PREFACE

This report covers the March 15, 1970, to September 30, 1970, activities of the NASA Biomedical Application Team at the Research Triangle Institute. The activities were performed in accomplishing Tasks A through F, Statement of Work, NASA Contract No. NASW-1950. Accomplishment of Task G, Supplementary Efforts, is reported separately. This work was performed in the Engineering and Environmental Sciences Division of the Research Triangle Institute under the technical direction of Dr. J. N. Brown, Manager, Systems Engineering Department, and Dr. F. T. Wooten, Project Leader and Director, Biomedical Application Team. Full-time members of the BATeam and other RTI staff members who participated in the project are Mr. Ernest Harrison, Jr., Dr. G. S. Hayne, Mr. E. W. Page, Mr. B. W. Crissman, and Mrs. Mary Carpenter. Assistance from other members of the RTI staff was obtained as needed.

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

ABSTRACT

This report presents the results of the activities of the NASA Biomedical Application Team at the Research Triangle Institute. This experimental program in technology transfer was supported by NASA Contract No. NASW-1950 for the reporting period March 15, 1970, to September 30, 1970. The RTI Biomedical Application 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 Biomedical Application Team Program included Dr. J. N. Brown, Jr., Electrical Engineer; Dr. F. T. Wooten, Electrical Engineer; Mr. Ernest Harrison, Materials Scientist; Dr. G. S. Hayne, Physicist; Mr. E. W. Page, Electrical Engineer; Mr. B. W. Crissman, Geophysicist; and Mrs. Mary Carpenter, Research Assistant. In addition, the Biomedical Application Team draws upon the capabilities of other members of the RTI staff as needed.

Ten medical organizations are presently participating in the RTI Biomedical Application Team Program: Duke University Medical Center, Durham, North Carolina; the Medical School of the University of North Carolina, Chapel Hill, North Carolina; the University of North Carolina Dental School and Dental Research Center, Chapel Hill, North Carolina; the Bowman Gray School of Medicine, Winston-Salem, North Carolina; the North Carolina State University, Raleigh, North Carolina; the Institute of Rehabilitation Medicine of New York University Medical Center, New York, New York; the National Cancer Institute, Bethesda, Maryland; Tulane School of Medicine, New Orleans, Louisiana; Brookdale Hospital Center, Brooklyn, New York; and Ochsner Clinic and Foundation, New Orleans, Louisiana.

The accomplishments of the Research Triangle Institute Biomedical Application Team during the reporting period are as follows: The Team has identified 41 new problems for investigation, has accomplished 11 potential transfers of technology, has closed 14 old problems, and on September 30, 1970, had a total of 81 problems under active investigation.

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LIST OF ABBREVIATIONS

ARAC	Aerospace Research Applications Center
ARC	Ames Research Center
BATeam	Biomedical Application Team
COSMIC	Computer Software Management and Information Center
FRC	Flight Research Center
GSFC	Goddard Space Flight Center
Hdqtrs	NASA Headquarters
IAA	International Aerospace Abstracts
KSC	Kennedy Space Center
LeRC	Lewis Research Center
LRC	Langley Research Center
MSC	Manned Spacecraft Center
MSFC	Marshall Space Flight Center
NCSTRC	North Carolina Science and Technology Research Center
RDC	Regional Dissemination Center
RTI	Research Triangle Institute
STAR	Science and Technical Aerospace Abstracts
TATeam	Technology Application Team
TUO	Technology Utilization Officer
WESRAC	Western Regional Applications Center

1.0 INTRODUCTION

1.1 Introductory Comments

Significant benefits are to be gained by applying the scientific and technological results of federally funded research and development (R & D) programs to problem areas other than those for which they were created. The size of the national investment in R & D programs and the very significant technological achievements which have been realized in the past decade demand that an effort be made to apply the results of these programs to the social, economic, environmental, and health-related sectors of our society.

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

More recently, NASA has established a program which uses an active, directed transfer methodology. In this program, NASA has established three Biomedical Application Teams (BATeams) and four Technology Application Teams (TATeams) at not-for-profit research institutions. The 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 the BATeams interact only with potential users who are involved in reaching selected national objectives. These technologies include biology and medicine for the BATeams and air pollution control, water pollution control, marine sciences, mine safety, and criminology for the TATeams. The three BATeams which have been established by NASA are located at the following institutions:

Research Triangle Institute
P. O. Box 12194
Research Triangle Park, North Carolina 27709

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

Southwest Research Institute
8500 Culebra Road
San Antonio, Texas 78228

This report covers the accomplishments and activities of the BATeam located at the Research Triangle Institute for the period March 15, 1969, to September 30, 1970. In the remainder of Section 1.0 are presented discussions of BATeam objectives and methodology.

1.2 Biomedical Application Team Program

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

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

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

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

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

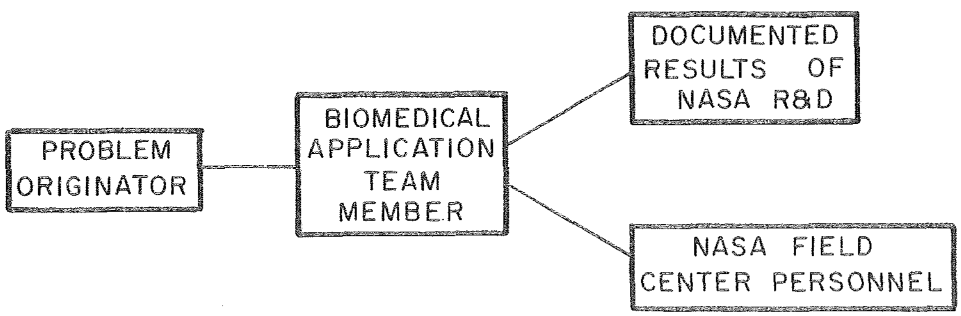

Figure 1. Possible Mechanisms for Transfer of Technology.

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

Generally, technology relevant to specific problems is identified through two approaches: (1) manual and computer searching of the aerospace information bank created by NASA as part of its R & D effort, and (2) direct contact with the engineering and scientific staff at NASA Field Centers. Technology representing potential solutions to problems is channeled through the BATeam to the problem originator for evaluation and implementation as a solution to his problem. Alternatively, and less frequently, the BATeam 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. The more direct the transfer, the more relevant, accurate, and complete is this transfer. Thus, the BATeam attempts to create these direct interchanges whenever appropriate and feasible.

Assistance to the problem originator in implementing solutions to problems is an important part of the BATeam program. This assistance may take any one of a number of different forms. Direct assistance to the problem originator in his efforts to implement a solution is frequently involved. During this reporting period, NASA's Technology Utilization Division has utilized a re-engineering or adaptive engineering program in the School of Engineering of the University of Virginia which is assisting in this program by adapting NASA technology to the needs of a limited number of problem originators. This adaptive engineering program is directed by Dr. M. L. McCartney of the Division of Biomedical Engineering. The BATeams are responsible for identifying the NASA technology which is potentially a solution to a specific problem and for specifying the changes required in this technology. This allows the BATeams to demonstrate that the technology is in fact a solution to the problem and allows the problem originator to make use of the NASA technology in his work.

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

A specific methodology is applied by the BATeam in its efforts to effect technology transfers. This methodology is discussed in the following section.

1.3 Methodology

The methodology used by the BATeam consists of four basic steps: problem definition, identification of relevant technology, evaluation of relevant technology, and documentation. This methodology can be better understood, however, if it is separated into the steps shown in Figure 2. These steps are described in the following paragraphs.

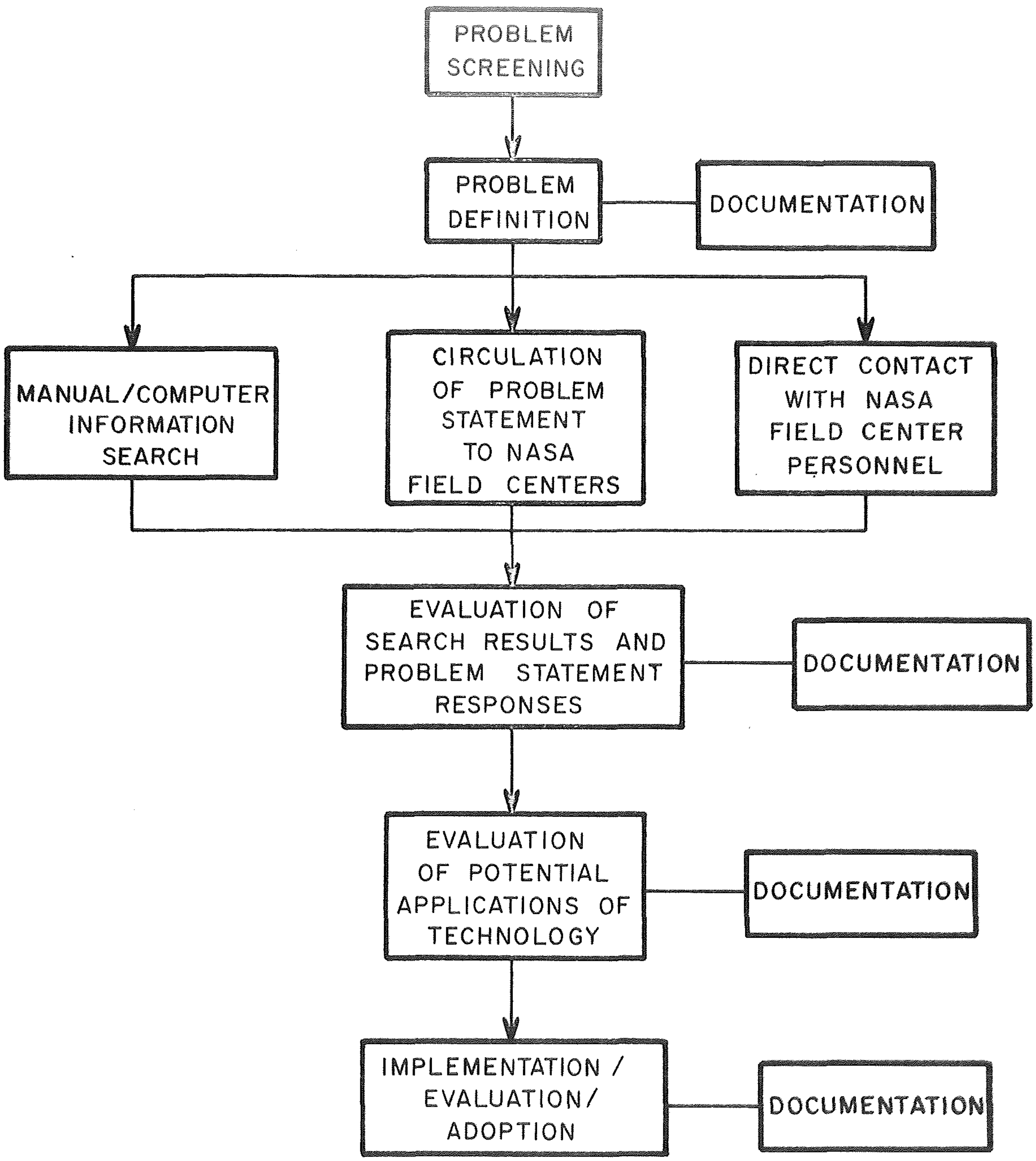

Figure 2. Flow Chart of Biomedical Application Team Transfer Methodology.

Problem Screening - Effective problem screening is at least as important to the success of the BATeam program as any of the operational steps identified in Figure 2. Analysis of the RTI BATeam's accomplishments over a period of three and one-half years indicates clearly that a very significant fraction of the problems which have been investigated unsuccessfully could have been rejected very early in discussions with the problem originators. Problem selection criteria have been developed with the objective being to increase the probability that a technology transfer can be accomplished for those problems accepted by the BATeams. At the present the following criteria are being applied:

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

OR

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

OR

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

AND

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

AND

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

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

Problem Definition - The objective of this step is to define precisely and accurately the characteristics of the technology required to solve a problem. It is important that all necessary constraints are included and--equally important--that no unnecessary constraints are included in characterizing the required technology. In many cases, following the characterization of required technology, it is found that the problem should be rejected or closed for any of a number of reasons. These reasons include, as examples, the following: (1) the problem can be solved using commercially available equipment; (2) the problem cannot be solved, so that an entirely different approach is indicated; (3) the real problem is medical and not technical in nature; and (4) the requirements cannot be specified because insufficient information exists on the objective involved.

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

Identification of Relevant Aerospace Technology - Aerospace technology which may be relevant to the solution of a problem is identified by three approaches. First, a manual or computer search is made of the aerospace information bank. These searches are made at one of NASA's six Regional Dissemination Centers (RDC). The RDC used by the RTI BATeam is the North Carolina Science and Technology Research Center (NCSTRC) located in Research Triangle Park, North Carolina. The information which can be assessed through the RDC's bank consists of approximately 700,000 documents, articles, and translations which have been abstracted in the Science and Technology Abstract Reports (STAR) and the International Aerospace Abstracts (IAA). Second, 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 BATeam, Technology Utilization Officers (TUO) at the NASA Field Centers, and other individuals at the Field Centers. Third, the BATeam in some cases contacts individuals at the Field Centers directly without circulating problem statements. This is done when a BATeam member can identify a relatively few individuals at the Field Centers who are likely to have a good overview of all work being done which is related to the requirements of a specific problem.

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

Second Evaluation - 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 BATeam may be asked to supply additional information and technical details in this evaluation.

Implementation, Final Evaluation, Adoption - The final step in the transfer process is the implementation and experimental evaluation of potential solutions. The BATeam is available for assistance in this step when required. Hopefully, when a potential solution is shown to be a valid solution to a problem, this solution is adopted by the problem originator and the transfer is completed.

Documentation - Documentation is an integral part of the BATeam methodology; it is involved at most steps in the process, as indicated in Figure 2. Documentation allows analysis of the transfer process and assessment of the program in general. At present, the BATeams report on a weekly, monthly, and semiannual schedule. Effective communication is required between BATeams, potential problem originators, and other individuals who are in a position to make use of information resulting from transfers accomplished by the BATeams.

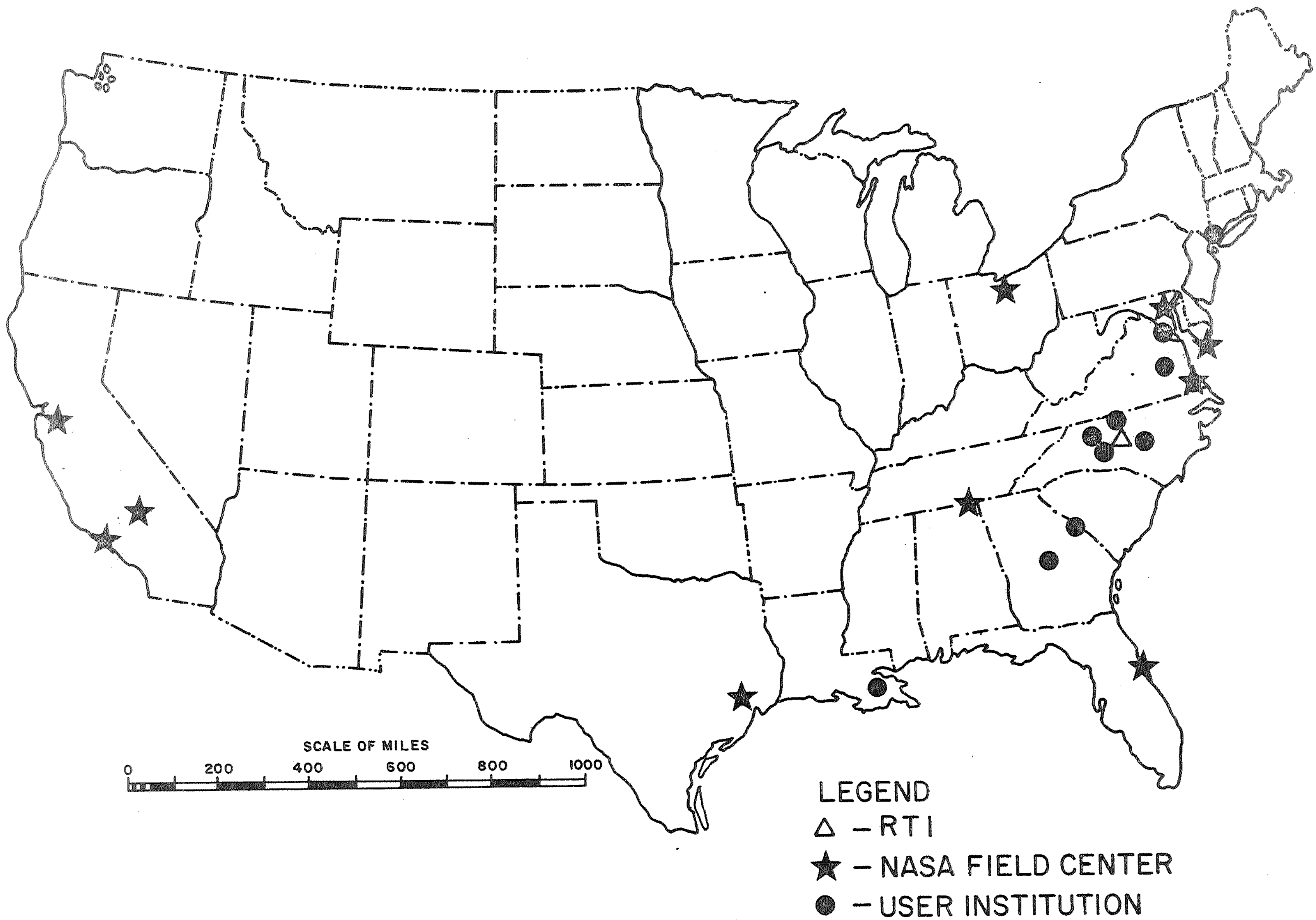

Figure 3. BATeam Activity Centers in the United States

1.4 Biomedical Application Team Composition and Participating Medical Institutions

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

Name	Background	Duty
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. G. S. Hayne	Physicist	Solution Specialist
Mr. E. W. Page	Electrical Engineer	Solution Specialist
Mr. B. W. Crissman	Geophysicist	Documentation
Mrs. Mary Carpenter	Research Assistant	Documentation

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

At present, ten medical institutions are participating in the RTI BATeam program. These institutions are as follows:

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

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

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

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

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

North Carolina State University, Raleigh, North Carolina;

Ochsner Clinic and Foundation, New Orleans, Louisiana;

Tulane University Medical School, New Orleans, Louisiana;

National Cancer Institute of the National Institutes of Health, Bethesda, Maryland;

Brookdale Hospital Center, Multiphasic Health Screening Clinic, Brooklyn, New York.

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

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

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

In addition, Dr. T. C. Pilkington and Dr. F. L. Thurstone, Biomedical Engineering Division, Duke University, are assisting the RTI BATeam in investigating the potential for transferring NASA digital computer applications programs to applications in medicine.

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

Louisiana State University School of Medicine, New Orleans, Louisiana;
Medical College of Virginia, Richmond, Virginia;
National Communicable Disease Center, Atlanta, Georgia;
National Institute of Mental Health, Washington, D. C.;
North Carolina Department of Vocational Rehabilitation, Winston-Salem, North Carolina;
University of Mississippi Medical School, Jackson, Mississippi.

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

BH - Brookdale Hospital Center
CP - Computer software-type problem
DU - Duke University School of Medicine
IRM - Institute of Rehabilitation Medicine at New York University
MCV - Medical College of Virginia
MISC - Miscellaneous
NCI - National Cancer Institute
NCSU - North Carolina State University
NCVR - North Carolina Department of Vocational Rehabilitation

NIMH - National Institute of Mental Health
OF - Ochsner Clinic and Foundation
TU - Tulane University School of Medicine
UNC - University of North Carolina Medical School
UNCD - University of North Carolina Dental School
WF - Bowman Gray School of Medicine at Wake Forest University

1.5 Definition of Terms

In the BATeam program, a number of terms have evolved which describe the elements and processes in this program. Because of their number and unfamiliarity to the majority of readers, these terms are listed and defined in this section for easy and quick reference.

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

Participating Institution - A medically oriented educational institution, hospital, medical center, or government agency having as one of its organizational objectives the improvement of medical health care for the general public or a particular sector of the general public and having agreed to participate actively in the BATeam program.

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

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

Problem - A specific and definable technological requirement that cannot be satisfied with commercially available equipment or through the application of information or knowledge available to the problem originator through routinely used information channels. Problems for investigation are accepted by the BATeam subject to the problem-screening criteria which are discussed in Section 1.3. Within the context of the BATeam program, it is explicitly assumed that problems investigated by the BATeam are problems which are impeding progress toward reaching an objective which involves improving medical and health care services for one or more sectors of the general public.

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

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

Computer Information Search - This is a computerized information search of the aerospace information bank established by NASA and made available through six Regional Dissemination Centers in the United States. This information bank consists of the approximately 700,000 documents which have been indexed and abstracted in the Science and Technical Abstract Reports (STAR) and International Aerospace Abstracts (IAA). Applications engineers at these centers design search strategies using information in problem statements. These search strategies allow the identification of those documents in the information bank which are relevant to the solution of a specific problem.

Impact - Information is transferred 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 transfer except that one or more of the requirements for a technology transfer are not satisfied.

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2.0 SUMMARY AND ANALYSIS OF TECHNOLOGY TRANSFERS

2.1 Introduction and Summary

During the period March 15, 1970, to September 30, 1970, the RTI Biomedical Application Team documented and reported to NASA eleven potential technology transfers and two impacts. All of the potential technology transfers were active as of September 30, 1970, and are listed in Table 1.

