N72-23065

# NASA



## APPLICATION TEAM PROGRAM

*Applications of Aerospace Technology in Biology and Medicine*

semiannual report

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RESEARCH TRIANGLE INSTITUTE
RESEARCH TRIANGLE PARK, NORTH CAROLINA

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## PREFACE

This report covers the medically related activities of the NASA Application Team Program at the Research Triangle Institute between April 1, 1971, and December 31, 1971. The activities were performed in accomplishing NASA Contract Nos. NASW-1950 and NASW-2273. This work was performed in the Center for Technology Applications of the Research Triangle Institute under the technical direction of Dr. J. N. Brown, Director. Full-time members of the Team who participated in the project are Dr. F. T. Wooten, Director of the Application Team; Mr. Ernest Harrison, Jr.; Mr. E. W. Page; 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. George S. Malindzak, Jr., Bowman Gray School of Medicine, Wake Forest University, Winston-Salem, North Carolina; Mr. William Z. Penland, National Cancer Institute, Bethesda, Maryland; and Professor Hal C. Becker, Tulane University School of Medicine, New Orleans, Louisiana.

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# ABSTRACT

This report presents the results of the medically related activities of the NASA Application Team Program at the Research Triangle Institute. This experimental program in technology application was supported by NASA Contract Nos. NASW-1950 and NASW-2273 for the reporting period April 1, 1971, to December 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 38 new problems for investigation, has accomplished 5 technology applications and 9 potential technology applications, has closed 50 old problems, has reactivated 2 old problems, and on December 31, 1971, has a total of 77 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* |

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TABLE OF CONTENTS

# 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

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

Southwest Research Institute
8500 Culebra Road
San Antonio, Texas 78228

This report covers the accomplishments and activities of the Team located at the Research Triangle Institute for the period April 1, 1971, to December 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.

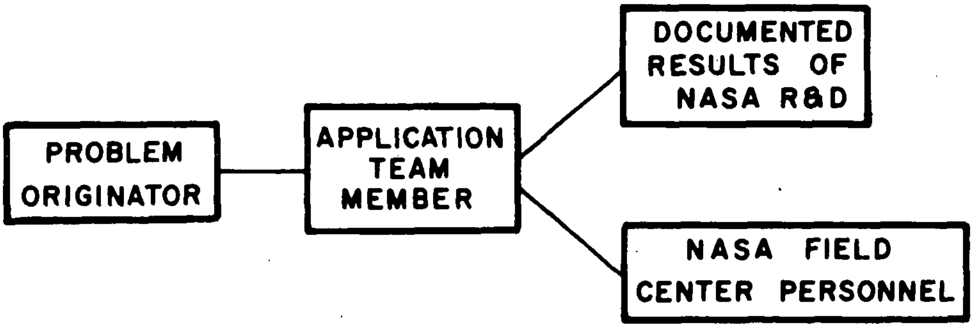


Figure 1. Possible mechanisms for transfer of technology.

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 reengineering or adaptive engineering facilities of various NASA centers in those cases where feasibility had to be demonstrated. The Teams are responsible for identifying the NASA technology 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.

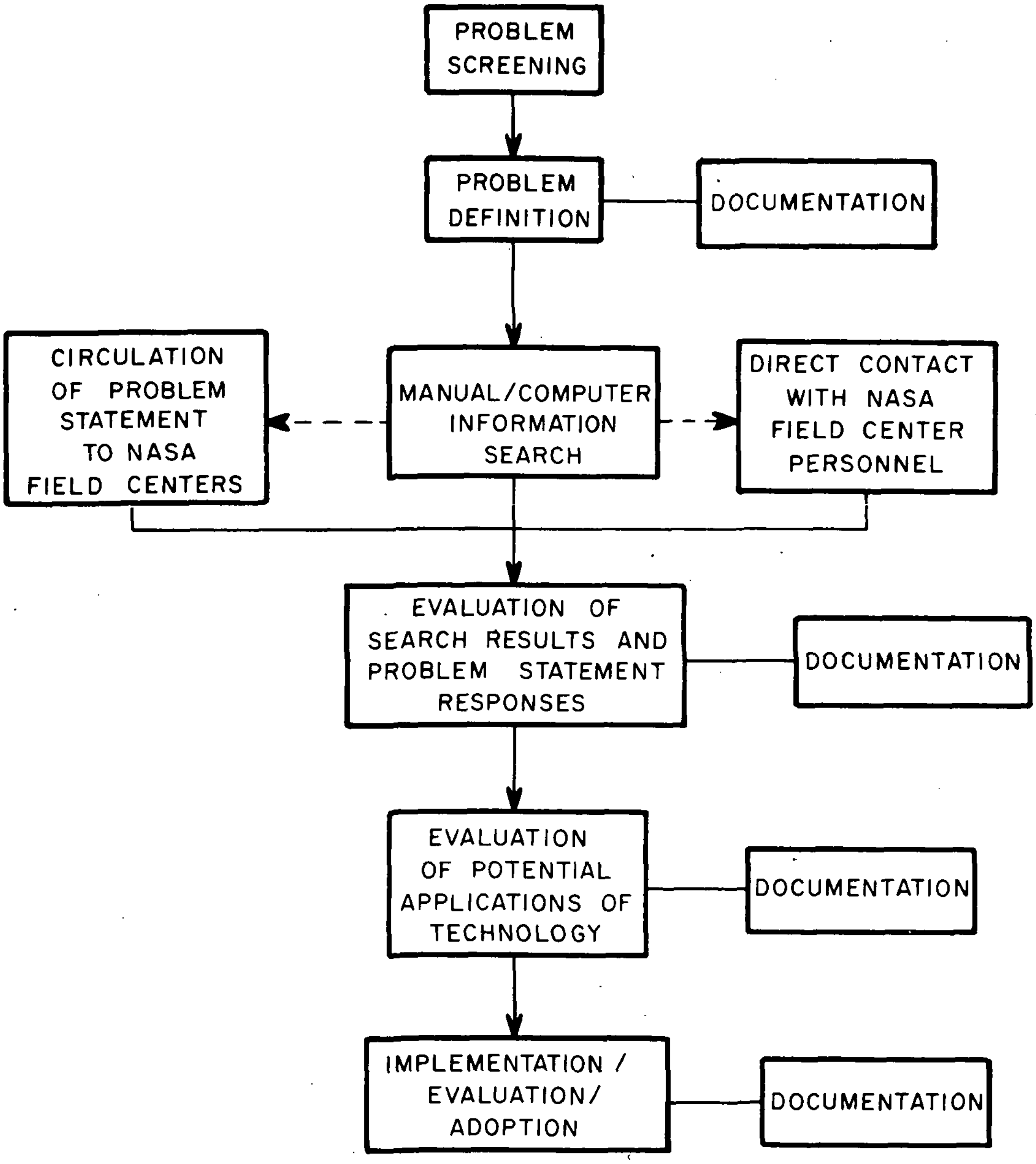


Figure 2. Flow chart of application team transfer methodology.

*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 cr 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 which completes the transfer.

*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 industry, education, and research at both basic and applied levels. The individuals who have participated in the Application Team Program during this reporting period are:

| *Name* | *Background* | *Responsibility* |
|---|---|---|
| Dr. J. N. Brown, Jr. | Electrical Engineer | Laboratory Supervisor |
| Dr. F. T. Wooten | Electrical Engineer | Team Director |
| Mr. E. Harrison, Jr. | Materials Scientist | Solution Specialist |
| Mr. E. W. Page | Electrical Engineer | Solution Specialist |
| Mrs. Mary Carpenter | Research Assistant | Documentation |

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

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

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

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

Emory University School of Medicine, Atlanta, Georgia;

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

Medical University of South Carolina, Charleston, South Carolina;

National Cancer Institute, Bethesda, Maryland;

National Heart and Lung Institute, Bethesda, Maryland;

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

Ochsner Clinic and Foundation, New Orleans, Louisiana;

Tulane University School of Medicine, New Orleans, Louisiana;

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

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

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

Virginia Department of Vocational Rehabilitation, Fishersville, Virginia.

Figure 3 shows the geographical distribution of the RTI Application Team user institutions as well as the location of the major NASA resources.

