The medical profession has awakened in the past decade to the need for advanced technology in medical research and health care. This awakening alone is not enough. Some effective avenues for the flow of information, ideas, and technology between the physical and medical sciences have been established, but more are needed. This program provides one such avenue.

2. METHODOLOGY

Technology utilization is the term applied to the task of finding second applications for technology. Many of the methods for implementing the concept

of technology utilization are largely passive in nature; passive in this case means the information is provided to those who seek it and thus, the physician must understand the information system in order to use it. One of the unique features of the Biomedical Application Team program is that the method is active. Active, in this sense, means that the problems and solutions are actively sought.

This search for problems is carried out by the members of the multi-disciplinary team. Team members visit major medical centers (the National Institutes of Health and medical schools) where suitable medical problems are identified with the aid of a consultant. The consultant, a medical center staff member, helps to insure that the problems selected meet certain minimum requirements. In general our team accepts only those problems which (1) have no solutions available on the commercial market, (2) are discrete and can be defined in specific terms, (3) impede the progress of priority efforts of the physician, and (4) appear amenable to solution by aerospace related technology. We impose these requirements because this program is designed for problem solving, not just information searching.

If a problem meets these requirements, it is defined by the physician and team member during one or more meetings. Personal interaction has been found to play a vital role in many aspects of the program, and problem definition is no exception. During problem definition, the team member determines the physical science or engineering requirement which is impeding the medical research.

Problem definition can probably best be explained by an example: Arthritis is a crippling disease which can result in the destruction of the ball and socket joint of the hip. One method of treating this problem is to replace the human hip ball and socket joint with an artificial material. An orthopedic surgeon asked the team to find an improved material. The team quickly determined that the basic problem was that existing materials have inadequate friction and wear characteristics. The team looked for improved low friction-bearing materials which were biocompatible and not just for prosthetic hip joint materials. Thus, the search could be broadened to areas unrelated to medicine.

After a problem is defined, a solution is sought using several approaches. First, a computer search of the NASA document bank is performed which covers the documents identified in Scientific and Technical Aerospace Reports (STAR) and International Aerospace Abstracts (IAA). The bibliography and related documents are analyzed by the physician and the team member to determine whether an adequate solution is available.

A second approach used in finding solutions is to request suggestions from NASA personnel by circulating concisely written problem statements to the NASA field centers. These documents are circulated by the Technology Utilization Officers (TUO) who are located at each center and who have a detailed knowledge of the research activities at their centers. The TUO provides a vital link between the teams and key NASA personnel.

A third approach is to contact field center personnel or NASA contractor personnel directly when the teams are aware that these personnel have knowledge about particular problems. These contacts, coordinated with each TUO, allow the teams to rapidly obtain advanced technological information.

After an idea or individual has been identified by these searching procedures, both direct and indirect contacts between physicians and NASA personnel are arranged. In the former case, physicians have visited NASA centers for discussions; in the latter case, the team members have provided the contact by visits and correspondence. Always the idea is to provide the physician with fresh insight into his problem from a discipline he does not normally encounter.

The team then acts as a catalyst to provide implementation of the ideas. Although the primary responsibility for implementation of the technology lies with the physician, the team assists in engineering consultation and in recommendations for ways of applying the technology. In addition, in a few instances NASA has implemented the technology directly when it is clear that no other avenues are open to the physician and when the necessary expertise is available only within NASA. At all times, the team feels that success comes only when utilization has occurred.

3. PROGRAM ANALYSIS

Because the transfer of technology in this active mode is a unique venture, significant efforts are made to analyze the transfer process so that improvements in transfer methodology can occur. This is done by careful documentation of all phases of the program and by a continuing analysis of the results.

Both the operations research approach and the goal oriented approach are used for analysis purposes. The operations research approach is needed to experimentally examine the tactics of the program, and the goal oriented approach is needed to insure that the operational phase of the program obtains realistic progress. Both approaches are correlated to achieve optimization of methods for maximum results.

The analysis phase of the program has disclosed several important facts about the problem of finding second applications for space technology. First,

although the searching of document files is one key aspect of the program, it is not the most important aspect. Most information systems are designed to retrieve information directly related to a subject. Information that is indirectly related to a subject cannot be easily retrieved unless the searcher has some initial clues. As an example, a search for methods of rapidly heating blood would probably not include semiconductor fabrication as a search term unless the searchers were aware that microwave heating is a vital aspect of semiconductor fabrication processes. Thus, search results are limited by the experience of the searcher.

