NASA

APPLICATION TEAM PROGRAM

Applications of Aerospace Technology in Biology and Medicine

final report

september 1973-august 1974

RESEARCH TRIANGLE INSTITUTE
RESEARCH TRIANGLE PARK, NORTH CAROLINA

PREFACE

This report covers the medically related activities of the NASA Application Team Program at the Research Triangle Institute between September 1, 1973, and August 31, 1974, performed in accomplishing NASA Contract NASW-2459. 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; Dr. J. L. Allison (deceased); Mr. Ernest Harrison, Jr.; Mr. R. W. Scearce; Mr. B. S. Wilson; and Ms. Sharon Commee. Assistance from other members of the RTI staff was obtained as needed.

Medical consultants who contributed significantly to the project are Dr. A. E. Johnson, Duke University Medical Center, Durham, North Carolina; Mr. William Z. Penland, National Cancer Institute, Bethesda, Maryland; Professor Hal C. Becker, Tulane University School of Medicine; New Orleans, Louisiana; Dr. Jacob Kline, University of Miami School of Medicine, Miami, Florida; and Mr. Edward Wallerstein, Mount Sinai Medical Center, New York, New York.

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

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ABSTRACT

This report presents the results of the medically related activities of the NASA Application Team Program at the Research Triangle Institute. This experimental program in technology application was supported by NASA Contract No. NASW-2459 for the reporting period September 1, 1973, to August 31, 1974. 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; Dr. J. L. Allison, Physiologist (deceased); Mr. R. W. Scearce Biomedical Engineer; Mr. B. S. Wilson, Electrical Engineer; and Ms. Sharon Commee. In addition, the Team draws upon the capabilities of other members of the RTI staff as needed.

Sixteen 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; Illinois Pediatric Institute, Chicago, Illinois; Johns Hopkins University Medical School, Baltimore, Maryland; Medical University of South Carolina, Charleston, South Carolina; Mount Sinai Medical Center, New York, New York; National Cancer Institute, Bethesda, Maryland; National Heart and Lung Institute, Bethesda, Maryland; Tulane University School of Medicine, New Orleans, Louisiana; University of Miami School of Medicine, Miami, Florida; University of Mississippi Medical Center, Jackson, Mississippi; University of North Carolina Dental School and Dental Research Center, Chapel Hill, North Carolina; Veterans Administration Hospital, Oteen, 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 40 new problems for investigation, has accomplished 7 technology applications, 6 potential technology applications, 4 impacts, has closed 54 old problems, and on August 31, 1974, has a total of 47 problems under active investigation.

1.0 PROGRAM PHILOSOPHY AND METHODOLOGY

1.1 Introductory Comments

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

In 1966, NASA established a program using an active and directed methodology. In this program, Application Teams were established under contract to the NASA Technology Utilization Office. The Application Team methodology is active in that specific problems are identified and specified through direct contact with potential users of aerospace technology. The process is directed in that Teams interact only with potential users who are involved in reaching selected national goals. Four Teams specializing in biomedicine have been established at the following institutions:

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

Southwest Research Institute
8500 Culebra Road
San Antonio, Texas 78228

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

University of Wisconsin
1500 Johnson Drive
Madison, Wisconsin 53706

This report covers the accomplishments and activites of the Team located at the Research Triangle Institute for the period September 1, 1973, to August 31, 1974. In the remainder of Section 1.0, Team objectives and methodology are presented.

1.2 Application Team Program

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

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

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

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

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

Generally, technology relevant to specific problems is identified through three approaches: (1) manual and computer searching of the aerospace information bank created by NASA as part of its R&D efforts, (2) direct contact with the engineering and scientific staff at NASA Field Centers, and (3) circulation of concise problem statements to a large number of NASA scientists and engineers. Technology representing potential solutions to problems is channeled through the Team to the problem originator for evaluation and implementation as a solution to his problem. Alternatively, 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 Office of Technology Utilization has utilized reengineering or adaptive engineering capabilities of various NASA centers in those cases where feasibility had to be demonstrated. The Teams are responsible for identifying the NASA technology that is potentially a solution to a specific problem and for specifying the changes required in this technology. The adaptive engineering activity allows the Teams to demonstrate that the technology is in fact a solution to the problem and allows the problem originator to make use of the NASA technology in his research that might otherwise be impossible.

The successful transfer of information on aerospace technology to an individual or group in the medical field followed by successful implementation of the technology 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.

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

1.3 Methodology

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

Problem Screening - Effective problem screening is at least as important to the success of the Application Team Program as any of the operational steps identified in Figure 1. Analysis of the RTI Team's accomplishments in the early days of the program indicates clearly that a very significant fraction of the problems that were unsuccessfully investigated 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) Some unique characteristics of the problem or the problem originator indicates that investigating the problem will enhance the overall Team program.

AND

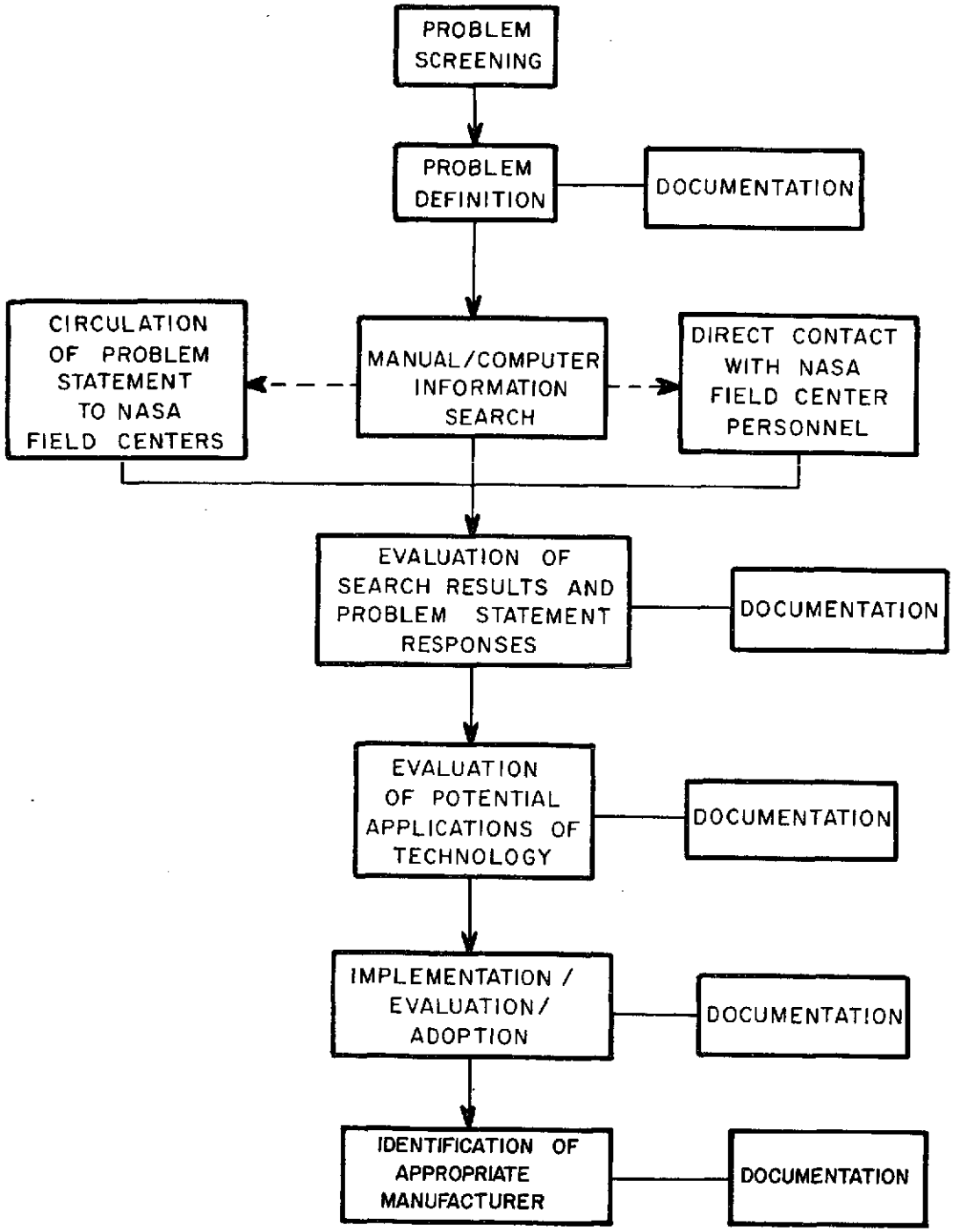


Figure 1. Flow Chart of Application Team Transfer Methodology.

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

AND

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

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

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

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

Identification of Relevant Aerospace Technology - Aerospace technology that may be relevant to the solution of a problem is identified by three approaches. First, a manual or computer search is made of the aerospace information bank. These searches are made at one of NASA's six Regional Dissemination Centers (RDC). The RDC used by the RTI Team is the North Carolina Science and Technology Research Center (NCSTRC) located in Research Triangle Park, North Carolina. In addition, searches are made utilizing the NASA Scientific and Technical Information Facility in College Park, Maryland. The information that can be assessed through the information bank consists of approximately 750,000 documents, articles, and translations that have been abstracted in the Scientific and Technical Aeropsace Reports (STAR) and the International Aerospace Abstracts (IAA). Second, the Team contacts individuals at the Field Centers directly without circulating problem statements. This is done when a Team member can identify a relatively few individuals at the Field Centers who are likely to have a good overview of all work being done that is related to the requirements of a specific problem. Third, problem statements are circulated to engineers and scientists at NASA Field Centers who may be able to identify relevant technology and suggest possible solutions to problems. These statements are circulated in a highly selective manner with the distribution being determined by the Team, Technology Utilizations Officers (TUO) at the NASA Field Centers, and other individuals at the Field Centers.

Evaluation - All potentially relevant technology identified in the preceding step is evaluated by the Team to determine whether a potential solution to a specific problem has been found. Those items of technology that represent potential solutions to problems are presented to problem originators along with available supporting data and information. Any required reengineering and the 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. This critical phase must occur in order for a technology application to be complete. The Team is available for assistance in this step when required, and attempts to identify the resources necessary to meet the implementation requirements. In many cases the actual implementation can be carried out by the problem originator and his staff. In some cases, however, skills not immediately available to the problem originator are required for implementation, and, in these cases, some other resource is utilized. This may require the use of a NASA capability at one of the Field Centers or at a NASA contractor. In other cases the implementation may be carried out by an industrial concern under contract to the problem originator. In general, the Team attempts to determine the most appropriate means of implementation and to make recommendations to the problem originator as required.

Identification of Appropriate Manufacturer - If maximum utilization of technology is to be achieved, then the technology must be available to physicians from a medical device manufacturer. To reach this goal, the Team actively seeks interested manufacturers for appropriate devices. Direct contacts are made to specific manufacturers, and, in addition, liason with the medical device community is maintained through the Aerospace Technology Committee of the Association for the Advancement of Medical Instrumentation.

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

1.4 Application Team Composition and Participating Medical Institutions

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

Name	*Background*	*Responsibility*
Dr. J. N. Brown, Jr.	Electrical Engineer	Laboratory Supervisor
Dr. F. T. Wooten	Electrical Engineer	Team Director
Mr. E. Harrison, Jr.	Materials Scientist	Solution Specialist
Dr. J. L. Allison (deceased)	Physiologist	Solution Specialist
Mr. R. W. Scearce	Biomedical Engineer	Solution Specialist
Mr. B. S. Wilson	Electrical Engineer	Solution Specialist
Ms. Sharon Commee	Secretary	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, 16 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;

Illinois Pediatric Institute, Chicago, Illinois;

Johns Hopkins University Medical School, Baltimore, Maryland;

Medical University of South Carolina, Charleston, South Carolina;

Mount Sinai Medical Center, New York, New York

National Cancer Institute, Bethesda, Maryland;

National Heart and Lung Institute, Bethesda, Maryland;

Tulane University School of Medicine, New Orleans, Louisiana;

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

University of Mississippi Medical Center, Jackson, Mississippi;

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;

Veterans Administration Hospital, Oteen, North Carolina;

Virginia Department of Vocational Rehabilitation, Fishersville, Virginia.

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

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

Name	*Speciality*
Dr. E. A. Johnson Duke University Medical Center	Cardiac Physiology
Professor Hal C. Becker Tulane Univeristy School of Medicine	Radiology
Mr. William Z. Penland National Cancer Institute	Engineering
Dr. Jacob Kline University of Miami School of Medicine	Engineering
Mr. Edward Wallerstein Mount Sinai Medical Center	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

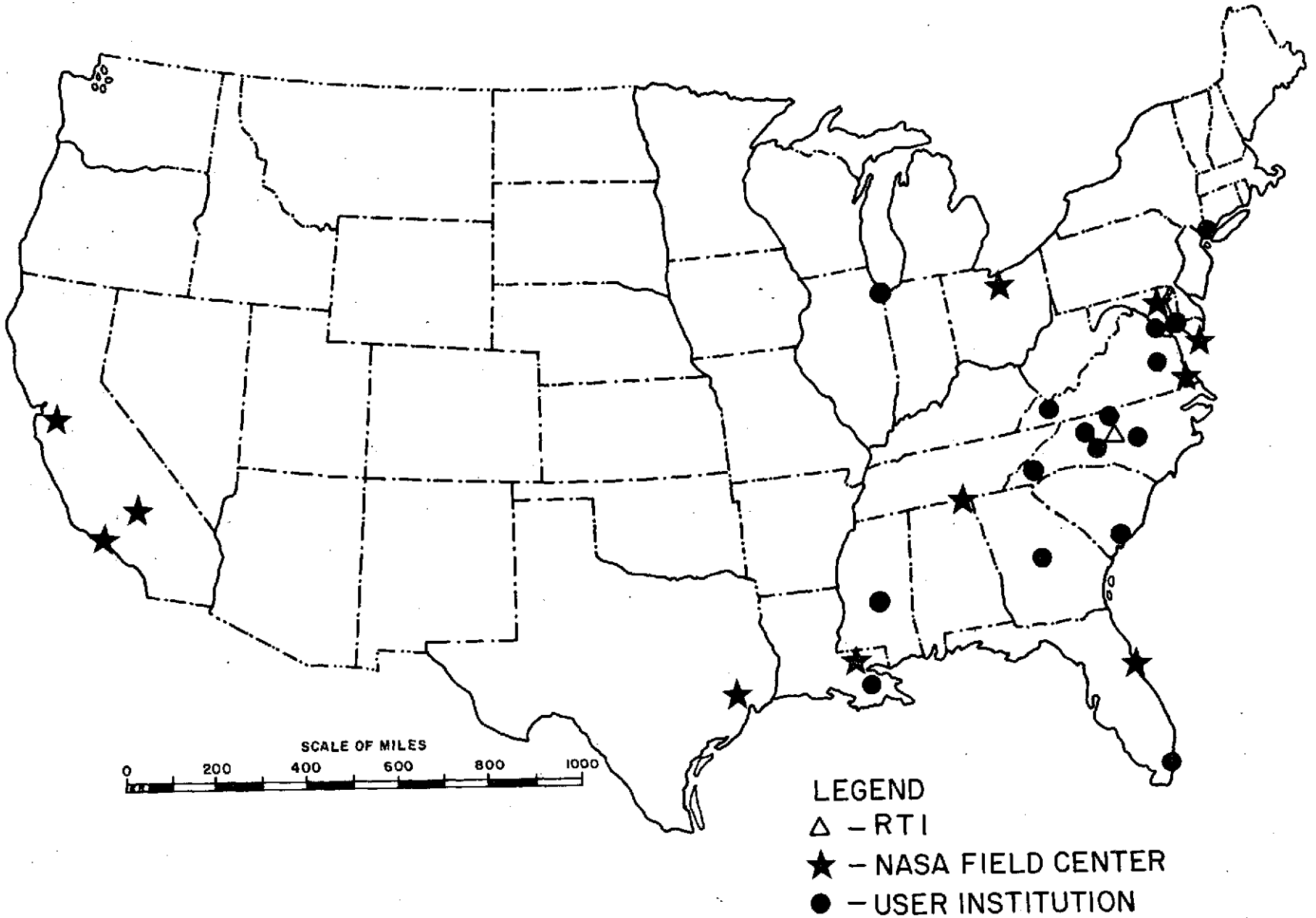


Figure 2. Team Activity Centers in the United States.

EU - Emory University School of Medicine
IPI - Illinois Pediatric Institute
JHU - Johns Hopkins University
MISC - Miscellaneous
MS - Mount Sinai Medical Center
MUSC - Medical University of South Carolina
NCI - National Cancer Institute
NHLI - National Heart and Lung Institute
TU - Tulane University School of Medicine
UMISS - University of Mississippi Medical Center
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
VAO - Veterans Administration Hospital
WF - Bowman Gray School of Medicine, Wake Forest University

1.5 Definition of Terms

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

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

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

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

Application Team (Team) - A multidisciplinary group of engineers and scientists engaged in problem-solving activities in medicine with the specific objective of effecting the transfer of aerospace technology to solve problems in medicine. The methodology used by the Team involves (1) problem selection, definition, and specification; (2) identification of potential solutions to problems by manual and computer information searching, circulation of problem statements to NASA Field Centers, and contacts with NASA engineers and scientists; (3) evaluation of potential solutions; (4) implementation and adoption by problem originators of aerospace technology as solutions or partial solutions to medical problems; (5) identification of appropriate manufacturers; and (6) documentation.

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

Problem Statement - This is a concise, written statement of a problem used for communicating (1) sufficient details to allow a computer search to be performed by the information search specialists, and (2) sufficient information to enable NASA engineers and scientists to consider possible solutions to the problem. This document should not be confused with a preliminary problem statement which is a one-half page brief introduction to the problem in a monthly report.

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 approximately 750,000 documents that have been indexed and abstracted in the Scientific and Technical Aerospace Reports (STAR) and International Aerospace Abstracts (IAA).

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

Potential Technology Application - The search for NASA technology by the application team leads to the identification of relevant technology that offers strong potential for solving the particular problem. A potential technology application occurs when the Team and the problem originator agree on the applicability of the specific NASA technology to the particular problem and when a reasonable plan for achieving implementation exists.

Technology Application - The key factor that permits a potential technology application to become a technology application is implementation. A technology application occurs when aerospace technology is implemented to solve a problem different from the one for which the technology was originally developed.

2.0 TECHNOLOGY APPLICATIONS, POTENTIAL TECHNOLOGY APPLICATIONS, AND IMPACTS

2.1 Technology Applications

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

PROBLEM CP-3 *Automated Measurement from Coronary Angiograms*

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

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

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

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

The Team determined that the information of interest was at the Jet Propulsion Laboratory. Details of the JPL VICAR software program were given to the researcher and he decided that the enormity of this project required that he work directly at JPL for a short period. Thus, he applied for and received a summer fellowship at JPL for 1970. During this period he learned the JPL image processing procedures, worked out his own algorithm, and determined that this approach could solve his problem. He then designed a modified system of image scanning and processing which was contracted by Dicomed Corporation. This equipment shown in Figure 3 was delivered and became operational in 1971.

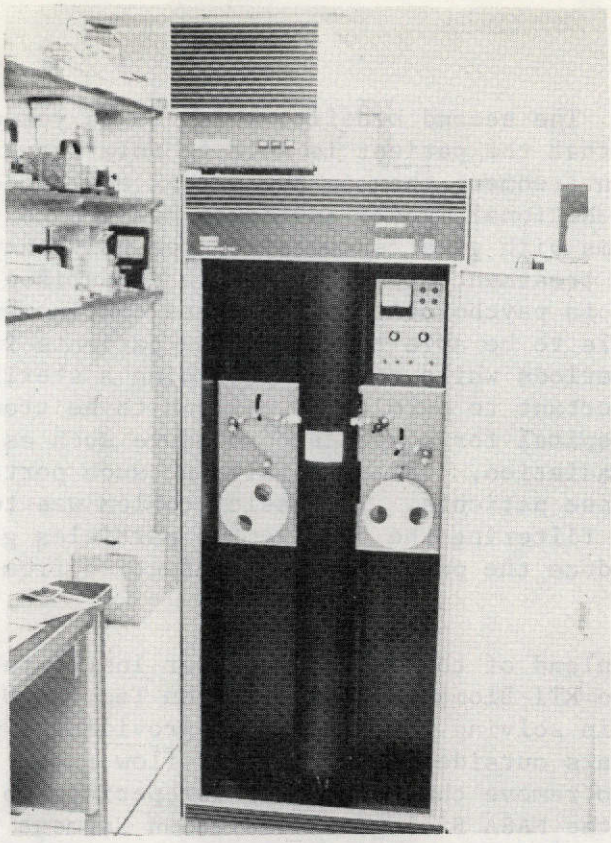
Following installation of the image scanning and processing equipment, a significant research effort was instituted in order to make the scanning procedures operational. At the present time, the technique has progressed to the point where a complete cardiac cycle can be followed by the automated equipment. Accordingly, the technique is now sufficiently operational to be used in clinical environment.

This technology application required many years to accomplish, but this time period was caused by the complexity of the technology as opposed to any inordinate delays in the transfer process. It is desirable to move as rapidly as possible in the accomplishment of technology transfers, but in cases of complex technological developments, a significant research program may require a long time period. This is perhaps the most complex technology application with which the Team has been involved, but its significance to medicine is truly great.