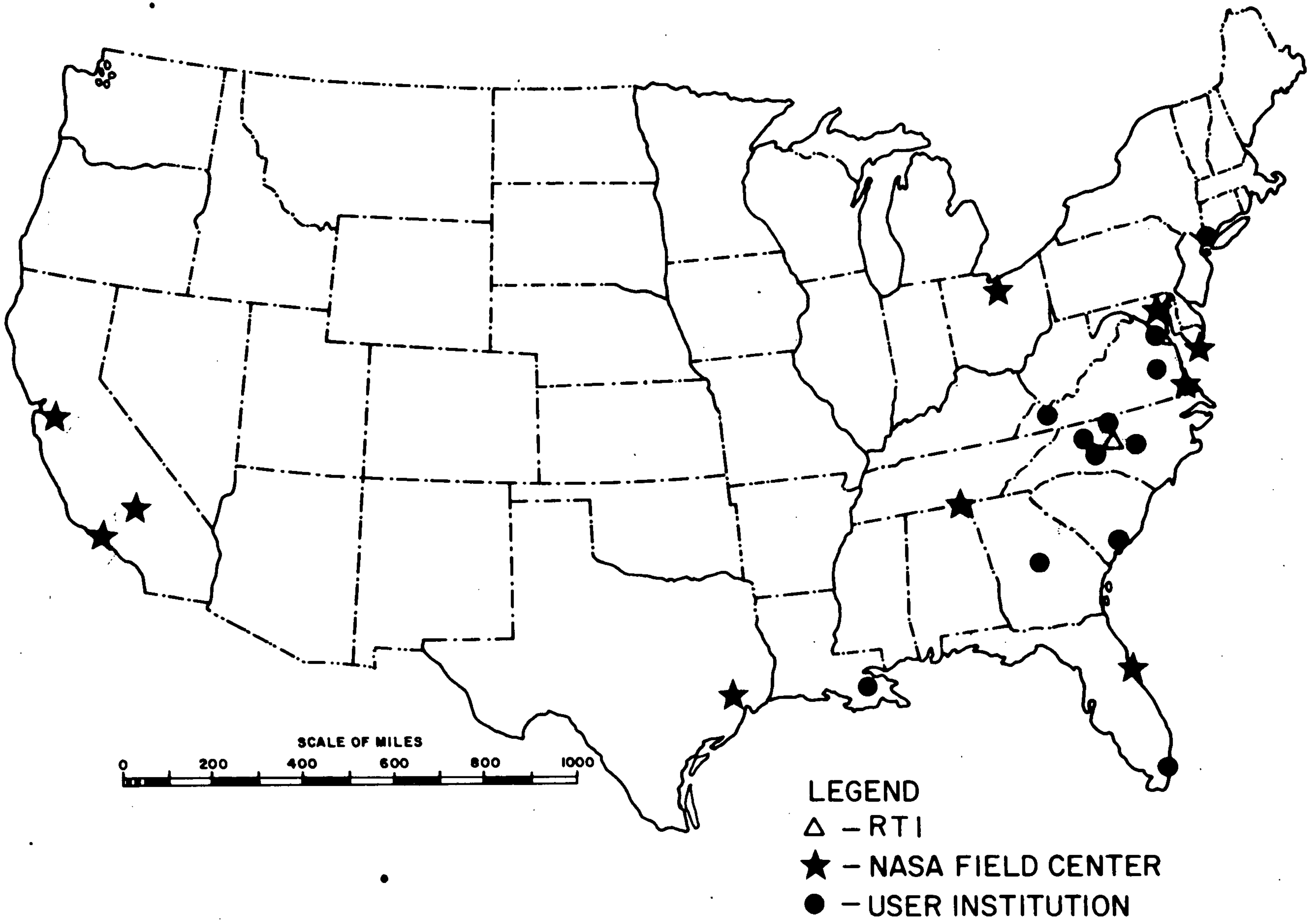


Figure 3. Team activity centers in the United States

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<br>Duke University Medical Center | Cardiac Physiology |
| Dr. George S. Malindzak, Jr.<br>Bowman Gray School of Medicine, Wake Forest University | Physiology |
| Professor Hal C. Becker<br>Tulane University School of Medicine | Radiology |
| Mr. William Z. Penland<br>National Cancer Institute | Engineering |

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

CP - Computer software-type problem
DU - Duke University Medical Center
EU - Emory University School of Medicine
IRM - Institute of Rehabilitation Medicine, New York University
MISC - Miscellaneous
MUSC - Medical University of South Carolina
NCI - National Cancer Institute
NEHSC - National Institute of Environmental Health Sciences
NHLI - National Heart and Lung Institute
NIMH - National Institute of Mental Health
OF - Ochsner Clinic and Foundation
TU - Tulane University School of Medicine
UNC - University of North Carolina School of Medicine
UNCD - University of North Carolina Dental School and Dental Research Center
VAM - University of Miami School of Medicine
WF - Bowman Gray School of Medicine, Wake Forest University

## 1.5 Definition of Terms

In the Application Team Program, a number of terms have evolved 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 aerospace technology which solves a 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.

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# 2.0 TECHNOLOGY APPLICATIONS, POTENTIAL TECHNOLOGY APPLICATIONS, AND IMPACTS

## 2.1 Technology Applications

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

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

A NASA development in electrocardiographic electrodes has been modified to solve a problem in measuring electromyographic (EMG) signals which are frequently measured in rehabilitation mediums.

In EMG studies of the spinal musculature, fine wire (25-micron) subcutaneous electrodes are hypodermically injected into the muscle whose EMG signal it is desired to monitor. The end of the electrode wire not in the muscle protrudes through the skin approximately 1 to 1-1/2 inch. The external end of the electrode wire must be electrically connected to the input of an integrated circuit preamplifier strapped or taped nearby. Soldering, welding, or other bonding techniques which pose a real or psychological danger to the patient cannot be employed. The technique in use when this problem was defined employs a coil spring which is attached to the input terminal of the preamplifier as the connector. Connection is made by pulling the spring apart, inserting the bare electrode wire, and allowing the spring to compress back down on the wire. Although handy and easy to use, electrical connection is essentially accomplished by means of "smeared" point contacts with this method so that reliable contact is not always achieved or maintained. Significant and time-consuming difficulties have been frequently experienced using this technique. A better method of connecting the electrode lead to the preamplifier is desired. The connection technique must be easy to use with this fine wire, must provide reliable and low impedance connection, and must not be hazardous or threatening to the patient.

The Team suggested a connection technique employing a conductive adhesive based on the NASA-developed dry electrode techniques as a potential solution to this problem. This technique is described below. The terminals to the preamplifier are constructed by forming two tabs or "lands" of copper separated by a small distance on a chip of printed circuit board (see Figure 4).

These terminals are attached to the preamplifier, and connection from the preamplifier to the terminals is accomplished by soldering. Because of the small size of the electrode wire and resulting difficulty in handling, it is necessary to fix the wire in place before the electrical connection can be made. To accomplish this, a small double-backed adhesive template shaped as shown in the illustration is applied to each terminal tab. Next, the electrode wire to be

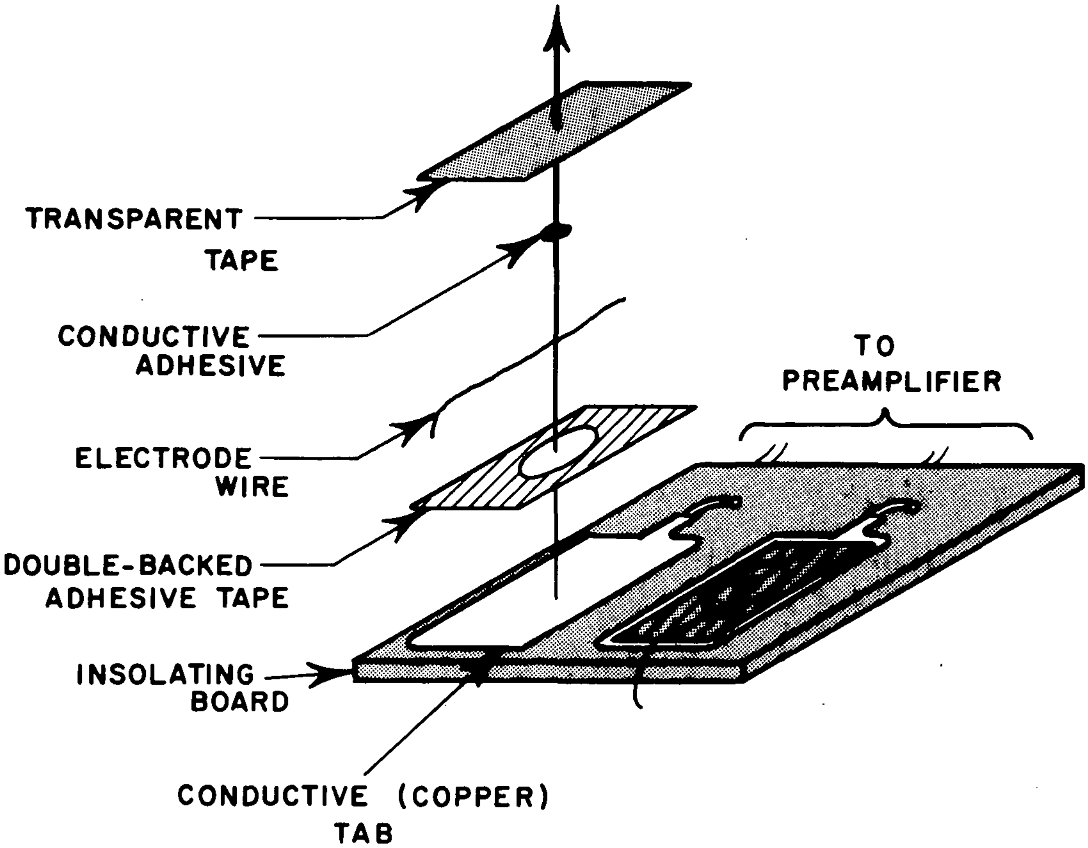



Figure 4. Connection technique for EMG electrodes.

attached is stretched across the tab and pressed into the adhesive at each end of the tab. This holds the wire in a fixed position so that the conductive cement can be easily applied. The conductive adhesive is applied using a camel's hair brush, a Q-Tip, or other convenient applicator. Using a small hand-held blower of the hair dryer type, the cement can be dried in less than 15 seconds. Then, to obtain additional mechanical strength, a piece of transparent adhesive tape is applied over the terminal. This technique has provided excellent electrical connection between the preamplifier and the electrode wires and has been very reliable. In addition, because of its ease of attachment, technicians have quickly learned the technique and become proficient in its application. Tests have been conducted clinically with human subjects and also in a research program in which gorillas were used as test animals. In both cases, this connection technique was highly successful. The researcher considers the connection problem completely solved and is using this technique routinely as a part of his standard procedures.