As defined in Section 1.5, a technology transfer is "the implementation and adoption of an item of aerospace technology by a problem originator to partially or fully solve a problem in biology or medicine. The medical application involved is one that is different from the one for which the aerospace technology was originally developed." Also, in the Introduction, an impact is defined as "the transfer of information to a problem originator with the result that he changes his activities in a way that enhances his progress towards a medical objective. An impact is thus analogous to a technology transfer except that one or more of the requirements for a technology transfer is not satisfied.

The definition of a technology transfer set forth in this report is not new. It has been proposed and discussed frequently but rarely applied rigorously. The reader should keep in mind that, although the transfer as it is defined here can be conceptualized easily, it is very difficult to implement. Thus, the impact was introduced in December, 1969, in order to allow more of the positive output of the BATeam to be documented and reported, and at the same time, allow the term "transfer" to be applied rigorously according to the definition given above. Introduction of the impact allows a clearer statement of the objective of the BATeam program. That objective is the accomplishment of transfers and not impacts. The impact is of value, but only in a secondary manner.

The present definition of a transfer is somewhat different from the definition used early in the BATeam Program. The increased emphasis on the new and tighter definition of a transfer requires more concrete evidence of implementation and use of NASA technology. During this reporting period, the RTI BATeam has continued to place emphasis on accomplishment of actual transfers but has delayed the reporting of a transfer in many cases until a later date in the implementation process. Thus, many of the problems reported in this report as potential transfers would have been documented as transfers in earlier reports. However, it should be realized that this new and more rigorous definition of a transfer will not prevent any of the real accomplishments of the program, but, in fact, will simply delay the date at which a transfer is reported.

2.2 Discussion and Analysis of Potential Transfers and Impacts

The potential transfers listed in Table 1 are significant problems in which implementation appears highly likely. For example, NCI-3 concerns the use of an ear oximeter which was designed for use on astronauts and which appears to solve the needs of a researcher at the National Cancer Institute in clinically monitoring the blood pressure of critically ill patients. The ear oximeter is presently being reconditioned at the NASA Ames Research Center and clinical trials are expected to begin in the near future.

Table 1. Potential Transfers and Impacts for the Period March 15, 1970, to September 30, 1970

Impacts

MCV-1	Applications of Image Processing Techniques in Radiography
MCV-2	High Intensity Soft X-ray Sources

Potential Transfers

DU-48	Urine Flowmeter
DU-59	Temperature Measurement on a Small Brain Probe
LSU-1	Improved Mechanical Respirators
NCI-3	Blood Pressure Measurement
NCI-4	Controlled Rate of Freezing a Liquid
NCI-8	Elliptical Lens
NIMH-1	Urinary Detection
TU-2	Respiratory Rate Measurement
WF-67	A Filter to Separate Physiologic Data Occurring at Nominal Heart Rates from Lower Frequency Data
WF-88	Accurate Determination of Arterial Pressure Pulse Transit Time
WF-89	Animal Restraints for Primates

In Problem TU-2 an impedance pneumograph designed for use on the Gemini spacecraft is being used to measure respiration rate of children in a clinical environment. The use of this equipment has already solved the basic problem, but the BATeam is waiting until a telemetry system is incorporated in the unit and it is evaluated in the clinical environment before reporting it as an actual transfer. This unit will enable a researcher to measure the respiration rate of children in a more natural play environment without disturbing the child. In addition to obtaining clinical data regarding the respiratory rate of children with respiratory diseases, the researcher can also determine normal breathing rates for young children.

In Problem NCI-8, a need existed for a means of designing an elliptical lens to be used in basic research at the National Cancer Institute. This problem appears to have been solved by using a computer program developed at NASA's Marshall Space Flight Center for designing complex optical surfaces. The computer program now being used at the National Cancer Institute appears to have solved this problem.

In Problem DU-48, a medical researcher has a potential solution to his problem of measuring urine flow in both basic research programs and clinical studies. The device to be used was originally developed by a NASA contractor and negotiations are under way regarding a contract to build a unit for the medical researcher.

In Problem WF-67, a medical researcher was interested in separating heart rate information from "noise" appearing on the EKG signal and originating with respiratory function. A technique developed at NASA's Ames Research Center for separating physiological signals having similar frequency spectra is being applied to this problem.

The two impacts that occurred probably would have been called transfers in previous reports using the older definition of transfers, but these cases are now reported as impacts because they do not meet the present definition; however, in both of these cases, a researcher used information gained from the BATeam in order to prepare proposals to the National Institutes of Health for research projects on systems approaches to handling X-ray diagnostic images in medical radiology. The medical researcher regarded the data supplied by the BATeam as instrumental in supporting his research grant requests.

2.3 Sources of Solutions of Potential Transfers

The sources of solutions for the potential transfers accomplished during the reporting period demonstrate the success of the shift in BATeam emphasis from information searching to Field Center contacts (directly and by problem statement.) Of the eleven potential transfers, seven solutions were obtained by direct contact with the Field Center staff. Two problems were solved by problem statement responses and one problem was solved by a manual information search. One potential transfer was obtained using a computerized search. Thus, it can be seen that direct contact with Field Center staff resulted in more than 60% of the solutions while computer information searching resulted in only 9% of the solutions. This solution data sample, although small, validates the basic BATeam philosophy that personal and direct contacts with Field Center staff is the best approach to identify aerospace technology having potential value in the medical field.

2.4 Analysis of Previous Transfers

In addition to considering the accomplishments of the BATeam during the reporting period, it is informative to analyze the BATeam efforts over a longer period of time. This section of the report analyzes transfers that have occurred since the establishment of the BATeam at the Research Triangle Institute in June, 1966. Table 2 shows the number of transfers accomplished and new problems identified as a function of contract year. Note that in the initial stage of the BATeam activity, the ratio of transfers to new problems was much lower than in later years. During the first contract year, 107 new problems were accepted, and this number continually decreased until the contract year 1968-1969 in which 53 new problems were accepted. Due to an increase in funding, the number of new problems accepted was increased to 83 in the contract year 1969-1970. The apparent reduction in number of transfers in the 1969-1970 contract year is due to the change in the definition of transfers as discussed in the preceding section.

Table 3 shows the number of transfers as a function of contract quarter for each of the contract years. Previous RTI BATeam reports (Ref. 1,2) have shown that there is a significant variation in BATeam activity as a function of contract quarter. These data have been updated in Table 3, and the previously established pattern has continued through the latest contract year. Note that the first quarter traditionally has the lowest level of activity. This is during the summer months when activity at most medical institutions slackens significantly. The reason for this is the fact that most medical institutions are geared to an academic year such that the summers are reserved not only for vacations but also for professional traveling. The most significant accomplishments occurred during the third contract quarter which is the middle of the winter when the major activity in medical institutions occurs.

An analysis of categories of technology transferred during the latest complete contract year (June 1969-June 1970) is given in Table 4 and is compared with the results of the preceding contract years. Note that in the latest contract year the majority of the transfers were in the sensor and instrumentation category. It is surprising to note the large increase in the percentage of transfers in the materials technology area. Materials technology accounted for 33% of the transfers during the most recent contract year; this is a fivefold increase over the three prior contract years. A slight decrease was seen in the number of transfers in the "approach" category. This is the category in which the BATeam is asked for an approach to the problem as opposed to a problem for which the researcher has already decided on the approach to the problem and wants to know of any aerospace technology utilizing this particular approach.

The BATeam also needs to study carefully the sources of information involved in transfers in order to determine the optimum search strategy to be employed in problem solving. Table 5 delineates these sources of solutions by contract year. The majority of the solutions have come from manual information searching. Manual information searching includes a variety of types of searching such as manual searches of STAR and IAA as well as personal contacts within the NASA Field Centers. Thus, if a BATeam calls a Field Center and asks for information directly, this is considered a manual search. Computer searches during the past year resulted in the same number of transfers as did responses from reports and the experience of the BATeam. Problem statement circulation resulted in 6.7% of the transfers during the 1969-1970 period. This is expected to increase during the upcoming year because of increased reliance on

Table 2. Transfers and New Problems as a Function of Contract Year (June 15-June 14)

CONTRACT YEAR	TRANSFERS	NEW PROBLEMS
1966-1967	4	107
1967-1968	20	68
1968-1969	17	53
1969-1970	15	83

Table 3. Transfers as a Function of Contract Quarter for the Contract Years

	CONTRACT QUARTER			
CONTRACT YEAR	1*	2**	3***	4****
1966-1967	0	1	3	0
1967-1968	0	4	8	8
1968-1969	4	1	9	3
1969-1970	4	7	4	0
1970-	0	-	-	-
Totals	8	13	24	11

* - June, July, and August

** - September, October, and November

*** - December, January, and February

**** - March, April, and May

Table 4. Transfers Categorized by Periods

CATEGORY		PERCENT	
		June 1966-June 1969	June 1969-June 1970
I.	Approach	27	20
II.	Sensors and Instrumentation	52	40
III.	Materials Technology	6.2	33
IV.	Experimental Data	14.8	7
		100	100

Table 5. Sources of Solution for Transfers

SOURCE		PERCENT OF TRANSFERS	
		June 1966-June 1969	June 1969-June 1970
A.	Problem Abstract	10.6	6.70
B.	Report Response	2.1	13.33
C.	Computer Search	27.6	13.33
D.	Manual Search	31.9	39.98
E.	Experience	21.4	13.33
F.	Commercial	6.4	13.33
		100.0	100.00

this valuable tool. The number of problems solved by commercially available equipment will decrease to zero during the upcoming year because this category of "transfer" is now called an impact instead of a transfer.

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3.0 SUMMARY AND ANALYSIS OF PROBLEMS INVESTIGATED BY THE BIOMEDICAL APPLICATION TEAM

The importance of an analysis of the problems investigated by the BATeam and an assessment of the effectiveness of the BATeam in applying tranfer methodology is second only to an analysis of the BATeam's success in achieving technology transfers. In this section the problems accepted, rejected, and closed during the reporting period and the problems active at the end of this period are summarized. These data are then analyzed primarily to determine the effectiveness of the BATeam in accepting problems appropriate for investigation and to quantitatively assess the potential impact which could result from solving active problems.

3.1 Problems Accepted, Rejected, and Closed

During this reporting period, the RTI BATeam accepted 30 problems, rejected 11 problems, and closed 14 problems. A problem statement for each of these problems is presented in Appendix D. The backlog of problems was increased by 16, and these data are summarized for each participating institution in Table 6. In this table, the change in the number of active problems, ΔP, at each institution is also shown. It is clear that problem activity is decreasing at certain institutions and increasing at others: for example, the major increases are at Tulane University and Wake Forest University. The large increase at Tulane University reflects the strong BATeam program in existence at Tulane at this time. The major decrease in problem activity occurred at Duke University which is a user institution that has participated in the program for four years; moreover, it is anticipated that problem activity will increase during the upcoming year. In addition, minor fluctuations are noted at many of the other user institutions.

The data in Table 6 are very interesting and give an accurate picture of the redirection of BATeam effort. But it is also constructive to analyze the reasons that problems have been closed. This allows an assessment of the success of the BATeam in screening problems and in accomplishing technology transfers. Table 7 shows an analysis of the problems closed for each of the problem closure categories. This table is particularly interesting in that it shows the shift in reasons for closing problems during the operation of the BATeam for 3 1/2 years. The major reasons for closing problems at this time are seen to be Category C and Category K. Category C (Researcher Has Found His Own Solution) indicates that the researcher continues to seek a solution during the entire time that the BATeam is operating. This, of course, is a positive approach and is to be encouraged. This indicates that the researcher is actively interested in the problem. The reason for the significant increase in Category K (Problem Priority Too Low) can possibly be attributed to a reduction in funds available for biomedical research. The significant reallocation of funds for medical research has caused a corresponding reallocation of problem priorities in medical institutions which probably affects this category.

The apparent reduction in the number of problems closed in Category A (Transfer Accomplished) does not imply that transfers are no longer being

Table 6. Problems Accepted, Rejected, and Closed During the Period March 15, 1970, through September 30, 1970

	Problems Accepted	Problems Rejected	Problems Closed	ΔP *
Computer-related	3	0	1	+2
Duke University	3	3	7	-4
Institute of Rehabilitation Medicine	1	0	0	1
Medical College of Virginia	0	0	1	-1
Miscellaneous	1	2	1	0
National Cancer Institute	3	1	1	+2
National Heart and Lung Institute	1	0	0	+1
North Carolina Division of Vocational Rehabilitation	1	0	0	+1
Ochsner Foundation	2	1	0	+2
Tulane University	8	3	1	+7
University of North Carolina				
Dental School	2	0	0	+2
Medical School	0	0	1	-1
Wake Forest University	5	1	1	+4
Totals	30	11	14	+16

* Change in number of active problems.

Table 7. Summary of Problems Closed

Problem Closure Categories	Percentages of Problems Closed		
	June 1967 to June 1969	Sept. 1969 to March 15, 1970	March 15, 1970 to Sept. 30, 1970
A - Transfer accomplished.	20%	21%	0%
B - Researcher has no further interest in the problem.	33	10%	14
C - Researcher has found his own solution.	4	7	22
D - As a result of personnel transfer in the medical institutions, the problem either has been closed or has been transferred to another institution along with the investigator and has been given a new number.	9	3	7
E - No present or foreseeable future NASA technology applicable.	7	7	14
H - Satisfactory solution identified by BATeam and verified by researcher but transfer cannot be completed by researcher for reasons of economy or lack of resources.	3	6	0
I - Problem as originally stated was too broad or general.	15	3	7
J - Problem is too difficult; i.e. the problem as given to the RTI BATeam is presently the focus of large expenditures of money, research, and development effort making the likelihood of success by the BATeam low.	8	30	7
K - Problem priority too low. Factors involved are cost/benefit ratio, BATeam resources, researcher resources, and enthusiasm.	1	0	22
L - Problem grouped under another number with other related problems.	0	0	0
M - Impact.	0	10	7
Total Numbers of Problems Closed	145	68	14

accomplished. Rather, a more stringent definition of a transfer has been utilized during the past six months so that a significant time lag in the accomplishment of transfers has resulted. This fact is discussed in more detail in Section 2.0 of this report. It is very encouraging that Category E (No Present NASA Technology Applicable) is still a very low number. Over the 3 1/2 years that these data have been accumulated, fewer than 10% of the total number of problems have been closed because of no applicable NASA technology. This indicates again that the basic concept of the BATeam program is valid. Another encouraging statistic in this group of data is that Category B (Researcher Has No Further Interest in the Problem) still remains relatively low and has been reduced from the first two years of the program. This is very likely attributable to the increased emphasis on problem selection criteria so that this category of problem can be eliminated by rejecting the problem instead of accepting the problem with a subsequent unsuccessful closing.

3.2 Active Problem Status

As of September 30, 1970, the RTI BATeam had a backlog of 81 active problems. These problems are listed in Appendix B along with a problem status designation and problem titles. The numbers of the problems in each of the six stages of the transfer process are presented in Table 8 and are compared with similar data for June 1968, June 1969, (Ref. 1), and March 1970 (Ref. 2). Two interesting facts can be seen immediately in Table 8. First, the major categories of problems lie in information searching and evaluation categories. This has been true since the beginning of the program; however, an interesting aspect is that in March 1970, and in September 1970, the distribution within these two categories shifted such that more problems lie in the evaluation category than was true earlier in the program. This is a highly encouraging result because it shows that more information is being obtained now than in the early days of the program when many of the problems remained in an information searching category.

Second, in September 1970, 14 problems lie in the potential transfer category. This is a significant increase over any of the previous reporting periods and is a reflection of the fact that the requirements for implementation in transfers have been significantly increased so that problems remain in a potential transfer category for a longer period of time. Thus, many of the problems which previously would have been reported as transfers are now in a potential transfer category.

3.3 Cluster Analysis

For analysis purposes, the BATeam records the amount of time spent on each problem and divides the time into six categories: problem identification, problem abstract preparation, information search, evaluation, follow-up, and documentation. These six categories have recently been replaced by a new set of eleven categories recommended by George Washington University. However, the original six categories were used over a period of several years, and analysis has been made of that bank of data.

Only those problems which have been closed are used in this analysis. If problems that are still active were to be used in this analysis, it would

Table 8. Active Problem Status

Problem Status	Numbers of Problems			
	June 1968	June 1969	March 1970	Sept 1970
A - Problem Definition	0	0	2	3
B - Information Searching	45	53	30	38
C - Problem Statement Circulation	1	0	8	6
D - Evaluation	19	24	23	30
E - Potential Transfer	2	1	2	14
F - Follow-up Activity	13	15	0	0
Totals	80	93	65	81

prevent uniform criteria being applied to each problem. Therefore, seventy-seven (77) problems which were identified and closed during the period of time that data on the six categories of activity were collected are included in this analysis.

Cluster analysis is a tool by which multidimensional data can be analyzed using applied computer techniques to determine whether the data lie in particular clusters or groups within the multidimensional space. In this particular situation, each of the six categories of time data represents one dimension; thus, a six dimensional space is defined and each problem represents a single point in this six dimensional space.

There are a number of ways that cluster analysis can be performed. Here, three methods of cluster analysis were used: the principal component approach, the dendogram approach, and the K-means approach. There were several possible groupings of clusters, but the best cluster distributions seemed to be the four shown in Table 9. Each of the dimensions shown in the table represents hours of professional effort.

In Table 9, note that the four clusters are of varying sizes from 6 to 34 problems. Also, note the significant difference of each cluster. For example, Cluster I is centered at 8.50 hours of problem identification and 4.071 hours of information search. In contrast, Cluster III has 5.44 hours of problem identification and 13.46 hours of information search. Also, note that Cluster IV has an unusual center of 18.83 hours of problem identification and 49.83 hours of information search. Another interesting fact is that Cluster III has the largest numbers of hours of evaluation and documentation, 8.16 and 5.0 hours respectively, which is several times higher than any other cluster.

Each cluster of problems was then studied to see whether any significant characteristic existed in each cluster. Table 10 shows an analysis of each of the clusters according to size, percent of the problems rejected, percent of the problems transferred, type of solution sought, and team member. From Table 10 the following conclusions can be drawn. Clusters I and II had the largest number of rejected problems (about 30%). This is to be expected since the clusters lie very near the origin so that a small amount of time is spent in each of the two sets of problems. Each of the sets of problems contains about 20% to 25% of transfers except for Cluster III which contains 52% of transfers. Note that this is one of the most well-balanced clusters with a significant amount of time spent in each category. The unusually large amount of time spent in documentation and follow-up is a direct result of the large number of transfers which require more documentation and follow-up.

The division of clusters by solution type reflects the types of categories that were used during the period of time that these problems were active. Note that a diversity of solution categories appears in each of the clusters although--in general--hardware appears to be the largest category as expected.

One of the most interesting categorizations of clusters is by team member. The significant diversification in each cluster by team member probably reflects the individual methodology used by each team member. Note that team member B had 68% of Cluster II's problems while team member A had 68% of Cluster IV's problems. Cluster I shows a fairly even distribution between team members A, B, and C. The most striking example is Cluster IV which is

Table 9. Cluster Analysis

Cluster Dimensions: Problem Identification, Problem Abstract Preparation, Information Search, Evaluation, Follow-up, Documentation.

Cluster I - Size 12 Problems

Cluster Center: 8.50, .643, 4.071, .714, .286, 1.071.

Problem Numbers: NCI-5, MCV-1, DU-57, DU-62, DU-64, MISC-1, NCSU-5, NCSU-8, WF-66, WF-70, WF-76, WF-87.

Cluster II - Size 34 Problems

Cluster Center: 2.306, 1.819, 1.806, .944, .667, 2.806.

Problem Numbers: DU-54, DU-55, DU-60, UNC-49, UNC-51, UNC-53, UNC-54, UNC-59, IRM-3, IRM-4, IRM-8, IRM-9, IRM-10, IRM-11, IRM-13, IRM-15, IRM-16, IRM-21, IRM-26, MISC-2, NCSU-3, NCSU-11, SV-1, TU-4, WF-59, WF-60, WF-63, WF-68, WF-71, WF-75, WF-78, WF-84, WF-85, WF-88.

Cluster III - Size 25 Problems

Cluster Center: 5.440, 1.560, 13.460, 8.160, 3.000, 5.000.

Problem Numbers: DU-38, DU-40, DU-41, DU-42, DU-43, DU-44, DU-45, DU-46, DU-49, DU-50, DU-52, DU-53, DU-56, UNC-47, UNC-48, IRM-1, IRM-6, IRM-7, IRM-17, IRM-20, NCSU-4, NCSU-6, NCSU-7, VU-1, WF-69.

Cluster IV - Size 6 Problems

Cluster Center: 18.833, 0.00, 49.833, 1.000, 0.00, 2.000.

Problem Numbers: DU-36, DU-37, DU-39, UNC-44, UNC-45, UNC-46.

Table 10

Cluster	Rejected %	Transfers (% of Accepted Problems)	Solution (% of Cluster Size)		Time of Team Member (% of Cluster Size)	
I	33	25	Approach	25	A	33
			Hardware	50	B	42
			Material	0		
			Data	25	C	25
II	30	21	Approach	30	A	15
			Hardware	52	B	68
			Material	15		
			Data	3	C	17
III	0	52	Approach	40	A	68
			Hardware	32	B	32
			Material	28		
			Data	0	C	0
IV	0	17	Approach	83	A	100
			Hardware	17	B	0
			Material	0		
			Data	0	C	0

all team member A. These six problems in Cluster IV were the first six problems assigned to team member A, and the large number of hours spent in searching with no fruitful results (see Table 9) can be attributed to lack of experience in searching methodology. Team member A clearly was able to improve results later as shown by the fact that 68% of Cluster III were handled by team member A, and Cluster III has 52% transfers. Thus, two rather clear results of the cluster analysis are that team members are relatively ineffective initially and that team members display significant variations in the amount of time spent on each problem. This individuality needs to be carefully considered to determine whether or not improved efficiency can result from modification of individual approaches. This does not imply that all team members must be fitted into a particular mold, but it does imply that a wide variation in the approach to problems is not necessarily the optimum approach to technology transfer.