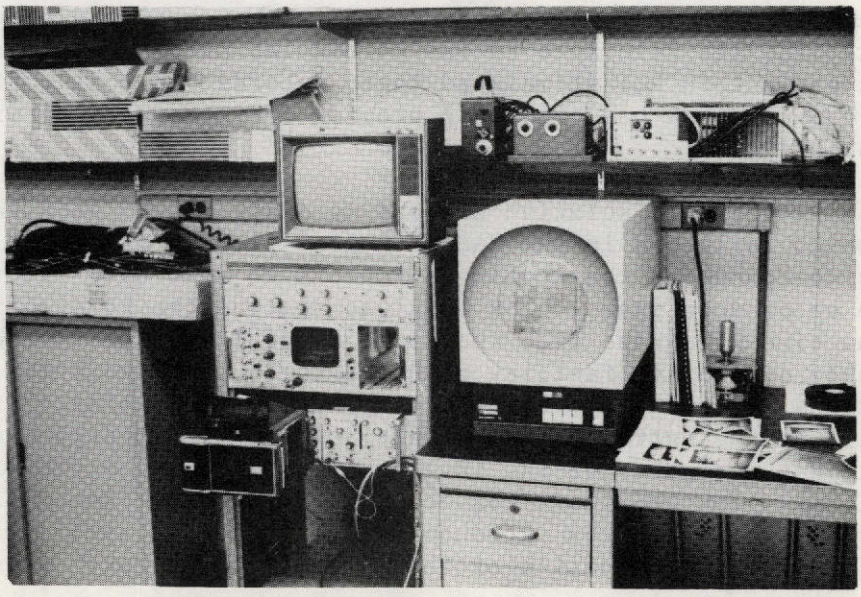
PROBLEM NCI-13 *Portable Isolation Garment*

A garment designed to isolate Apollo astronauts upon return to earth has been used to provide a portable sterile environment for cancer patients undergoing chemotherapy.

The National Cancer Institute (NCI) has pioneered in the use of laminar flow rooms to provide sterile environments for patients undergoing chemotherapy. This is required because the various drugs used in the treatment of diseases such as leukemia cause a severe reduction in the number of white cells, and thus the patient has a high risk of contracting



(A) Scanner



(B) Display

Figure 3. Image Scanning and Processing Equipment.

an infectious disease. The second benefit, which is as yet unexplained, results from the fact that the patient is able to tolerate higher drug doses in the sterile environment than in the normal environment. For the past several years the National Cancer Institute has treated adults in these laminar flow rooms with great success,and recently they have started using the rooms in the treatment of children. In comparison with adults, children are less able to psychologically tolerate confinement to one room, so it is desirable to be able to remove the patients from the laminar flow rooms for brief periods while still maintaining a sterile environment. In addition, it is important to permit the patient to be transported to another part of the hospital for a medical procedure such as diagnostic X-ray or therapeutic radiation. Unfortunately, no such portable isolation chamber existed for these patients. The basic problem was to provide a sterile environment by filtering the air (remove particles greater than 0.3 μm) in order to reduce the possibility of infection from a variety of airborne particles.

Mr. William Z. Penland of the National Cancer Institute contacted Dr. F. T. Wooten of the RTI Biomedical Application Team in October 1972 to ask for assistance in solving the problem of providing a portable isolation chamber for patients outside of the laminar flow room. It would be desirable to be able to remove these patients for periods up to 4 hours. Dr. Wooten identified the NASA Biological Isolation Garment (BIG) (see Figure 4) as a possible solution to this problem and contacted Mr. John T. Wheeler, Technology Utilization Officer at the Manned Spacecraft Center (MSC), who quickly identified Mr. Fred Spross as the cognizant technical staff member at MSC. Following technical discussion of the problem with Mr. Spross, Mr. J. C. Stonesifer of MSC forwarded a NASA BIG to NCI for their evaluation. The NCI staff used the BIG with normal individuals in order to determine its relevance to the particular problem. The quick loan of this garment to NCI stimulated their interest in this particular problem and expanded the basic idea to provide for its use in a wider range of applications.

The NASA Biological Isolation Garment is described in NASA Patent No. 3,516,404, which is listed in the NASA document file as N71-17599. The NASA BIG was designed for the Apollo astronauts to wear upon return to Earth in the splashdown phase. The unit was designed to be specifically worn from the time of egress from the command module to the time of arrival in the portable quarantine facility on board the recovery carrier. The NASA garment was designed to prevent contamination of the Earth's environment in the event that the astronauts were carrying some micro-organisms. Thus, the NASA unit was designed for the inverse of the problem at the National Cancer Institute. The NASA unit was designed to prevent contamination of the Earth's environment by the astronaut whereas the NCI application is designed to prevent contamination of the patient by the Earth's environment.

The major problem with the BIG concerned discomfort caused by heat and the claustrophobic aspect of the face mask. The NASA garment was designed for use with healthy adult males who are better able to tolerate a face mask than a seriously ill patient. The BIG face mask also accounts for part of the total weight of the garment, and it was desirable to reduce the weight. Thus the NCI personnel decided to add a positive pressure portable air supply, which offered advantages not only in the area of heat and weight reduction but also from the standpoint of contamination control. For example, many of the contaminants come from the surface of the patient's body; providing a directed flow of air from the top of the head downward reduces the danger of self-contamination. The reduction in sealing requirements also reduced the need for pressure sealing zippers, which are more difficult to operate than a simple Velcro fastener.

The NCI research team asked one of its contractors, Arthur D. Little, Inc., to design a garment based on the NASA design but modifying the face mask to better suit the needs of the NCI patients. The contractor performed extensive analysis of the flow in the existing BIG and was able to incorporate the relevant features of the NASA garment into the NCI garment. A prototype (Figure 5) of the NCI garment was built and delivered to NCI for clinical evaluation.

After modification of the prototype to meet the special needs of the NCI application, the garment was put into use with patients. This technology application has been an overwhelming success because the patient using the garment has been able to make frequent use of the garment over a one-year period. The speed by which this technology application was implemented was a major factor in its success and should be used as a model for future activities when clinical problems are encountered.

This garment is expected to have use wherever the laminar flow concept rooms are used in chemotherapy. These rooms are extensively used now by the National Cancer Institute, and several other hospitals are building facilities for their use.

A recent publication (D. G. Poplack, W. Z. Penland, A. S. Levine, Lancet, p. 1261, June 22, 1974) discussed this new technique for protection of patients susceptible to infection. As a result, a large number of requests for details of the garment have been received, and several newspaper articles have been written on the development. This is a further indication of the significance of this technology application.

Figure 4. Apollo 11 Astronauts Wearing Biological Isolation Garment.

Figure 5. Prototype Modified Biological Isolation Garment.

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

A new method for attaching EEG electrodes which was developed for the space program has been used with disturbed children.

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,and 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 these patients is 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 electro-encephalograms (EEG) are used as an index of dysfunction. In this technique, stimuli of various kinds (auditory, visual, tactile, etc.) are presented to the patient, and the EEG is recorded from electrodes attached to the patient's skull at points appropriate to the type of stimulus. Multiple electrodes are required, varying from 3 to 16 depending on the test. Attachment of these electrodes by conventional techniques (e.g., collodion) is very time consuming and frustrating to the patient, particularly to one who has received shock therapy.

Severely mentally retarded children present a particular problem. The problem originator wished to employ these techniques to determine neurologic dysfunction in these children who present very significant problems in handling. For example, it is virtually impossible to persuade such a child to remain seated for the 10 or 14 minutes required to attach the EEG electrodes. In addition, hostile reactions are not infrequent in which the child will remove an electrode while another is being applied. As a result, a simpler means for obtaining EEG data was required--specifically, a technique that would permit the installation of electrodes in a very rapid fashion.

Originally, the hard cap EEG helmet developed by NASA was identified as a potentially useful solution to this problem and one of the helmets was evaluated by the researcher. Clinical trials revealed that the quality of signal obtained using the EEG helmet was completely satisfactory. However, the difficulties in adjustment of the helmet still posed significant problems for use with children. The bathing-cap-type of EEG helmet developed at UCLA under NASA contract was then suggested as a configuration that might be easier to use. The techniques employed are basically similar to those used in the hard cap 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 adjustments to fit varying size skulls are not required. It is significantly lighter in weight than the hard hat helmet which is a distinct advantage with children. The problem originator developed a helmet (See Figure 6) based on the NASA design which has proved very satisfactory in clinical trials. He has made several innovations which have made the helmet easier to use and to fabricate.

Ease of fabrication has been considerably enhanced by employing the Beckman Silver-Chloride Electrode Biopotential Skin Electrode as the basic electrode unit. Special molds are employed to cast the Beckman electrode in a Silastic housing which mates with an attachment fixture on the helmet. Thus, electrodes can be attached and removed individually as required. In order to maintain electrode contact with the skin, the Beckman electrode is recessed, and a specially fabricated porous silicone rubber sponge with a cylindrical shape is inserted in the well into which the Beckman electrode is recessed. The sponge is filled with electrolyte, and when the cap is placed on the patient's head, the sponge is compressed providing contact between the skin and the electrode. The quality of signals obtained with these units has been comparable to the most carefully prepared individually attached electrodes. The ease of implacement, the light weights, all accomplished without degradation in quality of the received signals, have provided an extremely effective solution to this problem.

PROBLEM UNC-71 *Finger Joint Flexor*

A NASA innovation has provided improved rehabilitation procedures for patients with serious hand injuries.

A frequent task in rehabilitation is the preservation or restoration of mobility to the various joints of the hand. Unfortunately, several factors complicate this task. For example:

1. The patient experiences intense pain when the joint is moved.

2. The patient, especially the blind, experiences a feeling of claustrophobia when his hand is enclosed in a device from which he can't free himself.

3. As a result of the basic injury, the skin covering the hand and fingers is often extremely fragile.

Because of these complications, current treatment requires a skilled physical therapist to sit with the patient and manipulate the involved joint for 20 to 30 minutes. Besides restricting the therapist's activities, the treatment procedure itself has several limitations: (1) Since the patient is not in direct control, consistent maximal joint flexion is

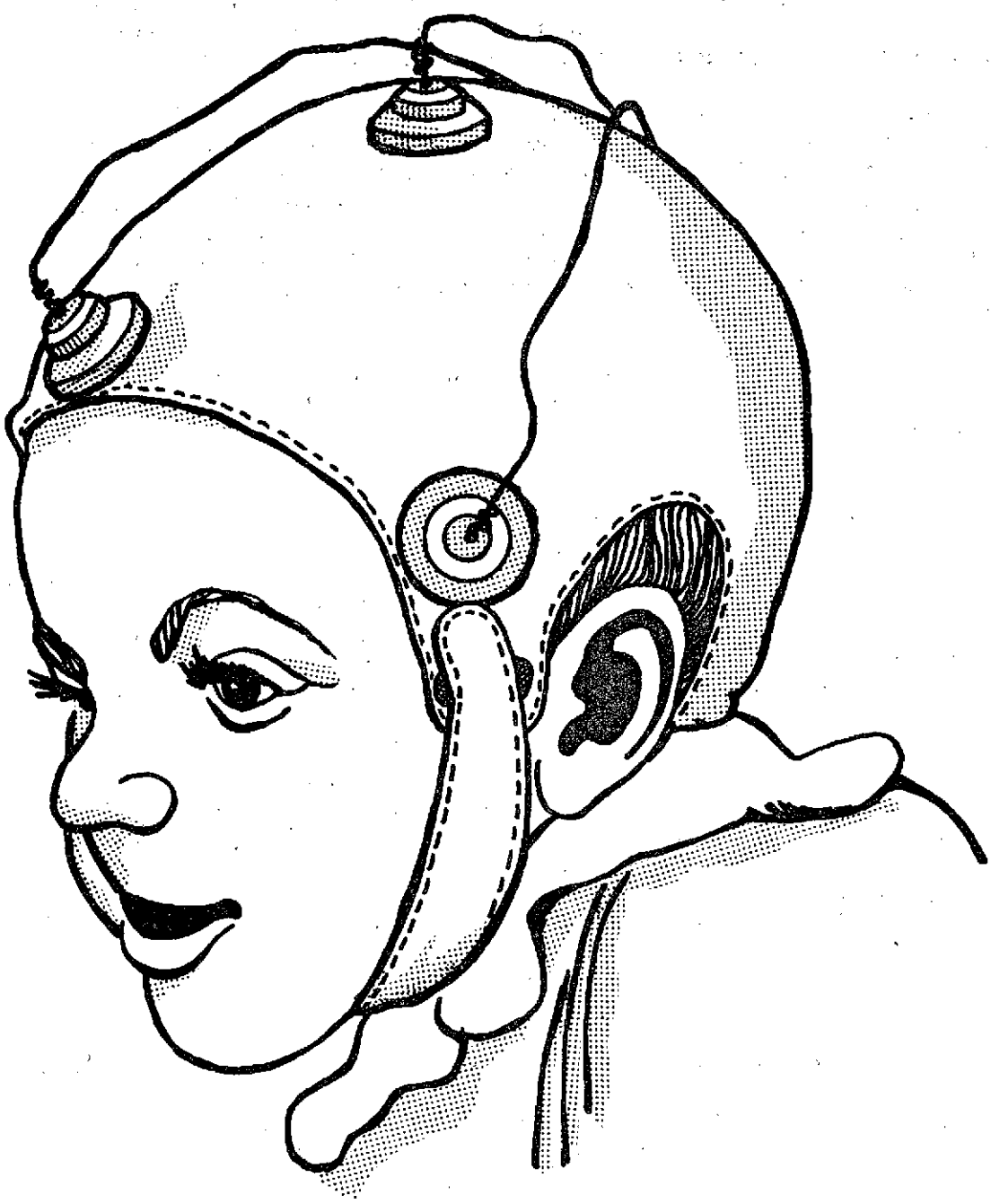


Figure 6. EEG Soft Helmet.

difficult. (2) The degree of flexion varies considerably with each manipulation. (3) When the patient leaves the Rehabilitation Center, therapy often becomes ineffective,and considerable joint flexibility is lost.

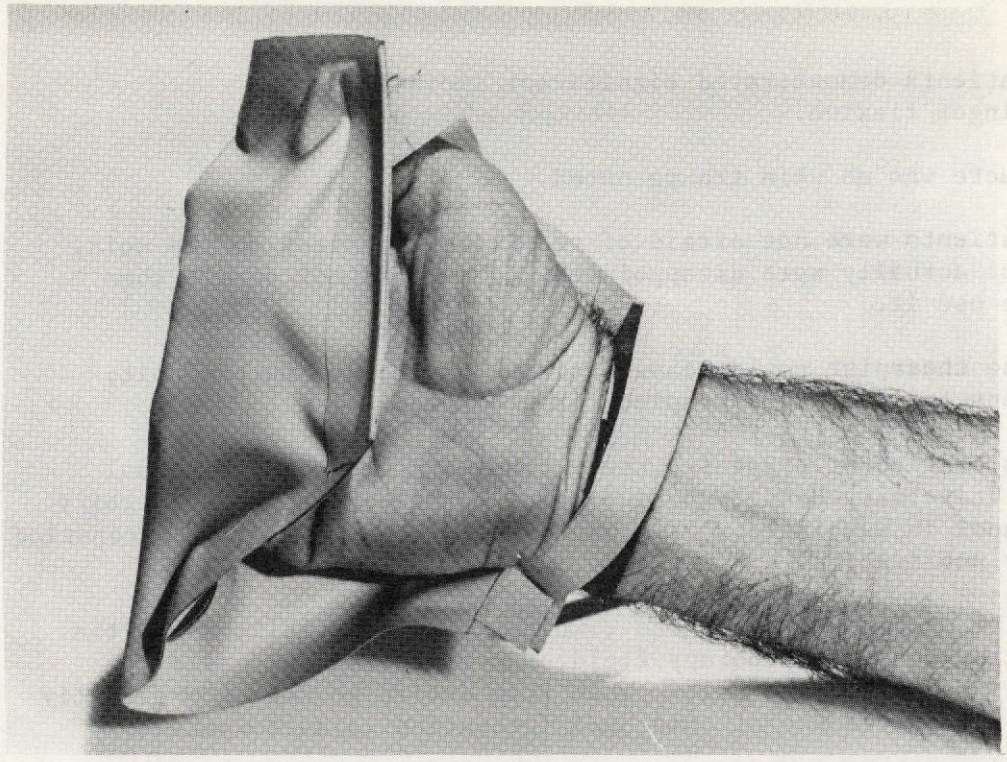
In an effort to solve these problems, personnel at the Hand Rehabilitation Center of the North Carolina Memorial Hospital developed a device which consists of an inflatable section of motorcycle innertube, a foot-operated pump, and a quick release pressure relief valve. The deflated innertube is placed across the palm,and inflation of the tube forces the fingers outward from the palm. Although the patient is in control, control of the orientation of the pressure applied to the joint and degree of flexion is not satisfactory.

It was apparent that a device was needed that would provide the desired therapy under the direct control of the patient. It must cause minimal trauma to the skin, and must be simple to operate, portable, and highly controllable.

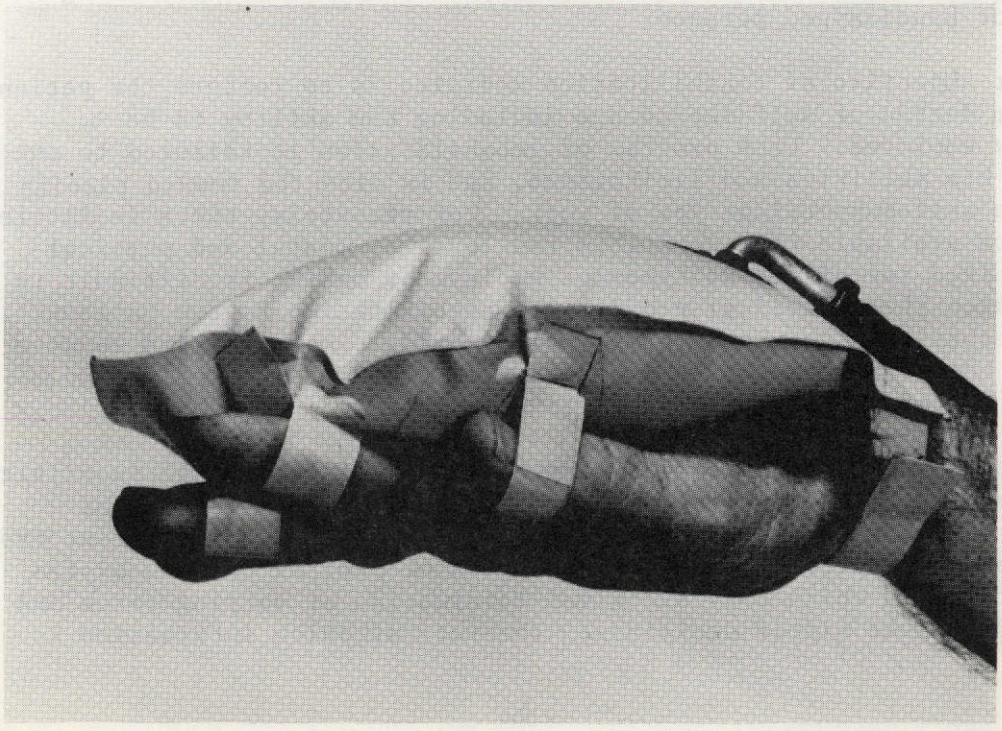
Mr. John Samos, Technology Utilization Officer at LRC, forwarded a suggestion from Mr. Donald E. Barthlome of the Systems Engineering Division. Mr. Barthlome, who has worked for several years on the design and development of the LX-1 Space Suit, proposed a mitt which is inflated by a highly controlled portable pumping system. The proposed system appeared to meet all requirements. However, evaluation of a prototype system at two hand rehabilitation centers (North Carolina Memorial Hospital, Chapel Hill, North Carolina; and Jackson Memorial Hospital, Miami, Florida) revealed several shortcomings. Mr. Barthlome made several design changes which provided additional control, an automatic inflation-deflation cycle, and a novel mitt design. This new system, shown in Figure 7, was demonstrated at the Hand Rehabilitation Center, North Carolina Memorial Hospital,in January 1974. Several force distribution problems were apparent. First, because fingers vary in length, the force exerted on the fingers was unevenly distributed. The longer fingers received more force, and the tips of the fingers were areas of very high pressure. There was also a high-pressure point associated with the strap about the wrist. In an effort to solve these problems, type T-38 Temper Foam (Dynamic Systems, Inc., P.O. Box 336, Arden, N.C. 28704) was placed between the mitt and the fingers and also under the wrist strap. The pressure points were eliminated, and the force was much more evenly distributed across the fingers. With this correction, patients have been able to use the Finger Flexor continuously for periods up to 20 minutes with significant improvement in finger flexion while developing no detectable skin irritation.

During the period January through April 1974, the problem originator conducted an extensive clinical evaluation. She kept the Finger Flexor in near constant use accumulating 6 hours operating time per day. Her results were:

1. The unit performed perfectly with no malfunctions of any kind.



(A) Open



(B) Closed

Figure 7. Finger Flexor.

2. Patients demonstrated significant improvement in finger flexion.

3. There was no skin trauma noted.

4. Patients were not afraid of receiving treatment on the unit, but actually were disappointed if time did not permit them to use it.

5. The therapist could leave patients unattended on the unit, thus freeing the therapist for other work.

The problem originator presented these results at the Second Annual Georgetown University Hand Symposium held at the Georgetown University Medical School in Washington, D.C. on April 18-20, 1974, and is preparing a paper for publication.