## PROBLEM NCI-8 *Elliptical Lens*

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

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

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

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

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

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

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

A direct contact was made with Juan Pizzaro at Marshall Space Flight Center who suggested a NASA-developed computer program which is used for designing complex optical systems. This program has not been used for elliptical lenses, but NASA personnel believed that the program would perform the desired design. The Fortran language program documentation and tapes were obtained from COSMIC and shipped to the researcher. The program, resulting from a study funded by the Jet Propulsion Laboratory, was capable of designing optical systems containing up to 100 planes, conic or aspheric surfaces, seven object points, six colors, and 200 rays. The program was written in Fortran IV for use on the IBM 7094 computer.

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

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

## PROBLEM NHLI-5 *Bonding of Metal to Ceramic*

A bonding technique developed by NASA for use in rocket nose cones has been used to solve a bonding problem in an artificial heart being developed under a National Institute of Health (NIH) contract.

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 also satisfy many stringent design and functional requirements typically demanded of high performance aerospace systems.

A variety of systems have been suggested for supplying electrical energy to an implantable artificial heart. An unanswered problem is that of the type of electrical-to-mechanical energy conversion system which will be used to carry out the pumping function of the heart. A piezoelectric system in which a column of ceramic disks is excited axially by electrodes interspaced between the disks is one of the candidates for this task. Such a device is illustrated below in Figure 5.

The ceramic disks are constructed so that they will exhibit piezoelectric properties, i.e., when subjected to electrical excitation they become mechanically deformed. Thus, 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. An alternating current excitation, therefore, results in successive expansions and contractions of the column. It is this mechanical energy that will power the blood pump.

Because of the importance of the physiological function performed by the energy conversion system, design configurations and techniques take on increased significance. In seeking to provide the desired longevity and high reliability of the energy conversion system, the technique of bonding the interspaced electrodes to the ceramic disks becomes an important consideration. In addition to the requirement for a mechanically strong bond, the bonding technique should neither contribute to the electrical breakdown of the ceramic disk nor decrease the conversion efficiency of the device.

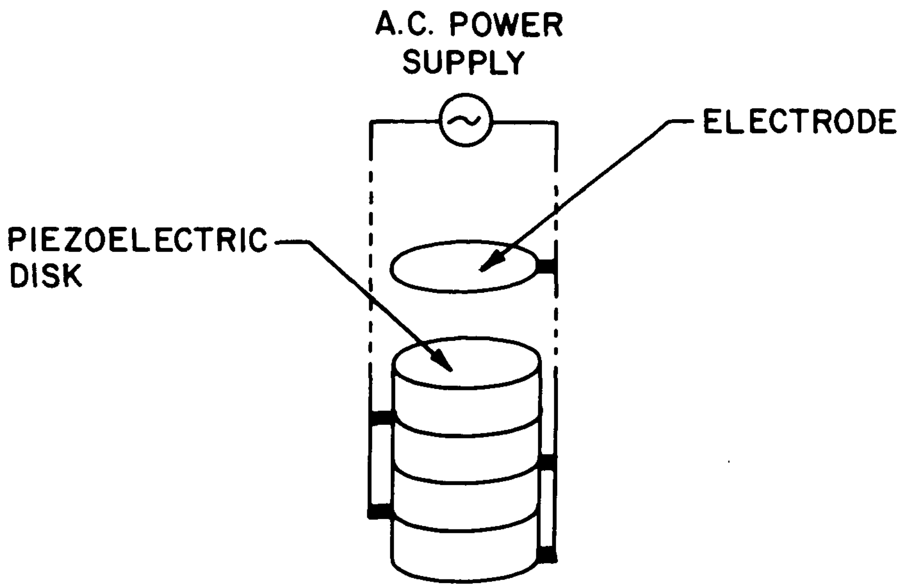



Figure 5. Piezoelectric stack bonding.

The Technology Utilization Office at Langley Research Center was informed of this problem, and Mr. John Samos was successful in locating an engineer, Mr. Ray Lovelady, who had constructed several piezoelectric stacks for preliminary investigations. The piezoelectric systems constructed by NASA were intended for use as ultrasound transducers to provide an acoustic signal to aid in locating rocket nose cones and other payloads which are submerged in water following reentry.

Of the variety of bonding techniques which had been explored by the Sensor Development Section at Langley, two techniques had emerged as being the best suited for the application in question: one employing epoxy and the other making use of mechanical loading. Epoxy bonding has been used at Langley in such devices as strain gauges and sound pressure sensors.

The NIH contractor was advised of the NASA development and tested the technique in the artificial heart. The bonding technique proved successful and was incorporated by the NIH contractor.

PROBLEM WF-103 *Liquid Crystal Sterilization*

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

The Team contacted MSFC with respect to this problem since MSFC has been active in using liquid crystals for nondestructive testing purposes. The medical researcher was placed in contact with personnel at MSFC, and the overall problem was discussed. The encapsulated liquid crystals developed for MSFC's use under NASA contract were considered to be an ideal solution to this particular problem. Mr. Juan Pizzaro of the Technology Utilization Office at MSFC obtained a variety of liquid crystal materials in encapsulated form. Also, personnel at Marshall who had experience in working with liquid crystals were consulted concerning the best means of sterilizing the encapsulated liquid crystals. Gas sterilization was suggested by the researchers at Marshall. Evaluation proved this to be the best solution to the sterilization problem. The liquid crystal material obtained from Marshall Space Flight Center was used by the researcher in several animal experiments to perform surgery on the kidney of dogs. The results of these tests indicated that the technique was very effective. The tests were performed in the following manner. The kidney of the dog was surgically exposed and then one of the arteries leading to the kidney was ligated. Then the kidney was placed in a cooling bath. Upon removal from the cooling bath, the artery not ligated furnished blood to the kidney, heating that portion of the kidney. The researcher was then able, using small strips of liquid crystals, to trace out the line of demarkation between the two arterial supplies. (See Figure 6). The juncture between the light and dark areas of the liquid crystal strips indicates the location of Broedel's line. This permitted incision into the kidney to be made without severing any major arteries.

Figure 6. Liquid crystal on canine kidney.

The advice on sterilization and the encapsulated liquid crystals supplied by the Marshall Space Flight Center was vital in the accomplishment of this transfer. The researcher is currently discussing, with a commercial supplier, the possibility of obtaining prepackaged sterile liquid crystal strips for general use in this surgical application.