Table 11 shows the correlation matrix that exists between each of the six categories of time spent on problems. This is informative in showing the relationship between the various types of activity on the program.

Perhaps the most striking fact about the data is the lack of correlation between the various categories. The only categories showing a correlation greater than 0.5 are problem identification and information searching with a correlation of 0.724. In addition, evaluation and follow-up are correlated by 0.400, and follow-up and documentation are correlated by 0.381.

Some categories which were expected to be correlated were not: for example, information search and problem abstract, as well as information search and documentation. In studying these correlations, one must realize that these data cover the early portion of the program, and since that time, significant improvements in methodology have shifted the correlation matrix. The most significant conclusion from this matrix is that the poor correlations exhibited are further proof of the need for the methodological changes which have taken place during the past eighteen months of the program.

Table 11. Correlation Matrix for Time Spent on the Problems of Table 1.

	Problem Identification	Problem Abstract	Information Search	Evaluation	Follow-up	Documentation
Problem Identification	1.000					
Problem Abstract	-0.125	1.000				
Information Search	0.724	0.075	1.000			
Evaluation	-0.002	-0.013	0.037	1.000		
Follow-up	0.167	0.003	0.002	0.400	1.000	
Documentation	0.068	0.100	-0.017	0.257	0.381	1.000

4.0 COMPUTER INFORMATION SEARCHES

4.1 Summary of Computer Information Searches at North Carolina Science and Technology Research Center (NCSTRC), RECON, and Defense Documentation Center (DDC)

During the reporting period, the RTI BATeam initiated twenty computer information searches at NCSTRC. The twenty searches and the associated problem numbers are shown in Table 12. Of the twenty problems for which searches were performed, only one has resulted in a potential transfer. However, the source of information in this case was a Field Center so that the initial results from these twenty searches have not yet resulted in a transfer or potential transfer.

In addition to the above searches, twelve searches were conducted at centers other than NCSTRC. Table 13 shows a list of these twelve searches and their associated problem numbers. From Table 13 it can be seen that five RECON searches were performed. The RECON searches were performed at the NASA Scientific and Technical Information Facility. A RECON terminal is a real-time interactive system for accessing documents on computer tape. As such, it provides a different mode of access to the documents and, ideally, will provide more information than a normal NCSTRC search. However, in a large number of cases, the BATeam found that the real-time access facility was inoperative so that the searches were actually performed by using an approach similar to the NCSTRC approach. Thus, the primary advantage of using RECON was lost, and, as a result, only a limited number of RECON searches were performed.

In addition, Table 13 shows that two searches were performed at the Aerospace Research Applications Center (ARAC), a Regional Dissemination Center (RDC). These searches were performed on problems with which difficulty in information retrieval had been experienced at NCSTRC. However, in these particular cases, neither new nor dramatic information was revealed.

The other five searches were performed at the Defense Documentation Center (DDC) in an experiment to determine whether additional aerospace-related information could be obtained. The Defense Documentation Center maintains a file of documents generated primarily within the Department of Defense. However, it was anticipated that some aerospace-related information was accessed by this information source that would not normally be uncovered in a NASA search. In each of the cases where DDC searches were performed, a parallel RDC search was performed, and the information was compared. In the five problems used for this experiment, the information disclosed in the DDC search was entirely different from that information disclosed in the RDC search. The primary sources of information from the DDC search were Air Force and Army documents, with some Navy documents disclosed. Thus, on the basis of this preliminary result, it appears that no NASA information can be obtained by using the DDC facilities. There is much problem-related information in the DDC search, but the source of the information is not NASA. No further DDC searches are planned by the BATeam because of this negative result relative to NASA information.

Table 12. NCSTRC Computer Information Searches Initiated during the Period March 15, 1970, through September 30, 1970.

Search Number	Problem Number
2111	NIMH-1
2116	MISC-4
2117	TU-6
2135	WF-89
2137	WF-90 WF-91
2185	*
2188	TU-10
2200	TU-9
2205	CP-7
2214	TU-11
2260	DU-72
2289	TU-14
2300	DU-74
2301	TU-13
2304	WF-92
2305	OF-1
2310	NCI-10
2311 2311	NCI-10 NCI-9
2325	NCI-11

* Not yet assigned.

Table 13. Other Computer Information Searches Initiated during the Period March 30, 1970, through September 30, 1970.

Search Number	Problem Number
RECON 50021	MISC-4
RECON T0005D	BH-6
RECON T0006D	WF-86
RECON T0007D	WF-84
RECON T0071	NCI-6
ARAC	WF-53
ARAC	NCI-7
DDC-RB-043157	DU-72
DDC-RB-045503	TU-13
DDC-RB-045631	DU-74
DDC *	NCI-9
DDC *	NCI-10

* Number not yet available.

4.2 Results of the Clingman Survey

The RTI BATeam discovered in December 1968 that information searches at different NASA RDC's disclosed different information. Thus, it appeared that search strategy had a significant effect on the information disclosed in a computer search. As a result of this preliminary study discussed in a previous report (Ref. 2), a comprehensive study of the search strategy procedures was started by W. H. Clingman & Company of Dallas. Dr. Clingman conducted parallel searches at different RDC's and compared the results. From these results, he was able to determine why different centers generated different information. The reasons were associated with the search strategy. In particular, he determined that the use of a larger number of synonyms, as well as using more groups of synonyms, significantly increased the amount of information available. Although his experiment is still under way, the preliminary results and recommendations have been presented to NCSTRC, and they have already had an effect on the search strategy used at NCSTRC. The primary effect has been to increase the number of synonyms used with a resultant increased number of accessed documents. It is too early to determine whether this strategy will increase the number of transfers. In addition, it is anticipated that further recommendations will be forthcoming from the Clingman study. However, it is clear from the Clingman study to date that significant improvements are needed in the searching procedures at the RDC's, and the careful scientific study of the problem by Dr. Clingman will materially improve the results of searching.

5.0 PROBLEM STATEMENT CIRCULATION AND RESPONSE

Information searching is a valuable tool in the search for information within a large system. However, because of the difficulty of accessing indirect information, it is very desirable to have a method for obtaining information or ideas which would not normally be accessed by information searching. One method for obtaining this information is the circulation of problem statements to NASA Field Centers. As explained in the introduction, a problem statement is a concise description of the problem which is circulated to the NASA Field Centers in an attempt to solicit fresh insight into a particular problem. In order for the problem statement to serve a useful function, it must include a clear description of what is required, as well as the approaches that have been tried previously in an attempt to solve a particular problem. One other vital piece of information in a problem statement is a description of the importance of the problem in order to motivate the NASA scientist or engineer to respond to the problem.

During the period March 15 to September 30, 1970, a total of eight problem statements were circulated to the NASA Field Centers. These problem abstracts are identified in Table 14, and the individual problem statements are contained in Appendix C.

Although 30 problems were accepted by the BATeam during the reporting period, only eight problem statements were circulated to the NASA Field Centers. There are several reasons for this relatively low number of problem statements being circulated to the Field Centers. First, a certain amount of information can be gained on a problem during the problem statement circulation. Secondly, another valuable approach in obtaining information from the Field Center is to call the Field Center directly in a case about which a Field Center appears to have relevant information. This, of course, is a more efficient method for obtaining information because it reduces the level of effort necessary to obtain a given amount of information. Finally, by the time the problem reaches the problem statement circulation stage, the BATeam has begun to realize in a more concrete manner the relative importance of a particular problem, as well as the likelihood of implementation of an idea by the problem originator. If it appears that the problem originator would not be eager to implement an idea, the BATeam will not circulate a problem. Thus, it can be seen that when a problem statement is circulated, it represents a significant problem for which no information has been obtained and for which it appears the problem originator is very likely to implement any worthwhile idea.

Table 15 lists the responses to 15 problem statements in circulation during the period March 15, 1970, to September 30, 1970. Eight of these were in circulation prior to March 15, 1970. This table not only reports the number of responses but records the utility or applicability of the response by a letter code (which is explained in Table 16). Thus, the Field Center producing the largest number of responses can easily be seen as well as the value of the suggestion. A total of 55 responses were received on the 15 problems which gives an average of 3.65 responses per problem statement. The only problem receiving no response was NCI-2, and the largest number of responses were received for CP-6 and NCI-4. It is interesting to note that

Table 14. Problem Statements Circulated During the Period March 15, 1970, Through September 30, 1970.

CP-1
CP-2
CP-4
CP-5
CP-6
MISC-4
DU-72
WF-92

Table 15. Responses for Circulated Problem Statements.

	NASA CENTER											UTILITY/APPLICABILITY OF RESPONSE						TOTAL
Problem No.	ARC	ERC	FRC	GSFC	JPL	KSC	LRC	LeRC	MSC	HQ	COSMIC	A	B	C	D	E	X	
NCI-1			A,A	A,D				C				3		1	1			5
NCI-4			A,B	A	A,A			C		B		4	2	1				7
DU-48				E						A		1				1		2
DU-61				E						E						2		2
NCI-6							A,C					1		1				2
NCI-3				A		C						1		1				2
CP-1	X	B					B,A					1	2				1	4
CP-2	X	C					C,E				D			2	1	1	1	5
CP-4		D					D,E				D				3	1		4
CP-5		B					B,E				D		2		1	1		4
CP-6		D					A,D,E	A	X		D	2			3	1	1	7
NCI-2																		0
MISC-4							C,A	A,A,A				4		1				5
NCI-7								A,B,C				1	1	1				3
DU-72		E					D,A					1			1	1		3
Applicability/ Utility of Response																		
A			3	3	2		5	5		1		19						19
B		2	1				2	1		1			7					7
C		1				1	3	3						8				8
D		2		1			3				4				10			10
E		1		2			4			1						8		8
X	2								1								3	3
Total	2	6	4	6	2	1	18	9	1	3	4	19	7	8	10	8	3	55

the two problems for which the largest number of responses were received both appear to have a high potential for solution. NCI-4 is listed in this report as a potential transfer, and CP-6, although not reported as a potential transfer, appears at this time to have a high likelihood of solution.

Table 15 also shows the number of responses by Field Center. The largest number of responses has been received from Langley Research Center followed by Lewis Research Center, both of which have been very active in the Technology Utilization Program in the past. In addition, both Goddard Space Flight Center and Electronics Research Center showed a moderate number of responses.

The major surprise in the responses from Field Centers is that Marshall Space Flight Center, which has a very active Technology Utilization Program, had no responses during this reporting period. It should be noted, however, that MSFC has been one of the most cooperative Centers in direct contacts, and several valuable solutions have resulted. Mr. Juan Pizarro of MSFC believes that changing the problem statement format would significantly improve the number of responses.

Table 16 allows an analysis of the applicability of the responses. Categories A, B, and C are basically relevant information while Categories D and E are for suggestions that are basically unusable. It is clear from these data that the majority of the solutions are definitely relevant to the particular problem. In fact, about one third of the responses lie in Category A which is the most relevant category. The distribution of applicability by Field Center is reasonably constant, indicating that the value of the response is approximately the same for each Field Center.

The average time for a response to reach the BATeam after circulation of the problem statement is 2.5 months. It would be desirable to reduce this response time to no more than one month, if possible. One of the difficulties in the BATeam Program is the relatively long period of time it takes to disclose a relevant response to a problem. Thus, it would be highly desirable to attempt quicker responses.

The major conclusion that can be reached about problem statement circulation and response is that the information is very useful. Three of the problems for which problem statements have been circulated are at the present time in potential transfer status. Thus, the general response to problem statement circulation is considered to be satisfactory.

Table 16. Applicability/Utility Code for Problem Statement Responses.

A - Relevant and suggests a practical solution.

B - Relevant but either the suggestion does not suggest a practical solution or the technique involved is unlikely to be applicable.

C - Relevant but suggests either a technique in current use by the Problem Originator, or one which has been tried and rejected.

D - Suggestion is impractical.

E - Suggestion is irrelevant.

X - Response incomplete.

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6.0 OTHER ACTIVITIES

6.1 Communications Technology in the Medical Community

In addition to normal BATeam activities relating to specific problems, a study is needed of some larger and more generic problems affecting the entire medical community. One such problem area is the use of advanced communication technology as applied to inter- and intra-hospital communications. The BATeam conducted a preliminary study in this area to determine the usefulness of a conference of selected medical personnel and NASA personnel at which general medical problems in the communications area would be defined and the NASA communication experts would be able to offer suggestions regarding solutions. In turn, the presentation by NASA personnel hopefully would stimulate the medical community by providing fresh insights into the ways in which communication technology can be utilized. In order to assure the success of such a conference, a preliminary study was made of the medical problem areas and the NASA technology that might be applicable to this important subject.

In studying this subject, the BATeam talked with a number of people within the NASA and medical communities. Discussions were held with NASA personnel at the Office of Space Science and Applications, personnel from a number of medical schools, the Social and Rehabilitation Service, and the Lister Hill National Center for Biomedical Communications. These discussions revealed that a number of activities are presently underway that demonstrate the existing interest in this problem area. For example, the Lister Hill National Center for Biomedical Communications is actively exploring the use of satellite communication technology in biomedical communications. This is particularly interesting because of the uniqueness of satellites in communication techniques. Other examples of interest in this field are the numerous seminars held on hospital information systems. Examples of the wide range of seminars available include seminars held during the past year by the Control Data Corporation and by the University of Southern California. Other examples of interest in this area can be seen by the frequent appearance of hospital information system articles in current medical journals.

A list of the information transmission needs was tabulated in order to determine the categories of information transmitted. This information is presented below to give a general idea of the range of problems.

I. Transmission on storage of a patient's physiological parameters
   A. Stationary patient
      1. In bed, in intensive care units
      2. In operating room, cardiac catheterization lab or research areas
      3. In a physician's office (example: ECG transmitted over telephone lines to a central computer analysis)
   B. Moving patient
      1. Patient in a moving ambulance or other vehicle
      2. Ambulatory patient
         a. Within a defined area in the hospital
         b. At home
         c. At large

C. Stationary instruments to which patients come (as in multi-phasic screening stations)

II. Transmission or storage of visual information

A. Film images--radiographs, photographs, etc.
1. Transmission of image to another point (facsimile, other)
2. Automated film storage and retrieval, local or remote
3. Image processing, pattern recognition

B. Video signals or videotape
1. One- or two-way transmission for audiovisual or educational purposes
2. One- or two-way transmission for diagnostic purposes, permitting remote diagnosis or consultation

III. Voice or audio transmission

A. Two-way voice link for remote consultation, discussion, conference
B. Dispatching or routing of any mobile units
C. Paging, signalling or summoning systems--especially addressing one or several doctors within a multi-building medical complex
D. Dictation systems

IV. Transmission or storage of textual material (fixed or free format, one or several locations)

A. Patient history data
1. Self-administered or other-person-administered previous medical history
2. Nursing chart information, including drugs
3. Physician observations and comments
4. Chemical laboratory and other clinical lab data from the patient
5. Administrative and cost data for individual patient

B. Other hospital records, especially various inventories
1. Record of full beds, patient census
2. Drug inventories
3. Food supplies, diet information

C. Information of regional or national interest
1. Blood bank inventories, organ and transplant inventories
2. Medical conferences, consultation for isolated regions, other
3. Biomedical communication networks, especially libraries, library materials, educational material
4. Patient histories for mobile, transient or migrant individuals or groups

D. Scheduling (including appropriate production and distribution of schedule copies)
1. Patient appointment and consultation scheduling
2. Special facility, special equipment scheduling, such as radiology treatment scheduling, dose planning, beam schedules, etc.
3. Hospital emergency command systems

V. Transmission of physical, engineering data

   A. Building and environment information--temperature, conditions of physical systems for possible control use
   B. Various physical research data--radiation counts in tracer experiments, etc.
   C. Special environmental problems--for instance, voice and data transmission from the high-oxygen environment of a hyperbaric chamber

A summary of the NASA contributions and applications to communication technology was made in order to possibly determine a match between the NASA technology and the problems listed above. These NASA contributions are listed below.

COMMUNICATIONS AREA	NASA CONTRIBUTIONS AND APPLICATIONS
T. V. (Conventional scan rate)	Development of spectrum conservation-low redundancy techniques. Improvements in wide band tape recorders and lightweight color T. V. techniques
T. V. (Slow scan)	Used in virtually all planetary and weather reporting missions. Development of digital, adaptive scan, and very low bandwidth systems; usable in severe environments.
CRT Displays	Development and application of alpha-numeric, interactive, and high ambient light CRT's and panel displays.
Modulation-techniques	Digital, LSI and computer compatible, random access, time sharing, time division discrete address, phase-lock and coherent techniques, pseudo-noise, frequency-time matrix, etc.
Telemetry	Error correcting codes, PCM techniques, adaptive bandwidth, low-noise antennas, masers, atomic standard time stability.
Millimeter and Laser Communications	Gigahertz bandwidth systems, deep space techniques, high-power C-W lasers, low-noise level photon detectors, millimeter LSA devices.
Communications Accessories	High energy-density batteries, solar cells, fuel cells, speech frequency translation techniques such as have been applied to deep-sea divers "Helium" speech, vocoders, satellite film readers, methods of optimally extracting signals in noise.

The above information clearly shows that many areas overlap between the NASA contributions in aerospace technology and the problems existing in hospital communications. One important consideration that must be given in any of these problem areas is not simply to determine where communication technology can be applied, but to determine what medical information could be transmitted that would justify the cost of transmission equipment. The Lister Hill Center has become acutely aware of this problem as they have moved into a general area where it is clear that satellite communications would improve remote area medical communications. Thus, perhaps more so than in most problem areas, the cost-benefit consideration must be understood early in the planning stage.

At the present time, no definite plans have been made by the BATeam for a communications conference. However, further action in this area has been taken by NASA Headquarters, and it is anticipated that at the spring meeting of the Aerospace Medical Association in Houston, a conference will be held on this important subject. It is hoped that the preliminary study reported here will be of value in the planning of this important meeting.

6.2 Seminars

At the request of the Department of Physiology of Bowman Gray School of Medicine, Wake Forest University, the BATeam arranged a seminar on the application of image processing techniques in clinical medicine. The seminar was presented on August 19, 1970. At the beginning of the meeting, Mr. Ernest Harrison presented a brief discussion of the Biomedical Application Team concept. Then Mr. Robert Beadles of the Research Triangle Institute professional staff presented the image processing seminar. The presentation was well received and stimulated expressions of interest by a number of people.

6.3 Visits to NASA Field Centers

On June 24, Dr. F. T. Wooten visited Marshall Space Flight Center for discussions on the lower body negative pressure (LBNP) seal and on hardness testing procedures. In addition, several research areas in the Astronautics Laboratory were discussed.

On June 19, Mr. Ernest Harrison visited Goddard Space Flight Center to broaden the Team's knowledge about Goddard and its programs and, at the same time, to present the BATeam Program to a group of researchers selected by Mr. Wayne Chen of the TU Office at Goddard. Discussions were held with researchers concerning the circulation of problem statements at the NASA Centers.

Mr. Ernest Harrison attended a meeting at Langley Research Center on July 16-17, 1970, which was arranged by Mr. John Samos, TUO at Langley. The meeting was held to present the BATeam Program and the sensory-aids-to-the-handicapped program, to discuss selected problems with the objective of fostering more productive interaction between the BATeams and the personnel at Langley, and to acquaint the BATeams with activities at Langley. Twelve Langley people attended the meeting at which selected problems were presented by Dr. Ed Dean of SwRI, Mr. Ken Crooks of Battelle, and Mr. Ernest Harrison of RTI. Suggestions were offered on a number of the problems, and follow-up visits were made to a number of laboratories at Langley.

On July 23, Dr. George Hayne attended a one-day medical information systems seminar at the NASA Manned Spacecraft Center in Houston. The seminar had been arranged by Dr. Robert Schuhmann of Southwest Research Institute as a result of a SwRI BATeam problem from the Scott and White Clinic. In addition to representatives from Scott and White, there were representatives from two other medical centers and several other Technology Utilization-related groups such as RTI and MRI. The major purpose of the seminar was to present Dr. Moseley's description of MSC's development and use of a medical information system derived from the MEDATA system originally developed by Tate Minckler, M.D., at the M. D. Anderson Hospital and Tumor Clinic of Texas. A tour of other MSC facilities including the Lunar Receiving Laboratory was also provided for the group attending the seminar.

6.4 Industrial Interactions

On May 19, 1970, Mr. Ernest Harrison visited Carolina Medical Equipment, Inc. in King, North Carolina, in response to a request for information about the BATeam from Mr. Charles A. Barefoot, Vice President of the firm. Carolina Medical Equipment (CME) has several interests in the BATeam Program. First, it does a limited amount of custom engineering in areas related to its product line and job shop capabilities. It is interested in providing this service to researchers for whom the BATeam has identified technology beyond the engineering capabilities of the researcher's facilities. The interests and capabilities of CME were discussed so that the BATeam can match appropriate researcher engineering and fabrication requirements to the capabilities of CME. It is not infrequent that the need for engineering and fabrication resources beyond the capabilities of the researcher's facilities results from the activities of the BATeam. Unfortunately, there are few custom engineering and fabrication firms in the geographic area of North Carolina from which a large number of our problems originate. Consequently, the identification of another such resource is potentially beneficial to the BATeam. Second, CME is interested in keeping abreast of NASA technology which has been identified by the BATeam.