The second important lesson learned from this program is that personal interaction is vital when two diverse disciplines are attempting to interact. In fact, disciplines do not interact, but people do. The interaction between two diverse disciplines really results when two people sit down to talk. If we simply give a physician an engineering document, the results are usually zero. The physician cannot begin to realize the significance of modern communications technology to his method of dispensing health care, and the engineer cannot recognize the significance of his cryogenic technology to leukemia therapy until face-to-face and repeated personal interaction occurs. Personal interaction between all elements of the team program (physician, team member, and aerospace engineer) has been found to be of major importance for success.

4. EXAMPLES OF RESULTS

In order to illustrate both the methodology and the results of the Biomedical Application Team, examples of particular problems will now be discussed.

In Figure 1, a prototype of a prosthetic urethral valve is shown. This valve is designed to meet the needs of patients with urinary incontinence or the inability to voluntarily control urination. In addition to the obvious social and hygienic implications of incontinence, this inability to control urination can result in tissue deterioration, infection, kidney damage, and eventually death. Previous attempts to solve this problem using electrical stimulation have not been satisfactory.

One problem in attempting to use a valve in the urinary system is that urine causes an incrustation that fouls most valves. This problem was posed to NASA engineers at Lewis Research Center who proposed the use of a corrosion resistant valve. A team engineer proposed a check valve that together with the bulb shown in Figure 1 forms a bistable valve which controls the urine flow. This device is now under construction for animal implantation in the near future. If it is

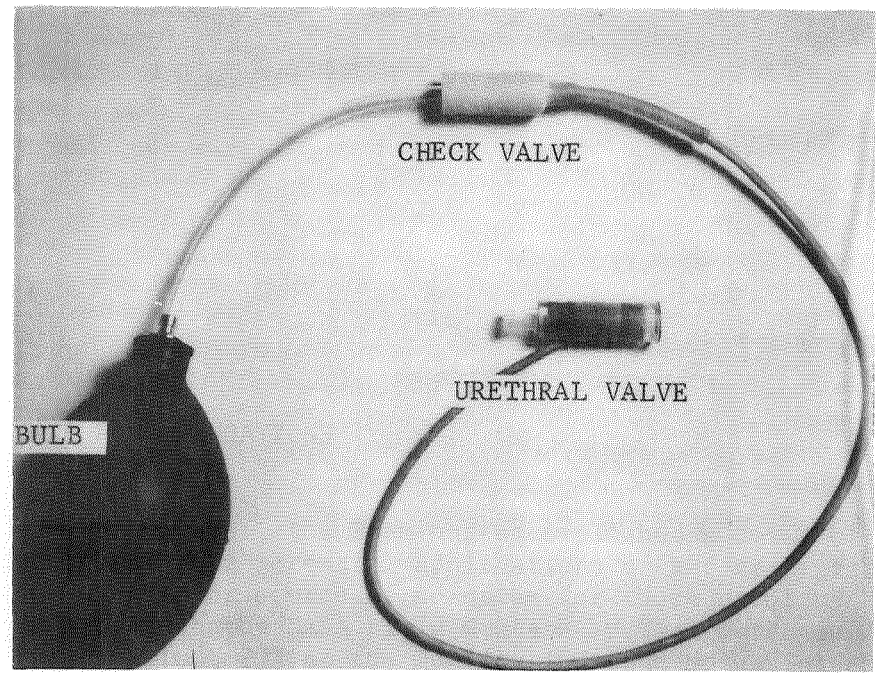

FIGURE 1 - PROTOTYPE PROSTHETIC URINARY VALVE

perfected, an estimated 15,000 patients per year could benefit from this device.

The next example concerns the use of heart pacemakers. When the heart becomes unable to maintain a completely regular beat, a small electrical pacing signal is supplied by a pacemaker. Two methods are used to connect the electrodes to the heart, but the principle difficulty with this device is the tendency of the heart to eject the catheter.

An alternate method for electrode placement is to open the chest by major surgery and insert the electrodes directly into the heart wall. These electrodes and the connecting wires must be in the form of a coiled wire or spring in order to solve the problem of material fatigue which occurs because the heart beats about forty million times a year. Although this method avoids the problem of ejection of the electrodes, the need for major surgery is a severe disadvantage.

The disadvantages of the latter technique can be solved without destroying its advantages by using an idea suggested by a NASA engineer. This idea utilizes the material Nitinol, shown in Figure 2, which exhibits a mechanical memory that is activated by heat. If the material is annealed in the form shown in Figure 2c and then crumpled into the shape shown in Figure 2a, it will regain its annealed shape when reheated.