## PROBLEM WWRC-14 *An Improved Axillary Strap*

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

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

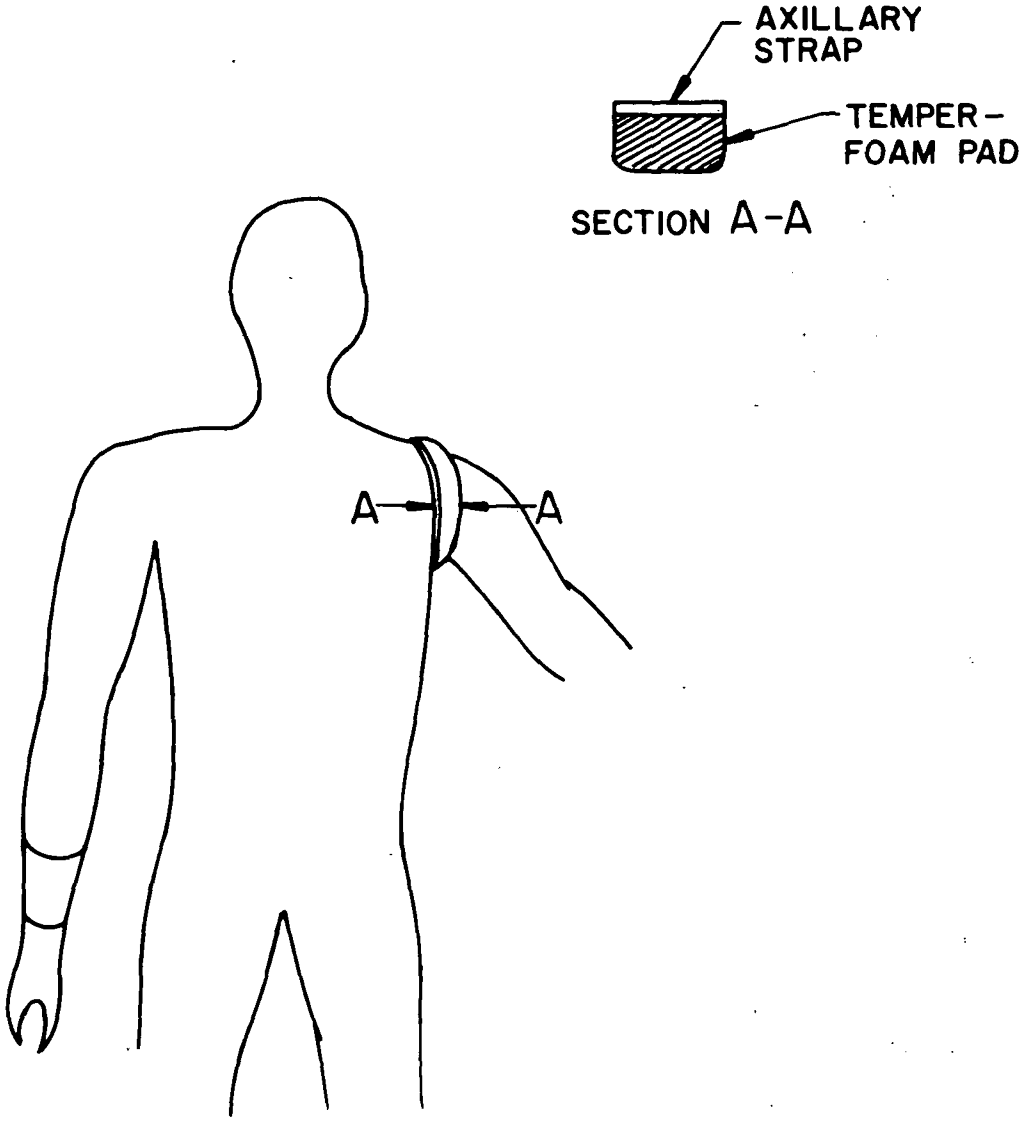



Figure 7. Axillary Strap Pad

that individually fitted straps that might be contoured to the patient's arm or shoulder would not be acceptable. This strap must be capable of being used by a large number of people.

The NASA-developed polymethane foam material proposed by Ames Research Center was felt to offer the possibility of solving this particular problem. (See Figure 7).The foam is a special material which has some unique characteristics. It absorbs energy which would make it attractive in this application because cushioning and spreading of the force exerted by the shoulder is considered to be the primary means whereby this problem can be solved. The material will mold to the form of the body with which it is in contact. Because of the thermal characteristics of the material, it is sensitive to temperature and pressure which both affect its elastic properties. This thermoviscous material, when used in a shoulder strap such as this, would conform to the body and with the application of pressure would deform to yield uniform pressure across the pad rather than concentrating the pressure which is the source of the problem. A sample of the material was obtained for the medical researcher who then initiated an evaluation program. Evaluation has proved that this material is better than anything previously tested in preventing soreness caused by the axillary strap.

## 2.2 Potential Technology Applications

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

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

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

Many studies involving gait, locomotion, spinal damage, etc. require time-spatial measurement of various bones with respect to each other or some external reference. These studies are important for the diagnosis of gait abnormalities and for the evaluation of the effectiveness of therapeutic procedures and prosthetic attachments in improving treatment of disabilities associated with locomotion. In the past, photographic and TV techniques against one or more reference grids have been employed to obtain this information in a more or less fragmentary and hard to measure fashion. These techniques require that the measurements be taken in a laboratory or other prescribed environment in order to maintain proximity to the optical recording apparatus and the reference grids. It is desired to obtain a method of measuring the position of bones of the legs and hips with respect either to an external reference point or to a movable reference point on the body. For preliminary applications the attachment of mobility limiting devices such as cables will be permitted to prove feasibility of the measurement techniques. The eventual goal of these studies, however, is to obtain such measurements when the subject is free-ranging in his normal environment. This will require telemetric transmission of these data to a remote point. Essentially, sensors which can provide quantitative data on their positions with respect to each other or some external reference are desired.

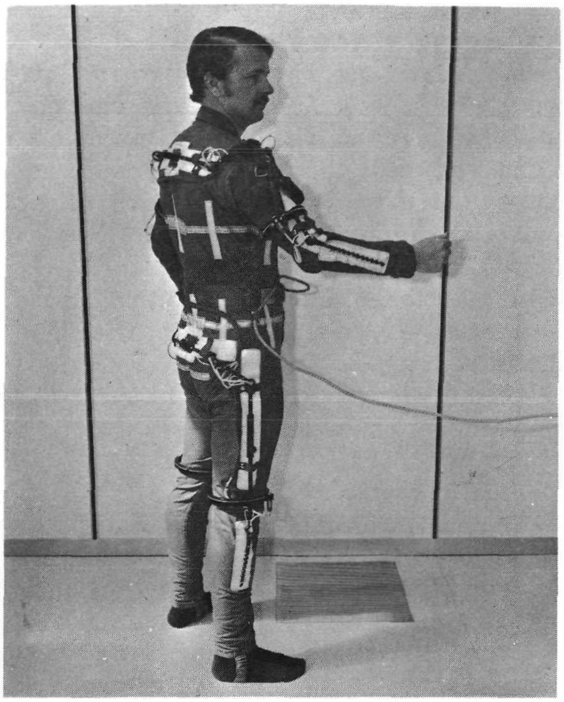


Figure 8. NASA exoskeleton suit.

The potential solution to this problem was discovered as a result of personal communications with personnel at the Langley Research Center. (See Figure 8). A specially instrumented suit for the Crew Vehicle Disturbances Study in the 1973 Skylab Mission was developed at the Langley Research Center. The suit essentially consists of a partial exoskeleton which is fitted to the individual by means of a suit. Potentiometers are used at the various joints and also on rings located on the arms and legs to provide information on the angular relationships between the joints. The rings on the arms and legs provide information on rotation of the arms and legs. This unit is lightweight and compatible with the overall requirements of the problem. The results at LRC indicate that precision of measurement of rotation of one member with respect to the other using this technique approaches plus or minus one percent. It is anticipated that some difficulty may be encountered in affixing the exoskeleton to the patient. However, this difficulty may be overcome by the light weight and relatively small size of the exoskeleton. For these preliminary studies it is anticipated that only the lower half of the exoskeleton unit will be required since the studies are primarily concerned with gait analysis. The present suit developed at LRC uses an umbilical cable to transmit data from the potentiometers on the exoskeleton to the data processing equipment. A study has been made of the requirements involved in instrumenting a telemetric system and the design of the telemetry apparatus has been completed. If evaluation of the exoskeleton proves that this approach will provide the necessary data for the analysis of gait abnormalities and the other aspects of the planned locomotion studies, then it is expected that telemetric techniques will be required to obtain the greatest utility and versatility in the use of this technique.