On August 5, the BATeam was visited by Mr. Hugh Willard of Physionics Corporation who is surveying the market potential of the transfer of the EMG electrodes and amplifier. Detailed technical discussions were held, including a visit to the Hand Rehabilitation Center at UNC. The BATeam is encouraged by this development.

6.5 NASTRAN

The RTI BATeam has been studying possible biomedical user interest in NASTRAN, the NASA Structural Analysis Computer Program, and in this connection, Dr. George Hayne visited Dr. John Jurist in Madison, Wisconsin, on May 13, 1970. Mr. Ralph Fritz of MRI's BATeam was also present. Dr. Jurist is a biophysicist with an appointment in the Department of Surgery at the University of Wisconsin Medical Center and is interested in the relationship between the resonant frequency for transverse vibration and the physiological condition of the ulna, one of the bones of the forearm. There is a possibility that this relationship is simple enough to allow developing the measurement of the ulna's resonant frequency in vivo as a technique for screening populations for osteoporosis, a major unsolved bone disease. Dr. Jurist has some experimental data indicating promise for this technique and wishes to determine the theoretically expected relationship between resonant frequency and the ulna's shape and condition. A computer or numerical technique is required for modeling the ulna's properties because the ulna is nonuniform, inhomogeneous, and has anisotropic elastic behavior; it appeared possible that NASTRAN would be appropriate for this.

Following this meeting, Dr. Jurist's problem was accepted as Biomedical Problem RTI/CP-7, and in July, 1970, a telephone conference was arranged between Thomas G. Butler at Goddard Space Flight Center, Dr. Jurist, and Dr. George Hayne. Mr. Butler is the NASTRAN Project Manager, and the purpose of the call was to determine the possibility of investigating Dr. Jurist's problem at Goddard. NASTRAN is so large and so general that it would require a considerable investment of time and effort to implement it on a computer other than the IBM Model 360/95 at Goddard.

The conclusion reached following the conference telephone call and various subsequent calls was that NASTRAN could easily handle Dr. Jurist's problem but that a large amount of time is needed either to teach Dr. Jurist and his group some structural engineering and vibration theory or to prepare Dr. Jurist's problem for him for NASTRAN. It appears that the priority of this problem is such that Dr. Jurist does not wish to invest the considerable amount of his time that would be required for him to master NASTRAN as a tool; therefore, eventual use of NASTRAN in this problem is not impossible but is quite unlikely. It may be possible to find alternatives to NASTRAN, simpler computer programs performing more limited types of problems, but which would be much easier to implement at Dr. Jurist's computer center in Wisconsin. The RTI BATeam is in the process of obtaining information about these possible alternatives.

One possibility is Dr. Y. King Liu at Tulane, an authority in biomechanics who has discussed NASTRAN's possibilities with Dr. F. T. Wooten. Dr. Liu and his coworkers have considerably more expertise in structural mechanics than Dr. Jurist's group, and thus may be in a better position to evaluate NASTRAN's possibilities. Information on NASTRAN and other programs has been sent to Dr. Liu to explore this possibility.

7.0 SUMMARY OF BIOMEDICAL APPLICATION TEAM STATUS AT USER INSTITUTIONS AND PROJECTED EXPANSION

7.1 Introduction

In Section 1.4 of this report, the ten medical institutions participating in the RTI BATeam program were listed, as well as six institutions that have participated on certain special problems. The major thrust of the activity of the BATeam has been at the primary institutions. In order to put into perspective the relative activity and history of the activity at each school, the following brief summaries are presented.

7.2 Summary Status for User Institutions Participating in the Program on March 15, 1970

Duke University Medical Center - This institution has been active in the Team program for four years, and a total of 74 problems have been accepted or rejected at this school. During the past year, there has been a noticeable slackening of activity because of the reduction in Federal funds, but the BATeam expects to see an increase of activity at this school during the coming year.

Bowman Gray School of Medicine of the Wake Forest University - This school has been active in the BATeam Program for four years during which a total of 93 problems have been considered at this school. Activity has slowed noticeably in recent months, and it is difficult to determine whether this is due to seasonal factors or is a general reduction in activity at this school. Bowman Gray has historically been one of the most productive in our program, and careful analysis will be made during the early fall to determine whether a continued major effort is justified.

University of North Carolina Medical School and Dental School - A total of 82 problems have been defined at the schools of medicine and dentistry during the past four years, but activity at the present time is at a virtual standstill. The primary reason for this is the lack of a suitable consultant at this school making it very difficult for the BATeam to reach the potential users of the program. No change in the low activity status at this school is anticipated in the near future.

Institute of Rehabilitation Medicine - Activity at this school was started in April, 1969, and since that time a total of 26 problems have been defined or rejected. This institution is a small group within a large university, and most of the acceptable problems have already been considered. Recent contacts with the consultant have indicated that no significant activity can be anticipated in the fall.

North Carolina State University - This school is a technical and agricultural school of the state of North Carolina, and very few suitable problems exist. During the three years that the program has existed, only eleven problems have been considered. When acceptable problems have been discovered at this school, the researchers have been active and enthusiastic; however, a continuing low level of activity is anticipated for this school.

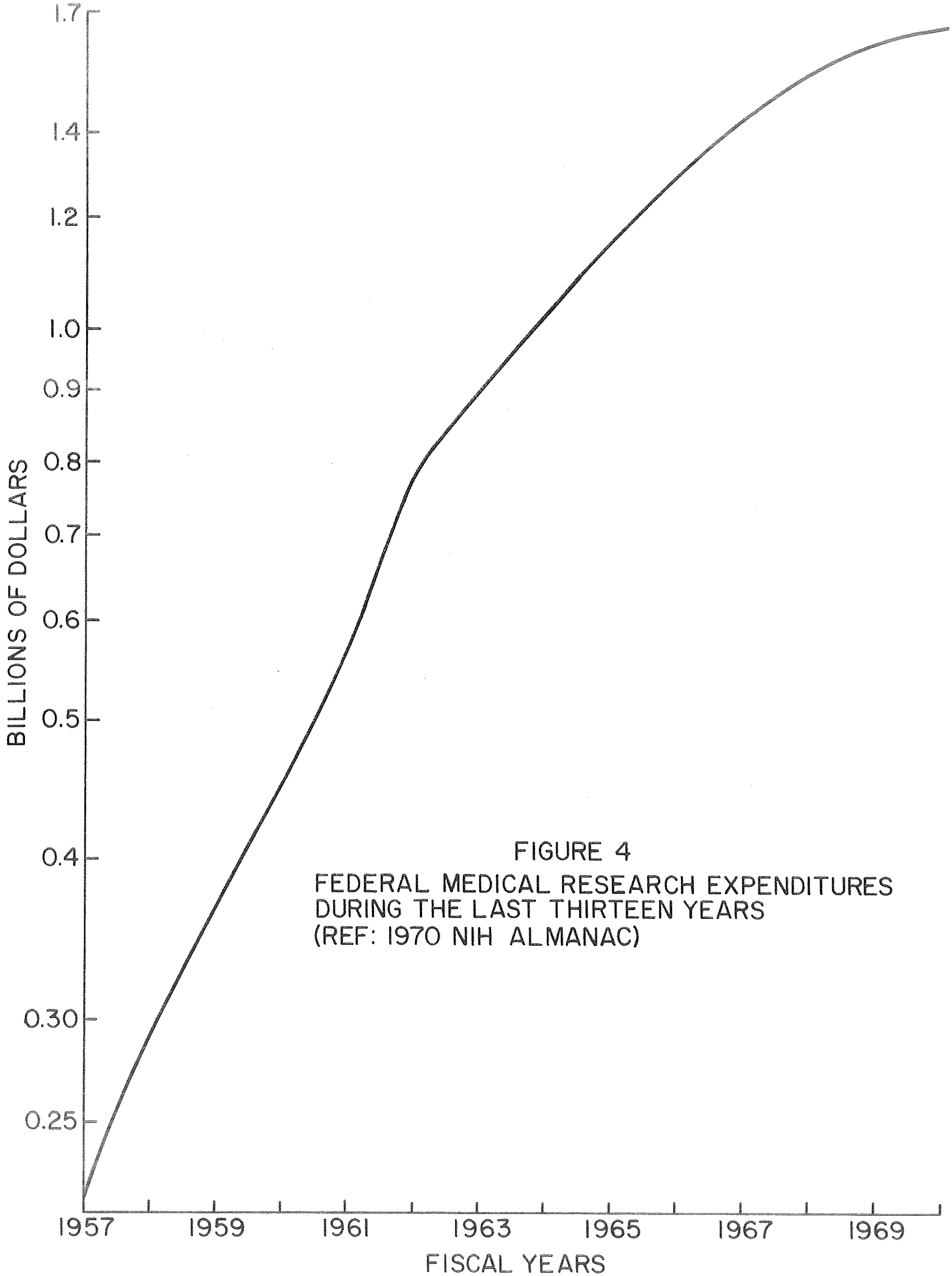

FIGURE 4
FEDERAL MEDICAL RESEARCH EXPENDITURES DURING THE LAST THIRTEEN YEARS (REF: 1970 NIH ALMANAC)

Tulane University Medical School - BATeam activity started at Tulane in December, 1969, making this school one of the more recent additions to the BATeam Program. The cooperation and enthusiasm of the Tulane staff have contributed to a very successful program. Thus far, a total of 17 problems have been considered, and activity is expected to continue at a very satisfactory level.

National Cancer Institute - Activities at the National Cancer Institute (NCI) started in August, 1969, and a total of 10 problems have been considered. This relatively low level of activity was designed to allow the NCI personnel to evaluate the program. It appears now that the NCI personnel are satisfied with the success of the program, and continued activity is anticipated during the coming months.

Brookdale Hospital Center - Activities at this institution were confined to problems associated with the screening clinic, and only six problems have been considered since BATeam activities started in January, 1970. No further problems are anticipated from this institution.

7.3 Plans for Expansion of BATeam Activity

A summary of BATeam activity at all institutions shows a decrease in activity at most of the schools where activity had taken place for a long period of time. The reason for this is that only a limited number of suitable problems for BATeam activity exist at each school, and after a BATeam has been active in a school for a number of years, the major portion of these problems have been attacked. Another reason for the decrease in activity at a number of schools can be seen by referring to Figure 4 which is a plot of Federal medical research dollars from 1957 to the present. Note that the flattening of the curve shows a relatively constant number of dollars being spent at the present time on medical research. This lack of increase from year to year is more critical at medical schools than at Federal medical institutions because the contract and grant monies have been reduced more than the Federal in-house expenditures. Thus, many medical schools experience an actual reduction in research funds from year to year. This reduction, occurring simultaneously with rapid inflation, is forcing the medical schools to reduce their expenditures for equipment in order to prevent a serious reduction in staff. This, of course, strikes directly at the heart of the BATeam Program because of the necessity of having the user implement the technology himself.

Because of the serious fund shortage in major medical schools, the BATeam has decided to look primarily to the Federal medical institutions for expansion of BATeam activity although some medical schools will continue to be approached.

7.4 Program Promotion and Expansion Activities

One of the keys to a successful BATeam Program is carefully planned promotion activity. Although BATeam activity is also increased by unsolicited requests from potential users, optimum expansion is brought about by controlled presentation of the BATeam Program. A number of presentations were made during this reporting period to potential users:

National Heart and Lung Institute - The National Heart and Lung Institute was contacted regarding BATeam activity, and they expressed an interest in having a BATeam visit. In September, 1970, Dr. F. T. Wooten and Mr. E. W. Page of RTI together with Mr. Jim Richards of NASA visited Dr. Frank Hastings, Chief of the Medical Device Application Branch. The BATeam program was explained, and problem definition was started.

National Cancer Institute - In June, 1970, the BATeam program was presented to Dr. Nathaniel Berlin, Clinical Director of the National Cancer Institute. Dr. Berlin heads a group separate from Dr. Perry's group within the National Cancer Institute where BATeam activities have existed for the past year. Dr. Berlin expressed an interest in BATeam activity, and when a convenient date can be arranged, the BATeam plans to present the program to Dr. Berlin's staff.

National Institute of Environmental Health Sciences - In August, 1970, an invitation was given to Dr. Paul Kotin, Director of NIEHS, to participate in BATeam activities. Dr. William Paine, Assistant Director of NIEHS, replied in Dr. Kotin's absence that he would like to learn more about the BATeam program, and a presentation to the senior staff of NIEHS is planned in October, 1970.

Ochsner Clinic and Foundation - The Ochsner Foundation is a private research group associated with the Ochsner Clinic in New Orleans. Investigation has revealed that Ochsner is a small, private, and prestigious group primarily serving the South. During a routine visit to Tulane by Dr. Wooten, a request was received from Ochsner to initiate activities. Approval was received from NASA to start a pilot program, and problem definition has begun.

Georgia Institute of Technology Bioengineering Center - The Georgia Institute of Technology has recently formed a Bioengineering Center which is designed to coordinate and stimulate biomedical engineering activities in the state of Georgia. Dr. E. J. Scheibner, Head of the Bioengineering Center, requested that the BATeam initiate activities at his center. The Bioengineering Center represents an unusual situation in that it will act as a coordinating activity for the medical and engineering schools within the State of Georgia. For this reason, the Center is in a unique position to choose appropriate problems for the BATeam and to stimulate activity in the implementation of solutions. Agreement was reached to start a pilot activity with the Bioengineering Center in which the Center will screen the major problems submitted to it and will submit only the appropriate ones to the BATeam.

Two medical schools are involved with the Georgia Tech Bioengineering Center: Medical College of Georgia and Emory University. A visit was made to the Medical College of Georgia in August, 1970, by Dr. F. T. Wooten and Mr. Ernest Harrison. The program was presented to Dr. F. Behal, Dean of Graduate Studies, and his senior staff. It is anticipated that a limited number of problems will be forthcoming from this school. The BATeam also contacted the Medical School of Emory University in September, 1970, and problem definition is expected shortly.

Virginia Department of Vocational Rehabilitation - As a result of publicity regarding a previous BATeam success, Mr. Paul T. Bassett, Director of Research Utilization of the Virginia Department of Vocational Rehabilitation, contacted the BATeam and suggested that there was a possibility of useful interaction with one of the units of the Virginia Department of Vocational Rehabilitation--specifically, the Woodrow Wilson Intensive Vocational Rehabilitation Center at Fishersville, Virginia. This unit is one of five intensive vocational rehabilitation centers in the nation supported by HEW. Mr. Bassett is involved in implementing research findings into the vocational rehabilitation program in Virginia, and he requested that the possibility of interaction be determined. The BATeam visited this group in September, 1970, to discuss possible interactions and soon thereafter received a formal request from the Fishersville unit for BATeam activity. Problem definition will begin shortly.

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8.0 CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations resulting from the activities of the RTI BATeam and from analysis of its activities for the period from March 15, 1970, to September 30, 1970, are presented in the following paragraphs.

During the remaining period of this contract, it is anticipated that the major problem activity will be shifted from some of the existing user institutions to new user institutions. The BATeam has contacted a number of new user institutions, and it is anticipated that the flow of new problems from these institutions will compensate for some of the stagnation of problem activity evident at the older user institutions. In addition, it is anticipated that a significant portion of these new problems will come from the National Institutes of Health.

The number of new problems that the BATeam has accepted has begun to increase when compared with the trend over the past four years. New problem definition had been decreasing as the BATeam put more effort into solving individual problems. Recently, an increase in new problem activity has been noted, and these problems must be carefully screened to insure that sufficient time can be devoted to each problem accepted.

The results of the various means used to obtain solutions to problems show that computer information searching is at this time a somewhat unproductive method of obtaining information. It is recommended that careful study be made of the Clingman survey, when available, in order to implement certain recommendations to improve the relatively low efficiency of this kind of computer information searching.

The response from problem statements circulated to NASA Field Centers has shown that each problem statement received an average of 3.65 responses with a response time averaging 2.5 months. It is recommended that some method of improving this time of response be implemented in order to speed the process of technology transfer. The quality of responses to problem statements is at present sufficient, but the time delay in receiving responses is unsatisfactory.

The primary source of information has been found to be direct contact with the NASA Field Centers by BATeam members. This is by far the most efficient method of obtaining information because less effort by NASA personnel is required, and a much faster response time is obtained. It is recommended that continued emphasis be placed on this method of problem solving.

The BATeam has reported eleven potential transfers during this reporting period making a total of fourteen active potential transfers at this time. This significant increase in the number of active potential transfers reflects the tighter requirements for transfers now in effect. It is recommended that this new and stricter definition of transfer continue to be implemented. It is concluded, however, that this more stringent transfer definition has resulted in longer time requirements for the accomplishment of transfers; as a result, an increase in the number of potential transfers has occurred.

It is also concluded from the results to date that most of the existing transfers are in the category of hardware (for example, sensors or instrumentation); however, an increase in the number of transfers in the category of materials information is available within the NASA system. It is anticipated that the BATeam will continue to accept these materials-related problems because of the potential success in finding solutions.

Finally, it is concluded that the major handicap at this time to accomplishing transfers is in the implementation phase. It is clear that valuable information is available to solve many of the problems, and that very few problems are closed because of lack of information; however, because of a reduction in Federal medical research funds available to our user institutions, the actual implementation is very difficult to accomplish. It is recommended that careful study be made of the existing potential transfers to determine whether some action on the part of NASA personnel in the implementation phase will significantly enhance the accomplishment of these transfers.

9.0 REFERENCES

1. "Biomedical Applications of NASA Sciences and Technology," Contract NSR-34-004-056, Final Report. N69-35786, Research Triangle Institute, Research Triangle Park, North Carolina, June, 1969.

2. "NASA Biomedical Application Team Program," Contract NASW-1950, Semi-annual Report, Research Triangle Institute, Research Triangle Park, North Carolina, March, 1970.

3. 1970 NIH Almanac. Office of Information, NIH, Bethesda, Maryland. 20014.

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APPENDIX A

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A.1 Potential Transfer Reports

This section presents potential transfer reports for the following problems which were reported as potential transfers during this reporting period and which were active as of September 30, 1970.

DU-48

DU-59

LSU-1

NCI-3

NCI-4

NCI-8

NIMH-1

TU-2

WF-67

WF-88

WF-89

POTENTIAL TRANSFER REPORT

RTI/DU-48

"Urine Flowmeter"

Dr. Saul Boyarsky, Washington University

Team Member - F. Thomas Wooten, Ph.D.

Problem Acquired - June, 1969
Potential Transfer Identified - August, 1970
Elapsed Time - 14 Months

Description of Problem

Kidney diseases are quite varied, but they attack all age groups and cause the death of 60,000 Americans each year. In order to understand these diseases, an improved understanding of the urological system is necessary. One of the parts of the urological system of particular interest is the ureter, i.e. the tubes that connect each kidney to the bladder. Urine flow measurements in the ureter are being used in a research study to understand ureteral physiology. Improved flow measurement techniques also could be used in clinical studies of kidney, ureteral, and bladder diseases. All existing techniques for measuring flow in the ureter involve collecting samples of urine over definite intervals of time and calculating average flow rates. These average flow measurements are not satisfactory when the pulsatile nature of flow in the ureter is being studied. This pulsatile flow of urine is felt to be very important in obtaining a better understanding of ureteral physiology. Urine flows through the ureter in small ellipsoidial masses, each of which is called a bolus. Each bolus leaves the kidney and is transmitted as a unit to the bladder through the ureter. Thus, at a given point in the ureter, an observer would see a series of bolus passing the particular point at a rate of about 1 to 5 per minute. This is the nature of the pulsatile flow in the ureter.

The requirement here is for a technique for measuring instantaneous rates of urine flow in the ureter. The transducer can be used either internally or externally. If an external transducer is used, the flow of urine can be diverted to a point outside the animal's body using a catheter. If a catheter is used, the diameter must be less than 2 millimeters so that the flow characteristics are not disturbed.

The flowmeter should measure transient urine flows of from 1 to 100 cc/min with an accuracy of ±1%. The pressure varies from 0-20 mm Hg. Size of the flowmeter is not important because the flowmeter can be outside the body. However, if the flowmeter is used in the body, the diameter must be less than 2 mm.

Potential Solution

A computer search of the NASA document bank disclosed no significant information. A detailed search of commercial liquid flowmeters revealed no suitable available devices.

A problem statement was circulated to all NASA field centers, and five replies were received. One reply, from Dr. S. P. Vinograd of NASA Headquarters, directed the team to Dr. H. F. Poppendiek of Geoscience, Ltd. Dr. Poppendiek had proposed to NASA, for aerospace purposes, a liquid flowmeter using the hot thermistor approach. The approach had several unique features which appear to solve the problem. Dr. Boyarsky is presently negotiating a contract to build the unit.

Note: This problem originated at Duke University. During the period of the problem, Dr. Boyarsky moved to Washington University to become Chairman of the Urology Department. The problem remained active because of Dr. Boyarsky's continuing interest.

POTENTIAL TRANSFER REPORT

RTI/DU-59

"Temperature Measurement on a Small Brain Probe"

Dr. Blaine S. Nashold, Duke University

Team Member - Dr. F. T. Wooten

Problem Acquired - September 1969
Potential Transfer Identified - April 1970
Elapsed Time - 7 months

Description of Problem

Parkinson's Syndrome is a disease affecting a significant number of people and the principal features of the disease are coarse tremors involving the head and the limbs, slowness of movement, slow or shuffling walk, and loss of facial expression. One method for treating this disease is the production of lesions (injured regions) in the brain. Several methods of producing these lesions exist, one of which is the use of a small rf (radio frequency) field probe. In order to control the production of the lesion, good temperature measurement is required at the site of the lesion.