The firm of Fred Sammons, Inc., which is well established in the rehabilitation and psychotherapy field, has expressed the desire to manufacture and market the unit. When this device becomes commercially available, widespread use of this NASA innovation is anticipated.

PROBLEM VAM-12 *Blood Pulse Rate Indicator*

The integration of two NASA devices has resulted in a new testing procedure for handicapped persons.

A major objective of rehabilitation medicine is to restore the patient to a maximum degree of self-dependence including the ability to be successfully employed. Each program of rehabilitation is tailored to the individual, his abilities and limitations, and is directed toward placing that patient in a self-supporting-type of work. Unfortunately, there is little reliable data available that describes the level of mental and physical ability required for different types of employment, making it difficult to optimally match the individual program of rehabilitation to the patient. Therefore, especially in the severely handicapped, rehabilitation success is limited, hospitalization time is excessive, costs are enormous, and ultimately, too many patients become financial wards of the State.

The problem originator is directing a study to identify and quantitize the mental and physical ability levels required by different types of employment. He is subjecting individuals, both normals from different types of employment, and patients with various types of central nervous system damage, to tests in which they are given information at varying rates and are expected to make simple decisions. The rate at which information is

furnished is increased until the person under test experiences difficulty in making decisions. This level of difficulty is quantitized using a number of parameters such as heart rate.

Two major obstacles were delaying the study. One was a need for a minimally traumatic method for continuously monitoring instantaneous heart rate,and the other was a technique for presenting test information at varying rates. Several heart rate measuring systems are available which require electrodes that may irritate the subject.

A Marshall Space Flight Center (MSFC) employee and a Langley Research Center (LRC) employee suggested solutions to the two problems. The MSFC employee suggested the cardiotachometer that was developed at MSFC to monitor the astronaut's heart rate during the Skylab Mission. Mr. Juan Pizarro of the Technology Utilization Office at MSFC loaned an available unit to the problem originator. The cardiotachometer consists of an ear plethysmograph together with associated tachometer circuitry. The plethysmograph employs a light source which transmits light through the ear to a photocell. As the heart beats, the quantity of blood in the ear changes, thus modulating the intensity of the light energy received at the photocell. The tachometer circuitry produces a voltage output that is proportional to the heart rate in beats per minute. A digital or analog voltmeter is used to display the heart rate with an expected accuracy of 1-2 beats per minute.

The LRC employee suggested the LRC-developed Complex Coordinator as the testing system. It had been developed to test the effects of space-craft cabin pollutants on astronaut activities. It was designed to be used by individuals having control of all four limbs,but for the suggested application, a modification was necessary. Mr. John Samos, Technology Utilization Officer, LRC,located an available unit and made the necessary modification. The complex coordinator incorporates a series of random problems in coordination testing. The problem appears as an individual light activated on each of four separate panels. The problem is solved by the individual by motion of a handle provided for each hand and a pedal provided for each foot. Adjustments activate lights next to the test row which must be matched. When the problem is solved, the machine automatically displays the next problem as programmed in the series. This problem appears as a different combination of problem row lights. The individual proceeds to solve the series of problems in the same manner of making appropriate adjustments with the handles and pedals. Success or failure is decided by correctly matching the lights within a selectable time period.

This integration of two NASA innovations (see Figure 8) has allowed the solution of a difficult problem in rehabilitation medicine.

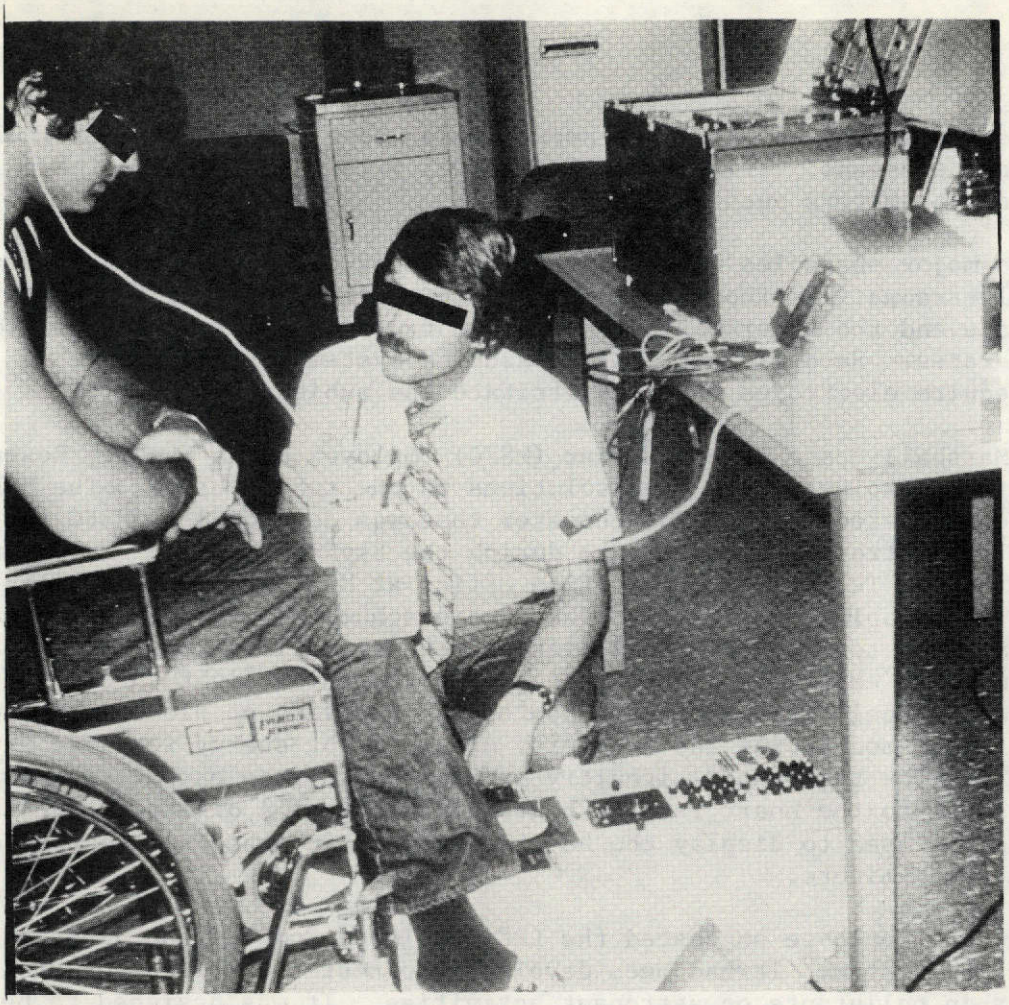


Figure 8. Performance Testing System.

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

A NASA development has improved the research capability of a cardiovascular research team.

In the arterial system, pressure is a function of distance and time; hence, it has wave properties. The wave speed of the pressure pulses is related to the elastic modulus of the arterial wall. In addition, wave reflections that occur in the arterial system perturb the pressure function. It is known that the elastic properties of the arterial wall change in human beings with age and arterial disease. One biological problem is to detect nondestructively changes in the material properties of the arterial vessel early in the process of arterial disease. Change in the properties of the

arterial wall are thought to be related to wave speed or transit time of the arterial pulse.

To validate the accuracy of this hypothesis,it is necessary to establish the relationship, if any, between arterial disease and wave speed or transit time of the arterial pulse. An accurate means of determining wave speed or transit time will aid in the determination of this relationship. Consequently, a reliable, accurate means of determining the wave speed or transit time of arterial pulses is needed. Specifically, the problem originator asked two questions: 1) Are there improved analysis or measurement techniques that can be employed to yield the transit time of the arterial pulse, with or without superposed wave train (reflections)? 2) Can these techniques be employed to permit a description of arterial system nonlinearities and the extent of the nonlinearities, and can the material properties of the arterial vessel such as characteristic impedance, terminal impedance, etc., be determined? At the present, the transit time is measured by employing two mercury strain gages, at different distances from the heart. The arterial pressure pulse is recorded at these two locations. By measuring similar points on the two pulses, an estimate of the transit time can be obtained.

If the relationships between arterial wall properties and transit time or wave speed measurements of the arterial pulse could be established using improved instrumentation or improved analysis techniques, it would be an important contribution to diagnosis of arterial disease.

The primary requirement of this problem was to determine arterial pressure pulse transit time with a precision of $\pm 5\%$. Secondary requirements were to obtain information about the material properties of the arterial vessel such as characteristic impedance, terminal impedance, etc.

Originally, a suggestion was received from the Southwest Research Institute (SwRI) that an ultrasonic Doppler unit designed and fabricated by SwRI for NASA and the Air Force might have potential application in the solution of this problem. Information on the unit,which is named the "Mark IV Ultrasonic Doppler Instrument for Indirect Blood Pressure Measurement," was received and discussed with the researcher. It was decided that the unit might be useful in the solution of this problem provided that a dual channel unit could be obtained. A dual-channel unit was not, however, available, and a single-channel unit was obtained on loan from SwRI to evaluate feasibility of the technique for detection of the arterial pressure pulse. A series of tests were performed on appropriate subjects to permit an evaluation of the unit. It was decided that the unit could indeed be used in the measurement of the arterial pressure pulse transit time provided a dual-channel unit could be fabricated. Efforts were made to obtain funding support to permit fabrication of such a dual-channel unit.

While these efforts were in progress, the carotid artery pulse detector (see Figure 9) developed at the Goddard Space Flight Center (GSFC) was

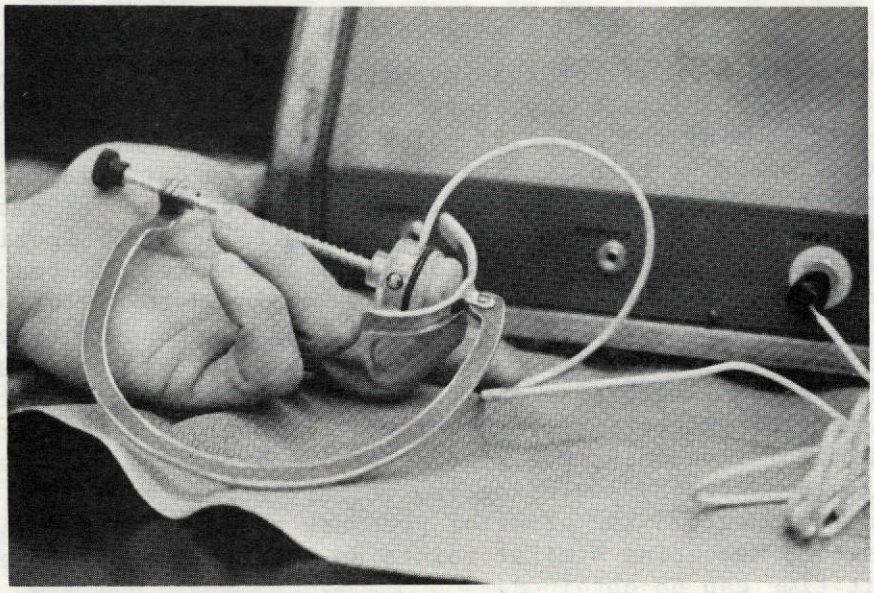


Figure 9. Carotid Artery Pulse Detector.

publicly demonstrated. The demonstrations convincingly showed the ability of the unit to detect arterial pressure pulses in vessels near the surface of the skin. In addition, the GSFC device provided an analog signal output that seemed to faithfully reproduce the arterial pressure pulse. Since the cost of this unit was significantly less than that of the ultrasonic Doppler unit, it was decided to pursue this approach. An additional benefit to be obtained from this approach is an accurate representation of the arterial pressure pulse wave shape.

Since arterial occlusive disease is one of the most significant health problems in the United States, early detection of the disease is an extremely important problem. Unfortunately, detection of arterial occlusive disease in its early stages, when little damage has been done, is extremely difficult. Often the disease reaches crippling catastrophic portions before it is detected. The consequences of advanced arterial disease are numerous and severe, not infrequently leading to death, with little advance warning.

Since it is felt that the presence of arterial disease affects the dynamic elastic properties of the arterial wall and since localized damage may lead to relative arterial constriction at the point of damage, sensitive observation of the arterial pressure pulse may be very useful in diagnosis. It is felt that changes in the dynamic and elastic properties or sudden changes in the diameter of the arteries will affect the shape of the arterial pressure pulse and its transit time. The relative changes in arterial pressure pulse wave shape with arterial occlusive disease are not known at the present time. The application of such a unit to the detection of arterial occlusive disease can be performed in the following manner: The pressure pulse wave shape could be measured at two points along an artery and the transit time required for passage of the pulse from one measuring point to another could be measured. If the wave shape has changed downstream, then changes in the diametric elastic properties of the arterial wall could be suspected. By moving the measuring apparatus along the artery, local constrictions can be detected. If, during a series of wave shape and transit time measurements over a number of segments of an artery, the wave shape should change and the transit time increase as one progresses downstream on the artery, this might indicate the presence of diffuse arterial occlusive disease.

Dual-channel units have been constructed by the researcher, and the ability of the equipment to detect arterial pressure pulses in near-surface vessels on the extremities has been clearly demonstrated. The usefulness of the device in detecting arterial pressure pulses has been clearly demonstrated as well as the ability to measure arterial pressure pulse transit times in peripheral arteries.

PROBLEM WF-120 *Determination of Frequency Response and Errors Due to Adiabatic Expansion in Volume Plethysmographs*

A NASA-developed device has allowed detailed analysis of volume plethysmographs.

The researcher uses small digital volume plethysmography to assess peripheral blood flow to the extremities of patients suffering from peripheral arterial disease. The volume plethysmograph consists of a small Lucite chamber which can be securely fitted around the digits (the fingers or toes) of the patient under study. The chamber is sealed by means of a clay-like material to insure against leakage. A strain gage transducer is connected through the Lucite shell of the chamber to the interior of the closed volume thus formed. The chamber is partially filled with water (approximately 75 percent) to reduce compression effects. Volume changes within the cardiac cycle are sensed as pressure changes within the chamber. By monitoring the pressure fluctuations thus sensed by the transducer, it is possible to relate the volume change of the digit under study as a result of inflow and outflow of blood during the cardiac cycle. This is the

primary noninvasive clinical method of assessing peripheral vascular disease in patients at the present time. While it is possible to check independently the infrequency response of the transducer, the researcher does not have a system that will permit testing of the frequency response of both the chamber and the transducer simultaneously in a configuration as used with the patient. In addition, the presence of a water-air interface in the chamber in conjunction with expansion and contraction of the air-water vapor mixture above the water surface in response to the volume pulse raises a question as to whether or not adiabatic expansion is producing a varying partial pressure of water vapor which may contribute to or influence in some manner the accuracy of the measured results. The volume changes in the digits are very small (>0.01 cc) so that there is a distinct possibility the adiabatic error could cause important errors.

A means of checking the frequency response of the entire system (volume plethysmography chamber and pressure transducer) is required. Further, it is desired to be able to generate pressure pulses of controlled magnitude within the pressure chamber with water present and a water-air interface in order to permit exploration of whether or not water vapor pressure contributions are influencing the dynamic response of the measurement system.

The pressure calibrator system previously identified as a solution to WF-56, "An Improved Fluid Pressure Calibration System," was clearly potentially useful in the solution of this problem. The pressure calibrator fabricated under NASA contract at the University of Virginia and used in a previous problem (WF-56) was obtained and frequency evaluation tests were made by the problem originator to determine its applicability to this particular problem. Using the pressure calibrator as a source of varying frequency pressure pulses, it was possible to obtain a frequency response curve for the volume plethysmographs presently in use. This technique was also employed to examine the effects of the water-air interface on the response of the pressure transducer in the volume plethysmograph chamber. As a result of these tests, the researcher was able to determine that the contribution to overall pressure as a result of adiabatic expansion over the liquid surface during pressure fluctuations was sufficiently small to not compromise the accuracy of the measurements made with the volume plethysmograph. Use of the pressure calibrator system by permitting verifications of the adequacy of the frequency response and elimination of adiabatic expansion as a potential source of error in use of the volume plethysmograph has permitted added confidence in the accuracy and reliability of the data accumulated with this apparatus in clinical trials.

2.2 Potential Technology Applications

During the reporting period, six 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 six problems are discussed in the following summaries.

PROBLEM DU-88 *Respiratory Measurement in Epileptics*

A device developed for measuring respiration of astronauts has proved useful in the clinical study of epileptics.

Epilepsy is an intermittent disorder of the nervous system caused presumably by sudden, excessive, disorderly discharge of cerebral neurons. This was the postulation of Dr. H. Jackson, the imminent British neurologist of the 19th century, and it is interesting to note that modern electrophysiology offers no evidence to the contrary. The discharge causes various degrees of reaction, but, in general, it results in an almost instantaneous disturbance of sensation, loss of consciousness, and, occasionally, convulsive movements.

The magnitude of the problem of epilepsy and its importance to society can hardly be overstated. Statistics show that at least 500,000 living persons in the United States are or have been subject to seizures. Epilepsy may begin at any age and may occur only once during the lifetime of an individual or as much as several times a day.

At the present time, an increasing quantity of research is being directed toward the various conditions of epilepsy. Recently, the Veteran's Administration established two Epilepsy Centers at Durham, North Carolina, and New Haven, Connecticut. The Epilepsy Center consists of four rooms for continuous monitoring of various physiological parameters for a patient who is undergoing a seizure. In addition, a video tape of the patient is made so that the nature of the seizure can be carefully studied. Monitoring takes place over a period from 8 to 24 hours. During this period, the EEG is monitored as well as ECG. Respiration rate is also monitored because, during the time of a seizure, apnea can occur for periods of 10 to 20 seconds. At the present time, respiration rate is monitored by a thermocouple mounted in the nose; however, this technique is unreliable and requires critical positioning. For example, if the patient breathes through the mouth instead of through the nose, an error in reading occurs. In addition, the thermocouple mounted in the nose provides some discomfort for the patient, particularly for long-term monitoring. A means was required for measuring respiration rate that avoids the problems encountered in thermocouple monitoring.

The NASA impedance pneumograph (ZPN), shown in Figure 10, was recommended for the solution of this problem. The NASA impedance pneumograph

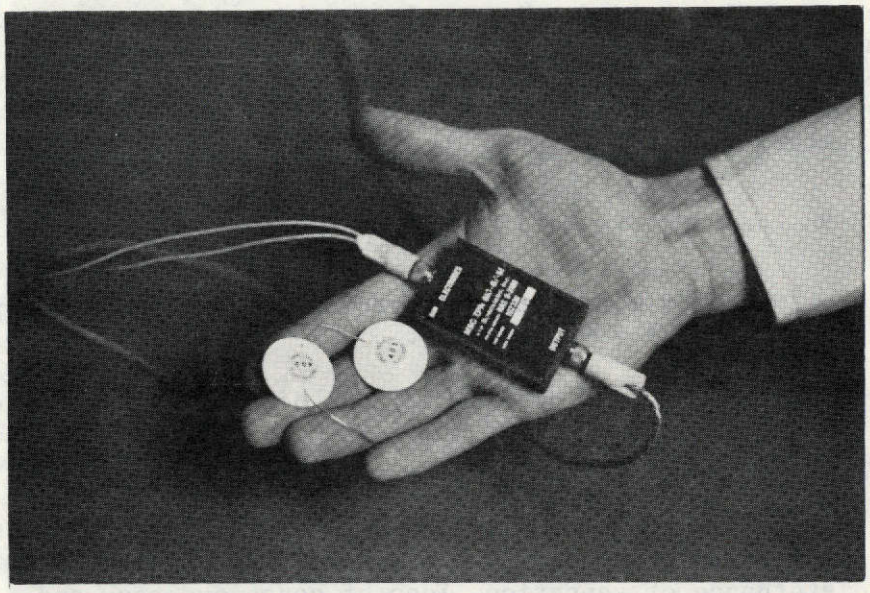


Figure 10. NASA Impedance Pneumograph.

was used on Mercury, Gemini, and Apollo missions to measure the respiration rate of astronauts in flight. The device works on the principle of applying a 100 kHz electrical signal across the thorax and measuring the change of impedance as the thorax changes in size. The electronic package is about the size of a cigarette lighter, and thus can be comfortably attached to the patient. It is electrically safe and is battery operated.

The NASA impedance pneumograph, which had been previously obtained from Johnson Space Center for use at the Tulane School of Medicine, was provided to the problem originator. Initial tests of the unit revealed that it was significantly more reliable and more comfortable than the previously used thermocouple. In addition, the small size makes it amenable to a proposed telemetry system which will be implemented shortly. In this system, patients will be free to move throughout the hospital while EEG, ECG, and respiration monitoring is accomplished. This will alleviate the need for monitoring in a single room as presently accomplished.

In summary, this technology appears to offer high potential for improving the measurement of respiration in epileptics.

PROBLEM MISC-35 *Weight Reduction in Braces for Children*

The Coastal Center is a rehabilitation unit for mentally retarded children. Most of these children are also physically incapacitated to various degrees. Many must wear leg braces and other orthotic support devices of varying kinds. These braces are conventionally constructed of steel, aluminum, leather, and some form of padding. Their weight is not insignificant and on children with reduced muscle strength (which is the case with those requiring such braces) the usefulness of the brace is severely limited by its weight. If braces could be designed for these children that are significantly lower in weight than those presently in use, the usefulness of the braces would increase significantly because the children would have greater use of their limbs. In many cases, children are marginally capable of using a brace. For example, some patients have sufficient muscle strength to move the limb without braces. If a brace is required that weighs as much as conventional braces, in many cases, the added weight is sufficient to greatly inhibit limb movement or to prohibit limb movement altogether by the children. A weight reduction of 50% is considered a worthy goal. Such a weight reduction would greatly facilitate the use of braces by children with limited muscle function.