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

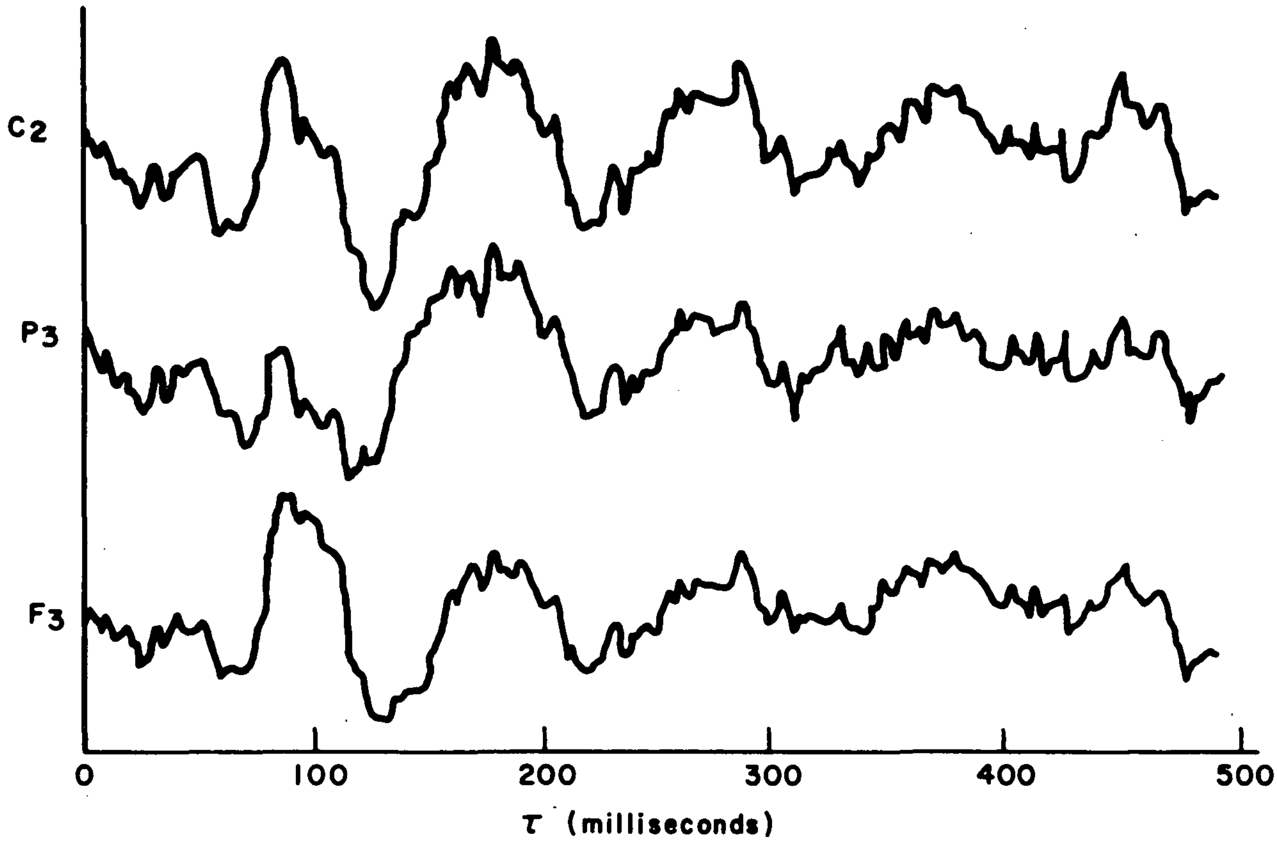
A special helmet developed by NASA may prove useful in measuring neurological disorders.

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

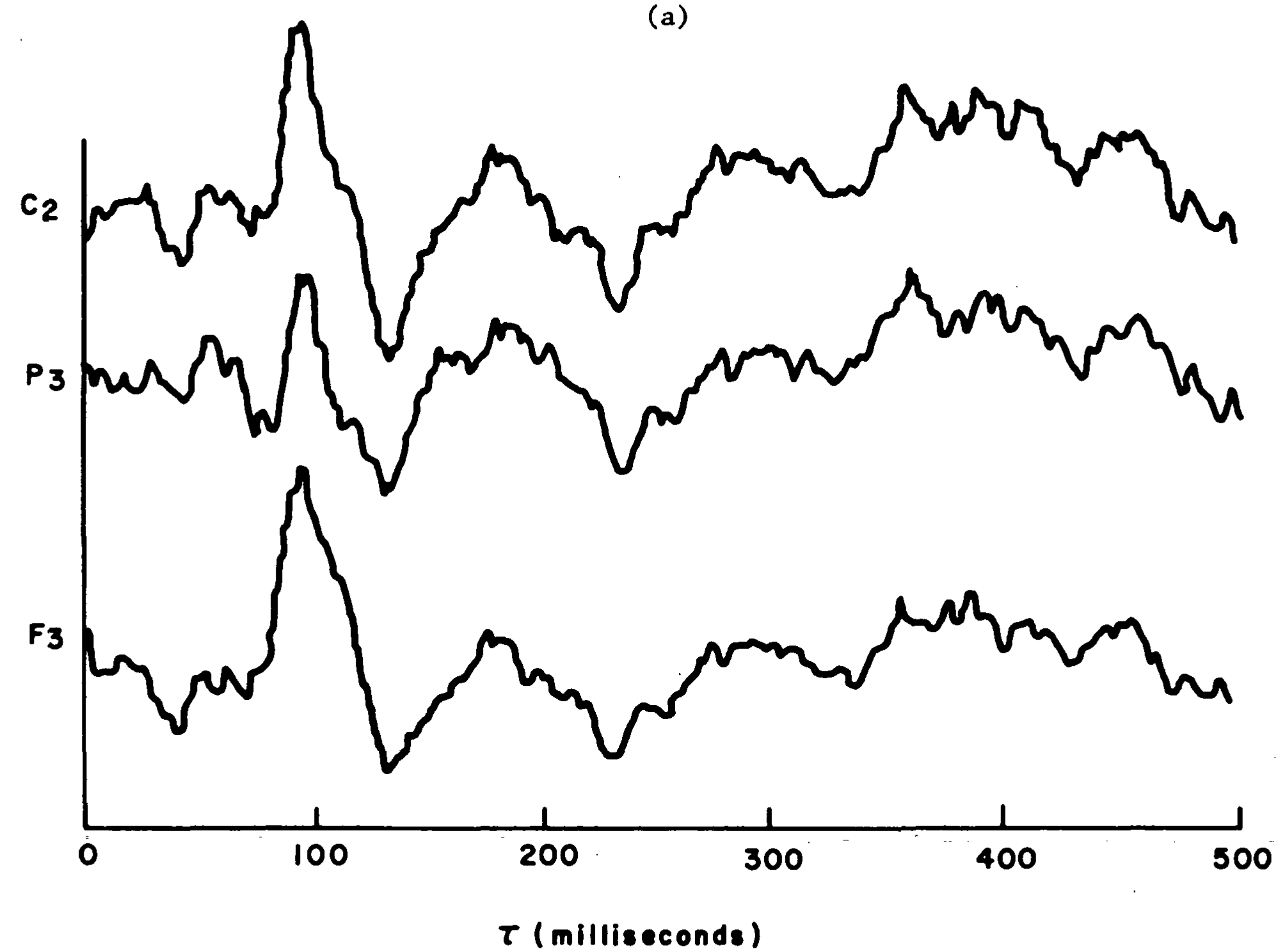
At the present time, evoked responses as measured by electroencephalograms (EEG) are used as an index of dysfunction. In this technique, stimuli of various kinds (auditory, visual, tactile, etc.) are presented to the patient, and the EEG is recorded from electrodes attached to the patient's skull at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

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

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




(a)




(b)

Figure 9. Visual Evoked Response with Conventional Electrodes (Average of 200 Trials).

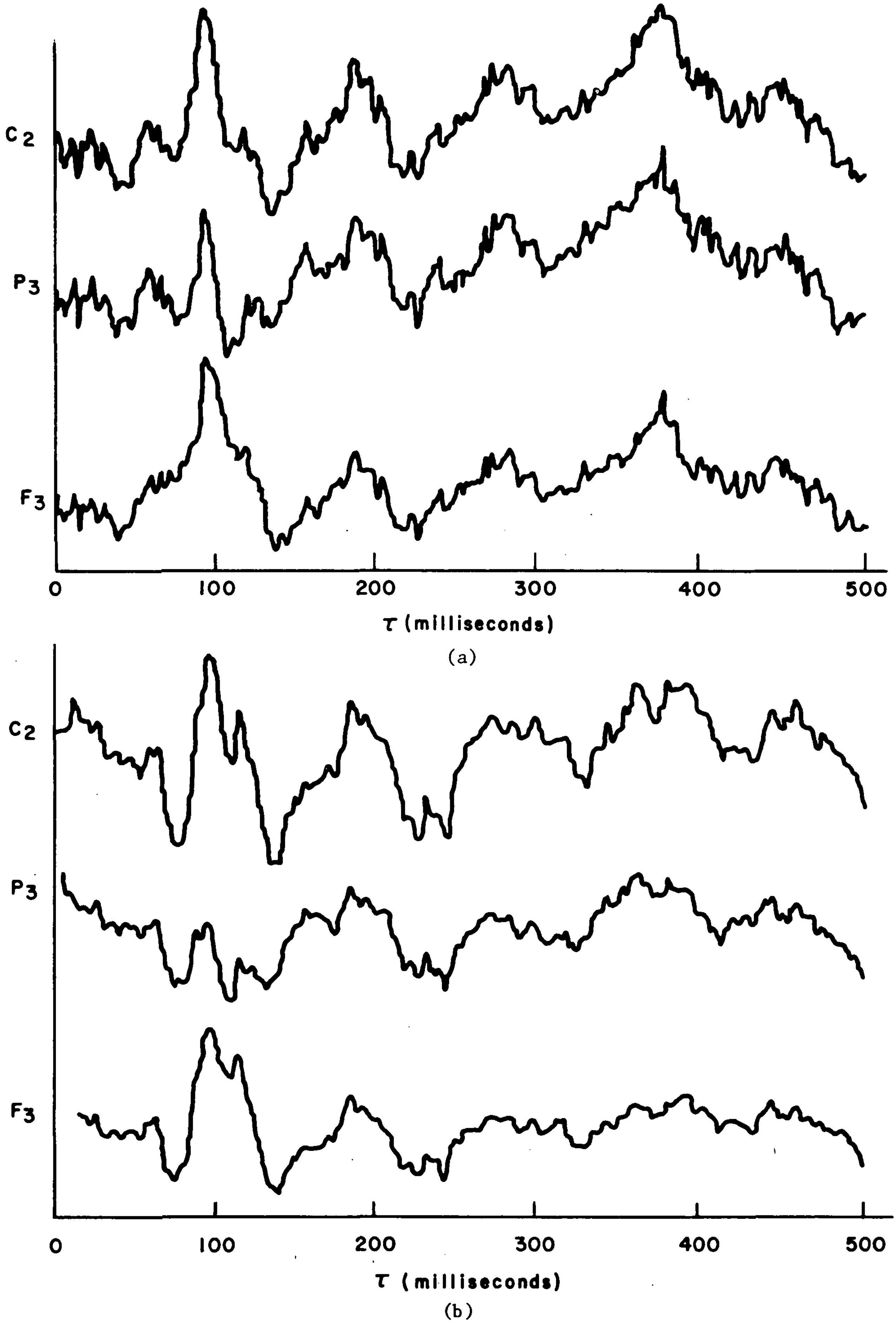



Figure 10. Visual Evoked Response with EEG Helmet (Average of 200 Trials).