Two types of rf lesion probes are used. One type is an inflexible cylinder 0.080" x 12" and the other type is an inflexible cylinder 0.080" x 10" with a flexible cylindrical tip with dimensions 0.20" x 1". In the first type of probe, a small thermocouple is mounted on the tip of the probe. In the second type of probe the temperature of interest occurs at the end of the flexible 0.020" diameter tip. The tip is so small that the researcher has been unable to mount a thermocouple on the end.

The researcher requires a means of measuring temperature on the end of the flexible probe tip.

The temperature measurement should have a precision of $0.2^{o}C$ and an accuracy of $0.5^{o}C$. The temperature range is $30^{o}C$ to $50^{o}C$. The measurement method should not significantly enlarge the diameter of the flexible tip.

Potential Solution

The basic solution to this problem is to use a thin film thermocouple or thermistor on the probe tip. This will allow essentially no change in the probe size or roughness, and in addition will allow fast time response in temperature measurement.

One method for applying a thin film thermistor is to use Hanovia Liquid Bright Platinum which is a liquid that can be fired to allow a thin film. This technique is described in the following documents: N66-18052, A64-25659.

The second possible method is the use of electroplating. Electroplated thermocouples have been used by a NASA contractor, TRW, which has indicated that this approach is feasible.

The third possible method for applying thin films is vapor deposition (vacuum or sputtering) which is somewhat more difficult on the cylindrical shape of interest.

In all the above methods it would be best to use one of the electrodes of the coaxial probe as a lead so that only one other lead would be needed. In addition, a coating of some wear resistant insulator would be desirable.

Source of Potential Solution

This potential solution resulted from a computer search No. 1838 "Thin Film Thermocouples," of the aerospace document bank.

Potential Benefits

With this temperature measurement, the surgeon can perform more precise lesion production with a resulting improvement in the control of Parkinson's Syndrome.

P O T E N T I A L   T R A N S F E R   R E P O R T

RTI/LSU-1

"Improved Mechanical Respirators"

Dr. James Arens, Oschner Foundation

Team Member - F. Thomas Wooten, Ph.D.

Problem Acquired - January, 1970
Potential Transfer Identified - July, 1970
Elapsed Time - 7 months

Description of Problem

Poliomyelitis is a virus infection which can result in varying degrees of paralysis including total paralysis of the body except for the head and neck. The incidence of poliomyelitis has been dramatically reduced by the use of a vaccine, but many of the victims of the epidemics of 1945-55 are still surviving with the aid of mechanical respirators. About 1500 of these victims are confined to "iron lungs" and improvements in these units are required.

Artificial respiration can be produced by applying a positive pressure or a negative pressure on the outside of the chest. The positive pressure method cannot be used for long periods of time because of the resulting constrictions in the cardiovascular system. Positive pressure can be applied for brief periods on the inside of the lungs, but this method is unsuitable because the patient cannot talk adequately.

Most suitable respiration methods use a negative pressure on the chest wall with various configurations for applying this pressure. The most familiar configuration is the tank respirator or "iron lung" which is simply a cylinder that encloses the patient from the neck to the feet. A moving piston produces a periodic negative pressure.

Another configuration for applying a negative pressure is the cuirass or "peanut shell" type which is simply a shell that fits over the top of the chest and a negative pressure is applied to the shell. This negative pressure provides the required seal between the shell and the chest as well as the force for moving the chest wall.

The tank respirators provide the best lung ventilation, but they are very bulky and confine the patient to a horizontal position. This means the patient finds it very difficult to perform simple tasks such as turning pages of a book (by a stick held in the mouth) and using a typewriter (with a stick also). The patient has no mobility, and also finds it difficult to remove nasal congestion which is quite prevalent.

Many of the problems can be solved if the patient can sit up. The cuirass units enable the patient to sit up and allow a fair degree of mobility in a wheel chair. Patients can travel and perform simple tasks which enable them to take a more active and useful role in society. Unfortunately, the cuirass units are about 30% - 50% as efficient in providing air to the lungs so that only very limited use can be made of these units.

The basic problem is to provide a method of lung ventilation that has the efficiency of the tank unit and the flexibility and portability of the cuirass units. It appears that in order to provide adequate ventilation, a total enclosure of the chest is required. Thus the new configuration should provide a means of enclosing the chest from the neck to the hip, provide an adequate seal for low negative pressures, and provide a flexibility such that a patient can sit up as well as lie down.

A negative pressure of from 0-40 centimeters of water is required. A breathing rate of about 15-20 times per minute is typical with an exchange of air in the lungs of about one liter per breath. Thus the exchange of air in the enclosure shell will be about 2 liters.

Potential Solution

During the scheduled NASA Skylab flights, the use of a tilt table for cardiovascular testing is precluded by the zero gravity. To solve this problem a negative pressure is placed on the lower half of the astronaut's body when it is placed in a chamber called the Lower Body Negative Pressure Device (LBNP). The LBNP requires a seal at the waist for the negative pressures of 40 mm. Hg.

This LBNP seal provides a major part of the requirement for a portable respirator. The seal fits a wide range of waist sizes and is lightweight. In addition, numerous lightweight plastics have been developed for aerospace applications and can be adapted for structural requirements.

Much of this technology is available at MSFC, and personnel there have suggested several air supply ideas which will provide cooling to the patient when required.

Personnel at MSFC are now attempting to obtain the necessary approval to start application engineering.

POTENTIAL TRANSFER REPORT

RTI/NCI-3

"Automatic Blood Pressure Measurement of Critically Ill Patients"

Dr. Edward Henderson, National Cancer Institute

Team Member - Dr. F. T. Wooten

Problem Acquired - September 1969
Potential Transfer Identified - April 1970
Elapsed Time - 7 months

Description of Problem

Leukemia, a major form of cancer, is a disease characterized by a self-perpetuating proliferation of white blood cell forming tissue.

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

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

The primary method for measuring blood pressure is the sphygmomanometer which is a cuff placed around the upper arm. The microphone of a stethoscope is placed under the cuff and over the brachial artery near the fold of the arm. The cuff is inflated to a pressure which is higher than maximum blood pressure and is then slowly reduced. When the cuff pressure reaches the systolic or maximum pressure, a pulse is heard in the stethoscope. When the cuff pressure is reduced still further to the diastolic pressure, the pulse sounds drop sharply.

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

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

Description of Potential Solution

The ear oximeter designed for measuring astronaut blood oxygen content is a potential solution to this problem. The oximeter is designed to clip on to the ear and measure blood oxygen by absorption of infrared radiation. Blood oxygen can be used to detect onset of shock and, in addition, the output signal is related to pressure so that the ear oximetry has a potential for solution to this problem.

Source of Potential Solution

During a trip to Ames Research Center by Dr. F. T. Wooten, a conversation was arranged with Mr. Joseph R. Smith by Mr. George Edwards, Technology Utilization Officer. Mr. Smith suggested this approach to the problem.

The researcher has indicated he would like to determine the efficacy of this approach by making measurements with the equipment in his clinical laboratory. Efforts are being made to obtain the equipment.

Potential Benefits to be Derived

If the efficacy of this approach can be proven, a significant advance in monitoring of leukemia patients will occur. This will potentially improve the mortality caused by shock in critically ill patients.

POTENTIAL TRANSFER REPORT

RTI/NCI-4

"Method of Controlling Rate of Cooling in Liquids"

Dr. Ronald Yankee, National Cancer Institute

Team Member - Dr. F. T. Wooten

Problem Acquired - November 1969
Potential Transfer Identified - April 1970
Elapsed Time - 5 months

Description of Problem

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

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

When this loss of bone marrow occurs, white cells must be resupplied to the patient. For this purpose a bank or storage facility of white cells is required. This is impossible at present because adequate storage procedures are unavailable. Although red cells can be preserved by freezing, many white cells are now destroyed by the existing freezing and thawing procedures. One important parameter in freezing white cells is believed to be the rate of temperature change. This parameter is believed to be important because experiments have shown that improved yields of white cells have resulted when rudimentary controls are placed on the rate of temperature change. Rate of temperature change cannot, at present, be adequately controlled because of the plateau in cooling rate when the latent heat is released at the freezing point.

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

The basic requirement is to have a method of detecting the onset of freezing and then increasing the heat transfer rate during the release of latent heat so that a nearly constant rate of temperature change with time can be maintained from room temperature to $-50^{\circ}C$.

The unit should be capable of freezing 100 milliliters of white cells at a constant rate which can be varied from 1 to $10^{\circ}C$ per minute. The thermodynamic properties of white cells are not known, but a good approximation is that they are similar to water. The freezing point, the only parameter well-known, varies from $-5^{\circ}C$ to $-20^{\circ}C$, depending on the particular sample.

Description of Potential Solution

As shown in the attached sketch, the white cells are contained in the bag or bladder. Cooling is supplied by the liquid nitrogen tubes and is controlled by heating the magnet wire. By reducing the air space between the magnet wires, good thermal contact is assured between the cells and the cooling coil.

When the freezing point is reached, heating is discontinued so that a sharp increase in thermal flow occurs.

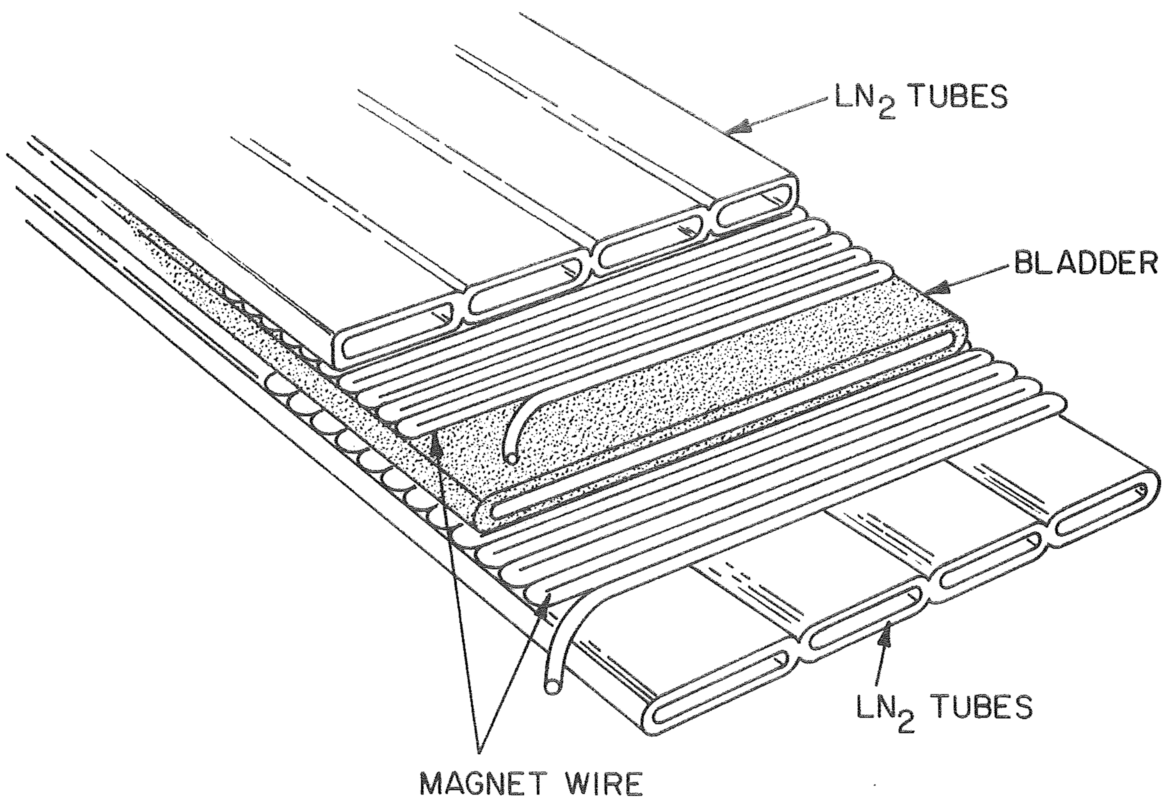
The temperature is controlled by a modified Wheatstone Bridge called a PWM Bridge and capable of temperature control of $0.001^{\circ}C$.

Source of Potential Solution

The solution resulted from the alert response to a problem statement circulated at Jet Propulsion Laboratory. Mr. L. S. Doubt of the Technology Utilization Office correlated the problem statement to the potential solution. The cooling coil was designed by Mr. W. M. Tener and the control by Mr. R. C. Heyser.

Potential Benefits to be Derived

If this unit can be built, the researcher will be able to verify the hypothesis that controlled cooling can increase the yield of white cells. If successful, this will remove a major obstacle in the path to white cell banks.



CONTROLLED FREEZING UNIT

POTENTIAL TRANSFER REPORT

RTI/NCI-8

"Elliptical Lens"

Mr. Phil Stein, National Cancer Institute

Team Member - Dr. F. T. Wooten

Problem Acquired - April 1970
Potential Transfer Identified - June 1970
Elapsed Time - 2 months

Description of Problem

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

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

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

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

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

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

Potential Solution

A NASA developed computer program was found which is used for designing complex optical systems. This program has not been used for elliptical lens but NASA personnel believe that the program can perform the desired design. The Fortran language program documentation was obtained from COSMIC and shipped to the researcher who has expressed strong interest in implementing this program on his computer.

Source of Potential Solution

This potential solution resulted from direct team contact with Marshall Space Flight Center and Jet Propulsion Laboratory. The program was called to the team's attention by Mr. Juan Pizarro of MSFC.

Potential Benefits

The availability of an elliptical lens will improve the ability of the NIH research staff to extract detailed histochemical data from human cells.

POTENTIAL TRANSFER REPORT

RTI/NIMH-1

"Urinary Detection"

Dr. Donald Pollock, National Institute of Mental Health

Team Member - Dr. F. T. Wooten

Problem Acquired - April 1970
Potential Transfer - July 1970
Elapsed Time - 4 months

Description of Problem

One of the significant problems facing the National Institute of Mental Health is concerned with geriatric patients. A frequent problem with these patients is incontinence of urine (the inability to control urination) and the lack of realization by the patient that urination has occurred. As an example of the extent of this problem, in one Veterans Administration Hospital, more than 200 of the 2,000 patients are incontinent, and the staff's time and effort required to keep the patients dry significantly reduce the staff time available for activities such as group therapy or occupational therapy.

Incontinence can be either physiological or psychological, but in the case under consideration, the problem is psychological, (i.e. the patients do not realize when urination has occurred). It is believed that, if the nursing staff could be made aware of the onset of urination, the patient could be retrained to respond to the sensation of a full bladder by simply taking him to the bathroom in much the same manner that a child is trained to solve the problem of incontinence.

A transducer is required for detecting the onset of urination. If an appropriate transducer can be found, the output of the transducer can be telemetered to a central nursing station. The patients wear cotton work pants with no underclothing, and it will be possible to measure moisture in the pants without requiring a direct attachment to the genitals. The transducer must be small and lightweight because the patients are generally confused and might not tolerate bulky equipment strapped to them. Total weight of the transducer must be on the order of ounces.

Proposed Solution

A study of the requirements indicated that a telemetry system might not be the only solution, but that a simple alarm attached to the patient might be sufficient. Consideration of this possibility, however, revealed that the power requirements for most suitable alarm systems were so great that the resulting package weight would be intolerable attached to the patient. However, a simple telemetry system appeared to be suitable.

The technical problem can be divided into three parts. The first part is detection of moisture, the second part is telemetry of the signal, and the third part is the receiver and alarm circuit. A search of the NASA document file revealed a number of documents on measuring moisture, but the simplest and most direct approach seemed to be a moisture sensitive resistor. This approach, discussed in document N65-31355, can be implemented using a commercial device made by Phys-Chemical Research Corporation. The sensor is a treated styrene copolymer which changes resistance by a factor of 30 over the range of 50% RH - 100% RH. Although the sensor is designed for a.c. operation, it can be used for d.c. operation with only a minor error.

The second part of the problem is the telemetry unit, and this can be easily solved using one of the Ames Research Center telemetry units developed by Tom Fryer. Several of the Ames telemetry units are designed to operate from a resistance change (e.g. thermister). The Ames transmitters are miniature FM units, and are well documented in design information.

Another alternative for the telemetry unit is a commercial transmitter made by Belair Electronic Laboratories. This small unit is a bio-potential unit, and it would be necessary to convert the resistance change to a potential change. Unfortunately, not much information is available about the Belair Transmitters so that it is impossible to determine whether the unit is reliable.

Both of the above transmitters are FM units, and a commercial FM receiver seems to be the best solution to the detection problem. The information transmitted to the receiver is simply an on-off signal so that the receiver will simply detect the appearance of a carrier in a particular frequency range. The appearance of the carrier can be used to trigger an alarm circuit. Since the transmission range is less than 50 feet, the power requirements for the transmitter and the sensitivity requirements for the receiver are easily met.

The alarm should be either a sound or flashing light indicator which will sit at the nurses' station. The system must be very simple to operate so that nontechnical personnel can operate it easily.

This potential transfer is being considered as a possible applications engineering project.

POTENTIAL TRANSFER REPORT

RTI/TU-2

"Respiratory Rate Measurement"

Dr. William Waring, Tulane School of Medicine

Team Member - Dr. F. T. Wooten

Problem Acquired - December 1969
Potential Transfer Identified - April 1970
Elapsed Time - 4 months

Description of Problem

Respiratory diseases are the major cause of illness in children from infancy through adolescence, and some of the more serious types of respiratory disease include asthma, cyctic fibrosis, and bronchitis. Much research is presently being conducted both on the causes and cures of respiratory diseases as well as better methods of diagnosis of the diseases. This problem statement is devoted to a method of improved diagnosis which will, in turn, improve the treatment of respiratory diseases.

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

The patients will range in age from infancy to adolescence, and the monitoring will occur in a hospital clinic. The rate measurement method should not encumber the child, and must allow quiet play to occur. It is anticipated that the data will be transmitted to signal processing equipment by a small unit on the child, but the telemetry aspect of the problem will be considered in a subsequent problem statement.

The range of rates will be from 12 to 80 breaths per minute and a precision and accuracy of 0.1 breaths per minute is required.

Description of Potential Solution

The impedance pneumography method used for measuring respiratory volume on the Gemini astronauts has a potential for solving this problem. The signal conditioning unit has been obtained from Manned Space Center and is now undergoing tests at Tulane. These tests will determine if impedance pneumography is a suitable approach to the problem.

Source of Solution

A computer search, #2019, "Respiratory Rate Measurement" performed by the Science and Technology Research Center revealed that impedance pneumography was a promising solution. Team members recalled that an offer for loan of impedance pneumography equipment had been made to another team on problem GLM-15. An inquiry to Manned Space Center revealed that the equipment was still available. Mr. Maxwell Lippitt of MSC provided the equipment and fabricated the accessories including electrodes, cables, and electrode paste.

Potential Benefits

If impedance pneumography proves to be an acceptable approach and if a subsequent problem of telemetry can be solved, an important tool in medical diagnosis will be added. Improved diagnosis also implies an improvement in treatment for respiratory diseases.

P O T E N T I A L T R A N S F E R R E P O R T

RTI/WF-67

"A Filter to Separate Physiologic Data Occurring at Nominal Heart Rates from Lower Frequency Data"

Dr. G. S. Malindzak, Jr.
Bowman Gray School of Medicine, Wake Forest University

Team Member - Ernest Harrison, Jr.

Problem Acquired - February 1969
Potential Transfer Identified - September 1970
Elapsed Time - 19 months

Description of Problem

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

Potential Solution

A computer search of the aerospace literature yielded no relevant information. Manual searching on a limited basis also yielded little relevant information. In addition to searching for specific solutions to specific problems, members of the BATeam scan the various abstracting services which are available and order documents that appear to have general interest to the program. Recently such a document of general interest was ordered. It was a NASA contractor report CR-85022 which described some techniques developed for NASA Ames Research Center in the field of vibrocardiographic instrumentation. One of the appendices to this document described a problem concerned with separating signals generated at the cardiac rate from signals occurring at the respiratory rate. The problem was solved using low pass filtering techniques. These techniques were judged directly applicable to this biomedical problem since NASA has used them to separate signals occurring in the same frequency ranges. From the CR a supplier who can furnish the filters was identified, and specifications and prices were obtained. These filters appear to be a valid solution to this problem.

POTENTIAL TRANSFER REPORT

RTI/WF-88

"Accurate Determination of Arterial Pressure Pulse Transit Time"

Dr. G. S. Malindzak, Jr.
Bowman Gray School of Medicine, Wake Forest University

Team Member - Ernest Harrison, Jr.

Problem Acquired - March 1970
Potential Transfer Identified - August 1970
Elapsed Time - 6 months

Description of Problem

In the arterial system, the arterial pressure is a function of distance and time; hence, it has wave properties. The wave speed of the pressure pulse is related to the elastic modulus of the arterial wall. In addition, wave reflections that occur in the arterial system perturb the pressure function. It is known that the elastic properties of the arterial wall change in humans with age and arterial disease. The biological problem is to detect nondestructively changes in the material properties of the arterial vessel early in the process of arterial disease. Changes of 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, it is desired to obtain reliable, accurate means of determining the wave speed or transit time of arterial pulses. Specifically, are there improved analysis or measurement techniques which can be employed to yield the transit time of the arterial pulse, with or without superposed wave trains (reflections)? In addition, 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, one placed nearer the heart than the other. The arterial pressure pulse is recorded at these two locations. By selecting 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 is to determine arterial pressure pulse transit time. Determination of this parameter to a precision of ±5% is required. The secondary requirements are to be able to obtain information about the material properties of the arterial vessel such as characteristic impedance, terminal impedance, etc.