NASA developments in the high strength lightweight structural composite field appear to be particularly appropriate to this problem. Dr. John Davis of the Langley Research Center has provided technical consultation in the choice of materials and has constructed a prototype pelvic brace, shown in Figure 11, for evaluation. This brace in which selected components of the brace have been constructed of a graphite epoxy resin material offers the promise of significant weight savings. The three heaviest components of the pelvic brace have been duplicated using the graphite epoxy composite. A weight reduction for these three components in excess of 50% has been attained. The pelvic brace has been reassembled using these three composite components. It has been delivered to the Coastal Center for evaluation of the composite components. In the meantime, evaluation of materials pertinent to this particular problem will be continued by Dr. Davis and personnel at the Langley Research Center and the Research Triangle Institute. The present status of the brace represents a preliminary prototype. Considerable improvement in weight and characteristics of the brace can be made with the application of additional engineering time and materials expertise. The significance of this problem in the field of orthotics is felt to warrant the expenditure of this additional time. In addition to the definition of materials with more desirable properties than the graphite epoxy resin system, the feasibility of injection molding of the leg brace and pelvic brace joints should also be investigated to attain the greatest amount of weight reduction.

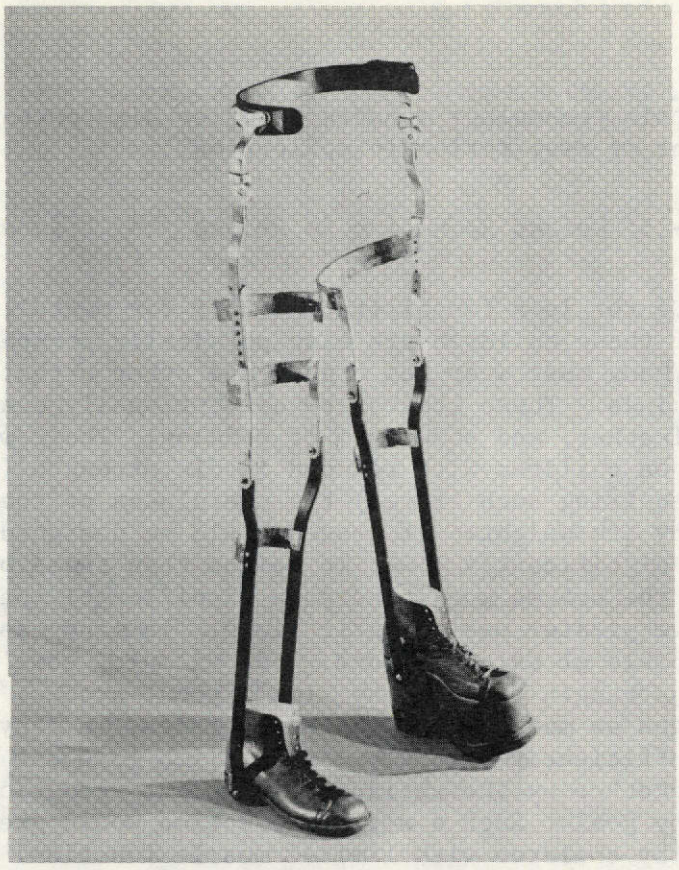


Figure 11. Pelvic Brace With Some Structual Members Replaced by Graphite Epoxy (Dark Material).

PROBLEM MISC-37 *A Means of Patient Manipulation Requiring Little Physical Strength*

The Coastal Center is a rehabilitation unit for mentally retarded children,and most of these children are also physically incapacitated to various degrees. Many weigh as much or more than the nurses who must care for them. Because of their disabilities, it is frequently necessary that individual care and asssistance be provided to the children during various specific activities involved in their daily routine. An example of an activity that many of the children cannot accomplish for themselves is the movement between wheelchair and bed. For nurses, this poses a severe problem in that great physical exertion is involved. For example, a wheelchair patient must be lifted from the wheelchair to the toilet seat (which is basically an unstable seat). During use of the toilet, the patient must be held in a stable position,and then he must be lifted

and steadied during use of the toilet tissue. Finally, he must be removed from the toilet seat and placed back in the wheelchair. This activity taxes the strength and manual dexterity of the person administering assistance, particularly if the patient weighs more than 50 pounds. A means was sought to accomplish the toilet activities of disable patients without the requirement for great strength and dexterity or the concurrent risks of injury to the patient.

Through the efforts of Mr. John Samos, Technology Utilization Officer at Langley Research Center (LRC), technology developed to simulate the lunar gravity environment at LRC has been brought to bear on this problem. Mr. Moses Long has proposed a modification of the Lunar Gravity Simulator, shown in Figure 12, used at LRC. Basically, the apparatus is a suspension device which provides support for any portion of a person's weight by means of a cable and harness arrangement attached to a unit consisting of a spring and variable radius pulley. This device, called a weight-alleviating device, provides a controlled method for supporting specific amounts of weight. The unit can be mounted on a track which would permit movement of the patient in the horizontal plane. The weight-alleviating device can be adjusted to support any desired percentage of the patient's weight; thus it would be possible, for example, with a 100-pound child, to support as much of the child's weight as desired to permit easy handling of the patient. For example, one could support 75 pounds of a child's weight with the weight-alleviating device leaving 25 pounds of apparent weight. The unique characteristic of this device as opposed to other techniques is the use of a spring and special pulley combination that provides uniform support throughout a fairly wide movement range without rebound or change in force exerted by the weight-alleviating device upon movement by the patient.

It is recognized that the proposed apparatus has a variety of applications in the medical environment, and it is suggested that evaluation of the subject apparatus should include a screening for additional applications in the hospital and rehabilitation center environment. A prototype unit is now being constructed at the Langley Research Center.

PROBLEM VAM-15 *Cooling of Metals Under Electron Bombardment*

A new method for fabricating thin metal films offers potential for the development of low cost radioactive materials for clinical use.

The Department of Nuclear Medicine at the University of Miami has installed a cyclotron at the Mt. Sinai Medical Center to produce the radioactive materials used in their clinical and medical research operations. Fortunately, a similar benefit is extended beyond the bounds of the Medical Center to all of central and south Florida. Medical personnel of that area now have ready access to many previously unavailable medically important radioactive materials. This means not only added capability to the physician, but the patient benefits through lower costs, shorter treatment times, and lower radiation levels.

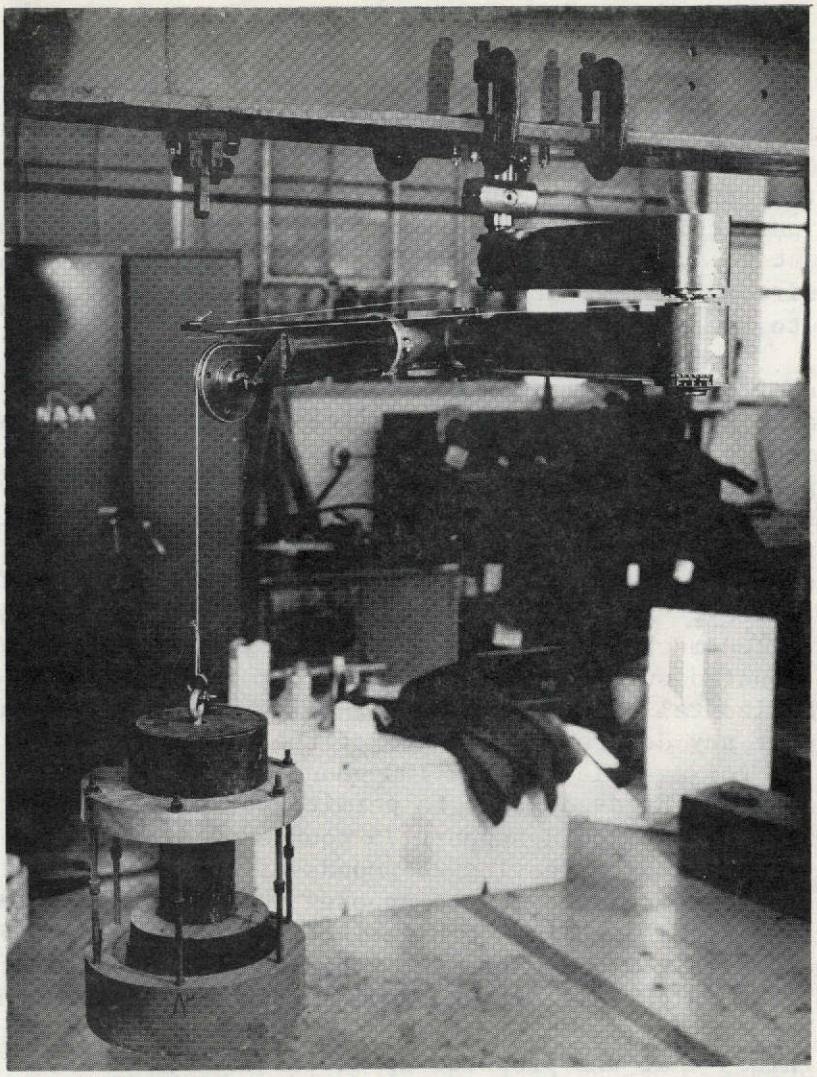


Figure 12. Lunar Gravity Simulator Test Apparatus.

Cyclotron production of many important tracer materials is acccomplished by bombarding specific metals with a high intensity electron, or proton beam. This bombardment will cause extremely high temperatures to exist in the metal. The rate at which this heat can be dissipated is a limiting factor in this type of cyclotron application. In order to maximize the heat dissipation, the metal to be bombarded is deposited on a small piece of oxygen-free copper called a target. This target is an integral part of a cooling system through which chilled water is pumped at a high volume rate. Thus, the bond between the metal and the target must be both a good thermal bond and a mechanically strong bond.

There is a continuing search for new techniques for producing medically useful radioactive materials on a cyclotron. With each additional technique, there is a twofold benefit. First, medical research and clinical personnel have the added capability provided by the additional radioactive material. Second, if the cyclotron is operated on a cost-sharing basis, the operating efficiency of the cyclotron is increased thus reducing production costs.

An important radionuclide that is finding growing applications in the medical community is Technitium-99m. If Technitium-99m could be cyclotron produced, its availability would be greatly increased. In addition, its sale would provide a major revenue source to offset cyclotron operating expenses. (It has been estimated that the Technitium-99m used by Mt. Sinai Hospital alone would provide the cyclotron unit in excess of $30,000 per year additional income.)

The problem originator has demonstrated the feasibility of producing lower cost commercial quantities of this nuclide on a cyclotron. He bombards the stable isotope molybdenum-100 with a proton beam. Following the bombardment, the Technitium-99m is isolated by chemical processes from the molybdenum. Since the production of the Technitium involves only a tiny loss of molybdenum-100, the molybdenum-100 is reclaimed and reused. This is extremely critical in the process because the molybdenum-100 costs $1,750 per gram. Unfortunately, the problem originator has been unable to find an acceptable method for depositing the molybdenum-100 on the copper target. The only known methods, vacuum deposition and sputtering, are known to cause sizeable losses of the material being deposited. Some technique is needed that is simple, inexpensive, and can efficiently bond molybdenum-100 to copper.

Through the efforts of Mr. John Samos, Technology Utilization Officer at Langley Research Center (LRC), this problem was brought to the attention of Dr. Jag J. Singh, Staff Scientist of the Instrumentation Research Division at LRC. Dr. Singh is a physicist with extensive experience in material deposition techniques especially as they apply to preparation of cyclotron targets. After studying the molybdenum-100 deposition problem, he suggested using a recently developed vapor deposition process in which the material loss problem has been largely eliminated. However, this new technique requires a compound of molybdenum rather than the basic element. He suggested either molybdenum pentachloride or molybdenum hexacarbonyl.

The basic process is a vacuum deposition process in which the molybdenum compound is vaporized by heating. The resulting vapors fracture upon contact with a heated surface into molybdenum and a gaseous residue. The molybdenum is deposited on the heated surface, and the gaseous residue is removed through the vacuum system. The area covered by the molybdenum can be further restricted through simple shielding techniques. With shielding and the fact that the compound fractures only on a heated surface, losses are reduced to near zero.

The temperature of several thousand degrees centigrade associated with depositing molybdenum is not required with many of the molybdenum compounds. As an example, in the suggested vacuum deposition process, molybdenum hexacarbonyl vaporizes at 150°C and the target must be at 350°C. This is a significant advantage of the proposed process since equipment cost and complexity are both significantly reduced.

The suggestion was discussed with the problem originator. He indicated that there was no problem in obtaining the molybdenum-100 in the necessary compound form. During the ensuing discussion, the process using molybdenum hexacarbonyl was agreed upon as the most acceptable, and a program was designed to evaluate the proposed solution. Using a furnished copper target, Dr. Singh will prepare the molybdenum-coated target. The problem originator will install the target in the Mt. Sinai cyclotron, subject it to a proton beam, and perform the necessary chemical analysis to isolate the Technitium-99m. The research project has been initiated.

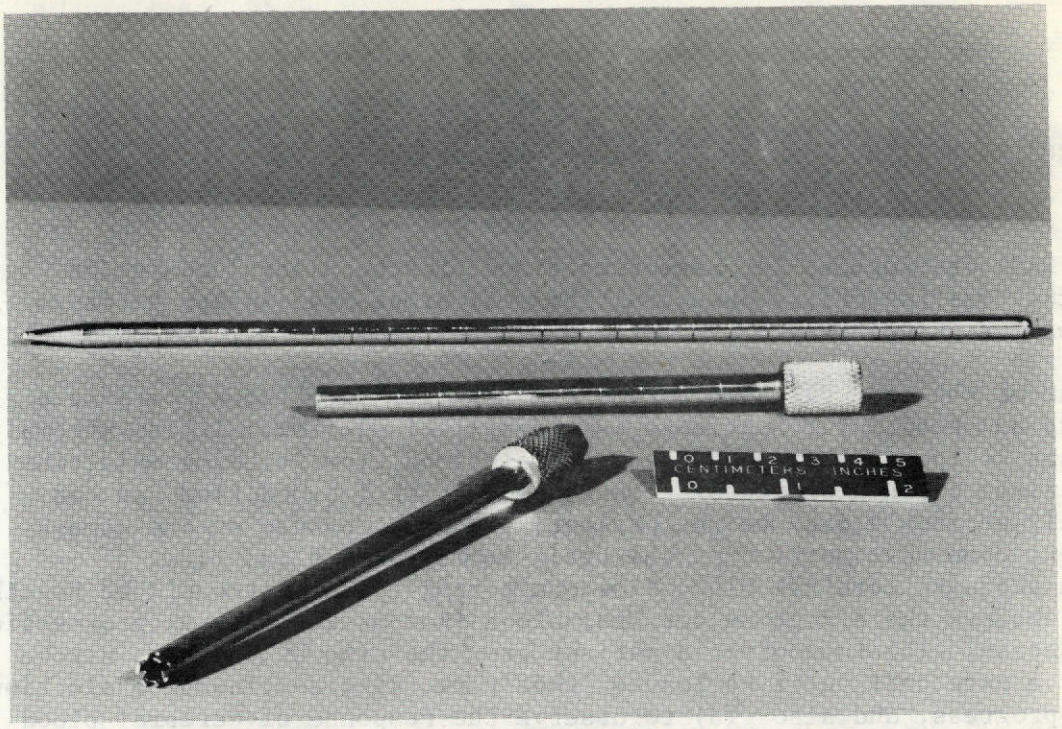
PROBLEM VAM-23 *Bone Biopsy Tool*

A NASA capability in materials fabrication has provided a new method for obtaining bone biopsy.

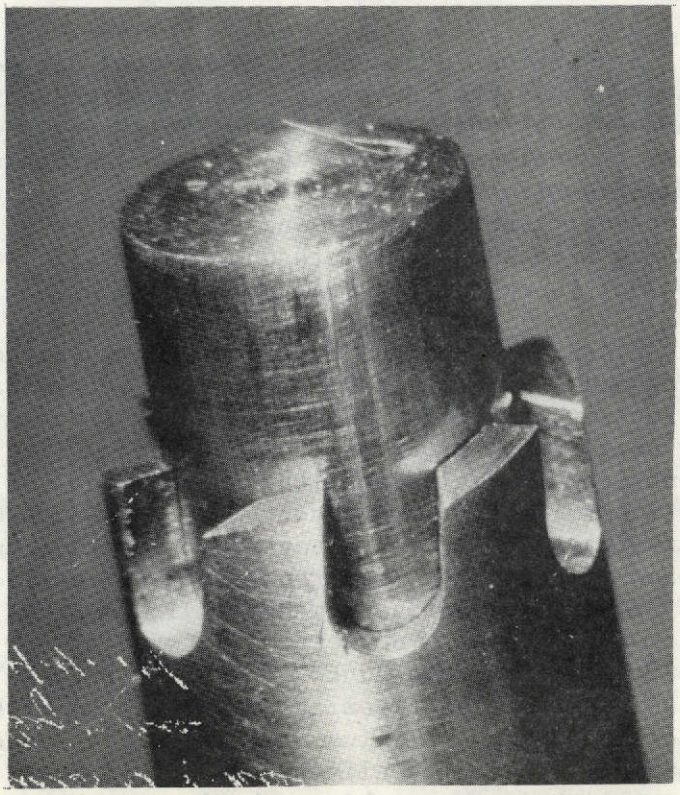
Bone biopsy provides information, not available from any other source, that is often vital in distinguishing between two or more disease states where each state requires completely different treatment plans. Moreover, biopsy findings have added to our knowledge of certain diseases, and, as a result, have improved our ability to provide treatment. Available tools have limited the use of bone biopsy techniques. Besides being expensive, the manual cutters quickly lose their cutting edge and their teeth become so badly deformed that the tool must be discarded. The problem originator needed a manually powered bone biopsy tool that obtains an adequate specimen size and that maintains its cutting ability through repeated use. The tool must involve minimal amounts of surgery.

Mr. John Samos, Technology Utilization Officer at Langley Research Center (LRC), referred the team to Mr. Barry Lisagor. Mr. Lisagor is a member of the ASTM Subcommittee on Stress Corrosion and chairman of the ASTM task group studying orthopedic implants. As a result, he is very familiar with material standards for surgical tools.

Mr. Lisagor suggested that a larger version of the commercially available biopsy tool with certain design changes made to the cutting teeth should prove satisfactory. Two such cutters, made of the same type of material, were delivered to the problem originator for evaluation. Staff surgeons were enthusiastic about the new tools, but a tooth failed on one cutter. Following advice from Mr. Lisagor, two new cutters were made from material made stronger with a heat treatment. These tools, shown in Figure 13, are currently undergoing evaluation at Jackson Memorial Hospital in Miami, Florida.



(A) Overall View



(B) Close-up of Cutting Tip

Figure 13. Bone Biopsy Tool.

PROBLEM WF-118 *Doppler Ultrasound Measurements of Cerebral Blood Flow*

A NASA development for measuring blood flow on pilots undergoing centrifuge testing offers potential for monitoring head injury patients in intensive care units.

One of the most valuable parameters that can be obtained on stroke patients and head injury patients is cerebral blood flow. It is extremely important to insure that adequate cerebral blood flow is being maintained at all times in such patients. Inadequate cerebral blood flow can cause extremely serious damage to the patient; the exact nature of the damage dependent upon that portion of the brain deprived of blood flow. With an adequate cerebral blood flow monitoring system, it would be possible (1) to observe the effect on cerebral blood flow of the natural progression of a disease, (2) to monitor a patient from the time he enters a stroke intensive care unit until he leaves, thus permitting continuous evaluation of his progress, and also (3) to observe the response of cerebral blood flow to different forms of therapy, permitting the selection of the best form of therapy for a given patient. Such information would decrease the mortality and morbidity of patients with diffuse cerebral injury and should also permit research into the pathophysiology of the progression of diffuse cerebral injury.

Although direct measurement of cerebral blood flow has been accomplished on animals, it is a dangerous procedure for human beings and is not employed in ordinary clinical use. A noninvasive technique is required. The use of ultrasonic Doppler technology appeared appropriate for this particular application. For example, if it were possible to obtain the velocity of blood flow in the internal carotid artery and the diameter of the internal carotid artery by using a noninvasive ultrasound system, it would then be possible from these data to calculate cerebral blood flow.