Using this concept, an electrode wire is annealed into the coil shape needed for fatigue resistance. The wire is then straightened and inserted into the

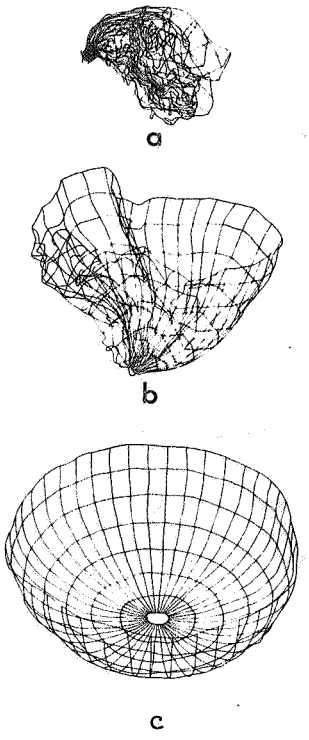

FIGURE 2 - MECHANICAL MEMORY ALLOY FOR ANTENNA APPLICATIONS

heart wall with a hypodermic needle. After the needle is withdrawn, the wire gradually assumes the coiled shape as it warms to the body temperature. This concept, which was called to the team's attention as a result of a problem statement circulated to a NASA field center, utilizes a technique used by NASA for design of space antennas.

A third example of a technology application resulted when the National Air Pollution Control Administration (NAPCA) wanted to study the effects of carbon monoxide on automobile drivers. A search revealed that a NASA scientist at Langley Research Center had developed an instrument, shown in Figure 3, which measured the coordination and reaction time of astronauts exposed to contaminants in spacecraft. This instrument was loaned to NAPCA and is now being used for planned experiments. Although this use of the equipment is not significantly different from the basic NASA use, it is interesting to note that NAPCA had planned to develop such an instrument on contract so that a significant savings in tax dollars resulted.

A fourth example is shown in Figure 4. This is a radiation dosimeter probe developed under NASA sponsorship for nonmedical purposes and is now being used to measure the radiation level absorbed around cancerous areas in order to

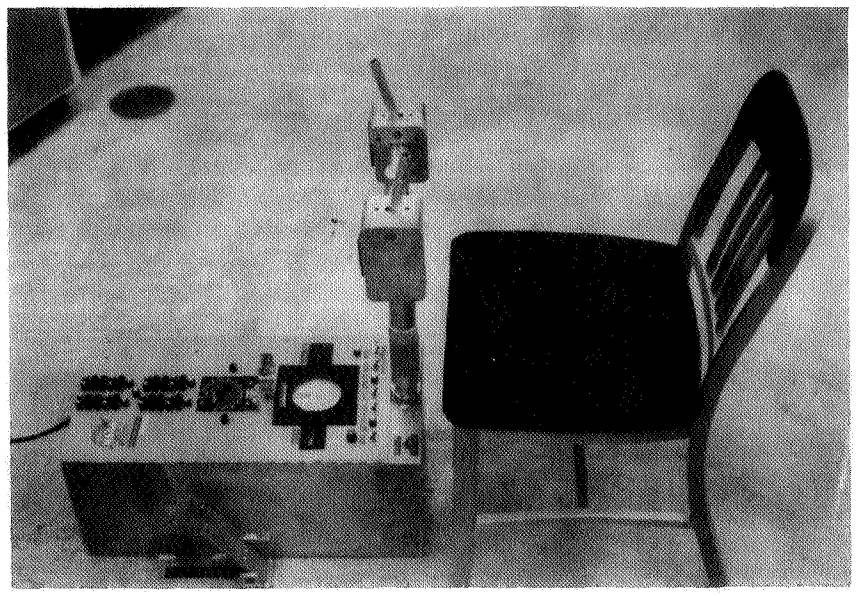

FIGURE 3 - COMPLEX COORDINATOR

determine the position of administered radioisotopes. This allows more precise definition of cancerous areas and prevents damage to surrounding healthy tissue.