Potential Solution

Mr. C. J. Laenger of the Southwest Research Institute suggested 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 "Mark IV Ultrasonic Doppler Instrument for Indirect Blood Pressure Measurement", was received and discussed with the researcher. It was decided that the unit might indeed be useful in the solution of this problem provided that a dual-channel unit could be obtained. Unfortunately, a dual-channel unit was not available. However, through the efforts of Mr. Laenger a single-channel unit was obtained on a loan basis from SwRI in order to determine feasibility of the unit in this application. Dr. Malindzak has performed a series of tests with appropriate subjects to permit an evaluation of the feasibility of the unit to make the required measurements. The single-channel unit has been returned to SwRI as requested since it could be borrowed for only a short time.

Analysis of the recorded data is proceeding. If the data analysis proves the feasibility of this approach, a dual-channel unit will be sought. Mr. Laenger has indicated that NASA Houston has several single-channel units and that, if proper support could be obtained, SwRI could modify one of the units to a dual-channel mode without technical difficulty.

POTENTIAL TRANSFER REPORT

RTI/WF-89

"Animal Restraints for Primates"

Dr. G. S. Malindzak, Jr.
Bowman Gray School of Medicine, Wake Forest University

Team Member - Ernest Harrison, Jr.

Problem Acquired - April 1970
Potential Transfer Identified - June 1970
Elapsed Time - 3-4 months

Description of Problem

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

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

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

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

Potential Solution

The potential solution to this problem was identified by calling Ames Research Center Technology Utilization personnel and asking for names of people involved in the Biosatellite Program who had responsibility for the restraint system used in that program. As a result, Mr. Louis L. Polaski was contacted at Ames. Mr. Polaski was very familiar with the restraint apparatus on the Biosatellite Program and was able to recommend specific approaches to primate restraint as applicable to this problem. In addition, Mr. Polaski provided valuable advice concerning the problem of maintaining indwelling catheters in primates for prolonged times as well as the overall problem of restraint. Mr. Charles A. Wilson, Biosatellite Project Manager, has provided a copy of Ames Research Center Working Paper No. 250, "Primate Restraint System," by Louis J. Polaski and William N. Hood, which describes the restraint apparatus developed for the Biosatellite Program. Although this apparatus was developed for long-term restraint in a spacecraft, it appears that the methods can be used in this application, with some minor modifications. Detailed evaluation of the Ames restraint apparatus is now being conducted by the researcher. When this is complete, means of fabricating the apparatus will be explored. In reference to the fabrication of an apparatus, Mr. Polaski has indicated that Ames might be able to provide some assistance in implementation of this transfer.

A.2 Impact Reports

Impact reports are presented for the following impacts which were claimed during this reporting period.

MCV-1

MCV-2

I M P A C T

RTI/MCV-1

"Applications of Image Processing Techniques to Radiography"

Team Member - Ernest Harrison, Jr.

Problem Acquired - January 1970
Impact Made - July 1970
Elapsed Time - 7 months

Description of Problem

This problem involves the application of image processing techniques to radiographic images. The problem was originally classified inactive because the researcher was not actively engaged in a formal research program in this area. Basically, the researcher is interested in the recording, storage, and retrieval of diagnostic X-ray images using a combination of image processing to reduce and enhance the data content of X-ray images and high speed computers for storage and retrieval. Although the problem was rejected, the team continued to provide information and consultation on a demand basis. A copy of computer search "Image Processing" No. 817 and a number of the documents cited therein have been supplied to the researcher.

Use Factor

The information in the search bibliography and documents was very relevant to the researcher's interests in this area. This material has been used by the researcher as background and supporting information in the preparation of a grant application to the National Institutes of Health for a research project on a systems approach to the handling of roentgen ray diagnostic images in medical radiology.

I M P A C T

RTI/MCV-2

"High-Intensity, Soft X-Ray Sources"

Team Member - Ernest Harrison, Jr.

Problem Acquired - January 1970
Impact Made - June 1970
Elapsed Time - 6 months

Description of Problem

Roentgen or X-rays are widely used in medicine for a variety of purposes ranging from tissue destruction for therapeutic purposes to visualization of structures within the human body for diagnostic purposes. A variety of sources from radioactive materials to electronic X-ray generators are employed. The X-radiation derived from these sources covers a broad band of wavelengths. In electronic X-ray generators, the wavelength is a function of the voltage applied to the X-ray tube. Typical values of wavelength and equivalent tube voltage for various applications are listed below.[1]

Application	KV	Wavelength A
Superficial therapy	5-10	5.0 - 2.5
General roentgenography	30-100	0.80 - 0.24
Intermediate therapy	140	0.18
Deep therapy	200-400	0.12 - 0.06
Supervoltage therapy	1000	0.02

Generally speaking, the higher the voltage (shorter wavelength), the more penetrating the radiation. The more penetrating the radiation, the more difficult it is to detect subtle differences in tissue or structure density. For example, with the high voltage X-ray sources, all tissue is essentially transparent to the radiation and only dense bony structures can be differentiated. On the other hand, as the voltage is lowered, smaller differences in density of tissues can be detected.

The researcher is interested in the use of X-rays to detect tumors in soft tissue. The specific application is mammography, i.e. the taking of X-ray photographs of the female breast, for the purpose of detecting tumors. Differentiation of tumors from normal tissue in the female

[1]Otto Glasser, Medical Physics, Vol. 1, Chicago, The Year Book Publishers, Inc., 1944, p. 1397.

breast with X-rays requires low voltage (long wavelength) X-ray sources, in the range of 20-35 KV peak. There are X-ray sources available in this voltage range, but there is one significant difficulty.

In order to achieve the tissue discrimination necessary to detect these tumors, very subtle differences in density on the exposed film must be evaluated. Available X-ray sources in this voltage range have a low energy output, so that relatively long exposures are required to obtain a useable image on film. Using the fastest commercially available high-resolution film, exposures in excess of six seconds are required. (It should be noted that faster X-ray films are available, but their resolution is insufficient for these purposes). Of course, in such a long exposure it is impossible to eliminate internal (and external) motion of the patient as a result of respiration and heart beat. This movement results in blurred images which render tissue discrimination all but impossible. To overcome this difficulty, a higher energy, low voltage X-ray source is desired.

The source should be in the range of 20-35 kilovolts peak. The exposure time desired to reduce movement artifact on the film is one-tenth second. It is expected that a beam current on the order of 10 amperes will be required.

Use Factor

A computer search of the aerospace literature, "High-Intensity, Soft X-Ray Sources," No. 2043, was made and delivered to the researcher. A total of 13 relevant documents were delivered to the researcher. Of particular interest were a number of documents concerning the design and development of state-of-the-art flash X-ray tubes and circuitry. This information was quite useful to the researcher in formulating an approach to the problem and in the preparation of a grant application to the National Institutes of Health for a research project in this problem area.

APPENDIX B

Problem Listings		Page

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B.1 Problems Accepted During Period March 15, 1970, to September 30, 1970

Problem Number	Problem Title
CP-5*	Determination of the Diseased State of the Heart from Electrocardiographic Surface
CP-6*	Utilization of Hodgkin-Huxley Equation for Determining the Propagation of Cardiac Action Potentials
CP-7	Determination of Relationship between Vibratory Properties and Strength of Bones
DU-72*	Shadow Coating in Electron Microscopy
DU-74	Testing of Neuropathic Patients
DU-75	Epicardial Electrodes
IRM-25	Small Battery Operated Suction Pump
MISC-6	Motor for Powering Prosthetic Unit
NCI-9	Improved Emulsion for Autoradiography
NCI-10	Scanning Tumors in Small Animals with Gallium-67
NCI-11	Depth of Field of Microscope Objectives
NCVR-1	A Special Purpose Adjustable Wheelchair Armrest
NHLI-1	Inter-Myocardial Pressure Measurement
OF-1	Blood Embolism Detection
OF-2	Bone Density Measurement
TU-8	Telemetry System for Impedance Pneumography
TU-9	Human Voice Analysis
TU-10	Quantization of Heart Tissue Hardness
TU-11	Electrodes for Evoked Response Studies

* Problem Statements circulated to NASA Field Centers.

** Problem Statement not yet prepared.

B.1 Problems Accepted During Period March 15, 1970, to September 30, 1970 (Cont'd.)

Problem Number	Problem Title
TU-13	Trace Analysis in Body Fluids
TU-14	Left Ventricular Volume Measurement
TU-15	Material for Prosthetic Stapes
TU-18	Improved Photoconductor for Xeroradiography
UNCD-28**	Miniature pH Sensor
UNCD-29**	Miniature Calcium Ion Sensor
WF-88	Accurate Determination of Arterial Pressure Pulse Transit Time
WF-89	Animal Restraints for Primates
WF-90	Blood Pressure in Primates
WF-91	Blood Flow in Primates
WF-92*	An Improved Indicator for Indicator-Dilution Studies

* Problem Statements circulated to NASA Field Centers.

** Problem Statement not yet prepared.

B.2 Problems Closed During Period March 15, 1970, to September 30, 1970

Problem Number	Code*	Problem Title
CP-4	E	Real Time Data Acquisition During Batch Processing
DU-47	D	Urethral Pressure Transducer
DU-58	E	Urine Disposal System
DU-61	J	Improved Resolution for X-ray Fluoroscopic Images
DU-63	I	Measurement of Single Nerve Cell Activity
DU-65	K	Strain Measurements in Ligaments
DU-66	B	Tissue Oxygen Monitoring During Childbirth
DU-67	B	Synthetic Resins for Cell Separation in Immunological Research
MCV-2	M	High Intensity Soft X-Ray Sources
MISC-3	K	Mechanism for Operating Piano Pedals
NCI-1	C	Noise Reduction in Laminar Flow Rooms
TU-1	C	Shock Wave Measurement
UNC-55	K	Non-Contacting Method for Human Infant Position Determination
WF-82	C	Prevention of Tip Washout in Dye Injection Techniques

* See Table 7 on page 23.

B.3 Problems Rejected During Period March 15, 1970, to September 30, 1970

Problem Number	Problem Title	Rejection Code*
DU-70R	Eye Movement Utilization for Communication and Control	G
DU-71R	Measurement of Electrical Potentials Correlated with Myotonic Dystrophy	A
DU-73R	Telemetry Unit to Detect Tongue Pressure on Teeth	F
MISC-5R	Physiological Monitoring of Infant	G
MISC-7R	Phase Measurement of Respiratory Complance Data	A
OF-3R	Effects of Ionizing Radiation on Steroid Production	E
NCI-5R	Human Cell Culture	G
TU-12R	Method of Unblocking EEG Amplifiers	E
TU-16R	Teaching Methods	C
TU-17R	Voice Analysis	F
WF-93R	Nervous Activity During Hemorragic Shock	A

*Key

A - Apparent solution commercially available.
B - Apparent solution not expected in present or foreseeable NASA technology.
C - Problem not biomedically oriented.
D - Problem not amenable to problem-solving oriented program goals.
E - Problem too broadly stated; not sufficiently defined.
F - Problem "priority" too low (Cost/benefit ratio, available resources, enthusiasm).
G - Other.

B.4 Status of Active Problems as of September 30, 1970

Problem Number	Problem Status	Problem Title
RTI/BH-1	B	Respiratory Measurement During Exercise
BH-2	B	Respiratory Gas Analysis During Exercise
BH-3	B	Blood Pressure During Exercise
BH-4	B	Blood Flow During Exercise
BH-5	D	ECG During Exercise
BH-6	D	Exercise Capacity and Standardization During Human Stress Testing
CP-1	C	Data Compression Techniques: Software
CP-2	C	Mathematical or Computer Methods for the Determination of Material Properties of Cardiac Muscle
CP-3	B	Automated Measurements from Coronary Angiograms
CP-5	C	Determination of the Diseased State of the Heart from Electrocardiographic Surface
CP-6	D	Utilization of Hodgkin-Huxley Equation for Determining the Propagation of Cardiac Action Potentials
CP-7	D	Determination of Relationship Between Vibratory Properties and Strength of Bones
DU-31	D	Catheter-Mounted Pressure Transducer
DU-48	E	Urine Flowmeter
DU-59	E	Temperature Measurement on a Small Brain Probe
DU-68	D	Grooves in Glass for Cell Growing
DU-72	C	Shadow Coating in Electron Microscopy
DU-74	B	Testing of Neuropathic Patients
DU-75	B	Epicardial Electrodes
IRM-2	B	A Body Power Energy Storage System
IRM-5	D	An Improved Flexible Lead Wire for Implantable Devices
IRM-14	D	Motion Force Amplifier
IRM-22	E	A Means of Tracking Eye Movements While Viewing Printed Matter, Geometric Forms, and Pictures
IRM-23	E	A Respiration Alarm
IRM-24	D	Waste Management Technique
IRM-25	D	Small Battery Operated Suction Pump
LSU-1	E	Improved Artificial Respirators
MISC-4	D	Freezing Unit for Smallpox Vaccine
MISC-6	D	Motor for Powering Prosthetic Unit
NCI-2	D	Lactate/Pyruvate Measurement in Blood
NCI-3	E	Blood Pressure Measurement
NCI-4	E	Controlled Rate of Freezing a Liquid
NCI-6	C	Separation of White Cells
NCI-7	D	Method of Fast Warming of a Frozen Liquid
NCI-8	E	Elliptical Lens
NCI-9	B	Improved Emulsion for Autoradiography

B.4 Status of Active Problems as of September 30, 1970 (Cont'd.)

Problem Number	Problem Status	Problem Title
RTI/NCI-10	B	Scanning Tumors in Small Animals with Gallium-67
NCI-11	B	Depth of Field of Microscope Objectives
NCSU-9	D	Analysis Techniques for Physiological Data
NCVR-1	D	A Special Purpose Adjustable Wheel Chair Armrest
NHLI-1	B	Inter-Myocardial Pressure Measurement
NIMH-1	E	Urination Detection
OF-1	B	Blood Embolism Detection
OF-2	A	Bone Density Measurement
TU-2	E	Respiratory Rate Measurement
TU-3	D	Lung Sound Detection
TU-5	D	Measurement of Change in Heart Wall Dimensions
TU-6	D	Measurement of pCO_2, pO_2, and pH in Blood
TU-8	D	Telemetry System for Impedance Pneumography
TU-9	B	Human Voice Analysis
TU-10	D	Quantization of Heart Tissue Hardness
TU-11	B	Electrodes for Evoked Response Studies
TU-13	B	Trace Analysis in Body Fluids
TU-14	B	Left Ventricular Volume Measurement
TU-15	B	Material for Prosthetic Stapes
TU-18	B	Improved Photoconductor for Xeroradiography
UNC-50	D	General Purpose, Indicating, Pressure Sensitive Muscle Trainer
UNCD-28	A	Miniature pH Sensor
UNCD-29	A	Miniature Calcium Ion Sensor
WF-29	D	An Electrode for Measuring Hydrogen Ion Concentration and CO_2 Partial Pressure in the Blood
WF-53	B	Means of Obtaining the Velocity Spectrum of Blood Flowing in Arteries and Veins
WF-56	E	An Improved Fluid Pressure Calibration System
WF-61	B	An Improved Method of Determining Volume Elasticity of Blood Vessels
WF-62	D	An Extremely Thin Pressure Transducer to Measure the Pressure Exerted on Tissue by Support-Type Hosiery
WF-64	B	Improved Method of Making Volume Plethsymographic Measurements Related to Volume Changes in Tissue Caused by Influx and Efflux of Blood During the Cardiac Cycle
WF-67	E	A Filter to Separate Physiologic Data Occurring at Nominal Heart Rates from Lower Frequency Data
WF-72	D	Automatic Control System for a Tilt Bed
WF-73	B	Determination of the Site of Bleeding in the Intestine
WF-74	D	Assay of Amino Acids in the Brain
WF-77	D	A Means of Measuring Evaporative Heat Loss from the Skin

B.4 Status of Active Problems as of September 30, 1970 (Cont'd.)

Problem Number	Problem Status	Problem Title
RTI/WF-79	D	Computer Processing of Chromosome Data
WF-80	D	A Miniature Infusion Pump
WF-81	B	A Means of Detecting Turbulence in Blood Flowing in a Tube
WF-83	D	Identification of Infrared Spectra Using Computer Techniques
WF-85	B	Use of Computer in Planning Radiation Therapy
WF-86	B	Reduction of Anxiety by Noncontacting Stimulation
WF-88	E	Accurate Determination of Arterial Pressure Pulse Transit Time
WF-89	E	Animal Restraints for Primates
WF-90	B	Blood Pressure in Primates
WF-91	B	Blood Flow in Primates
WF-92	C	An Improved Indicator for Indicator-Dilution Studies

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* See Problem Status Code on the following page.

Active Problem Status

A - Problem Definition

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

B - Information Searching

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

C - Problem Abstract Dissemination

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

D - Evaluation

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

E - Potential Transfer

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

F - Follow-up Activity

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

APPENDIX C

Problem Statements Circulated to NASA Field Centers
During the Period March 15, 1970, to September 30, 1970

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RTI/CP-1
February 1970

PROBLEM STATEMENT

"Data Compression Techniques: Software"

What is Needed

Computational techniques developed for data compression or data redundancy reduction to be used in transmission of medical data.

Background

There are not enough physicians now. Even if a decision were made tomorrow to sharply increase the output of the medical education system, about a decade would elapse before an increase in the number of doctors in clinical practice would appear. A partial solution to the problem of inadequate health care is a more efficient utilization of the doctor's time and talents, and here is where computer and electronics technology should make a large contribution. For instance, an appropriate hospital-to-hospital data transmission system (using digital computers at each hospital) would permit medical specialists at a large medical research center to assist the more general staffs at smaller outlying hospitals. The information to be transmitted would include electrocardiograph signals and X-ray images.

Taking the X-ray as an example, there is clearly a large degree of redundancy in the image. Large connected areas of the image are of one density, and the real medical information content occurs at the regions where the density is varying (thus defining edges of bones or organs). Instead of digitizing the image and transmitting directly, computer processing of the digitized image may permit substantial reduction in the redundancy of information to be transmitted. A redundancy reduction, or data compression, by a factor of ten or more may be possible. This would permit reduction in bandwidth necessary in the transmitter link, hence, reduction in cost, and may make this approach feasible for health care delivery. Also there may be reasons to wish storage of X-ray images in computer memories. Here again, an order of magnitude data compression, leading to corresponding reduction in computer memory required, can make the difference between the possible and the not possible.

The researcher is one of a group at the Duke University Community Health Science Department which is planning alternative future health care systems built around data transmission, processing and storage techniques. He wants information about computer programming techniques in data compression for this system planning. Although the numbers of bits involved are very different, he is interested both in ECG signals and X-ray images.

Constraints and Specifications

The ultimate use will be sufficiently specialized in terms of the computer and its hardware interfaces so that the researcher and his colleagues will have to write completely new programs for this task. Although they are very capable of doing so, considerable savings of time will occur if they can be provided with good program documentation from computer programs performing data compression. Such documentation should include general discussion and appropriate flow charts as well as the actual program source listing itself.

Bibliography

Gardenhire, L. W., "Data Redundancy Reduction for Biomedical Telemetry", in Biomedical Telemetry, C. H. Caceres, ed., New York: Academic Press, 1965.

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RTI/CP-2
March 1970

PROBLEM STATEMENT

"Mathematical or Computer Methods for the Determination of Material Properties of Cardiac Muscle"

What is Needed

(1) Theoretical elasticity and computer software developments which utilize geometrical and external force data to determine stress and strain distributions in elastic and viscous materials to be used in a study of heart muscle.

(2) Materials science software which utilizes time and spatial stress and strain distributions to characterize viscous and nonviscous material properties to be used in study of heart muscle.

Background

A problem of major concern to the clinical cardiologist is to evaluate the time-varying properties of cardiac muscle. A knowledge of these properties would be very beneficial to the clinician in characterizing muscular diseases by noting abnormalities in the values of properties. Such an indirect determination of cardiac diseases would also be valuable to surgeons in deciding whether or not to undertake cardiac surgery.

Clinical cardiologists in major medical centers obtain simultaneously ventricular pressures from cardiac catheterizations and chamber dimensions from cineangiocardiograms. These data are a major consideration in performing cardiac diagnosis. However, a more exact diagnosis could be performed if these data could be utilized to determine the material properties of the cardiac muscle. This requires the development of adequate analytical or numerical models in myocardial mechanics.

Constraints and Specifications

The only in vivo experimental data that can be obtained for determining these properties are closed-chest determinations of the ventricular dimensions by cineangiography and the ventricular pressure by catheterization. The in vivo data are corrupted by noise and are probably accurate to approximately two significant figures. Thus, proposed methods should be stable and accurate when there is considerable noise in the data.

Bibliography

The following list provides a good starting point for further reading in this problem from the cardiologist's viewpoint.

Fry, D. L., D. M. Griggs, and J. C. Greenfield, "Myocardial Mechanics: Tension-Velocity-Length Relationships of Heart Muscle", Circulation Research, Vol. XIV (1964), pp. 73-85.

Hugenholtz, P. G., *et al.*, "Myocardial Force-Velocity Relationship in Clinical Heart Disease", Circulation, Vol. XLI (1970), pp. 191-202.

Mirsky, I., "Left Ventricular Stresses in the Intact Human Heart", Biophysical Journal, Vol. 9 (1969), pp. 189-208.

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P R O B L E M   S T A T E M E N T

"Real-Time Data Acquisition During Batch Processing"

What is Needed

Computer programming to permit asynchronous real-time data acquisition during batch processing using an IBM 1130 Model 2B computer in a long-term research project in gerontology, the study of aging.

Background

The IBM 1130 computer is used by a research group studying the process of aging. A number of different measurements including electrocardiograms (ECG) and electroencephalograms (EEG) are being carried out at one-year intervals on a selected group of several hundred older people. When this longitudinal study is completed five or more years from now, valuable data on aging processes and changes will be the result. The computer was obtained for analyzing the EEG's and ECG's in this project but is also heavily used for a number of statistical analyses and other computations, all performed in batch processing. The usefulness of the computer would be considerably increased if it could be used for asynchronous real-time data collection during the batch processing upon a suitable interrupt from the external data source.