The Ames Research Center (ARC) has been actively involved in the application of ultrasonic Doppler techniques to blood flow measurement and flow detection for several years. The ARC application involved measurement of flow to cerebral arteries in pilots undergoing high acceleration forces on a centrifuge. Analysis of the requirements of the Team problem indicated that the temporal artery transducer developed at ARC by Mr. Sal Rositano has potential value. A cerebral artery transducer and signal processing system shown in Figure 14 was requested and received on loan for evaluation from ARC. Preliminary measurements indicate that adequate capability exists for the system to detect the carotid artery pulse and to provide return Doppler spectrum related to blood flow through the carotid artery. The basic unit as received from ARC was complete with telemetry. Since the new application is in a clinical setting without need for telemetry of the data, this capability will be eliminated. Preliminary results indicate the direct applicability of this technology to the problem of monitoring cerebral blood flow in the Stroke Intensive Care Unit at the

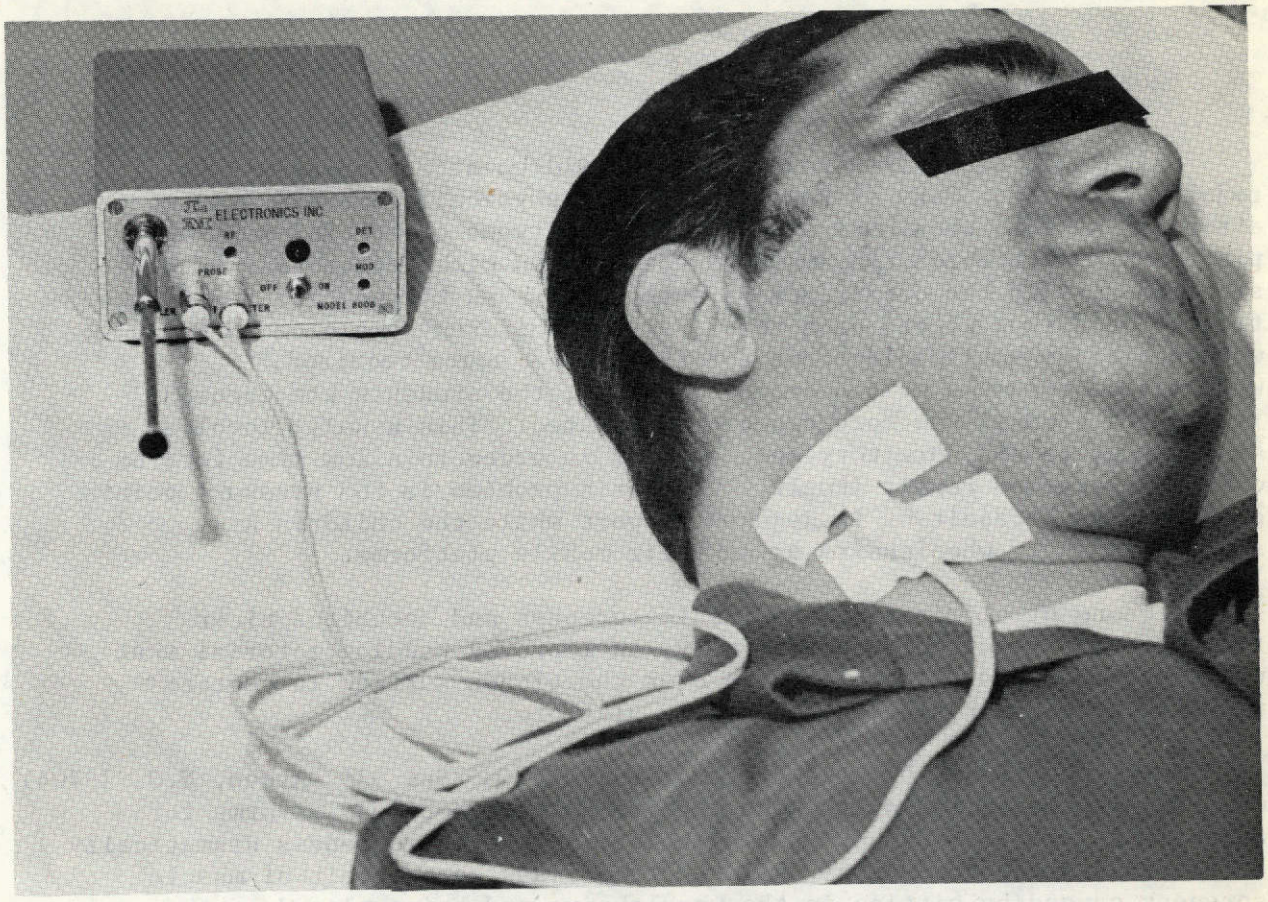


Figure 14. Blood Flow Measurement System.

Bowman Gray School of Medicine. Active use of the ultrasonic Doppler system in the Stroke Intensive Care Unit on patients will permit thorough and conclusive evaluation of the applicability of these techniques to the clinical problem.

2.3 Impacts

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

PROBLEM MISC-38 *Improved Padding*

In certain rehabilitation centers, children attend classes on a regular schedule. Many of the children are physically disabled and must attend classes in wheelchairs and on various types of special mobile platforms. A chronic problem which has reduced class attendance rather significantly is the occurrence of sore muscle and tissue, and the formation of decubitus ulcers as a result of the children remaining on their wheelchairs or mobile platforms for the 3 or 4 hours required. When tissue soreness or tenderness develops, the students are excused from classes until the soreness can be treated. This usually involves confinement to the dormitory and bed rest in order to allow time for the damaged tissue to repair itself. The basic problem is the pressure points developed as a result of inadequate support while the children are sitting in their wheelchairs or on their mobile platforms.

A means of eliminating the muscle soreness and decubitus ulcer formation was required ; specifically, an improved padding material that would permit pressure equalization over the tissue surface in contact with the wheelchair seat or the mobile platform.

The Temper Foam (Dynamic Systems, Inc., P.O. Box 336, Arden, N.C. 28704) material was installed on the wheelchairs and the mobile platforms for approximately 2 1/2 months. During this time, tissue soreness dramatically decreased,and the absence of children from class as a result of muscle soreness caused by sitting in the wheelchairs and being placed on the mobile platforms for classroom drastically declined.

PROBLEM UNC-75 *Improved Antigen Assay Sensitivity*

Successful cancer treatment depends on early detection,and mass screening methods such as the Pap Smear prove to be very effective.

In this technique, small quantities of blood serum are subjected to an automated chemical analysis. During this analysis, the offending antigen combines with a specific antibody to form a much larger molecule present in a very minute quantity. Thus, the success of this diagnostic technique depends on the ability to detect the presence or absence of this large molecule. Unfortunately, the existing chemical analyzer does not have the necessary sensitivity for this measurement.

The Technicon Autoanalyzer (Technicon Instruments Corporation, Tarrytown, New York 10591) is a fast automated chemical analysis system. The material to be analyzed is in a specially designed rotor that causes the fluids to move outward along the radius following channels and containers. The fluids mix in the proper proportion, and the resulting solution is collected in

a measuring cuvette at the peripheral edge of the rotor. As the rotor spins, it passes over a light source that beams through the measuring cuvette. The amount of light that passes through the cuvette is a measure of the concentration of the material suspended in fluid.

A more sensitive measuring system could be realized by measuring the light that is reflected at 90° from the axis of the light beam. Such a technique is called nephelometry. Unfortunately, a nephelometer is not available on the Technicon Autoanalyzer nor, because of the design of the Autoanalyzer, does it appear feasible to adapt one to the analyzer. Therefore, a method (preferably adaptable to the Technicon Autoanalyzer) was needed that permits the accurate detection of particles 500 to 3000 angstroms in diameter that are suspended in serum in concentrations of 5 micrograms per 100 millimeters.

The Oakridge National Laboratory, Atomic Energy Commission, developed the Miniaturized Rapid Analyzer for NASA. That unit, which appears to hold real promise for remote health care delivery applications, has its rotor located on top of the unit. In this position, a nephelometric measuring system could easily be used.

The Team contacted Oakridge National Laboratory and tentative arrangements were made for members of the N.C. Memorial Hospital team to visit Oakridge National Laboratory. A general system concept was conceived in which a laser would be beamed through the measurement cuvette. The incident beam would be blocked with some type of obstruction so that reflected light could be measured. A major advantage of the concept is that it could be used on the Technicon Autoanalyzer.

The problem originator and his staff worked with Technicon Instruments Corporation to develop a prototype system. The unit has been put into operation with very promising results. Reading time has been reduced from 20 to 2 minutes. In addition, while previous measurements were not repeatable, the new system does provide repeatable results.

PROBLEM UNC-81 *Relief of Pressure Points*

A major problem in bedridden patients who must have casting involving the entire lower extremity is that pressure points develop over boney projections, such as the ankle and the side of the knee, interrupting blood flow. In a short time, a painful sore develops which is often resistant to treatment. Besides the obvious discomfort and danger to the patient, these sores add significantly to the cost of medical care. Since the cast must remain in place, the pressure must be redistributed over a wider area. Attempts to do this have been made using various types of padding material (e.g. foam rubber) with unsatisfactory results.

Some material is needed that could be placed over the critical areas at the time the cast is being applied, this material distributing the problem pressure more evenly over a wider area. Obviously, such material would have to have very special characteristics and be nontoxic to the skin.

A unique foam material called Temper Foam was used by Ames Research Center to counteract crew discomfort associated with their sitting for long periods in space vehicle seats. The material's remarkable temperature and compression rate sensitivity characteristics combine at body temperature to form a perfectly fitted cushion which counteracts high pressure points by promoting soft low-pressure uniformity.

Several samples of Temper Foam (Dynamic Systems, Inc., P.O. Box 336, Arden, N. C. 28704) were supplied to the problem originator who used the samples to pad sores of several different patients. Although these sores had previously resisted treatment, they completely cleared up following use of the Temper Foam.

PROBLEM WF-119 *Noninvasive Intracranial Pressure Measurement*

Subtemporal decompression, in which a segment of the skull is removed, is used to relieve pressure on the brain caused by tumors, stroke, etc. When such operations are performed, indeed,when any craniotomy is performed, it is important to prevent the build up of pressure within the cranium either as a result of pathologic disease or reactions resulting from the surgical procedure. A noninvasive technique for monitoring the pressure within the cranium, as evidenced by tissue firmness over the soft tissue portion where the bone has been removed,would be most desirable. At the present time, such pressure is monitored noninvasively by a simple, subjective technique. The physician merely palpates the skin and tissue over the area in which the bone of the skull has been removed. The relative firmness or softness of the tissue in this area is used by the physician to determine the progress of the patient. If the area feels too firm, it is necessary to surgically intervene in order to prevent the buildup of intracranial pressure. This process of determining excessive pressure through tactile examination of the skull is a subjective and qualitative procedure. It is desirable to relate these pressure changes to a more objective and quantitative technique. Quantitation of the degree of hardness or softness of the tissue over the area of such operations should provide the required quantitative information provided that reliable measurement techniques can be developed.

Mr. John Schell of the Marshall Space Flight Center suggested a modification of the commercial hardness tester for soft sponge rubber. Information on the various types of hardness testers was supplied to the researcher, and a commercially available softness tester was obtained. The commercial unit, shown in Figure 15, has been used on a number of patients

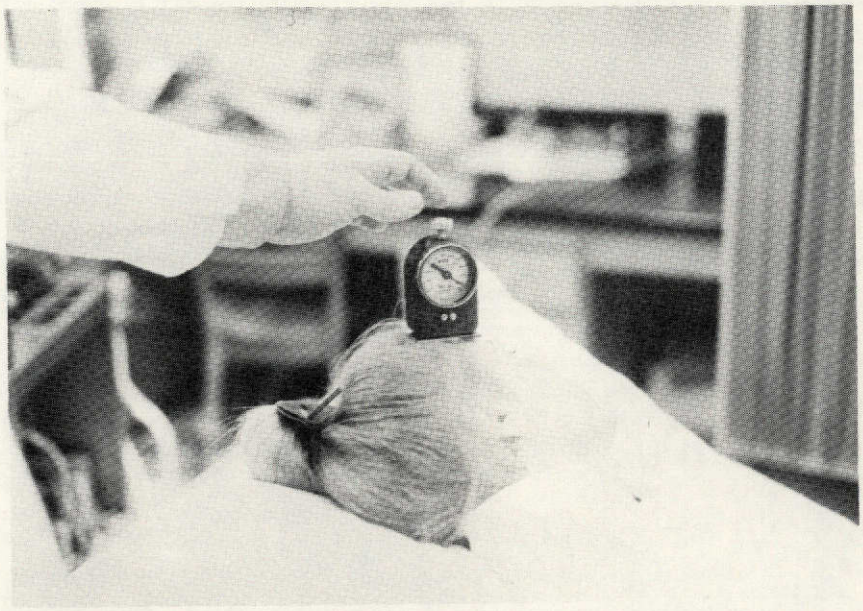


Figure 15. Hardness Tester Used for Intracranial Pressure Measurement.

to evaluate its effectiveness in quantitating the pressure build up. Using the unit, it has been possible to detect the presence or absence of edema resulting from the surgical procedures. The sensitivity of the unit appears adequate to provide quantifiable outputs. Standardization of techniques for measurement is expected to yield better data. At the present time, this technique is being employed on patients as they become available. When final evaluation is complete, recommendation of detailed techniques for use of the hardness tester in a standardized fashion plus documentation of the efficacy of this technique in detecting elevated cerebral pressures will be documented in the literature.

3.0 SUMMARY OF TEAM ACTIVITY DURING REPORTING PERIOD

The following is a summary of project activity undertaken by the RTI Team during the period September 1, 1973, to August 31, 1974.

New Problems Accepted	*40*
Problems Rejected	*3*
Problems Inactivated	*54*
Problems Reactivated	*2*
Total Problems Currently Active	*47*
Preliminary Problem Statements Prepared	*40*
Problem Statements Disseminated	*2*
Responses to Problem Statements	*3*
RDC Computer Searches Initiated	*16*
Impacts	*4*
Potential Technology Applications	*6*
Technology Applications	*7*

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

4.0 APPLICATIONS ENGINEERING PROGRAM

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

PROBLEM DU-74 *Testing of Neuropathic Patients*

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

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

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

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

The Team learned of this research at LRC and arranged a visit to talk with two of the pioneers in pilot modeling. Upon discussing this problem with the LRC researchers, it became evident that the tests they had devised to determine pilot characteristics had much in common with the requirements

for testing patients with motor disorders. The Team was given a demonstration of a tracking task that was employed at LRC. In this case, aircraft pilots were required to track an oscilloscope trace of a noisy signal using a joystick manipulator. With this configuration, it was possible to record both pilot response and instantaneous error in tracking random disturbance. Included in the LRC tasks were control stick and aircraft dynamics. The Langley researchers suggested that the stick and aircraft dynamics be removed from the tasks in order to acquire a better measurement of the motor performance of neuropathic patients. The modified LRC tracking unit, shown in Figure 16, is being evaluated by the problem originator.

The LRC system will provide much quantitative information on human motor performance; however, a modified version of the manipulator will be required to make the test results less sensitive to the patient's perceptual performance. Engineers at LRC built a unit for administering and analyzing the results of tracking tasks which is being employed in a clinical environment at Duke University School of Medicine.

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

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

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

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

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

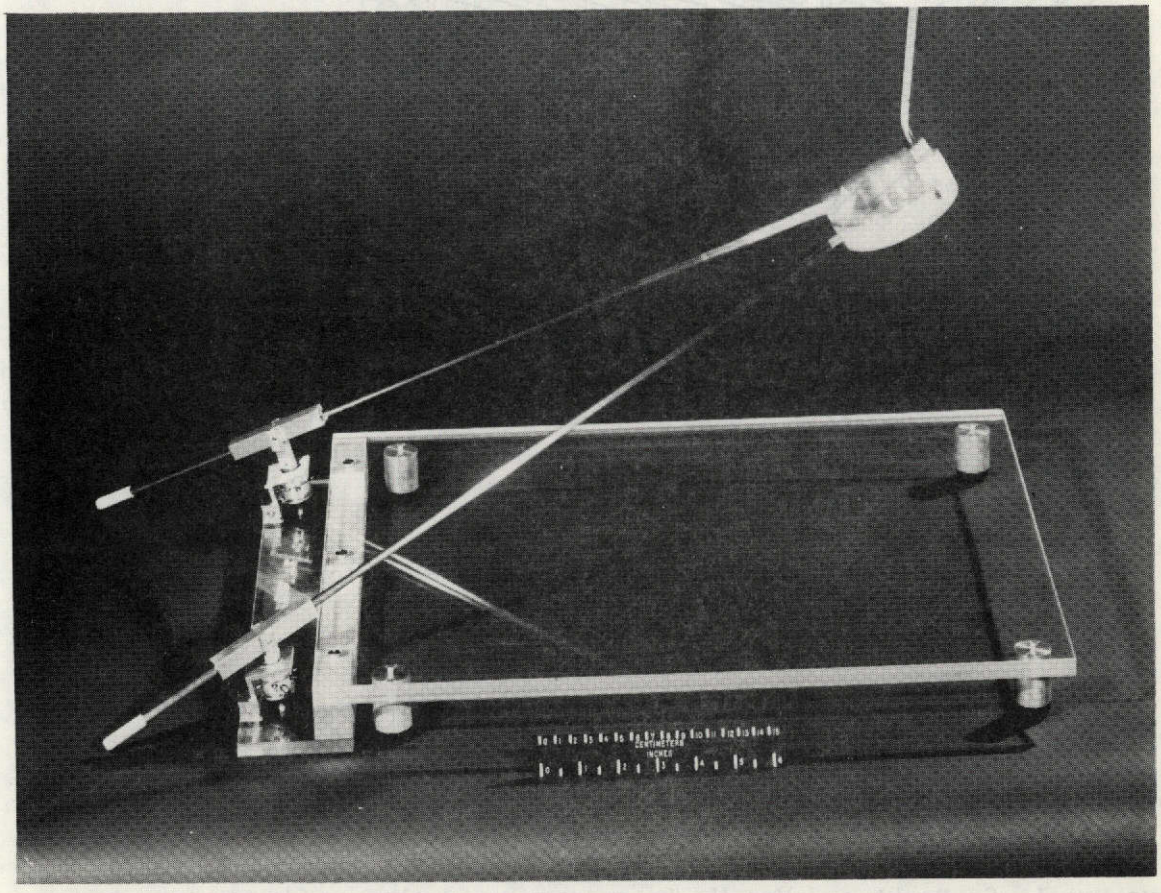


Figure 16. NASA Designed Tracking Unit.

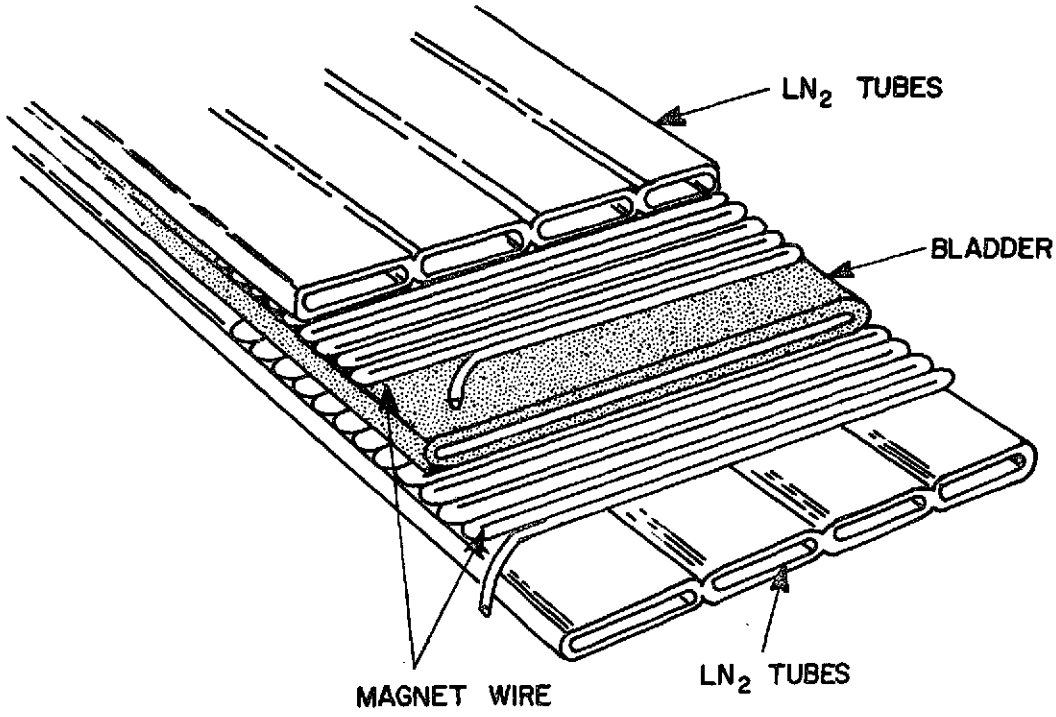


Figure 17. Freezing Cell Sandwich.

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

The problem was forwarded to the Jet Propulsion Laboratory (JPL) where Mr. L. S. Doubt and Mr. W. Tener suggested the configuration shown in Figure 17. The cells are held in a Teflon bladder, which is surrounded by a copper heating element and liquid nitrogen tubes. During the cooling cycle from room temperature to the freezing point, the heating coils control the cooling rate. At the freezing point, the heat is turned off and the latent heat of the cells is rapidly removed. Then the heat is turned on again to control the rate until -50°C is reached.

Although the proposed solution originated at JPL, implementation of this idea was pursued by the Goddard Space Flight Center (GSFC) because of

the geographic proximity of NCI and GSFC. GSFC personnel used computer-aided design to optimize the basic configuration before hardware construction. The computer analysis utilized the same techniques that NASA uses in space applications such as thermal balance in spacecraft. Coordination between NCI and GSFC research staff members was closely maintained to insure that the final device met all medical and engineering requirements.

Initial studies showed that a minor modification of the initial concept was required. A computer simulation model was developed that allowed design modifications to be quickly evaluated. Following this phase, an experimental model of the design was built and successfully tested. An improved model was delivered to NCI in early 1974 for evaluation.

PROBLEM UNC-67 *Noninvasive Technique for Detecting Implanted Artificial Heart Valve Deterioration*

The heart is a unique pump designed to pump blood through the circulatory system in response to the demands of that system. The heart's output, commonly referred to as cardiac output (approximately 5.5 liter/min in man), varies considerably, but must be sufficient to assure an adequate blood supply to the using tissue. Unfortunately, many pathological conditions reduce the heart's pumping ability. As cardiac output fails to meet system demands, the patient is increasingly incapacitated or even dies.