First, a subject was fitted using EKG solution and conventional silver dish electrodes mounted with collodion. Three electrodes were employed, one each at the $C_z$, $P_3$, and $F_3$ positions, with all signals referred to the left ear. Visual evoked potentials, obtained by using a strobe lamp, were recorded for 200 stimuli. The data were averaged by computer and the average evoked potential for each lead was plotted (See Figure 9a). The test was repeated using the same electrodes in order to obtain some idea of the variation to be expected with this subject. These data are plotted in Figure 9b.

The conventional electrodes were removed, the skull carefully cleaned to remove collodion, and the helmet was fitted. Electrode placement was adjusted to obtain, as nearly as possible, the same locations as in the previous trials. The subject was then stimulated using the strobe for 200 flashes as before, and the averaged EEG curve for each lead was plotted (See Figure 10a). Since the electrode conductor in the helmet electrode is actually saline solution, it was decided to inject saline into the electrodes (as might accidentally occur occasionally). Saline was injected until it ran down the sides of the patient's head and the tests were repeated. The data from this test are shown in Figure 10b. It can be clearly seen that excess saline has little observable effect on the records. It was concluded from these tests that (1) the helmet technique provides EEG records that are of comparable quality to those using conventional techniques, and (2) the helmet method is faster and easier than conventional techniques if more than one electrode is involved. Further, it would be significantly faster and easier for the application of seven electrodes on children as is desired by the researcher.

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

The EEG helmet has fully demonstrated its capability to solve the researcher's problem, and efforts are being made to obtain one for his use through the reengineering activities of TUD.

## PROBLEM MISC-6 *Motor for Powering Prosthetic Unit*

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

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

The basic problem is to design a prosthesis that will permit the boy to go up and down stairs. The researcher has contacted many specialized prosthetics and rehabilitation centers both in Europe and the United States. Unfortunately, little practical experience is available to draw upon in the rehabilitation of one so severely handicapped. The researcher has evolved a design in which the prosthetic legs can be made to telescope by means of a drive motor in the leg. (See Figure 11). Such a telescoping prosthesis would allow one of the legs to be lengthened to the height of the stair tread so that the other foot could be placed on the next step. The boy would then transfer his weight to the upper leg, and the extended leg would be shortened to the proper height to permit him to stand on the level with both feet on the upper stair tread. The process would then be repeated, thus allowing the boy to traverse the stairs.

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

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

Figure 11. Hydraulic version of prosthesis.

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

## PROBLEM NHLI-1 *Intramyocardial Stress Measurement*

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

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

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

A search of the aerospace literature uncovered many interesting types of pressure and stress transducers; however, none was well suited for the application in question. The Team was aware of two NASA-developed pressure transducers that are significantly smaller than commercially available devices: one developed by Mr. Grant Coon at Ames Research Center, the other by Dr. Wilhelm Rindner, formerly at Electronics Research Center (ERC). The Ames transducer is potentially applicable to this problem; however, more developmental work is necessary. The ERC transducer appears to offer a possible solution to the problem.

The Team loaned an ERC transducer to the problem originator, Dr. Karl Weber, of the National Heart and Lung Institute (NHLI) and assisted in a preliminary experiment with a live animal. Although the preliminary experimental results are not yet fully understood, it is evident that mechanical stress in the heart muscle does undergo changes as the region surrounding the transducer becomes ischemic. Additionally, Dr. Weber has detected changes in the myocardial stress characteristics as the hemodynamic properties of the heart are altered by the administration of certain drugs. Dr. Rindner has provided the transducer in the form of a needle in order to make it somewhat more suitable for probing the heart ; evaluation tests are underway. (See Figure 12).

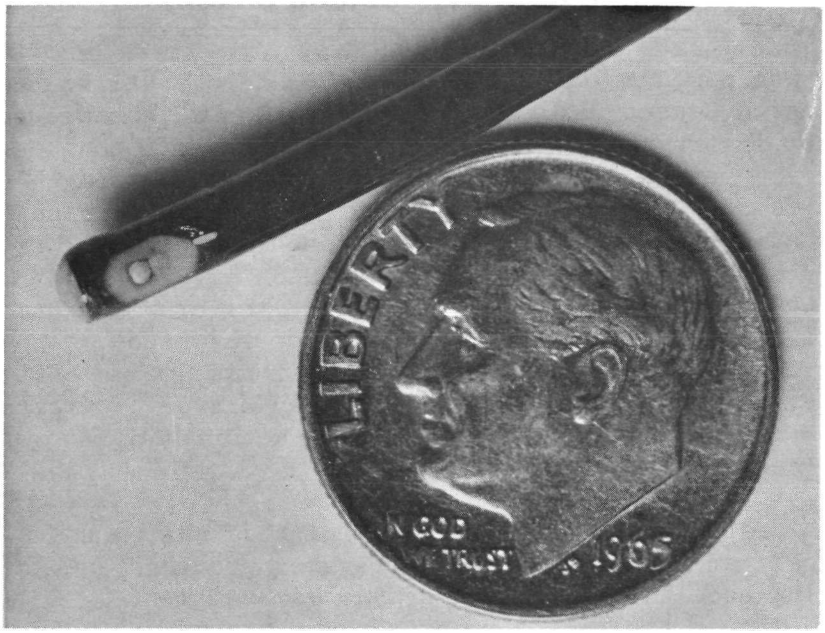



Figure 12 NASA pressure transducer. (ERC)

PROBLEM VAM-2 *Diagnosing Gait Abnormalities*

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

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

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

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

The problem was posed to Mr. John Samos, Technology Utilization Officer at Langley Research Center (LRC), who contacted an LRC engineer experienced in accelerometer instrumentation. Discussions with this engineer revealed that there were several problems involved in instrumenting a patient with accelerometers and that an alternate approach should be considered. He suggested that we contact the LRC staff concerned with the Crew Vehicle Disturbances study which is scheduled for NASA's 1973 Skylab mission. This experiment was designed to assess the effects of crew motion on the attitude stability of a manned spacecraft. To conduct the study, a device for determining the position of an astronaut's limb segments relative to the torso was developed. This system is actually a type of exoskeleton incorporated into a pair of coveralls which measures joint rotations in real time. (see Figure 8).

Team members discussed the applicability of this system to the study of pathologic gait and concluded that the system provides an excellent method of determining acceleration of the body's limb segments. In addition, the system yields the actual position of the limb segments in space which will be of even greater benefit than the acceleration data alone. The Team has made arrangements with the principal investigator for the Skylab Crew Vehicle Disturbances experiment to obtain the limb position sensing system on loan to assess its potential in rehabilitation of patients with gait abnormalities.

## PROBLEM 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 compresses the tube thus preventing the flow of urine except when the patient wishes to empty the bag. The presently used 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 large 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. Whatever valving system is employed must permit easy operation. Exertion of pressure is the most effective mode in which these patients can perform a controlled action. Therefore, the best method for operation as far as the handicapped patient is concerned would be in a compression mode; that is, it is desired that the valve technique be capable of operation by the application of pressure not to exceed two pounds, preferably less.

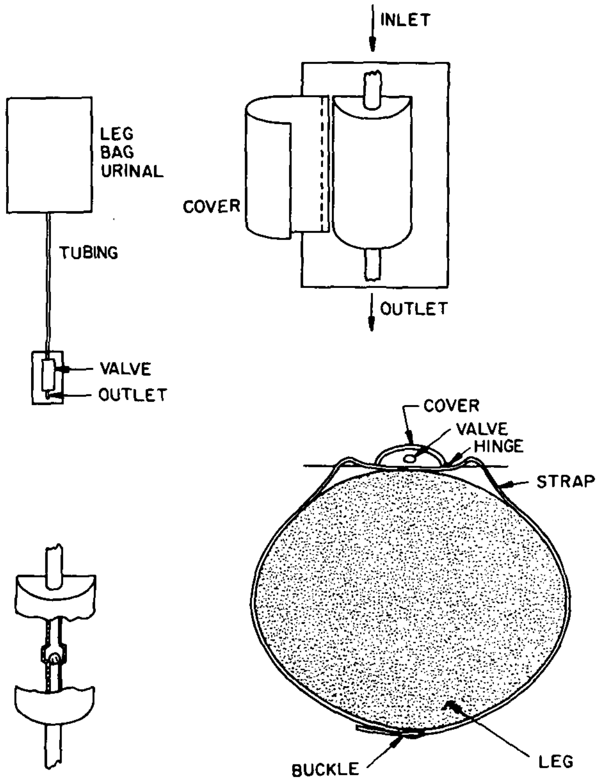



Figure 13. Urinal leg-bag valve (prototype).