Constraints and Specifications

The computer is an IBM 1130 Model 2B (8 K words, 3.6 microsecond cycle time, built-in disk) with an IBM 1132 printer, an IBM 1442 reader-punch and a Redcor A-D converter and 1130 interface, operating with the IBM Disk Monitor System Version 2. The programming task, to be done in 1130 Assembler language, will have the following time sequence:

a. The 1130 is operating normally on a batch-processing job.

b. An asynchronous interrupt signals that data collection is to occur.

c. The current batch job is rolled out onto the disk and the data collection and conversion routine is rolled in from the disk. Timing is not critical in this problem and several seconds may be taken in this step.

d. The data are collected and stored on the disk for later batch processing. The data collection process lasts only several seconds in this application.

e. At the end of data collection, the initial batch job is restored and the system continues operating as in step a. (until the next interrupt occurs, when the whole cycle will be repeated).

Information is desired which is related to the experience of other 1130 users in doing similar data collection upon interrupts; the information can range from program listings and documentation through discussions with 1130 users to identify possible problems or difficulties which might be encountered. If this information can be found, the researchers in this problem will be able to do the necessary programming in a time considerably shorter than would be the case without this help.

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RTI/CP-5
April 1970

P R O B L E M   S T A T E M E N T

"Determination of the Diseased State of the Heart from Electrocardiographic Surface-Potential Recordings"

What is Needed

For a model attempting to represent the heart's electrical activity by a set of on-off dipoles, computer programs and numerical methods are needed to determine the optimum set of dipoles $\vec{p}(t)$ to fit a given set of potentials $\vec{\emptyset}(t)$ determined at the body's surface.

Background

The "forward problem" in electrocardiography considers the generation of electrical potentials within the body and on its surface resulting from the electrical activity of the heart. The heart's activity is represented by a suitable set of generators, and a set of dipoles or some type of multipole expansion, plus the fact that in solving the forward problem, proper account has to be taken of body inhomogeneities, anisotropy and shape. The "inverse problem" is concerned with determination of the generators representing the heart, given the electrical potentials measured at the body's surface and given the body's geometry. Thus, the inverse problem represents the clinical situation in which one tries to infer the disease state of the heart from measured torso potentials. Because it is fundamental to electrocardiography, the inverse problem has a long history, but only with access to modern digital computation facilities has there been much hope for a clinically or diagnostically useful solution to the inverse problem.

In general, at a particular instant of time the N separate potentials measured at N points on the torso can be represented by a N dimensional vector $\emptyset$. The heart generators can be represented by a M dimensional vector p. Then at that instant,

$$\vec{\emptyset} = \vec{\vec{C}}\,\vec{p} \qquad (1)$$

where C is a N x M matrix with N > M in the present work. Most of the models used to date have been time independent; that is, the cardiac generator moments or multipoles have been obtained at various instants in time and the results combined to obtain the moments as a function of time[1,2]. The only time dependent model work of which the problem originators are aware was done by Bellman *et al.*[3] and by Baker *et al.*[4]. Both of these approaches assumed a time dependent sequence that was Gaussian shaped and have multiple minima difficulties when applied to real data. A recent time independent model by Barr *et al.*[5] suggests that a model which assumes that the dipoles are on or off may be useful. This problem statement arises from an attempt to extend Barr's time independent model to include time dependent constraints.

Letting both $\vec{\phi}$ and $\vec{p}$ be time dependent, equation (1) becomes

$$\vec{\phi}\,(t) = \vec{\vec{C}}\,\vec{p}\,(t) \tag{2}$$

The on-off pulses $\vec{p}(t)$ turn on at τ_i, $i = 1, 2, \ldots, M$ and turn off at τ_i'. The amplitude of a pulse is K_i. The problem is to find the 3M variables $(\tau_1, \tau_2, \ldots, \tau_M; \tau_1', \tau_2', \ldots, \tau_M'; K_1, K_2, \ldots, K_M)$ which will minimize

$$\int_0^T \left[\vec{\phi}(t) - \vec{\vec{C}}\,\vec{p}\,(t)\right]^2 dt \tag{3}$$

Other optimization criteria (e.g. mini-max) other than least squares might be useful. Computer programs or methods to permit determination of the optimum pulse set $\vec{p}(t)$ would have considerable impact on the possibilities for detection and assessment of heart disease by the noninvasive technique of body surface potential measurements.

Constraints and Specifications

The only in vivo experimental data that can be obtained for determining these properties are torso potentials, $\vec{\phi}$, and geometrical data, $\vec{\vec{C}}$. The potentials are corrupted by noise and the geometrical data are biased by noise and anatomical uncertainty. The net result is that $\vec{\phi}$ is probably accurate to at most two significant figures and $\vec{\vec{C}}$ is less accurate than $\vec{\phi}$. Thus, proposed methods should be stable and accurate when there is considerable noise in the data.

References

1. C. L. Rogers and T. C. Pilkington, "Free-Moment Current Dipoles in Inverse Electrocardiography", IEEE Trans. on Bio-Medical Engrg., BME-15, 312-323 (1968).

2. Robert Plonsey, Bioelectric Phenomena, New York: McGraw-Hill, 1969.

3. R. E. Bellman, et al., Quasilinearization and Nonlinear Boundary Value Problems, New York: Amer. Elsevier Publ., 1965.

4. C. M. Baker and T. C. Pilkington, "The Use of Quasilinearization Techniques in Inverse Electrocardiography Problems", Proc. of 8th ICMBE, 16-10 (1969).

5. R. C. Barr et al., "An Inverse Electrocardiographic Solution with an On-Off Model", IEEE Trans. on Bio-Medical Engrg., BME-17, 49-56 (1970).

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RTI/CP-6
April 1970

PROBLEM STATEMENT

"Utilization of the Hodgkin-Huxley Equations for Determining The Propagation of Cardiac Action Potentials"

What is Needed

Computer programs or information about computer methods to solve numerically the Hodgkin-Huxley equation (given below) for the case in which the sodium and potassium conductivities vary with position, time, and potential, to be used in basic research on the heart.

Background

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

In 1952 Hodgkin and Huxley [1] developed and tested a set of differential equations which describe the electrical properties of the excitable membrane of the squid nerve fiber. Since then the range of application has been extended in two ways. First, the original equations have been applied to a wider variety of phenomena in squid nerve, including the effects of temperature on the propagated action potential, the repetitive firing observed in low calcium concentrations, the prolonged action potentials produced by tetraethylammonium ions, and the hyperpolarizing responses observed in high potassium solutions. Second, the equations have been applied to other excitable tissues [2] including myelinated nerve and cardiac muscle.

The work described in this problem statement is concerned with incorporating recent cardiac muscle data for the dependence of potassium (g_K) conductivity [3] into the Hodgkin-Huxley equations to study the propagation of cardiac action potentials. A solution to this basic research problem in cardiac physiology would have important clinical and diagnostic consequences.

Constraints and Specifications

The Hodgkin-Huxley partial differential equation, for which computer or numerical methods of solution are required, is

$$\frac{\partial^2 V}{\partial x^2} = C \frac{\partial V}{\partial t} + g_K(V - V_K) + g_{Na} (V - V_{Na}) + g_e(V - V_e)$$

where V_K, V_{Na}, V_e, g_e, and C are known constraints and g_K and g_{Na}, the potassium and sodium conductivities, are given functions of time, voltage, and position. V is the desired potential distribution.

Closed form solutions to the Hodgkin-Huxley equations for specialized geometries and time dependent conductivities have been studied [4]. In order to simulate cardiac disease such as myocardial infarction, it is necessary to include both time dependence and spatial dependence in the potassium and sodium conductivities g_K and g_{Na}. Additionally, the spatial dependence is only piecewise continuous. In addition to the desired computer solution for the potential distribution, V, in the above equation, it is desirable to determine the g_{Na} and g_K required for wave reflection.

References

1. A. L. Hodgkin and A. F. Huxley, "A Quantitative Description of Membrane and Current and Its Application to Conduction and Excitation in Nerve", J. Physiol. (London), Vol. 117 (1952), pp. 500-544.

2. Denis Noble, "Application of Hodgkin-Huxley Equations to Excitable Tissues", Physiol. Rev., Vol. 46 (1966), pp. 1-50.

3. E. A. Johnson and J. Tille, "The Repolarization Phase of the Cardiac Ventricular Action Potential: A Time-Dependent System of Membrane Conductances", Biophys. J., Vol. 4 (1964), pp. 387-399.

4. Wilfrid Rall, "Distributions of Potential in Cylindrical Coordinates and Time Constants for a Membrane Cylinder", Biophys. J., Vol. 9 (1969), pp. 1509-1541.

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PROBLEM STATEMENT

"Shadowing Methods for High Resolution Electron Microscopy"

What is Needed

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

Background

A man, or any other of the higher animals, is a collection of individual cells, each cell an anatomically independent unit bounded by a cellular membrane. Yet these cells clearly are organized and their actions coordinated; thus any proper definition of life or intelligence must take into account the transmission of information from cell to cell in the multicellular animal to achieve the overall organization and coordination. Answers to questions about intercellular communication are being found by basic research on the function and structure of the cellular membrane.

The problem originator is investigating details of cellular membrane structure, and the principal tool in this important fundamental research is the transmission electron microscope [1]. The biological specimen is prepared by the freeze-fracturing process [2] and "shadowed" with platinum to enhance contrast and to reveal three-dimensional detail. While modern electron microscopes have resolution limits of several Ångstroms, electron micrographs of cellular ultrastructure are generally limited in resolution to the range 20-100Å, and much of this limitation is due to the shadowing process itself. Improvement in shadowing is the subject of this problem statement.

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

Constraints and Specifications

The uniformity and homogeneity of the shadow coat is the serious problem. Platinum seems to form microcrystals with dimensions of 20 Å or greater. Also, the platinum is evaporated from a carbon rod heated by electric current so that carbon is present as an impurity in the platinum shadow coat. The goal is a shadow coat with irregularities of only 5-10Å. A paper by Preuss [3] states that shadowing is nothing more than the specific application of vacuum science and distillation technology and that ideal shadowing requires

1. that the dispersion of the evaporant be spherical and symmetrical,

2. that the source be essentially a point source, not subtending a significant angle with the specimen,

3. that the path of flight of the evaporant be linear without elastic collisions so that the evaporant atoms arrive with parallel flight paths at the specimen,

4. that the evaporant be pure, remain precisely at the point of impingement on the specimen, and form a structurally homogeneous layer having the best electron scattering properties,

5. that the shadow contour be an exact geometric projection of the specimen profile, and

6. that an optimal thickness of the shadowing material be deposited on the specimen.

There is in this problem the additional constraint that the shadowing technique to be used should be relatively simple so that it can be used by different medical researchers in the problem originator's laboratory. Time and resources are not available for long research projects in shadowing as a process; it is simply one of the tools, however important, and not an end in itself.

Shadowing in practice involves necessary compromises among the above requirements, and one can view shadowing as both a science and an art. Hopefully, this problem statement will elicit suggestions concerning both the art and the science aspects of shadowing.

Characteristics of Relevant Technology

Two different aspects may be considered:

1. How can a pure, uniform platinum shadow coat be deposited on the specimen in such a way that the maximum crystallite size is only 5-10Å?

2. What shadowing material should be used instead of platinum? Why? How should it be applied?

Either theoretical knowledge or practical experience and details may be helpful, and the desired information might be found in the following groups, among others:

1. Metallurgists who may know how to vacuum deposit heavy metals in a manner minimizing crystallite sizes.

2. Optical engineers and scientists with experience in optical coatings and related processes.

3. Surface phenomena scientists who could analyze the processes occurring in the shadow coat condensation.

4. Semiconductor device experts with experience in thin film processes.

5. Electron microscopists, particularly those working on cellular structure.

References

1. There are a number of reference books on electron microscopy, such as Fundamentals of Transmission Electron Microscopy, R. D. Heidenriech, (New York: John Wiley & Sons, 1964). For a more biologically oriented source, see Electron Microscopy of Cells and Tissues: Vol. I. Instrumentation and Techniques, F. S. Sjöstrand, New York: Academic Press, 1967.

2. A concise description of the freeze-fracturing process is found in "The Technique and Application of Freeze-Etching in Ultrastructure Research", James K. Koehler, in Advances in Biological and Medical Physics, Vol. 12, J. H. Lawrence and J. W. Goffman, eds., New York: Academic Press, 1968.

3. L. E. Preuss, "Shadow Casting and Contrast", Laboratory Investigation, Vol. 14, No. 6, Part II, (June, 1965), pp. 919-932. This paper is included in the proceedings of a symposium "Quantitative Electron Microscopy", March 30 - April 3, 1964, edited by G. F. Bahr and E. F. Zeitler, Laboratory Investigation, Vol. 14, No. 6, Part II, (June, 1965), pp. 729-1340.

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P R O B L E M   S T A T E M E N T

"Freezing Unit for Smallpox, Measles, and Yellow Fever Vaccines"

What is Needed

A portable self-powered freezing unit for storing vaccines in remote, tropical regions for periods up to twenty days.

Background

Smallpox, measles, and yellow fever are highly contagious diseases which can result in permanent disfigurement, disability, and death. The World Health Organization has set a goal of eradicating smallpox from the earth by 1977 and, to reach that goal, massive vaccination programs are underway under the auspices of the National Communicable Disease Center and the Agency for International Development. The program is particularly active in Africa because the disease is endemic in the tropics. Measles vaccine is simultaneously administered to the 6-18 months old age group receiving smallpox. Measles control is an integral activity of the West Africa Smallpox Eradication Programs. West African mobile field units are also administering yellow fever vaccines.

Measles and yellow fever vaccines must be stored at 0° C or lower from the time of production to the time of administration to the patient. This degree of temperature control is particularly difficult in the remote regions of tropical Africa since the vaccine must be transported by truck to the remote regions, and the vaccine must be stored in portable truck borne freezers for periods up to 20 days. Several types of units have been tried but all have been unsatisfactory. Kerosene operated units have not been mobile enough and thermo-electric units have not provided adequate temperatures and control. It may be possible to use low pressure gas operated units if reliable units can be found. Liquid nitrogen units have been too expensive.

Requirements and Specifications

The constraints on weight and size of the freezer are approximately 150 pounds, and 30 inches x 30 inches x 30 inches, with a 2.5 - 3 cubic feet capacity. Internal temperatures of 0° or lower must be maintained in remote areas for 20 days in regions where the ambient temperature is 38° C. Internal temperatures can be as low as liquid nitrogen temperatures. The freezing unit must be opened once a day to remove the day's supply of vaccine. Simplicity of operation is required.

Characteristics of Relevant Technology

Technology is required which will result in the desired freezer unit. This includes both the refrigeration unit as well as improved thermal insulation. Any new technology in these areas will be valuable but constraints of ruggedness and portability must be considered.

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RTI/WF-92
August 1970

P R O B L E M   S T A T E M E N T

"An Improved Indicator for Indicator-Dilution Studies"

What is Needed

A normally inert indicator substance which can be mixed with blood (preferably in solution) and can be instantaneously activated by external energy to an appropriate state wherein it can be detected externally, noninvasively, and nondestructively.

Background

The indicator dilution technique is one of the basic methods employed in the study of the cardiovascular system. Using this technique, a number of important parameters concerning the cardiovascular system can be determined including cardiac output, blood transit time, and vascular (blood vessels) volume. Accurate determination of these parameters will permit greater understanding of how the human body responds in shock. In addition, a simple technique which can be applied clinically could be very beneficial in the detection and diagnosis of disease states which accompany or precede the shock state.

Conventionally, the indicator-dilution technique requires the rapid injection of an indicator substance at one point (injection site) in a blood vessel and the detection of the indicator concentration at a downstream point (sampling site). If the indicator concentration is recorded continuously as a function of time, normally a curve resembling that of Figure 1 will result.

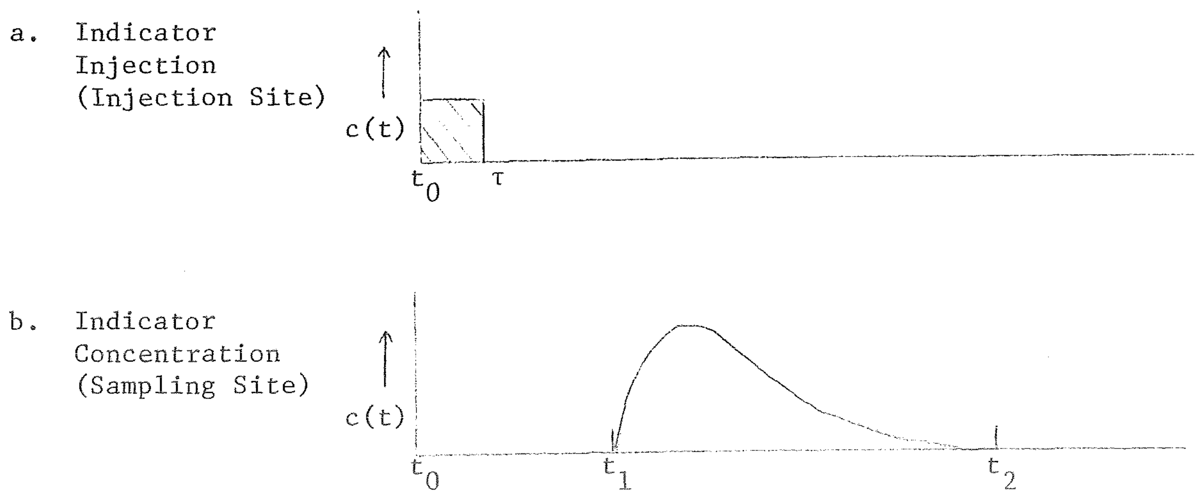

Figure 1. Idealized Indicator Concentration Curve

The average flow rate, $\overline{F}$, is equal to the volume through the sampling site divided by the time $(t = t_2 - t_1)$. The volume through the sampling site is $V = I_A/\overline{C}$ where I_A = amount of indicator added and $\overline{C}$ = average concentration. Hence,

$$\overline{F} = \frac{I_A}{\overline{C}t} .$$

The denominator can be obtained by integrating to obtain the area under the concentration curve in Figure 1b.

$$\overline{C}t = \int_{t_1}^{t_2} C\,dt$$

So that, average flow rate or cardiac output is

$$\overline{F} = \frac{I_A}{\int_{t_1}^{t_2} C\,dt}$$

Various other parameters of interest can be calculated using the appropriate mathematical formulae; e.g.

$$\text{mean (particle) transit time (MTT)} = \frac{\int tC(t)dt}{\int C(t)dt} \text{, and}$$

$$\text{vascular volume (Q)} = \overline{F}.\text{MTT} .$$

This system has been used with considerable success for measuring cardiac output $(\overline{F})$, but not too successfully in determining MTT or Q. There are, it appears, experimental errors associated with this technique. For example, it is assumed that the injection of indicator occurs as a square wave pulse (bolus) and that it is distributed uniformly and instantaneously across the tube at the time of injection. In actual practice, this is extremely difficult to accomplish. To achieve a square wave pulse injection, washout of indicator from the injector tip must be eliminated. Of greater significance is the inability to achieve a uniform instantaneous distribution of indicator across the tube at the time of injection. Nonuniform distribution, of course, contributes error to the measurement and causes unequal loading of flow streamlines. The error is compounded by the laminar flow generally considered to be present in large blood vessels. In laminar flow, the velocity of the fluid varies from zero at the walls of the tube to a maximum value in the center of the tube (i.e. parabolically). Consequently, if the dye injection is not uniform across the cross section, those portions of the cross section receiving the greater amount of dye will bias the results by showing a larger contribution, thus causing the indicator concentration curve to be biased in time either negatively or positively, depending on whether the excess dye concentration is injected into a portion of the tube cross section flowing at a slower or faster rate than the mean flow rate.

Various means, such as specially designed bolus injectors and mechanical mixers at the tube injection site, have been attempted to solve these two problems, but complete success in eliminating these errors has not been achieved.

Constraints and Specifications

In order to eliminate these errors introduced at the injection site, a new kind of indicator tagging is desired, specifically, an inert substance which can be activated so as to become an indicator by irradiation with energy from external sources. In this approach the inert substance could be injected in the cardiovascular system and allowed to circulate until thoroughly mixed. Then at the "so-called" injection site, a small segment of the blood vessel would be irradiated uniformly to "activate" the indicator. The indicator concentration would be sensed at the sampling site using the appropriate detector.

Ultimately, a biocompatible system is required. Specifically, the indicator in its "inert" and "activated" states should be nontoxic, blood-compatible, nonclotting, and the particle size should be no greater than 20 microns. In addition, the energy required to activate the indicator should not cause damage to human tissue, and the indicator should remain in its "activated" state for at least several minutes but no more than 20 minutes.

Initial experimentation, however, will be carried out using a model system so that, at least for the preliminary experiments, the requirements can be greatly relaxed. Potential solutions will be considered for use in model systems.

Characteristics of Relevant Technology

The researcher is interested in obtaining any information concerning substances (which can be mixed with fluids circulating in tubes) that can be activated to some energized or excited state so the substance is capable of detection using external sensors. The material should remain in the excited state for several minutes (1 - 20) to permit detection at downstream sites. All potential solutions will be considered, and no restraints are imposed on the means for activating the material or in detecting the activated material except that they must be accomplished externally. As in any research project, however, all potential solutions will be evaluated on a trade-off basis in which ease of implementation within the researcher's laboratory and overall cost will be factors.