Competent valves are one of the key elements needed to insure that a heart can meet this output requirement. These valves, of which the heart has four, are stopcheck valves which prevent back flow while offering little or no resistance to forward flow. If they leak, energy is wasted pumping blood in the wrong direction. If they fail to open fully, or in some way obstruct forward flow, energy is wasted forcing blood through this restriction. These energy loses reduce the total energy available to pump blood; therefore the volume of blood delivered by the heart is reduced. Also, the turbulence caused by the obstructed or back flow is apparently thrombogenic (clot producing), and circulating clots produce such disastrous results as stroke or heart attack. Unfortunately, valves are subject to damage, principally by bacterial invasion. This damage can be so severe that the patient's only hope is a replacement valve.

Fortunately, cardiac valve replacement is a well established surgical procedure. However, it is recognized that the implanted valve prosthesis is subject to a number of failure modes. Wear and deterioration, for example, produce suboptimal closing and opening characteristics thus reducing the cardiac output. Blood clots, tissue interference, and leaks around the valve mounting are other failure modes. Any of the modes can produce a catastrophic valve failure which will result in almost certain death. Valve repair or replacement can be accomplished in most instances if the condition is detected soon enough.

The problem originator is seeking an atraumatic or minimally traumatic means, which can be used during a patient's routine physical checkup, to detect the onset of these failure modes. Detection could be accomplished by identifying changes, which are produced by the failure mechanism, in one or more parameters, such as cardiac output, valve motion, or valve sound.

The problem originator primarily uses the Lillehei-Kaster Pivoting Disc Prosthesis (see Figure 18). In this particular design the disc movement is distinct and relatively large (see Figure 19). The noise spectrum associated with the operation of this prosthesis is very characteristic. With the exception of a distinct closing click, which is audible, the valve is quiet. In some cases of valve malfunction patients have actually detected changes in this click. In addition, because of the valve's excellent hemodynamic design, flow-generated noise is negligible. Exception to this is in the case of a malfunction where the resultant turbulent flow would possibly be a source of flow-generated noise.

In response to a problem statement, Mr. Jim Monteith, Instrumentation Research Division of Langley Research Center (LRC), suggested subjecting the noise associated with the operation of this prosthesis to a broadband real-time spectral analysis and correlating the resulting spectrum changes with various pathological states. In order to evaluate this suggestion, Mr. Monteith designed a sound-measuring system with a flat frequency response from 50 Hz through 5000 Hz. Using this system, the problem originator recorded sounds from several patients, all of whom had implanted Lillehei-Kaster valves. Analysis of these sounds at LRC revealed the presence of excessive background noise. Several modifications to recording techniques have eliminated most of this interference. Hopefully, a recent modification to the microphone-chest wall interface will eliminate the remainder of the interference. The evaluation of this modification is planned for September 1974.

PROBLEM VAM-6 *Negative Pressure Chamber*

Respiratory distress syndrome (also called hyaline membrane disease) is a major cause of death in the newborn. It is estimated that more than 20,000 babies succumb to this disease in the United States each year. Respiratory distress syndrome is a condition in which the lungs progressively lose their ability to oxygenate the blood. It is thought to be due to the absence of a surfactant material normally present in the alveoli. This material tends to equalize the tension exerted on the alveolar wall. The smaller alveoli tend to collapse and the baby does not have the ability to expand the collapsed alveoli. The number of collapsed alveoli increases until the lungs are no longer capable of performing the oxygenation function.

Recently, researchers at several medical centers in the United States and Canada have produced encouraging results with the use of continuous

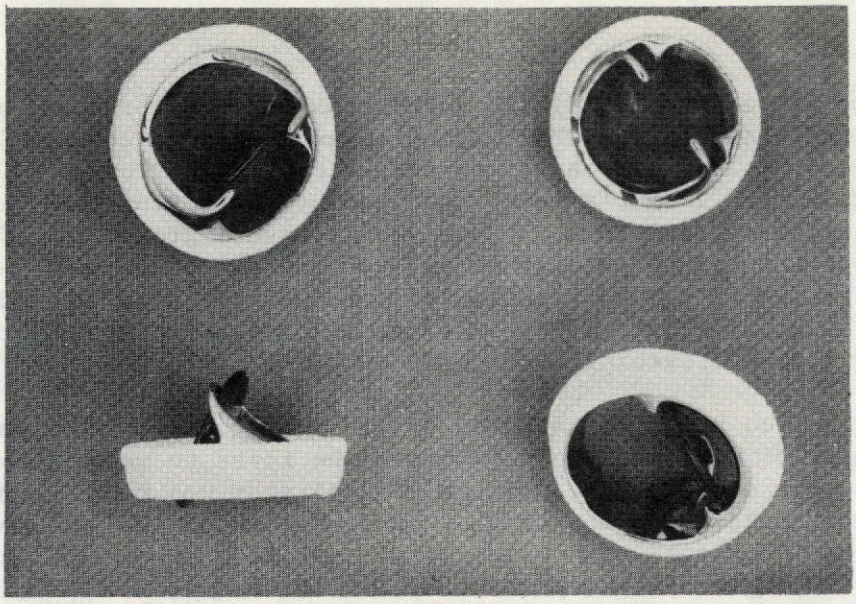


Figure 18. Lillehei-Kaster Pivoting Disc Prosthesis.

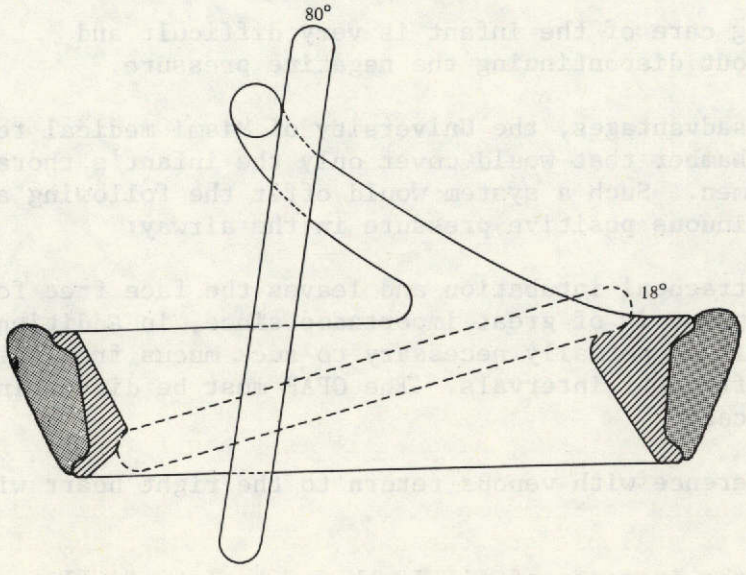


Figure 19. Cross-sectional View of Disc Prosthesis.

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

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

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

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

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

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

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

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

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

The technology employed in the construction of the Lower Body Negative Pressure System (Figures 20 and 21) for NASA's 1973 Skylab mission has direct application in providing therapeutic treatment for respiratory distress syndrome. A Marshall Space Flight Center (MSFC) engineer, Mr. Ted Knowling, visited the University of Miami medical team to consider the applicability of the NASA Lower Body Negative Pressure System to this problem. The major problem to be encountered in the design of the needed CNP system is the air seal that will be required at the waist. (The neck seal that is used on commercially available respirators is thought to be adequate.) The waist seal that was designed for NASA's Lower Body Negative Pressure System appears to provide an excellent solution to the problem of sealing the CNP unit at the infant's waist. Additionally, the NASA seal is adjustable, which will allow the CNP chamber to accommodate infants of various sizes.

A mechanical engineer from the University of Miami, visited Mr. Ted Knowling at Marshall Space Flight Center during November of 1973 and a preliminary design for the CNP was made. A prototype based on that design was completed by June 1974. However, during preliminary evaluations, medical personnel noted certain technical problems. The necessary design changes to correct these problems have been made and a second generation unit is currently under construction. Patient trials are scheduled during the fall of 1974.

PROBLEM UNC-73 *Image Intensifier for Microscopes*

The human disease-producing micro-organism, Mycoplasma Pneumoniae, is responsible for about half of all pneumonia occurring during adolescence and young adulthood. Basic research to identify a vaccine to combat this micro-organism is being conducted. This research uses the technique of immunofluorescence microscopy.

Immunofluorescence microscopy takes advantage of the phenomenon of fluorescence to locate and quantitize a micro-organism present in a tissue specimen or culture. A fluorescence dye is attached to an antibody. The tagged antibody attaches itself to a specific antigen which is the disease-producing micro-organism. A tissue specimen containing the antigen is then illuminated with ultraviolet light while being examined under a microscope. The fluorescent dye gives off tiny amounts of light, thus revealing the location and quantity of the micro-organism present.

Since the specimen is constantly changing a record is made by photographing the specimen through a microscope. Polaroid black and white film having a film speed of ASA 3000 is used. Unfortunately, the results are not altogether satisfactory. Illumination of the specimen is limited because excessive light burns out the fluorescent dyes. The limited lighting requires long exposure times, but the length of exposure is limited because the fluorescent dye has a relatively short half-life. As a result very little detail other than the fluorescence can be caught on film.

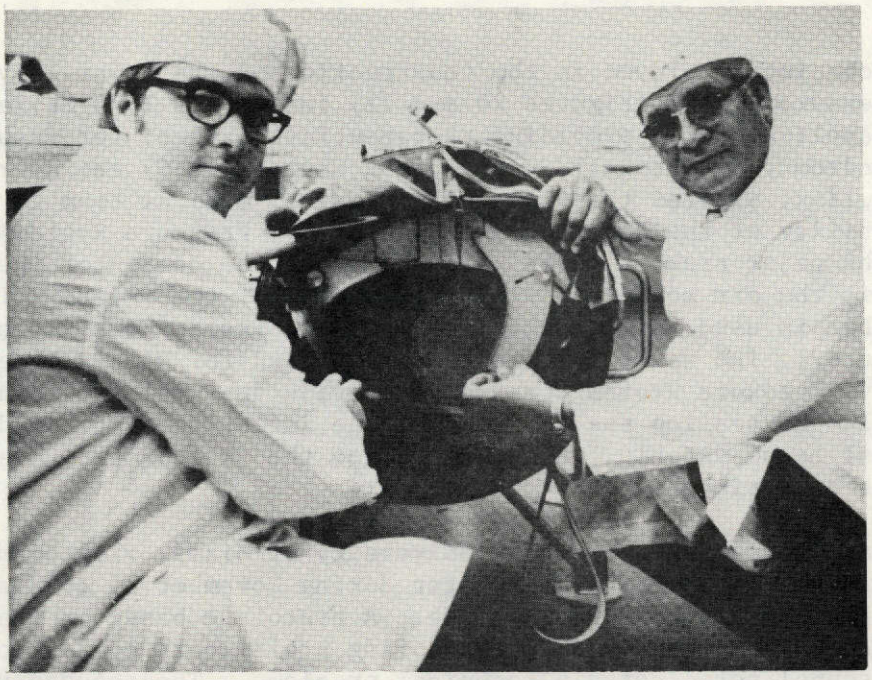


Figure 20. NASA Lower Body Negative Pressure Chamber Seal.

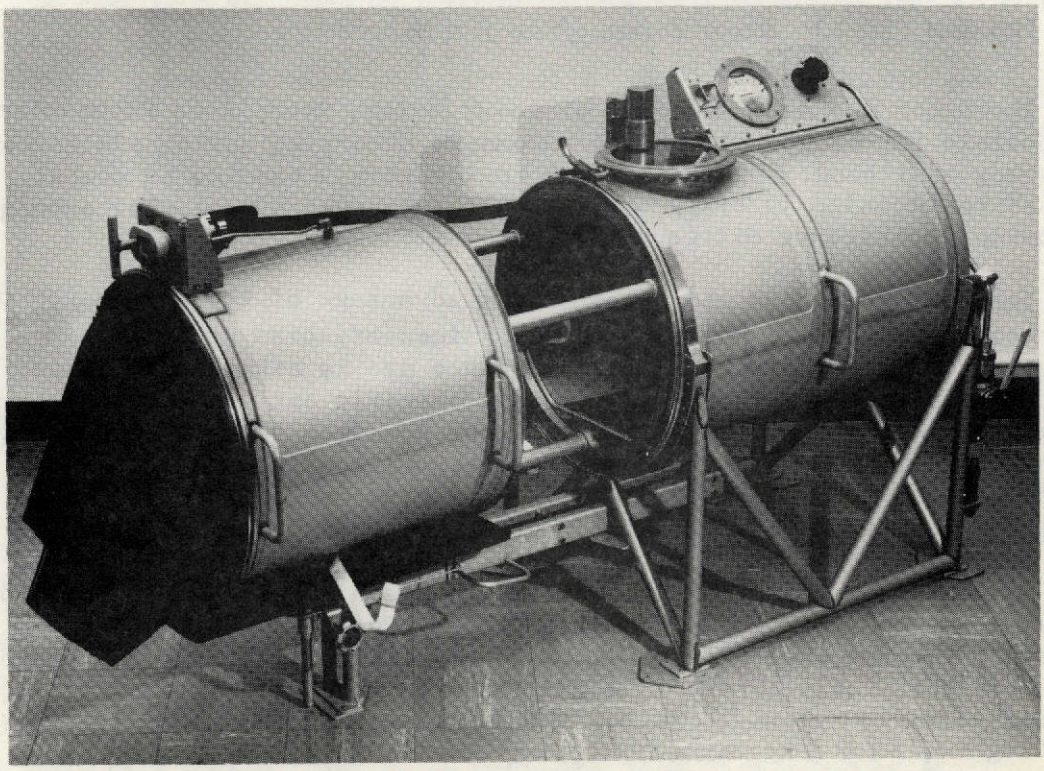


Figure 21. NASA Lower Body Negative Pressure Chamber.

Mr. Wayne Chen of Goddard Space Flight Center (GSFC) suggested the use of a special image intensifier used in NASA astronomy photographic work. The image intensifier is mounted in a 35mm camera and provides an apparent thirtyfold increase in film speed. It has been used extensively and very successfully by Mr. Larry Dunkelman of GSFC.

The problem originator discussed the technique with Mr. Dunkelman and Mr. Chen, and plans were made to evaluate the proposed solution. Using a NASA camera with an image intensifier, several laboratory evaluations were conducted. Photographs usually requiring time exposures of 2 to 6 minutes were obtained in less than 15 seconds. Although negatives of sufficient quality to provide useful data were obtained, there was degradation of the image. It was believed that a later version of the image intensifier, using more advanced fiber optic technology, would largely correct the degradation problem. An order was placed for a later version of the image intensifier and delivery of that unit is expected in September 1974 with laboratory evaluations scheduled to begin upon receipt of the intensifier.

5.0 CONCLUSIONS AND RECOMMENDATIONS

During this reporting period, six potential technology applications and seven technology applications were accomplished. The primary source of solution of these problems was direct interaction between NASA personnel and Biomedical Application Team personnel. Eleven of the problems were solved by direct contact with NASA personnel, and two problems were solved by literature searching. This fact continues a trend that has been evident for the past 4 years in that direct interaction with NASA personnel and problem statement circulation have accounted for approximately 90 percent of the solutions to problems with about 10 percent of the problems being solved using the computerized literature search. Because of the Team's awareness of the productivity of direct contact with the Field Centers compared to information searching, a tendency exists to neglect information searching as a tool. Since this tool can be used at a very nominal cost, it must not be neglected. It is anticipated that direct contact will remain the primary source of solution for the Team in the future, but increased emphasis will be placed on information searching.

In order for a technology application to be accomplished, implementation of the technology must occur. The means of implementation varies with each problem, but for the seven technology applications reported during this period, the sources have been expenditure of funds by the problem originator, NASA equipment loan, or applications engineering funding. For this particular reporting period, the source of implementation funding for four of the problems was the problem originator. In two of the problems, applications engineering funding was the source of implementation, and in only one problem was NASA equipment loan utilized. Although applications engineering funding is a valuable resource, the problem originators continue to be a major source of implementation funding. In order to assure the maximum program accomplishment, applications engineering funding should not be used as the primary source of implementation funding.

One of the major strengths of the Biomedical Application Team program is the breadth of technology available throughout the nine NASA Field Centers. In order for the Team to achieve maximum production, close interaction with all the Field Centers is required. This broadens the base of technology available to the Team and enhances the probability of solution of a particular problem. During this reporting period, six of the nine Field Centers were involved in problem solution. Thus, the Team is utilizing a broad base of NASA technology in solving the problems. Undue reliance on any single Field Center would clearly be a weakness to the program.

One of the vital lessons learned in this program concerns the need for fast action by everyone associated with the program. When fast action occurs, the probability of a problem solution is significantly enhanced. A good

example of this situation is the technology application NCI-13, "Portable Isolation Unit." In this problem, the Team was able to provide the National Cancer Institute with technical information and a Biological Isolation Garment within 3 weeks. The National Cancer Institute personnel responded quickly and were able to build a prototype in less than 3 months from the time of initial contact with the Team. The technology was implemented and has been in constant use since that early date, and the rapid response of all persons connected with this problem significantly enhanced the solution. Delays in any phase of the transfer process will inhibit the probability of problem solution.

In a program of this type, the large number of individual activities that contribute to the total program create a requirement for a significant volume of reporting. At the present time, the Team generates weekly reports, monthly reports, and a final report that require a significant portion of the Team activity. Each hour spent on reporting reduces the time available for problem solution and implementation. Thus, to the degree that reporting can be reduced, program output can be increased. The volume of reporting must be under constant review to assure that the goals of the program are being met in optimum fashion.

When a technology application has been accomplished, a problem has been solved for a single medical investigator. If this technology application is to have full impact on society, the technology should be available to other medical groups. This availability can be directly achieved if a manufacturer for the technology can be found. The problem of finding suitable manufacturers for completed technology applications is a major one which the Team has attacked in two ways. One way is direct interaction with certain industries, and the other is through the formation of the Aerospace Technology Committee of the Association for the Advancement of Medical Instrumentation. Through these activities, the Team has learned that it is extremely difficult to approach a large company with a prototype device with the expectation that the company will eventually manufacture the device. Efforts in this direction have largely failed. The major interest in this type of activity comes from the small entrepreneural companies that are aggressively seeking new product opportunities. In the discussions of the Aerospace Technology Committee, many lessons have been learned about the philosophies of companies in marketing new products in the medical device area as well as in regard to the interest in these companies in the NASA Technology Utilization Program. Because of the necessarily small size of the Committee, the data base for this information is small but should be expanded to add reliability to the information. Accordingly, the Team recommends that a national survey of medical device manufacturers be conducted in order to expand the data base in regard to this problem area.

The Biomedical Application Team at the Research Triangle Institute has continued to expand the base of problem activity throughout the Southeastern United States. A limited amount of problem activity has occurred in the Northeastern United States which has a high concentration of major medical institutions. The Team recommends that its activities be expanded in the Northeastern United States to provide an increased problem base from these prestigious institutions.

APPENDIX A

PROJECT ACTIVITY SUMMARY

TECHNOLOGY APPLICATIONS ACCOMPLISHED

CP-3 *Automated Measurement from Coronary Angiograms*

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

NCI-13 *Portable Isolation Garment*

UNC-71 *Finger Joint Flexor*

VAM-12 *Blood Pulse Rate Indicator*

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

WF-120 *Determination of Frequency Response and Errors Due to Adiabatic Expansion in Volume Plethysmographs*

POTENTIAL TECHNOLOGY APPLICATIONS IDENTIFIED

DU-88 *Respiration Measurement in Epileptics*

MISC-35 *Weight Reduction in Braces for Children*

MISC-37 *A Means of Patient Manipulation Requiring Less Physical Strength*

VAM-15 *Cooling of Metals Under Electron Bombardment*

VAM-23 *Bone Biopsy Tool*

WF-118 *Doppler Ultrasound Measurements of Cerebral Blood Flow*

IMPACTS

MISC-38 *Improved Padding*

UNC-75 *Improved Antigen Assay Sensitivity*

UNC-81 *Relief of Pressure Points*

WF-119 *Noninvasive Intracranial Pressure Measurement*

APPLICATIONS ENGINEERING ACTIVITIES

DU-74 *Testing of Neuropathic Patients*

NCI-4 *Controlled Rate of Freezing a Liquid*

UNC-67 *Noninvasive Technique for Detecting Heart Valve Deterioration*

UNC-73 *Image Intensifier for Microscopes*

VAM-6 *Negative Pressure Chamber*

CURRENTLY ACTIVE PROBLEMS AS OF AUGUST 31, 1974

Problem Number	Status Code*	Problem Title
DU-74	E	*Testing of Neuropathic Patients*
DU-87	C	*Acoustic Isolation of Ultrasonic Transducers*
DU-88	E	*Respiration Measurement in Epileptics*
JHU-1	C	*Development of Vibrotactile Stimulator for Psychophysical Studies in Deaf Children*
JHU-2	D	*Development of a System to Apply Step Changes in External Pressure to the Canine Neck*
JHU-3	C	*Method for Measuring Blood Volume in IC Patients with Normal Hepatic Function*
JHU-4	C	*Development of Computer Technology for Relating the BCG and Carotid Pressure*
JHU-5	B	*Positioning of Sonomicrometer Transducers on the Endocardial Surface*
LSD-1	D	*New Methods for Cleaning Teeth*
LSD-2	B	*New Materials for Dental Restoration*
MISC-24	D	*Metal pH Electrode*
MISC-25	D	*Micro-Connector for Magnetically Guided Catheter*
MISC-35	E	*Weight Reduction in Braces for Children*
MISC-36	D	*Reduction of Sound Level in Rooms Used by Groups of Mentally Retarded Children*
MISC-37	B	*A Means of Patient Manipulation Requiring Less Physical Strength*

*See explanation of status codes at end of listing.