When this problem was received, the Team realized that the specially developed check valve used in the fabrication of Applications Engineering Project WF-3, "Prosthetic Urethral Valve," might potentially be useful in this particular application since this check valve could be actuated by a simple pressure application. The details of this check valve were discussed with the medical investigator. As a result of the evaluation of this suggestion, it was concluded that the check valve from the prosthetic urethral valve had potential as a solution to this problem. In order to perform an actual "in use" evaluation of the valve, one was obtained from Dr. McCartney at the University of Virginia who performed the application of engineering on the prosthetic urethral valve. The main question was whether or not the patients could actually actuate the valve whenever desired. The "in use" evaluation by the medical investigator has indeed determined that the patients could operate the valve very effectively.

It was also apparent that the small diameter of the valve would require an inordinantly long time to empty the leg-bag urinal. The medical investigator now feels that if two prototype valves can be obtained and modified to the proper size, then full evaluation could be completed. In addition, the medical investigator intends to contact commercial suppliers to discuss the possibility of having a commercial supplier manufacture these devices for widespread use. The Team is fabricating one of the valves for evaluation by the medical investigator. (see Figure 13).

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

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

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

The patients requiring such a signalling system generally have voluntary control of one or all of the following functions which could 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.

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

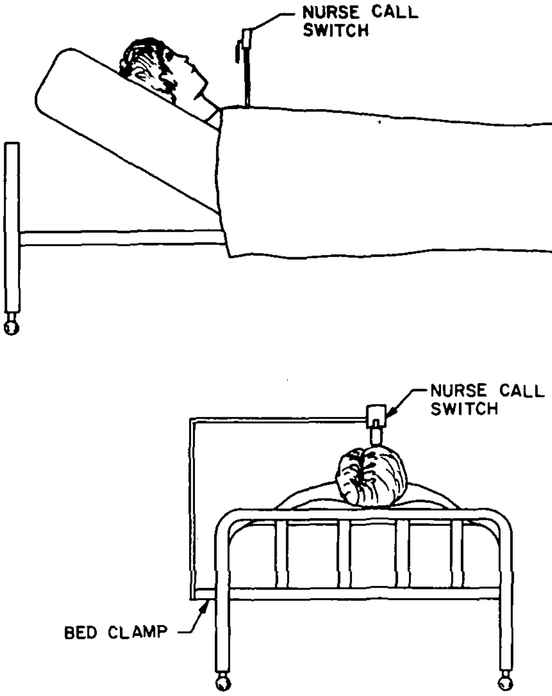



Figure 14. Breath-actuated switch.

The Southwest Research Institute (SwRI) Team has been working for some time with the Marshall Space Flight Center and the Langley Research Center on a device to permit paraplegics to perform a number of functions from their beds. The system which is being developed employs a breath-actuated switch suggested by personnel at the Langley Research Center along with a logic circuit which permits the patient to control a number of electrically activable devices from his bed. The system being developed for the application identified by the SwRI Team is more complex than that required by the problem at WWRC. The Problem at WWRC is merely to call the nurse and, essentially, a substitute for the hand activated nurse-call button is required. (see Figure 14). At WWRC a commercially available unit is used to permit communication between the nurse station and the patient by means of an intercom system. The system is activated by a call button. Although the problem at WWRC does not require the complexity of that required at SwRI, the breath-operated microswitch suggested by LRC as the control element for the more complex system can be used in conjunction with the commercially available system at WWRC. The Langley suggested breath-actuated switch appears to be completely compatible with the current installation at WWRC. This, of course, is a very significant advantage. One of the breath-actuated switches has been obtained for evaluation at WWRC. Should the evaluation prove that the breath-actuated switch is a viable solution to the problem, it is anticipated that WWRC will convert all multiple sclerosis and paraplegic call stations to the use of the breath-actuated microswitch.

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

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

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

This problem was discussed in the Langley Researcher Newspaper by Mr. John Samos, Technology Utilization Officer at the Langley Research Center. In June 1971 we received a suggested solution from Mr. George M. Dudley of the Force Measurements Section, Instrument Research Division of the Langley Research Center. The suggested solution involved a vacuum pickup with a transport mechanism operated by an electric motor. Mr. Dudley was interested in this problem and decided to fabricate a working model shown in Figure 15 for evaluation by the researcher at the Woodrow Wilson Rehabilitation Center. In December the unit was completed, and the Team visited Langley for a demonstration. The device will be placed in the hands of the researcher at the Woodrow Wilson Rehabilitation Center for evaluation. It is expected that a refinement of the model to reduce size and mechanical complexity will be undertaken should this phototype model be acceptable to the researcher.

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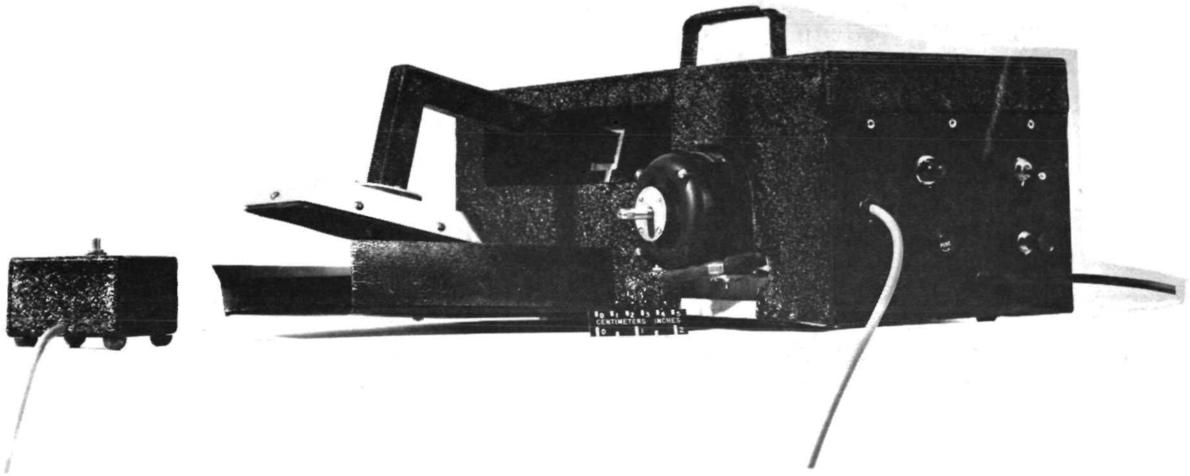

Figure 15. Paper transport device.

## 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 three such problems which are discussed in the following summaries:

### PROBLEM NCI-7 *Method of Fast Warming of 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 adquate 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, "Method of Controlled Rate of Cooling in Liquids." The second part of the storage problem being studied by the National Cancer Institute (NCI) is the warming or thawing of the frozen white blood cells which is the subject of this problem.

One important parameter in the successful warming of cells is believed to be the rate of temperature change 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. (To prevent contamination of the cells, it is desirable that any new technique allow the use of a Teflon container). This infrared system is unsuitable because the cells are warmed neither uniformly nor fast enough. Because of the high rate of thermal energy transfer required, it is unlikely that any system utilizing conduction as the major mode of heat transfer will be sufficient.

The basic requirement is to have a method of rapidly and uniformly warming a volume of frozen liquid from -150°C to room temperature. The method should be capable of warming a 20 milliliter volume of cells from -150°C to room temperature in one minute. The thermodynamic properties of white cells are not known, but a good approximation is that they are similar to water. A problem statement was circulated to the NASA Field Centers, and the use of microwave heating was suggested by Mr. Charles H. Gresslin of Lewis Research Center. Mr. Gresslin's idea was relayed to the NCI researcher who stated his strong interest in the approach. The Team then calculated the microwave requirements and identified a commercial microwave oven as a possible solution. Although this oven had been used for other biological purposes, it had not been used for thawing of frozen or white cells.

After careful study of the microwave oven characteristics, the researcher has ordered the oven. The use of this oven will enable the researcher to determine whether the proposed rapid warming of frozen white cells is a valid solution to the cell preservation problem. Successful conclusion of these tests will permit a partial solution to the major problem of cell preservation.