Bibliography

For additional information on indicator-dilution techniques, the reader is referred to the following articles:

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APPENDIX D

Problem Statements Prepared During the Period
March 15, 1970, to September 30, 1970

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Problem Statements Prepared During the Period
March 15, 1970, to September 30, 1970

This appendix contains problem statements for those problems accepted during this reporting period with the exceptions of UNCD-28 and UNCD-29 which have not yet had problem statements prepared and with the exceptions CP-5, CP-6, Du-72, and WF-92 which were circulated to NASA Field Centers and are presented in Appendix C. In addition, a problem statement is presented for NCI-8 which was reported as accepted without a problem statement during the previous reporting period.

RTI/CP-7
May 1970

P R O B L E M   S T A T E M E N T

"Determination of Relationships Between Vibratory Properties and Strength of Bones"

What is Needed

Digital computer techniques for modeling the vibratory properties of bones.

Background

As a noninvasive in vivo technique to detect osteoporosis, a bone disease of major importance, the investigator measures transverse vibration resonant frequencies in a patient's ulna (inner forearm bone). A simple model for the vibratory behavior is impossible since bones are irregularly shaped, inhomogeneous and anisotropic, but there is empirical correlation of the experimental results with skeletal condition. To further develop methods for objective determination of bone status, computer modeling of bone behavior would be extremely valuable. NASA computer methods for modeling dynamic properties of irregular beams may be applicable to this important problem in orthopedics.

Constraints and Specifications

As input, the investigator can supply a variety of physiological and engineering data. The objective is to model the transverse vibration resonant frequencies of bones and determine how the frequencies change as the bone parameters of interest are varied. It would be desirable to run this problem at a NASA center rather than try to transfer the appropriate computer programs to the investigator's own institution.

Other Comments

The RTI BATeam has been looking for a biomedical researcher interested in using NASTRAN, the NASA Structural Analysis Program, for biomechanical problems. Dr. Jurist's problem may be appropriate for NASTRAN, or there may be other suitable computer programs within NASA.

Problem Status

The problem definition is completed. A copy of an earlier computer search on computer analysis of structures was given to the problem originator, and a preliminary copy of a NASTRAN Theoretical Manual was loaned to him. A computer search on transverse vibrations of irregular beams is being run.

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RTI/DU-74
August 1970

PROBLEM STATEMENT

"Testing of Neuropathic Patients"

What is Needed

A means of quantitatively determining the degree to which patients can exercise voluntary control over their muscles.

Background

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

Modern therapeutic treatment allows many thousands of patients to improve the degree to which they can exercise voluntary control over their muscles and, therefore assume a more active and useful role in society. Therapeutic treatment, however, is presently hampered by the difficulty of measuring the improvement that individual patients make during the course of therapy. As an example of a currently employed technique for measuring a patient's progress, the patient is presented with a drawing of a thin-lined geometrical pattern and is asked to trace the pattern with a pencil. From this experiment, one can make a subjective judgment regarding the degree to which a patient is able to control the movements 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.

Constraints and Specifications

Any device to be held in the hand or attached to a limb should be of minimum weight. Furthermore, any instrument used by the patient must require little or no training period. The wide range of performance from patient to patient makes the specification of the required precision difficult; various precision categories should be considered.

Other Comments

Although the primary objective is to measure the degree to which an individual can move a limb in a prescribed manner, a measurement of the rate of movement is desirable if it can be made compatible with the primary objective.

Problem Status

Literature search initiated.

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RTI/DU-75
September 1970

PROBLEM STATEMENT

"Epicardial Electrodes"

What is Needed

A method for quickly attaching multiple electrodes to the heart wall to be used in basic heart research.

Background

The principal tool in diagnosing heart disease is the electrocardiogram (EKG). This consists of measuring potentials at the chest surface which are generated by heart action. A more meaningful, but more dangerous and difficult measurement, would be at the epicardial surface. If correlations could be drawn between epicardial and conventional EKG's, a more accurate interpretation of conventional EKG data would be possible. The researcher is making these studies in an ongoing program, but electrode placement on the epicardial surface is a problem.

Constraints and Specifications

A method for quickly attaching 40 electrodes to the atrial surface is required. The electrodes must occupy an area not greater than 1 mm. They will be attached during open chest surgery and must be capable of remaining implanted for several weeks.

Other Comments

This problem has some similarity to problem DU-46, but the detailed requirements are quite different since DU-46 involved pacemaker electrodes which were attached without surgery.

Problem Status

The problem has been defined.

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RTI/IRM-25
May 1970

P R O B L E M   S T A T E M E N T

"Small Battery Operated Suction Pump"

What is Needed

A small battery-operated suction pump.

Background

The researcher is designing a system to be used in cases of female incontinence. Briefly, a sensor in a specially designed fitting which is in contact with the female urethra is used to detect the presence of urine. Presence of urine causes the sensor to turn on the battery-operated pump which pumps the urine from the fitting to a collection bag.

Constraints and Specifications

Pump must be small; less than one pound and not significantly larger than 8 cubic inches. The unit must be battery operated. Flow-rate averaging less than 25 ml/second is acceptable.

Problem Status

Several units have been identified and the researcher is evaluating specifications.

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RTI/MISC-6
September 1970

PROBLEM STATEMENT

"Motor for Powering Prosthetic Unit"

What is Needed

A small, powerful motor which can be used to activate a specialized prosthetic limb.

Background

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

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

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

Constraints and Specifications

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

Problem Status

A manual search of the aerospace literature has been initiated. In addition an authority on small motors at Duke University has been consulted. He advised us that brushless d.c. motors designed under NASA contract by Sperry Marine Systems Division to provide motive power in positioning satellite solar panels and unfurling antennas is the most likely to fit this particular application. Information on the motors has been obtained from Sperry, and preliminary evaluations indicate that these d.c. brushless motors are potentially capable of fulfilling the motive function in this prosthetic application.

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RTI/NCI-8
April 1970

P R O B L E M   S T A T E M E N T

"Elliptical Lens"

What is Needed

Procedures for grinding elliptical lens to be used in basic research on characteristics of human cells.

Background

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

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

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

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

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

Constraints and Specifications

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

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RTI/NCI-9
August 1970

P R O B L E M   S T A T E M E N T

"Improved Emulsion for Autoradiography"

What is Needed

A faster or more easily exposed emulsion for beta rays to be used in clinical cancer studies.

Background

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

Constraints and Specifications

The new emulsion should have a grain size of 0.1 - 0.4 microns and have a sensitivity greater than that of Kodak NTB-3 or Gevaert NVC-715 which have a sensitivity of about 1.5 grain count/unit area/isotope content of specimen.

Problem Status

A computer search has been initiated.

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P R O B L E M   S T A T E M E N T

"Scanning Tumors in Small Animals with Gallium-67"

What is Needed

A high resolution radiation detector which is sensitive to Gallium-67 and can be made suitable for scanning the entire body of small animals.

Background

Gallium-67, a radioactive isotope, possesses a special property: concentrating around various types of tumors when administered orally or intravenously to a patient. By scanning the patient with an instrument which will detect the presence of radioactive substances, the location as well as the relative size of a tumor can be determined. Clinical investigators currently employ a variety of detectors which are useful in locating large tumors in humans but are relatively ineffective where small tumors are concerned. What is lacking at present is a high resolution radiation detector which is sensitive to Gallium-67 and can be made suitable for scanning the entire bodies of small animals (e.g., mice). Such a detector would offer a unique opportunity to study tumor growth in small animals on a day-to-day basis which will supply much needed information in the search for drugs to inhibit or retard tumor growth.

Problem Status

A computer search has been initiated.

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RTI/NCI-11
September 1970

P R O B L E M   S T A T E M E N T

"Depth of Field of Microscope Objectives"

What is Needed

A method for measuring depth of focus or depth of field for microscope objectives to be used in basic cancer research.

Background

Basic medical science requires more information on cellular activities; technology plays a critical role in extracting this information. At the National Cancer Institute an optical microscope is being used to obtain quantitative microspectrophotometric histochemical data. This study has been underway for some time, but efforts to obtain optimum system performance have been hampered by the inability to measure the depth of focus of the microscope objective with sufficient precision.

Constraints and Specifications

A method for measuring depth of field of lens with focal lengths of 0.5 - 25 mm. is required with an accuracy of ±2%.

Problem Status

A literature search has been initiated.

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PROBLEM STATEMENT

"A Special Purpose, Adjustable, Wheel Chair Armrest"

What is Needed

A special armrest which can be adjusted to permit proper placement of the right arm of a wheel chair patient so that he can operate a Morse code key.

Background

A patient being aided by the North Carolina Division of Vocational Rehabilitation is physically disabled and is almost without muscular control. Since he is a writer, communication is very important. He does not have sufficient muscular control to write, type, or speak effectively. To permit this patient to communicate, NCVR is sponsoring the development of a Morse code-typewriter conversion unit which will enable the patient to type on an electric typewriter using a Morse code key. The patient is confined to a wheel chair, and because of a spastic condition it is extremely difficult using "conventional" armrests for the patient to operate the key comfortably.

Constraints and Specifications

An adjustable arm support structure that can be fitted to a wheel chair is desired. The arm support should completely support the arm so that the patient can concentrate on operating the Morse code key. It must be adjustable to permit movement so that the optimum positioning of the arm and the Morse code key can be experimentally determined. Information on an existing design or configuration is desired so that the researcher will not be forced to design an armrest essentially from "scratch".

Problem Status

Problem identification complete. As a result of BATeam work at the Institute of Rehabilitation Medicine, the BATeam member was aware of special armrests which have been employed for similar purposes at the Institute of Rehabilitation Medicine. Information on these armrests has been obtained from IRM and has been given to the researcher for evaluation.

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RTI/NHLI-1
September 1970

P R O B L E M   S T A T E M E N T

"Inter-Myocardial Pressure Measurement"

What is Needed

A means of measuring pressures within the heart muscle.

Background

Myocardial infarction is a damaged or dead area of the heart muscle resulting from a reduction in the blood supply reaching that area. This condition can usually be diagnosed by electrocardiography; however, the precise location of the affected area is necessary to assure the success of surgical procedures for repairing the injured muscle.

Since the damaged or dead tissue results in a "weak area" of the heart muscle, it is expected that a measurement of the pressure sustained during the contraction and successive relaxation of the heart will differ from similar measurements made in unaffected areas. A probe which could be used to make pressure measurements within a small region of muscle tissue would lead to a refined location of the area which needs to be removed by surgery. This would in turn lead to improved surgical procedures and, therefore, to a higher probability of successful recovery for the thousands of Americans who must undergo surgery for this disorder each year.

Constraints and Specifications

The pressure measuring device must be responsive over the range 1800-2200 mm. Hg./sec. The required precision should be on the order of ±10 mm. Hg. It is felt that the probe must be inserted into the heart muscle; if so, it should be needle shaped with a diameter on the order of 20 - 30 mils.

Problem Status

A computer search has been initiated.

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RTI/OF-1
August 1970

PROBLEM STATEMENT

"Blood Embolism Detection"

What is Needed

A method of detecting embolisms in blood which occur during open heart surgery.

Background

When open heart surgery is conducted, a heart-lung machine is used to provide the oxygenated blood supply. The existing heart-lung machines can produce gas embolisms or the surgery can break loose small particles, either of which can stop blood circulation if lodged in a small artery. It is estimated that 20% of open heart cases result in a neurological deficiency (reduction in blood flow to the brain). If the embolisms could be detected in the heart-lung machine, corrective action could be taken.

Constraints and Specifications

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

Problem Status

A computer search has been started. Personnel at Ames Research Center have been contacted regarding their ultrasonic blood flow detector which appears applicable.

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PROBLEM STATEMENT

"Bone Density Measurement"

What is Needed

A method of measuring bone density in experimental animals to be used in basic research on cancer.

Background

Neoplasms secrete hormones which leach calcium from the bone. This can produce hypercalcemia and can also provide a site in the leached bone for cancerous cells. As an example, 20% of lung cancer victims and 40% of breast cancer victims have hypercalcemia. Although hypercalcemia can be treated, the fundamental cause of its occurrence is unknown. In studies of experimental animals, measurements of bone density would be useful in order to follow the progress of demineralization.

Constraints and Specifications

The technique will be used on the rat tibia which is 3 cm. x 0.5 cm. in size. The technique should also ideally be applicable to humans. Changes of bone density as high as 50% are expected, and the accuracy of detection should be ±5%. Preferably the rat will not be sacrificed, and repeated measurements will be made during a 14 week period.

Other Comments

The team suggested indirect methods such as stiffness or hardness measurement. Dr. Rice felt that this might be a good approach.

Problem Status

The other BATeams are being contacted to determine whether they have a similar problem. In addition, this problem will be discussed with the appropriate NDT people at MSFC during Dr. Wooten's visit on October 1, 1970.

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RTI/TU-8
May 1970

PROBLEM STATEMENT

"Telemetry System for Impedance Pneumography"

What is Needed

A small analog telemetry system for transmitting the output of an impedance pneumograph to be used in studies of respiratory diseases in children.

Background

A previous problem (TU-2) concerned measuring respiration rate in children. This problem has been solved using an impedance pneumograph and the researcher has been able to obtain not only rate but inspiration and expiration times as well. In order that the pneumograph can be used on an unencumbered child, a small telemetry system is required.

Constraints and Specifications

The impedance pneumograph output voltage is ±10 millivolts with an output impedance of five thousand ohms. The respiration rates vary from 12 to 80 breaths per minute. Transmission range should be a maximum of 50 feet. Transmitter size should be less than one cubic inch.

Problem Status

Information is being analyzed on transmitters built by Tom Fryer of Ames Research Center

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PROBLEM STATEMENT

"Human Voice Analysis"

What is Needed

Method for quantizing human voice characteristics to be used in speech therapy.

Background

Approximately 6-7% of the population is considered to have speech defects. Therapy for these patients is hampered by a lack of a means of quantizing the changes in a voice. Speech consists of a broad fundamental frequency and many harmonies. Small shifts in fundamental frequency and amplitude can cause large changes in voice quality.

Constraints and Specifications

Frequency spectrum analysis must be able to detect fundamental frequency (150-225 cps) to a precision of 1 cps and amplitude to 1 db accuracy. Real time analysis is not required but would be desirable. Analysis techniques must include the harmonics.

Problem Status

A computer search has begun.

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P R O B L E M   S T A T E M E N T

"Quantization of Heart Tissue Hardness"

What is Needed

Method of measuring hardness of heart tissue to be used in pathological examinations.

Background

Careful analysis of the human heart condition following the death of a patient can disclose significant information about the cause of death. Following death the tissue hardness changes in a process called autolysis. In order to carefully analyze this process, a simple means of measuring the hardness of the heart surface is required. The physician has tried conventional eye tonometers but found them to have poor reproducibility.

Constraints and Specifications

No useful units for the range of hardness can be supplied but the hardness is similar to a soft rubber. The test must be for an area equal to or less than one square millimeter.

Problem Status

A computer search of the NASA literature has been started.

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PROBLEM STATEMENT

"Electrodes for Evoked Response Studies"

What is Needed

Electrodes for deep brain stimulation to be used in basic neurological studies.

Background

Basic neurological studies on schizophrenia are carried out by evoked response studies (i.e. stimulation at point A and recorded response at point B). A need exists in these studies for stimulative electrodes which will be placed deep in the brain and which will not develop contact potential and capacitance effects after long periods of implantation. Stainless steel and silver have not been satisfactory.

Constraints and Specifications

The electrode must be capable of high current densities and must be made in small electrodes 1 mm. in diameter.

Problem Status

A computer search of the NASA data bank has been made.

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RTI/TU-13
July 1970

PROBLEM STATEMENT

"Trace Analysis in Body Fluids"

What is Needed

A method for measuring trace elements in body fluids.

Background

Prosthetic devices are widely used in medicine and continual improvements in materials are needed. Evaluation of new materials is particularly difficult because of the uncertainty as to whether the body will absorb trace amounts of the prosthetic material. If better analysis techniques are available, the evaluation of new materials can be significantly enhanced.

Constraints and Specifications

Trace amounts of materials with atomic number greater than 14 are required. Analysis of body fluids such as blood, lymph, and urine will be required.

Problem Status

A computer search has been initiated.

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RTI/TU-14
July 1970

P R O B L E M   S T A T E M E N T

"Left Ventricular Volume Measurement"

What is Needed

A new method for measuring left ventricular volume.

Background

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

Constraints and Specifications

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

Other Comments

One possible approach is mechanical resonance if enough energy can be sonically coupled into the heart.

Problem Status

A computer search has been initiated.

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RTI/TU-15
July 1970

P R O B L E M S T A T E M E N T

"Material for Prosthetic Stapes"

What is Needed

An improved material for prosthetic stapes.

Background

The stapes is a stirrup-shaped bone in the middle ear which couples sound from the outer to the inner ear. Many patients lose hearing because of the deterioration of the stapes. Hearing can be regained by replacing the stapes with a prosthetic material. Unfortunately, most work to date has been with easily available materials rather than materials designed for coupling sound.

Constraints and Specifications

Materials that can be fabricated in small components are needed. Material characteristics of importance are mass, density, propagation velocity, and modulus of elasticity.

Problem Status

Problem definition is nearly complete.

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RTI/TU-18
September 1970

PROBLEM STATEMENT

"Improved Photoconductor for Xeroradiography"

What is Needed

An improved photoconductor to be used in xeroradiography.

Background

Xeroradiography is a technique for recording an X-ray image by a totally dry process without the necessity of a darkroom. The powdered surface of an electrically charged photoconductor plate records the X-ray image, and a print is made from this plate. The major advantage of this technique is the speed with which the finished image can be produced. The disadvantage is that selinium's photoconducting characteristics require too large a radiation dose for many parts of the body.

Constraints and Specifications

A photoconductor with an improved resolution and quantum efficiency over the commonly used selinium is required.

Problem Status

A computer search has been initiated.

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RTI/WF-88
May 1970

P R O B L E M   S T A T E M E N T

"Accurate Determination of Arterial Pressure Pulse Transit Time"

What is Needed

A more accurate method of determining the transit time of arterial pressure pulse transit times.

Background

In the arterial system, the arterial pressure is a function of distance and time; hence, it has wave properties. The wave speed of the pressure pulse is related to the elastic modulus of the arterial wall. In addition, wave reflections that occur in the arterial system perturb the pressure function. It is known that the elastic properties of the arterial wall change in humans with age and arterial disease. The biological problem is to detect nondestructively changes in the material properties of the arterial vessel early in the process of arterial disease. Changes of 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, it is desired to obtain reliable, accurate means of determining the wave speed or transit time of arterial pulses. Specifically, are there improved analysis or measurement techniques which can be employed to yield the transit time of the arterial pulse, with or without superposed wave trains (reflections)? In addition, 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, one placed nearer the heart than the other. The arterial pressure pulse is recorded at these two locations. By selecting 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.

Constraints and Specifications

The primary requirement of this problem is to determine arterial pressure pulse transit time. Determination of this parameter to a precision of ±5 percent is required. The secondary requirements are to be able to obtain information about the material properties of the arterial vessel, such as characteristic impedance, terminal impedance, etc.

Problem Status

Problem identification complete.

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RTI/WF-89
April 1970

P R O B L E M   S T A T E M E N T

"Animal Restraints for Primates"

What is Needed

An animal-restraint system suitable for rhesus monkeys is required which will inhibit vigorous action of the animal and will prevent the animal from removing attached instrumentation.

Background

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

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

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

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

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RTI/WF-90
April 1970

P R O B L E M   S T A T E M E N T

"Blood Pressure Measurements in Primates"

What is Needed

An improved means of continuously monitoring blood pressure in the aorta of the rhesus monkey is desired. If implanted, the equipment must remain operable for six months. Whether implanted or externally attached, it is desired that the sensors remain in place for the total experimental time of six months.

Background

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

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

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

Requirements and Constraints

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

In previous dog experiments, blood pressure has been measured using a Statham P23Db strain gage. The strain gage was inserted through a polyethylene cannula placed in the aortic arch through a cutdown in the left common carotid artery. If cannula techniques were employed with the rhesus monkey, the cannula would most likely be introduced through the subclavian artery and thence to the aorta.

A telemetric blood pressure measuring system which could be implanted for a six-month period would be the ideal solution. The available volume which could be used for the blood pressure instrumentation is approximately 6 cubic inches.

Although a self-contained telemetric system would be ideal, useful suggestions concerning nontelemetric approaches to long-term monitoring of aortic blood pressure in monkeys are actively sought. Basically, suggestions regarding long-term monitoring of blood pressure in animals which offer a reduction in instrumentation complexity and accuracy or which render installation easier than in the classic cannula method of measuring aortic blood pressure are encouraged.

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RTI/WF-91
April 1970

PROBLEM STATEMENT

"Blood Flow Measurement in Primates"

What is Needed

An improved, implantable blood flow sensor that can be used to monitor blood flow in the coronary artery of a rhesus monkey for periods of three to six months.

Background

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

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Requirements and Constraints

The monkeys will be monitored for three to six months during the course of the study. During this period, it is required that the blood flow in the coronary artery be monitored for approximately one hour during each experimental period which may last up to four hours. Although continuous monitoring is desired during each of these periods, repetitive flow measurement at intervals not exceeding one second apart is acceptable. The flow rate to be measured is in the range of 5 to 500 cc/min. and an accuracy of ±5 percent is desired. The coronary artery of the rhesus monkey is approximately 3 to 5 millimeters in circumference.

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

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

Although this is the ideal, it should not be interpreted to exclude useful suggestions concerning nontelemetric approaches to long-term monitoring of blood flow in monkeys. Essentially, suggestions which represent an improvement in simplicity or performance over electromagnetic flowmeters in the long-term monitoring of blood flow in animals are solicited.

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