Problem Number	Status Code*	Problem Title
MISC-40	B	*Storage Technique for X-rays*
MISC-41	B	*Fire Protection in Paraplegic Homes*
MISC-42	B	*Whole Body Movement Measurement*
NCI-4	E	*Controlled Rate of Freezing a Liquid*
NCI-10	C	*Scanning Tumors in Small Animals with Gallium-67*
NINDS-1	C	*Cerebral Blood Flow*
TU-9	E	*Human Voice Analysis*
TU-10	E	*Quantization of Heart Tissue Hardness*
TU-22	E	*X-Ray Microplanigraph*
TU-24	D	*Transmission of Clinical Urinary Isotope Data*
TU-35	C	*Subcutaneous Temperature and Power Density Measurement in a Microwave Field*
UMISS-1	B	*Criteria for Selection of Computer Systems in Biomedical Simulation*
UMISS-2	B	*Fluid Mechanics Studies in the Artificial Heart*
UMISS-5	F	*Leg Brace Weight Problem*
UNC-66	D	*Determining Tissue Perfusion Adequacy*
UNC-67	D	*Noninvasive Technique for Detecting Heart Valve Deterioration*
UNC-71	F	*Finger Joint Flexor*
UNC-73	E	*Image Intensifier for Microscopes*
UNC-78	B	*Platelet Aggregation Detection in Whole Blood*
UNC-79	B	*Retractable Cover for a Bronchofiberscope*
UNC-80	D	*Medical Equipment Inventory and Management System*
UNC-82	A	*Method for Measuring Villi Motion*

Problem Number	Status Code*	Problem Title
VAM-6	D	*Negative Pressure Chamber*
VAM-15	D	*Cooling of Metals Under Electron Bombardment*
VAM-21	A	*The Artificial Tendon*
VAM-22	A	*Artificial Teeth*
VAM-23	E	*Bone Biopsy Tool*
VAM-24	D	*Processing of Rapid Microfluorimetry Data*
VAO-2	B	*Improved Artery Shunt Prosthesis*
WF-112	B	*Method of Correlating Composition with Differences in Surface Morphology of Kidney Stones*
WF-118	E	*Doppler Ultrasound Measurements of Cerebral Blood Flow*
WWRC-17	A	*Redesign of a NASA Electrically Steered Wheelchair*

STATUS CODE DEFINITIONS

A. PROBLEM DEFINITION

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

B. INFORMATION SEARCHING

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

C. PROBLEM ABSTRACT DISSEMINATION

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

D. EVALUATION

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

E. POTENTIAL TECHNOLOGY APPLICATION

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

F. FOLLOWUP ACTIVITY

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

APPENDIX B

DESCRIPTION OF CURRENTLY ACTIVE PROBLEMS

(CATEGORIZED BY HEALTH AREAS)

(This description does not include those active problems previously discussed in Section 2 as technology applications, potential technology applications, or impacts or in Section 4 as an applications engineering project.)

HEALTH AREAS

PROBLEM MISC-36 *Reduction of Sound Level in Rooms Used by Groups of Mentally Retarded Children*

The Coastal Center is an organization for the care, training, and education of mentally retarded children. Implementation of these functions results in numbers of the children gathered together in single rooms. Noise has been a continuing problem with these groups of children. High noise levels disturb the children and, of course, cause them to be noisier so that there is accumulative effect. Adults engaged in teaching,supervision, etc. with these children are also negatively affected by the very high noise level. The investigator feels that, if the ambient noise level could be reduced by absorption of sound within the room, the overall noise levels might then remain low enough not to stimulate the children to loud and excitable behavior.

The noise problem is most pronounced in the dining area which consists of a large room some 25 x 50 feet with 8-foot ceilings and a large skylight in the center of the room. The floors are concrete covered with vinyl tile. The walls are painted concrete block, and the ceiling is a suspended plastiboard. One wall consists almost entirely of glass windows while the opposite wall has a large number of steel doors which lead to offices, storage area, etc. As can be seen from this description, little in the way of sound reduction techniques have been employed. The problem basically consists of the determination of those techniques that can be applied most effectively and efficiently to reduce the effects of child-generated noise on the overall noise level within the room.

A meeting was arranged with Messrs. Harvey Hubbard and William Maze of the Langley Research Center (LRC) to discuss the details of this problem. Several suggestions were made by Messrs. Hubbard and Maze and the various costs of the techniques were considered. Carpet was suggested as being one of the best ways in which to reduce noise in such a room. Replacement of the ceiling tiles with acoustic panels rather than the presently employed plastiboard should also provide an effective reduction. Axillary wall-mounted absorber panels such as employed in the activity center at LRC were also suggested as being potentially useful in a room such as the cafeteria at Coastal Center in which no single large wall surface was available. The axillary wall-mounted absorber panels are particularly appropriate where the wall is broken up by a large number of doors or other openings. The use of free standing absorber petitions placed at various locations within the room was discussed and rejected as an effective measure in this particular case. It was also suggested that a music perfume system employing an adequate number of speakers to provide a masking background music level might be very effective and even the most cost effective measure in this application. Results of these discussions plus literature on commercial suppliers of acoustical absorbing materials were supplied to the investigator at Coastal Center. The relative

merits of each of the suggestions listed above were discussed and the investigator is presently evaluating the costs involved in implementation of these techniques to determine those techniques that will be implemented.

PROBLEM MISC-41 *Fire Protection in Paraplegic Homes*

The Department of Housing and Urban Development (HUD) is supporting a 3-year study that is designed to provide adequate housing for paraplegics. Initially, four mobile homes will be built for students at St. Andrews College because of the unusual commitment that St. Andrews College has demonstrated for handicapped students.

One serious difficulty encountered by handicapped persons is the lack of adequate housing, i.e., housing that is designed to meet the needs of a handicapped person. It is for this reason that the Federal Government has initiated a study to provide mobile homes that are especially designed to meet the needs of these persons. Initially, the contract will provide for the design and construction of four mobile homes to be used by St. Andrews College students, but it is anticipated that a mobile home manufacturer will eventually incorporate the design features in a line of mobile homes available for use throughout the country. Since North Carolina is the fourth largest manufacturer of mobile homes, the problem originator does not anticipate any difficulty in finding an interested manufacturer.

The mobile homes should provide sufficient fire protection so that a handicapped person will have time to escape in the event of fire. Mobile homes are notoriously dangerous because of their flammability and lack of egress routes.

NASA technology at Ames Research Center and Johnson Space Center for fire prevention is being evaluated as a solution to this problem.

PROBLEM UMISS-5 *Leg Brace Weight Problem*

Leg and pelvic braces are constructed of steel, aluminum, leather and some form of padding. Their usefulness is severely diminished because of the brace's weight. A weight reduction would greatly enhance the brace's utility. In order to reduce the weight of the braces, it is necessary that they be constructed of lighter weight, higher strength materials. The materials employed must also be deformable so that brace dimensions can be altered according to need. Finally, the brace materials must be cost effective and amendable to relatively simple manufacturing techniques.

Messurs. John Davis and Robert Beaucom of Langley Research Center have invested a considerable amount of research effort toward the solution of this problem. In a previous problem, MISC-35, "Weight Reduction in Braces for Children," they designed and fabricated brace members made from a graphite-nylon-epoxy composite material. At least a 50 percent weight reduction was realized with the new material. However, the problems of deformability and ease of manufacture were not solved with the use of this composite. A new brace is being fabricated from a graphite-polysulphene-epoxy composite, which is thermoplastic and amenable to simple manufacturing techniques.

PROBLEM VAM-21 *The Artificial Tendon*

In rehabilitation medicine, severely damaged hands are often encountered in which the tendon is so badly scarred that the hand is left a useless claw. If these damaged tendons could be replaced, the hand could be restored to its normal condition. Some tendon transplants can be done, but they are limited primarily by the availability of replacement tendons. An artificial tendon would solve this need.

The problem originator has suggested the use of polypropylene. He noted that one objection was its elastic properties and wondered if the elasticity could be varied by braiding or some other mechanical alteration rather than by using single, solid tubular construction. Some method would also be necessary to anchor the device to the muscle tissue.

The material used in an artificial tendon must be biocompatible, extremely fatigue resistant, and have sufficient elasticity to allow a tendon to elongate one tenth or one twelfth of its length. Additional descriptive characteristics are being accumulated by both the Team and by biomedical engineering personnel of the University of Miami. As this data is made available, a problem statement will be written.

PROBLEM WWRC-17 *Redesign of a NASA Electrically Steered Wheelchair*

NASA designed an electrically steered wheelchair that would be inexpensive and easily controlled by a quadriplegic. Although the NASA design was a good one which basically solved these problems, there were some difficulties with the prototype. Among these difficulties were the inability for the patient to adequately control the chair, inability to see where the chair was headed on a start, poor low speed torque and problems encountered with getting the patient in and out of the chair. The problems involved with adequately interfacing quadriplegics with wheelchair control devices are difficult ones and often patient specific.

These interface problems were discussed with Messrs. Harlan Caldwell and Robert Roth, the NASA personnel who designed the original wheelchair. They agreed to consider the interface problems and redesign the wheelchair in light of their findings.

ARTIFICIAL ORGANS

PROBLEM UMISS-2 *Fluid Mechanics Studies in the Artificial Heart*

A technique is needed for detecting and measuring vortices, recirculation regions, fluid velocity profiles, region of turbulence, and stagnation areas in liquid flow through the artificial heart. Replacement of the natural heart with an artificial heart pump has a profound influence on circulatory homeostasis with subsequent circulatory deterioration inevitably ensuing. Preimplantation evaluation of currently used, as well as proposed, artificial heart designs by mock circulation testing is essential in attempting to delineate the optimal performance characteristics necessary for successful implantation.

The problem originator plans to initiate an experimental investigation, utilizing a pneumatically driven sac-type prosthetic heart and a mock circulatory system, into the flow properties of different artificial hearts. The mock circulation loop parameters (e.g., flow resistance, capacitance, etc.) as well as the pneumatic drive system parameters (e.g., systolic and diastolic pressures, flows, frequencies, etc.) will be varied to obtain information regarding the systolic flow, diastolic flow, the effects of valve type, sac thickness and thickness distribution, inlet and outlet size and orientation, etc. on the flow patterns. These studies should lead to improved preimplantation test procedures as well as suggesting design changes for improved performance.

The measurement technique should provide data on fluid velocity, velocity profile, and vortex motion, as well as delineating regions of recirculation, high velocity and stagnation. The sac walls are relatively opaque and vary in wall thickness and geometry.

DETECTION AND TREATMENT OF HEART DISEASE

PROBLEM DU-87 *Acoustic Isolation of Ultrasonic Transducers*

A means is needed for the acoustic isolation of ultrasonic transducers to be used in heart research.

Ultrasonic radiation is being increasingly used to visualize internal organs, particularly the heart. In addition to A-scan and B-scan displays, recent work has been directed toward a phased array imaging which is based on the same principle as phased array radar. In work underway at Duke

University, a 16 element linear array of ultrasonic transducers is being used to obtain a ±30° sector scan. One of the difficulties with this approach is acoustic interaction between transducer elements in the receive mode. A means is required to isolate a 16 element array 25 mm x 14 mm pulsating ultrasonic energy at 2.5 MHz.

An information search has been conducted, and a problem statement has been circulated.

PROBLEM MISC-25 *Micro-Connector for Magnetically Guided Catheter*

Researchers at Massachusetts General Hospital are developing a system to aid in guiding a catheter to various locations in the cardiovascular system. This system is expected to provide a nonsurgical means of correlating certain cardiovascular disorders that are now correctable only through surgery. One of the procedures that is now being employed in experimental animals requires that a latex balloon be inflated and deposited in an artery. The balloon is guided to the proper location and then inflated by the injection of serum albumin through the catheter. Should the patient show untoward effects or the balloon be found to be improperly positioned, the balloon must be quickly deflated and withdrawn. If the balloon is positioned properly, the ferromagnetic catheter tip is heated by an external R.F. field which causes localized hardening of the serum albumin thus sealing the balloon. The catheter is then withdrawn leaving the balloon in the artery. The balloon simply slips off of the tip of the silicon catheter. It is felt that heating the ferromagnetic tip could be done simpler and less costly by providing a small heating element inside the tip. In this case it appears necessary to employ a miniature electrical connector which disconnects when the catheter is withdrawn. Technological assistance is needed in designing and fabricating such a device. This idea is suggested only as a possible approach; alternate approaches to sealing and detaching the balloon should be considered.

The solution to the problem of sealing and detaching the balloon should satisfy the following requirements:

1) The technique should permit the balloon to be pretested and must permit the balloon to be deflated if it is improperly positioned.

2) Sealing and detaching must be done without allowing any substances in the catheter that would be harmful if spilled into the blood stream.

An engineer at Langley Research Center has suggested an approach to the problem which is presently under evaluation.

PROBLEM VAO-2 *Improved Artery Shunt Prosthesis*

Recent technological advances have helped to combat the major class of fatal disease in Americans, disease of the cardiovascular system. One such development is the use of prosthestic grafts to replace damaged arteries. The problem originator is presently concerned with grafts of the femoral artery which, after implantation, cause some problems in clotting on the downstream end of the vascular graft.

It has been suggested that an appropriate modification of the blood velocity pulse shape at the downstream end of the prothesis might prevent thrombosis. The pulse shape can be controlled by the shape and wall compliance of the graft within certain physiologic requirements the prothesis must satisfy. The graft must have a certain mean length and diameter and, for a tapered tube, must have at least a minimum diameter so that the prosthesis can be sutured at the downstream end. A mathematical analysis of the flow in the graft region will probably be required in order to determine what changes in the graft are needed in order to reduce the clotting problem. These changes probably will include a change in the geometry of the graft as well as a change of the compliance of the graft wall in order to modify the velocity of blood.

A literature search of the NASA data bank in the area of tapered tube flow dynamics has been undertaken to identify NASA technology and personnel appropriate to the solution of this important problem.

DETECTION AND TREATMENT OF CANCER

PROBLEM MISC-42 *Whole Body Movement Measurement*

A long standing problem in psychoanalysis is the quantitative measurement of body movements. Body movements measurement is of interest because specific movement patterns are highly correlated with specific emotional illnesses (just as physiologic disorders have their specific movement patterns, e.g., the characteristic tremor of Parkinson's Disease). This clinical observation has been documented with the aid of motion picture analysis of patient movement. A measure of the periodic nature of the body movement pattern would be an excellent diagnostic tool and would be useful for determining the effectiveness of drug therapy.

The desirable characteristics of the measurement system include body movement measurement without the patient's awareness so that his characteristic behavior patterns will not be modified by the measurement technique, a measurement system that would be sensitive to minute movement patterns such as small hand movements, a system output that would be amenable to direct Fourier analysis (as opposed, for example, to the exorbitant data reduction required for motion picture analysis), and a system that would be inexpensive

so that its use could be widespread. The system does not have to be sensitive to the amplitude of individual body movements, but must be sensitive to the periodicities of total body movement as affected by individual movement.

A NASA data bank search has been undertaken in the movement measurement area. Static electromagnetic field sensing and ultrasonic Doppler sensing are the most promising potential body movement measurement techniques revealed by this first preliminary search.

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

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

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

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

PROBLEM TU-22 *X-ray Microplanigraph*

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

Cancer is the second largest cause of death in this country, and according to a recent survey, is the disease most feared by the American people. The state of cancer treatment today is such that generally those cancers that are found early can be successfully treated. The easiest

cancers to detect are those that are on the surface of the body, and those most difficult to detect are those deep within the body. Thus, cancers arising deep within the body usually result in the death of the patient because detection of the cancer occurs too late.

It is desirable to develop an instrument capable of detecting tumors deep within the body. In addition, it is desirable to be able to determine whether or not the tumor is malignant or benign and the extent to which the tumor has spread. One common method of detecting tumors is by X-ray. Unfortunately, when the entire body is X-rayed, small tumors cannot be detected because the background level of signal of the X-ray is vastly increased by the thickness of the body. It would be highly desirable to develop a technique whereby X-rays should be made of lamina regions only. If X-rays could be made of thin laminae, smaller tumors could be detected. The basic problem then is to develop a method whereby X-rays of thin laminae can be made of a patient instead of the conventional X-ray technique.

The technique of making X-rays of thin laminae with high resolution is called X-ray microplanigraphy. This technique has been theoretically possible for many years. Recently, a development in NASA has significantly increased the possibility of developing such a technique. NASA developed such a technique for inspecting multilayer printed circuit boards layer by layer with a resolution of 0.001 inch. This technique has been well developed by a NASA contractor at Illinois Institute of Technology (IIT). Basically, it involves moving the X-ray source and detector in a particular geometrical arrangement in such a manner that only thin laminae are measured. The work was funded by Marshall Space Flight Center (MSFC), and the Team was apprised of the work through a computer search. The Team then contacted MSFC for additional information and was referred to the IIT investigator. The problem originator has discussed this technique in detail with the NASA contractor and has decided that this work is highly relevant to his investigation. An example of the use of the technique is shown in Figure B-1.

The device has been implemented at the Tulane School of Medicine. The researcher indicates that tests to date have shown that it is possible to distinguish malignant from benign lesions in the breast. This will eliminate the need for much surgery in cases of suspected breast cancer. The National Cancer Institute has also funded a major study using this approach.

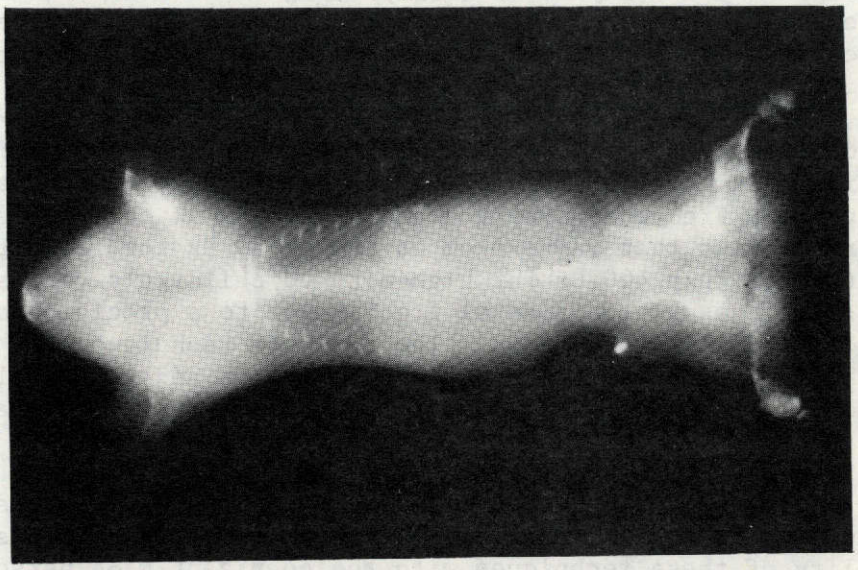


Figure B-1. X-Ray Microplanigraph of Mouse.

ECOLOGY

PROBLEM TU-9 *Human Voice Analysis*

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

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

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

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

Spectral analysis techniques developed by the NASA Michoud Assembly Facility is applicable to this problem. The problem originator discussed the applicability of these techniques with the cognizant NASA personnel, and the NASA personnel agreed to process clinical data collected by the problem originator. Data from 18 patients have been analyzed and work is continuing.

KIDNEY DISEASE DETECTION AND TREATMENT

PROBLEM TU-24 *Transmission of Clinical Urinary Isotope Data*

A means is needed of transmitting clinical data from scintillation camera in a satellite hospital to a computerized analyzer in a central hospital. Early detection of urinary tract abnormalities leading to the estimated 8 million cases of kidney disease is important in its prevention. The problem originator has been a leader in the use of isotope techniques for detection. Use of this technique is significantly enhanced by an expensive computerized analyzer system. It would be more efficient to use the analyzer in a central hospital with the scintillation camera in a satellite hospital.

Three channels of analog data are transmitted with a 4 volt pulse height and at least 40 levels of discrimination required. Pulse rate is 5×10^5 per minute and it is possible to digitize the data.

Use of the Applications Technology Satellite is being explored at Goddard Space Flight Center.

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

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

Information obtained as a result of the cooperation of NASA personnel at the Marshall Space Flight Center is providing for Dr. W. A. Boyce a number of scanning electron micrographs of various characteristic kidney stone types and has been extremely useful in Dr. Boyce's studies. The scanning electron microscope studies, however, indicated that there are certain lamellar characteristics on the kidney stone surfaces observed. These surface characteristics showed up in many of the scanning electron micrographs as striations on the surface. In order to probe further into the mysteries of kidney stone formation, Dr. Boyce has considered it extremely important to determine whether or not these striations or lamellar-appearing variations on the scanning electron micrographs are related to compositional changes of the kidney stone itself. Consequently, Dr. Boyce wishes to compare certain kidney stones using scanning electron micrographic techniques on the same kidney stones to determine, using the best available techniques, the microcomposition of the kidney stone surface. Essentially, a method of obtaining the microcomposition (the composition of portions of the kidney stone surface 1 or 2 micrometers in diameter) of kidney stones is desired to permit comparison of the surface morphology with composition. The possession of this information will provide an answer to the question of whether the lamellar-like structures, shown on many of the kidney stones, are actually associated with compositional differences in the kidney stones.