## PROBLEM WF-67 *A Filter to Separate Physiologic Data Occurring at Nominal Heart Rates from Lower Frequency Data*

At the Bowman Gray School of Medicine, large quantities of data have been and are being accumulated on blood flow, blood pressure, heart rate, and other measurable and derivable quantities that are related in time to the heart rate. These data are recorded on magnetic tape and strip charts. The heart rate is, of course, periodic, nominally occurring approximately once per second. Superimposed on this data, and appearing as noise, is a much more slowly occurring waveform. The undesirable long period data appear to be related in some fashion to the respiration cycle. The amplitude of this slower rate waveform is large with respect to the heart rate related data. It causes serious baseline distortion and makes interpretation of the data difficult. The researcher wishes to obtain a filter which will separate the low rate waveform from the heart rate data. The researcher has requested that the Team aid him in identifying a low-cost filter design that can be used in this application.

The researcher made inquiry to the Team independently of this problem concerning a source for a high rate cardiotachometer to be used on primates. The Team suggested a Model MTH cardiotachometer manufactured by Microtronic Corporation, Carrboro, North Carolina. The design of this unit makes use of R-wave detection principles evolved by NASA. The researcher purchased one of the Microtronics cardiotachometers and has been using it in his laboratory. This unit has input filters that are very effective in removing the unwanted, respiratory-related signal fluctuations. It has been used in a number of applications, and tests have shown it to satisfy all the problem requirements.

## 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 one-quarter 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 attached to the night bag. Presently, the connection to the leg-bag consists of a sleeve slightly larger than the tubing, over which the tubing must be forced to complete the connection. This requires considerable grip and strength in the hands. Removal of the tubing from the leg-bag is much more difficult and can be quite hard for a person of normal hand strength to accomplish. Many of these patients have reduced strength and partial loss of function in their hands, so it is even more difficult for them. Upon arising in the morning, the tubing must be removed from the night bag and connection again made to the leg-bag. It is extremely important that these patients be made as self-sufficient as possible, not only from a practical standpoint, but also to lower their sense of dependence and thus improve their mental outlook.

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

The month following acceptance of this problem, Mr. R. R. Zimmerman of George Washington University suggested that a commercially available connector from the Cole-Parmer Instrument Company might prove to be a solution to this problem.

Information on the connector was obtained from the manufacturer and forwarded to the medical investigator who then ordered one of the connectors to determine its applicability to this problem. The connector has been evaluated in the clinical environment and has been found to be completely acceptable as a solution to the problem.

## 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 April 1, 1971, to December 31, 1971.

| | |
|---|---|
| *New Problems Accepted* | *38* |
| *Problems Rejected* | *6* |
| *Problems Inactivated* | *50* |
| *Problems Reactivated* | *2* |
| *Total Problems Currently Active* | *77* |
| *Preliminary Problem Statements Prepared* | *38* |
| *Problem Statements Disseminated* | *3* |
| *Responses to Problem Statements* | *22* |
| *RDC Computer Searches Initiated* | *25* |
| *Impacts* | *3* |
| *Potential Technology Applications* | *9* |
| *Technology Applications* | *5* |

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 May 6, 1971, Dr. F. T. Wooten presented a discussion of the Application Team Program to the Sanderson High School in Raleigh, North Carolina.

On May 18, 1971, Mr. Ernest Harrison presented, by invitation of the Long Island Rehabilitation Association, a discussion of the Application Team Program with particular emphasis on the relationship of the program to rehabilitation problems.

TABLE I

IMPACT AREAS OF ACTIVE PROBLEMS

| HEALTH AREA IMPACT CATEGORIES / PROBABLE SOLUTION REQUIREMENT | ANALYTICAL INSTRUMENT SYSTEMS | SYSTEM COMPONENTS (EQUIPMENT) | COMPUTER PROGRAMS | PROSTHETIC DEVICES | MATERIALS, CHEMICALS | THERAPEUTIC EQUIPMENT | OTHER | TOTAL |
|---|---|---|---|---|---|---|---|---|
| TOTAL | 31 | 26 | 2 | 2 | 7 | | 9 | 77 |
| OTHER, MISCELLANEOUS | 3 | 7 | | | 2 | | 1 | 13 |
| BASIC MEDICAL RESEARCH PROBLEMS | 7 | 2 | | | | | 3 | 12 |
| DETECTION AND TREATMENT OF DENTAL AND ORAL DISORDERS | 1 | | | | | | | 1 |
| IMPROVED SURGICAL PROCEDURES | 2 | 1 | | | | | | 3 |
| RESPIRATORY DISEASE DETECTION AND TREATMENT | 3 | 2 | | | | | | 5 |
| REDUCTION OF INFANT MORTALITY | | 2 | | | | | | 2 |
| KIDNEY DISEASE DETECTION AND TREATMENT | 1 | | | | | | | 1 |
| PROVISION OF MORE/BETTER MEDICAL/PARAMEDICAL PERSONNEL | | | | | | | | |
| REMOTE HEALTH CARE SERVICES | | | | | | | | |
| HEALTH CARE COST REDUCTION | | | | | 1 | | 1 | 2 |
| ECOLOGY | | | | | | | | |
| DETECTION AND TREATMENT OF CANCER | 5 | 1 | | | | | | 6 |
| DETECTION AND TREATMENT OF HEART DISEASE | 3 | 3 | 2 | | | | 2 | 10 |
| MENTAL HEALTH | | | | | | | | |
| ORGAN ASSIST DEVICES | 1 | 2 | | | 1 | | | 4 |
| ARTIFICIAL ORGANS | | 1 | | | 2 | | | 3 |
| REHABILITATION MEDICINE | 5 | 5 | | 2 | 1 | | 2 | 15 |
| MULTIPHASIC HEALTH SCREENING, CLINICAL DIAGNOSIS | | | | | | | | |
| COMMUNICABLE DISEASE DETECTION AND PREVENTION | | | | | | | | |

On May 18, 1971, Dr. F. T. Wooten presented a discussion of the Application Team Program to two civic clubs in eastern North Carolina.

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

On October 14, 1971, Mr. Ernest Harrison presented the keynote address at the Regional Physical Therapist Association meeting in Asheville, North Carolina. This presentation included a discussion of the Application Team Program as well as a movie of the Apollo 15 flight.

On November 1, 1971, Mr. Ernest Harrison presented the keynote address at the annual American Occupational Therapy Association meeting in Cleveland. This paper is attached as Appendix D of this report.

On November 17, 1971, Mr. E. W. Page presented Dr. Wooten's paper entitled "Advancements in Medicine from Aerospace Research" at the National Space Congress in Huntsville, Alabama. This paper is attached as Appendix E of this report.

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

### 3.4 Association for the Advancement of Medical Instrumentation (AAMI)

In order to enhance the impact on the medical community of technology applications, the Team is actively seeking industrial manufacture of marketable devices. One approach being used is a committee within the Association for the Advancment of Medical Instrumentation (AAMI) which is considering ways to advise and interest the industrial community in applications of technology. The second meeting of this committee was held on November 3, 1971, in association with the Conference on Engineering in Medicine and Biology in Las Vegas, Nevada. During this meeting, a number of significant problem areas were discussed. It is interesting to note that a major conclusion of the committee was that simplification of the patent right availability procedures is not a significant factor in whether a manufacturer will consider a particular product. A second significant point concerned how a particular industry selects a new product for marketing. This discussion seemed to indicate that some initial market research was necessary in developing significant interest in a new product. This particular point will be explored by correspondence of committee members before the next meeting of the committee in April, 1972.

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# 4.0 SUMMARY OF BIOMEDICAL APPLICATION TEAM STATUS AT USER INSTITUTIONS

## 4.1 Introduction

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

## 4.2 Summary Status for User Institutions Participating in the Program on December 31, 1971

*Duke University Medical Center* - This institution has been active in the Application Team Program for five years, and a total of 84 problems have been considered at this school. During the past two years, there has been a noticeable slackening of activity because of the reduction in Federal funds at this school.

*Bowman Gray School of Medicine of the Wake Forest University* - This school has been active in the Application Team Program for five years during which time a total of 107 problems have been considered. Activity has slowed noticeably in recent months and this lower level of activity is expected to continue at this school over the next year.

*University of North Carolina Medical School and Dental School* - A total of 90 problems have been defined at the schools of medicine and dentistry during the past five 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 level 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 26 problems have been considered and activity is expected to continue at a very satisfactory level.

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

*National Cancer Institute* - Activities at the National Cancer Institute (NCI) started in August 1969, and a total of 12 problems have been considered. NCI personnel have expressed satisfaction with the success of the program and 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 and problem definition started in November 1970. A total of 16 problems have been considered at this institution. Activity over the next year will emphasize implementation of existing potential solutions.

*National Heart and Lung Institute* - Activities started within the Medical Devices Application Branch of NHLI in September 1970. A total of seven problems have been defined and continued interaction is anticipated with 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 sixteen problems have been considered. Continuing substantial activity is anticipated at this school.

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

*Medical University of South Carolina* - In answer to an unsolicited request, the Team initiated activities at this school in March 1971. Activities are presently concentrated in one group of individuals in the Department of Surgery but efforts are being made to expand this activity to other departments.