The final example of technology application concerns the need for an improved electromyographic muscle trainer. When muscles of the hand become damaged or atrophied, an electromyographic muscle trainer is employed to determine whether or not a specific muscle is being used. The trainer consists of

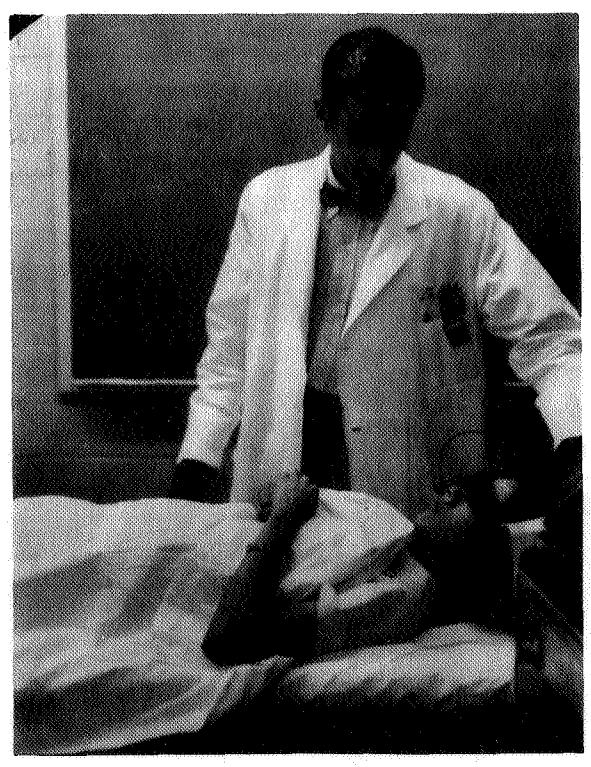

FIGURE 4 - RADIATION DOSIMETER

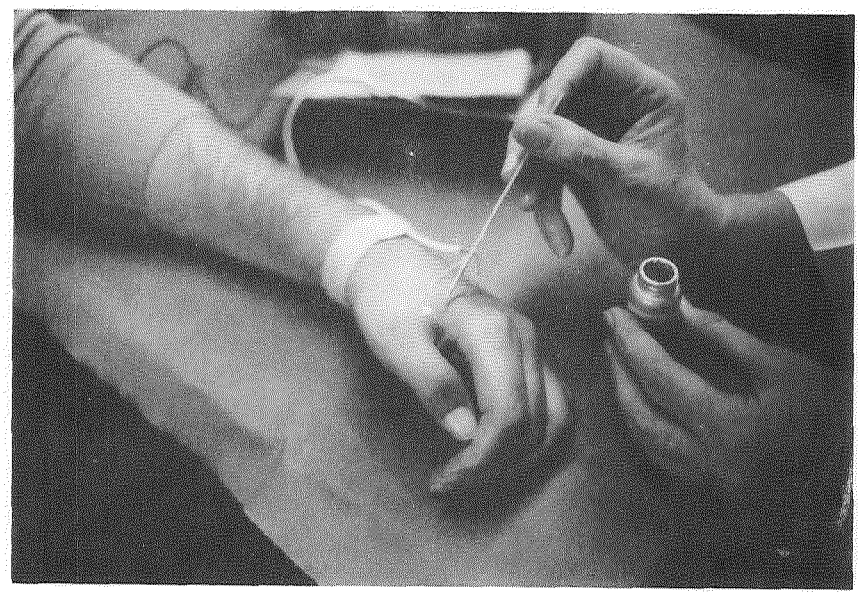

FIGURE 5 - ELECTROMYOGRAPHIC ELECTRODES

two electrodes, an amplifier, and a speaker which allows the patient to hear when a specific muscle is being used, but the bulky electrodes previously employed were too large for proper results.

Figure 5 shows the use of small electrodes devised from NASA-developed spray-on electrode formulations. With these electrodes no further attachment mechanism is needed for the wires, and the electrodes provide extremely satisfactory results.

The improved access to the muscle being exercised permits improved rehabilitation procedures for a significant number of patients. The technique is already in use in several rehabilitation centers.

5. CONCLUSIONS

This paper has described a new and exciting approach to the process of finding new applications for space technology. NASA has taken the lead in implementing the concept of technology utilization, and the Technology Utilization Program is the first vital step in the goal of a technological society to insure maximum benefit from the costs of technology. Experience has shown that the active approach to technology application is unique and is well received in the medical profession when appropriate problems are tackled. The problem-solving approach is a useful one at the precise time when medicine is recognizing the need for new technology.

It is significant that the decade which heralded the space age is also the decade that signaled the awakening of medicine to the need for technology. Whether the coincidence is directly related, indirectly related, or unrelated can be argued by philosophers. But this simultaneous occurrence cannot be ignored, and this program is one step in the many that are needed to fulfill medicine's needs. Thus, the Biomedical Application Team program clearly fits the purpose of this First Western Space Congress which is to "explore how space technology can be applied to the betterment of elements of world society."