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

RESPIRATORY DISEASE DETECTION AND TREATMENT

PROBLEM UNC-79 *Retractable Cover for a Bronchofiberscope*

In medical applications, fiber optic scopes provide a unique non-surgical means of visually inspecting the interior surfaces of the stomach, colon, and bronchial tubes. Built into these scopes is a hollow, open channel approximately 1.5 mm in diameter and 600 to 700 mm long which runs parallel to the fiber optics. Through this channel, tissue biopsies can be made or sputum samples can be taken from deep within the body. If the scope is passed through the mouth into the bronchial tubes, the samples from the bronchial area may be contaminated by material picked up in the mouth. Some method is needed to keep the sampling channel sealed until it is desired to take a sputum sample.

Mr. John Samos of Langley Research Center has forwarded five suggested solutions. Each has been discussed in detail with the problem originator. While some hold promise, all require modification to meet the extreme requirements. The problem originator is currently studying ways in which these suggestions might be adapted.

DETECTION AND TREATMENT OF DENTAL AND ORAL DISORDERS

PROBLEM LSD-1 *New Methods for Cleaning Teeth*

A new method of cleaning teeth is needed to remove food particles and plaque. Preventive dentistry is an important aspect in reducing cavities, periodontal disease, and loss of teeth. The teeth need to be cleaned on all surfaces including the areas between the teeth as well as the areas beneath the gums. Conventional brushing of teeth is partially successful in cleaning. In addition, the use of dental floss and water-cleaning devices help to significantly reduce instance of dental disease. However, improvements are clearly needed in the area of cleaning methods, and a new approach to the problem is needed. The technique should be amenable to use by the general public at home as well as in the dentist's office. Either chemicals or mechanical methods can be used, but they must be of a nature that will not cause damage to the teeth and gums as well as the rest of the body in the event of the use of toxic chemicals.

A suggestion from Marshall Space Flight Center is being evaluated as a solution to this problem.

PROBLEM LSD-2 *New Materials for Dental Restoration*

There are two main classes of material commonly used in dental restoration. One material class is amalgams which are commonly used for cavities. The other material commonly used is gold which is used for inlays and crowns. However, gold has had a dramatic increase in price during the last several years, and further price rises may make the use of gold prohibitedly expensive. A material that can replace gold is required, but this material must have a number of specific mechanical properties.

The material must have a Knoop hardness between 65 and 300. It must have a compressive strength in excess of 44,000 psi and a sheer strength greater than 14,000 psi. Youngs modulus should be between 1.7×10^6 psi and 6.7×10^6 psi. The material should have a chemical inertness in the oral environment and should be capable of fabrication by the investment process.

Specialists in materials at Lewis Research Center are being consulted in an attempt to solve this problem.

PROBLEM VAM-22 *Artificial Teeth*

The L. D. Pankey Institute is dedicated to the improvements of dentistry. The Institute uses the most modern teaching techniques not only to equip the dentist with the latest dental knowledge, but also to expand the concept of dentistry from one of repair to one of preventive medicine.

The Institute makes extensive use of life-like manikins which have artificial teeth made of plastic. Each tooth can be individually removed, but, unfortunately, when one attempts to drill these teeth, the teeth melt.

An artifical tooth is needed that simulates the approximate characteristics of teeth that can be drilled. Hopefully, the artificial teeth can be made with simulated disease states in the laboratory.

The three major divisions of tooth structure are enamel, dentin, and the pulp. The pulp is the center section and is the location of the nerve and blood vessels. Its simulation need be only coloring. However, the enamel and dentin must be more closed simulated with materials having the same general texture as the natural structure.

Several commercially available artificial teeth have been located. Each has certain shortcomings that makes them unacceptable. Literature searches have revealed much work in implantable dental materials, but these materials have not been designed to simulate drilling characteristics. This literature has provided many parameters which describe the desired material. Since no solution has been located, a problem statement is in preparation.

BASIC MEDICAL RESEARCH PROBLEMS

PROBLEM JHU-1 *Development of a Vibrotactile Stimulator for Psychophysical Studies in Deaf Children*

Failure of the auditory system produces serious problems in the development of the normal communication abilities of the young child. Probably the single most damaging effect of early profound deafness is the loss of the feedback which the auditory system normally provides in speech development. The loss of this feedback leads to retarded speech development and then to further retardation of intellectual development.

The skin is endowed with several sensory systems which respond to mechanical deformations of the body surfaces and has been used as a supplementary communications channel in the blind (e.g., Braille). The laboratory in the Department of Biomedical Engineering at Johns Hopkins University has taken the point of view that the pertinent characteristics of speech can be mapped onto vibrotactile stimulators and provide profoundly deaf children with speech feedback or tactile speech communication in real time. In the design of the tactile displays, the stimulus parameters must be chosen according to the psychophysical functions as well as the receptor properties in order to obtain a device that is optimal from a discriminatory point of view. Consequently, the primary need of this group is an instrument that will enable them to test vibrotactile stimulus parameters in a systematic manner.

A vibrotactile stimulator with variable rate and amplitude of displacement, repitition, and contact area of individual stimulators, as well as different anatomical locations of the stimulator matrix. The stimulator system will be driven by a hybrid computer interfacing between the speech encoder and stimulator matrix.

A literature search has been initiated.

PROBLEM JHU-2 *Development of a System to Apply Step Changes in External Pressure to the Canine Neck*

Arterial blood pressure is maintained at a relatively constant level by a variety of complex, interrelated control systems. One of these pressure control systems, the carotid baroreflex system, has been examined under

numerous open loop and closed loop conditions, in both unconscious and conscious animals. Dr. Kiichi Sagawa of the Department of Biomedical Engineering at Johns Hopkins University is attempting to define the role of anesthesia on baroreflex dynamics under experimental conditions such as hemorrhage etc. The major problem is to develop a pneumatically controlled pressure reservoir which may be fitted around the canine neck such that desired changes in external pressure may be applied.

Changes in pressure should be localized to the carotid bifurcation and be restricted to 50 mm Hg ± atmospheric pressure with a rise and fall time of less than 500 msec. The system should accommodate different neck geometries and sizes and produce no longitudinal pressure gradients along the neck.

A literature search has been initiated.

PROBLEM TU-10 *Quantization of Heart Tissue Hardness*

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

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

A suggestion from Marshall Space Flight Center (MSFC) on the use of a hardness tester for sponge rubbers has been implemented by the researcher. A research program is underway using the device, shown in Figure B-2.

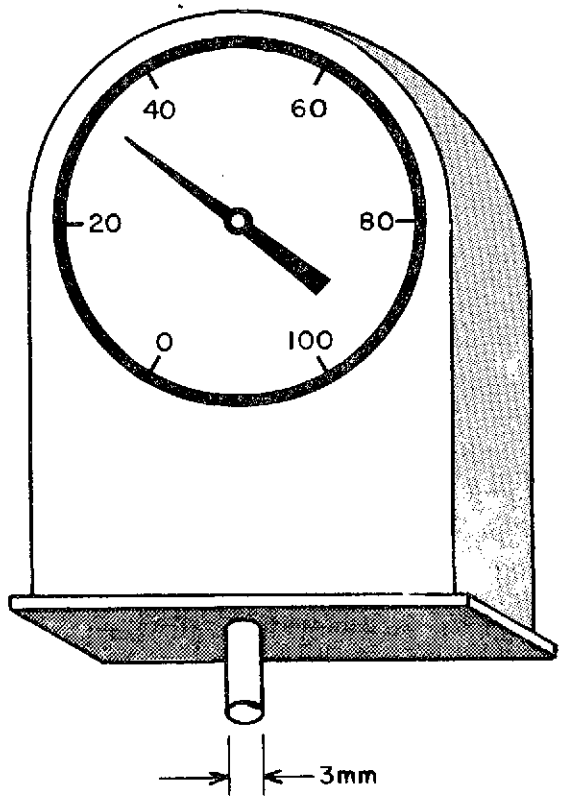


Figure B-2. Hardness Tester.

PROBLEM NINDS-1 *Cerebral Blood Flow*

Stroke, which results from an impairment of cerebral blood flow, is the third most common cause of death, exceeded only by heart disease and cancer. In addition, those that survive a stroke are often severely disabled and require expensive special care.

In the diagnosis and treatment of stroke, the detection of blood flow to the cerebral arteries is of major importance. At the present time, both total and regional blood flow measurements are usually made by some type of indicator dilution technique. Typically, this involves the inhalation of a Krypton-doped gas or the injection of a radioisotope in the carotid artery.

Other methods include the injection of a radiopaque dye into the artery so that an X-ray or cerebral angiogram can be made. However, because of vascular puncture, significant X-ray exposure, use of radioactive materials, etc., these techniques are unsuitable for use by community hospitals or group practices of physicians as a method for screening or serial followup of patients. For this type of application, some new approach to the problem of measuring cerebral blood flow is needed.

If possible, the method should be noninvasive and should have the potential for repeated measurements over short periods of time. In addition, the tests should be repeatable over several days. A patient preparation time of less than 15 minutes would be desirable. A problem statement has been circulated to the NASA Field Centers.

PROBLEM TU-35 *Subcutaneous Temperature and Power Density Measurement in a Microwave Field*

The widespread use of microwave generating equipment in this country has created a significant level of microwave exposure for the general population. The accepted safe limit for microwave exposure in this country is taken as 10 milliwatts per square centimeter, but it is interesting that the accepted safe exposure limit in the Soviet Union is now 0.1 milliwatt per square centimeter. For this and other reasons, considerable research is underway to determine the adequacy of the United States limit. Part of the difficulty in determining the microwave effects on the biological system is caused by the difficulty of making measurements in experimental animals exposed to a microwave field. It is likely that the introduction of an animals into an existing field would disturb the field and in addition the measurement of temperature in an animal is complicated by the fact that the microwave radiation may produce a different heating effect in the temperature sensor than in the experimental animal. A means of making a subcutaneous temperature and power density measurement in a microwave field is required that eliminates the above problems.

An information search has been conducted,and a problem statement has been circulated. The problem originator is now evaluating the initial responses from the problem statement circulation. One suggestion from the Skylab prime contractor on sea state measurement appears applicable.

PROBLEM UNC-82 *Method for Measuring Villi Motion*

The small intestine is the site of practically all of the transfer (absorption) of water and nutritive material from the gut into the bloodstream. The problem originator, in studying this transfer process, discovered a material which she named Villikinin. It appears that Villikinin plays an important role, but she has been unable to accurately document its effect.

Villikinin exerts its effect on intestinal villi. These are tiny finger-like projections approximately 1 mm long and 0.2 mm in diameter which are crowded together over the entire internal surface of the small intestine The villi intermittently contract along their long axis. Often a villus will completely disappear before relaxing to its mormal length. This pumping action is believed to increase the rate of absorption, and to microstir the material along the gut wall. Studies indicate that Villikinin, which is released as food stuff, comes in contact with the gut wall, significantly reduces the period between contractions, and thus apparently gears the absorptive process to meet the demand.

In the experimental setup, a small section of a dog's gut is exposed and observed under a 40-power microscope through a 2-mm by 2-mm grid. Thus 6 to 8 villi are within a grid. Average contraction rates with and without Villikinin are computed by actually counting the contractions during repeated 30-second periods. Because an individual must count in real time, critics believe that this technique is too subjective. Photographic techniques have difficulty with gut movement caused by the animal's respiration. However, it is believed that some photo technique holds promise. A problem statement is currently being prepared for distribution.

PROBLEM VAM-24 *Processing of Rapid Microfluorimetry Data*

One of the three common characteristics shared by all cancer cells is anaplasia. This is a structural abnormality in which the cells resemble more primitive or embryonic cells and in which adult functions are absent or diminished. These differences are also reflected in distinct changes in the cell's metabolism processes.

As part of an ongoing cancer research program to study cellular metabolism, the problem originator is assembling a sophisticated microfluorimetric system which will make 15,000 measurements per second. This system is identical to that developed by Dr. Hongsuk H. Kim of NASA. Dr. Kim has also developed computer software to allow computerized data processing and data analysis. Because of the enormous quantities of data involved, the problem originator must develop the same computerized data processing and analysis capability. Considerable cost and time will be saved if he can utilize that system already in existence in NASA.

Dr. Kim visited the problem originator and inspected the microfluorimetric instrumentation system. He discussed at length the proposed research and verified that the proposed system was basically identical to the one he developed. He also verified that the computer software would be directly

applicable if certain experimental constraints were followed. Since that visit, arrangements have been made to authorize Dr. Kim to provide technical assistance to insure compatibility of data and computer software. In addition, Dr. Kim has been given authorization to process certain portions of the problem originator's experimental data. Initial work should begin in September 1974.

OTHER, MISCELLANEOUS

PROBLEM JHU-3 *Method for Measuring Blood Volume in IC Patients with Normal Hepatic Function*

Blood volume is regulated by a number of autoregulatory and neuro-endocrine control systems, which normally enables the vascular system to fill to an optimal degree of distension. When the filling pressure to the heart is lowered by reducing blood volume, the transport of metabolic fuel is inadequate; conversely, when the filling pressure of the heart is greater than normal, the heart dilates and overfills to pump the same volume. Surgical trauma frequently produces variations in blood volume and a condition known as shock generally ensues. Shock, generally speaking, may be defined as a generalized disturbance of fluid balance resulting in a circulatory deficiency, characterized by decreased blood volume, decreased cardiac output, hemoconcentration,and by impaired renal function. For these and other reasons, frequent measurements of blood volume and cardiac output are essential for detecting and treating shock conditions in surgically traumatized patients.

Cardiac output and blood volume measurements are done by injection of known quantities of a blood soluble material which is confined to the intravascular space and is slowly metabolized. Although Cardio-Green has been used extensively for both measurements by numerous investigators, the urgery epartment at Johns Hopkins University has found Cardio-Green to be unsatisfactory in patients with normal hepatic blood flow due to its rapid metabolism to the liver. The problem is thus to find a suitable indicator for cardiac output and blood volume measurements that is nondiffusable and metabolized slowly by the liver or to develop a two compartment circulatory model that compensates for the hepatic uptake of Cardio Green.

A method is needed that will enable blood volume and cardiac output measurement to 5 percent accuracy. Repeated measurements approximately every 5 minutes should produce no discoloration or interference with the measurement system.

A literature search has been initiated.

PROBLEM JHU-4 *Development of Computer Technology for Relating the BCG and Carotid Pressure*

Ballistocardiography (BCG) is a noninvasive method of measuring the lumped forces associated with differential blood mass movements between the arterial and venous systems. Blood mass movements may be related quantitatively to volumes ejected by the heart by measuring displacements, velocity, and accelerations of the whole body mass. In addition, the characteristics of pressure pulses in the head, neck, limb, and torso segments lend themselves to secondary calculation of prevailing forces associated with mass movement of blood during the pulse. The problem originator is attempting to utilize the BCG as a mass screening tool for detecting the onset and types of peripheral vascular changes associated with hypertension. In this study BCG records and carotid pressure data are obtained from large numbers of subjects and a computer search is conducted for the relationship between BCG wave tips and the carotid pressure data. The basic problem is how to automate the epoch detection from a rather noisy carotid arterial pressure waveform (i.e., an automated procedure for detecting the onset of a pulse).

The sample is restricted to no more than 13 cardiac cycles. ECG information is not possible due to recorder limitations. Desired accuracy is 80 to 95 percent. Signal processing routines are acceptable.

A literature search has been initiated.

PROBLEM JHU-5 *Positioning of Sonomicrometer Transducer on the Endocardial Surface*

Cardiac function can best be assessed by considering the heart's performance both as a hydraulic pump and as a contracting muscle. Although the capacity of any pump can usually be expressed by its flow output and the pressure it can generate, the unique performance characteristics of the cardiac pump also require evaluation of muscle performance through simultaneous measurement of an appropriate left ventricular dimension. Measurement of the left ventricular transverse diameter with a sonomicrometer provides a technique that is simple and continuous, requires a minimum of equipment and facilities, does not significantly interfere with normal cardiac function,and is suitable for use in conscious animals. Measurement of internal left ventricular diameter with sonomicrometer transducers placed on the endocardial surface of the ventricle directly measures the diameter of the chambers and minimizes errors due to wall thickness changes. Although the transducers function well for 2 to 3 months after successful implantation, only 33 percent of implantation attempts, by the problem originator, yield satisfactory results. Failures are occasionally due to mitral insufficiency; however, the most common cause of failure is due to malposition of the transducers (i.e., the two piezoelectric crystals are not facing each other in the same horizontal plane). The problem originator

believes this problem is due to the irregular endocardial surface and/or the excessive directionality of the ultrasonic beam. Remounting of the probes in the endocardial surface is not feasible due to excessive trauma from multiple incisions to the ventricular wall. The large cost and effort associated with the preoperative, operative, and postoperative phases of each experimental preparation suggests that improved transducer orientation techniques during implantation are not only desirable but essential for economical acquisition of accurate and reliable data.

The technique should improve the current success rate (33 percent) and provide a reliable and accurate measure of the left ventricular transverse diameter (e.g., by excluding variations of vertical or lateral wall movement, etc.). The technique may include modifications in surgical implantation procedure and/or changes in present signal detection methods.

Specialists in ultrasonic technology at Ames Research Center have been consulted.

PROBLEM MISC-24 *Metal pH Electrodes*

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

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

The renewed use of antimony as a pH electrode material was pointed out to the problem originator. Using specialized manufacturing techniques, he developed a prototype electrode and subjected it to an extensive laboratory evaluation with favorable results. Currently, the problem originator is planning a publication on this work.

The problem originator noted, in an aerospace literature search, NASA's work with palladium as a electrode in fuel cells. A more detailed study of the literature led him to fabricate a pH electrode using palladium. Initial laboratory evaluation has been very favorable. Currently, he is conducting an extensive laboratory and clinical evaluation of the electrode.

PROBLEM MISC-40 *Storage Technique for X-rays*

A method of automatic storage and retrival of X-rays is needed that eliminates the existing manual storage and retrival system. Large hospitals have significant difficulty in storage and retrival of X-ray films. At the problem investigator's institution, approximately two million films are stored, and the retrival in a smooth fashion of these films is a difficult and expensive procedure. The primary shortcoming of the system is in the waste of physician time, and a new method of information storage and retrival is required.

The system must be capable of storing two million films with a quality of four line pairs per millimeter. The systems will be required to store this data for 5 years. About 10^{13} bits of information will be required in the storage, and a display system is also required for this data.

Technology for the storage of aerial photographs at Ames Research Center is being explored as a solution to this problem.

PROBLEM UMISS-1 *Criteria for Selection of Computer Systems in Biomedical Simulation*

A set of criteria is needed for selecting a specific computer technology in simulating different biological systems. Biological simulation, or modeling, is the process by which one observes some biological system in operation and attempts to evolve a mathematical description of the system. This evolution is an iterative procedure whereby one makes an over-simplified first order approximation as to the nature of the equations governing the behavior of the system. These equations may be deterministic or probabilistic etc., and may vary in number from one to many thousand. Once a set of equations has been obtained, however, the task of familiarization with the behavior of these equations remains. The hardware and software used as a solution tool can vary from large-scale digital or analog computers to hybrid computer systems, different simulation languages, input-output devices, etc., depending on the needs of the investigator. Selection of the ideal computer system for a particular type of model is a function of the modeler's needs and resources, and is a most difficult and time-consuming task. The problem originator is directly responsible for matching the appropriate computer system to a wide variety of biomedical problems and modeling efforts and would like to obtain information that could enable him to perform this duty with minimal time, cost, and effort.

A procedure, or formalized guidelines, is needed that may be systematically applied in matching model, or equation, form to the most appropriate computer system.

PROBLEM UNC-66 *Determining Tissue Perfusion Adequacy*

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

If the cause is vascular blockage, in most cases it can be accurately located and removed or bypassed. This restores the blood flow but not necessarily the tissue perfusion. Physiological control systems allow large portions of the blood-flow increase to bypass the nutritional capillary beds. In addition, the tissue deterioration could be too extensive to permit perfusion. In either case, additional corrective action is necessary, preferably before the ongoing surgery is terminated. Unfortunately, the physician does not now have a method for quickly evaluating the adequacy of tissue perfusion. Such a method would save the patient the trauma and expense of additional surgery. It would also provide more effective treatment.

One possible indicator of increasing stages of tissue deterioration would be the levels of the proteolytic enzymes that are present in the affected tissue. A joint investigative program with Ames Research Center using the proteolytic enzyme assay is being pursued.

PROBLEM UNC-80 *Medical Equipment Inventory and Management System*

A system for inventory and maintenance management for medical equipment at a university hospital is needed. The increasing availability of advanced technology and clinical facilities has resulted in an uncoordinated assembly of medical equipment and devices in many hospitals. As a result, no standard inventory and maintenance records are kept which results in poor maintenance of this equipment. No records are kept as to which pieces of equipment fail most often, and no routine maintenance is scheduled to attempt to reduce failure rates. In addition, many hospital departments are unaware of similar equipment in other parts of the hospital. A system is needed that can maintain accurate inventory and repair records so that maximum utilization of equipment can be accomplished.

The system should be capable of cataloging on a computerized basis all equipment and determining at the end of the year the frequency of repair records for all classes of equipment. In addition, the system should indicate which pieces of equipment are in need of routine maintenance on a monthly basis.

A system for equipment inventory at the Langley Research Center (LRC) has been identified, and the problem originator has contacted the NASA personnel at LRC.