REPORT

THE APPLICATION OF AEROSPACE TECHNOLOGY TO BIOMEDICAL PROBLEMS

QUARTERLY REPORT NO. 1
15 June - 31 August 1969

Contract No. NASW-1936

MRI Project No. 3332-E

For

National Aeronautics and Space Administration
Office of Technology Utilization
Technology Utilization Division
Washington, D.C. 20546

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by

David Bendersky
Donald E. Roberson

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PREFACE

This report covers the activities of Midwest Research Institute Biomedical Applications Team during the period from 15 June - 31 August 1969. The MRI BA Team is concerned with the application of aerospace-generated technology to problems in the nonaerospace biomedical field. This work is under the technical direction of NASA's Technology Utilization Division, Office of Technology Utilization, Washington, D.C.

The MRI BA Team is directed by David Bendersky, Principal Engineer, under the supervision of Paul C. Constant, Jr., Manager of Technology Utilization and Assistant Director of the Engineering Sciences Division. Other MRI technical staff who contributed to the activities reported herein are Edward T. Fago, Senior Engineer, Wilbur E. Goll, Associate Engineer, and Donald E. Roberson, Assistant Engineer.

The coordinators at the participating medical institutions are Dr. John W. Trank, University of Kansas Medical Center; Blair A. Rowley, University of Missouri; Drs. R. Heber, and Robert H. Schwarz, University of Wisconsin, Dr. William G. Kubicek, University of Minnesota; Dr. I. C. Wells, Creighton University College of Medicine; and Dr. Harold W. Shipton, University of Iowa.

The important contributions of the biomedical investigators at the participating medical institutions, whose names appear in the text, are gratefully acknowledged.

Approved for:

MIDWEST RESEARCH INSTITUTE

Paul C. Constant for

Harold L. Stout, Director
Engineering Sciences Division

2 October 1969

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SUMMARY

During the period 15 June - 31 August 1969, the NASA-supported Biomedical Applications Team at Midwest Research Institute was active on 53 biomedical problems submitted by the medical institutions which are participating in the BAT Program. The methodology employed by the MRI BA Team is described in the Introduction. The Team's activities resulted in 11 potential transfers of aerospace-related technology to the solution of these biomedical problems. Sixteen new Problem Statements were prepared and 10 computer searches were conducted and evaluated.

Two additional medical institutions, Creighton University School of Medicine, and Iowa University College of Medicine, were added to the medical institutions associated with the MRI BA Team project. Also, meetings have been scheduled at the University of Nebraska College of Medicine, Mayo Clinic, and Washington University School of Medicine, to discuss their possible participation in the project.

In addition to serving the participating medical institutions, the MRI BA Team furnished a variety of information requested by nine organizations.

Some significant changes in the operations of the MRI BA Team have been instituted during this contract period. The experience of the MRI BA Team indicates that the number of transfers is in direct proportion to the number of participating medical institutions and the number of biomedical problems submitted by the medical institutions. Therefore, it has been decided to increase the number of participating medical institutions. It is tentatively planned to add five additional medical institutions to the MRI BAT Program. A medical clinic is to be included as an experiment in serving such a medical institution. The problems submitted by the participating medical institutions will be carefully screened to maximize the return on the BA Team's efforts.

Additional MRI staff members will be added to the MRI BA Team so that all of the participating medical institutions can be properly served. Each member of the MRI BA Team will maintain personal contact with the research and clinical staff at their assigned medical institutions, to assist in the definitions of the biomedical problems, and to encourage the use of the applicable technology identified by the MRI BA Team.

Experience has shown that the most productive source of aerospace technology is computerized searches of the NASA literature. This source of aerospace technology will continue to be fully utilized by the MRI BA Team, through the services of the ARAC NASA Regional Dissemination Center. However, another source of aerospace technology which has not been fully exploited in the past is the NASA Research Centers. Members of the MRI BA Team will visit the NASA Research Centers, with coordination through NASA-TUD, to become more familiar with the activities at these centers and to encourage their participation in the BAT Program.

I. INTRODUCTION

In the course of its concern with the well-being and functional capabilities of man in aerospace environments, the National Aeronautics and Space Administration (NASA) has generated an extensive body of science and technology pertaining to medicine and biology. In addition, the aerospace program has led to the development of technological developments in other fields that may be adaptable to the solution of medical and other problems. To encourage the use of aerospace generated science and technology outside the aerospace field, NASA has established a Technology Utilization (TU) Program whose major purpose is to facilitate the transfer of this knowledge to secondary applications. Three multi-disciplinary Biomedical Applications Teams have been established under the NASA-TU Program to assist in the transfer of aerospace-generated technology to the field of biomedicine.

The procedure used by the Biomedical Applications Team consists of five basic steps. The first step is to define specific biomedical problems which may be solved through the application of aerospace technology. The problems are obtained from the research and clinical staffs at participating medical institutions. The second step is to identify potential solutions to the biomedical problems. The identification of potential solutions is done through computerized and manual searches of the aerospace literature, circulation of Problem Statements to the NASA Research Centers, and personal contacts. The third step is to modify the original technology, if required, to adapt it to the biomedical problem. The fourth step is the evaluation of the technology by the investigator who submitted the problem. The final step is to document and disseminate information on successful applications of aerospace technology.

Six medical institutions are presently associated with the MRI-BAT program. These are: the University of Kansas Medical Center, Kansas City, Kansas; the University of Missouri, Columbia, Missouri; the University of Minnesota Medical School, Minneapolis, Minnesota; the University of Wisconsin, Madison, Wisconsin; Creighton University School of Medicine, Omaha, Nebraska; and Iowa University College of Medicine, Iowa City, Iowa.

II. STATUS OF BIOMEDICAL PROBLEMS

A. Transfers

There were 11 potential transfers of aerospace technology during this report period. Descriptions of these potential transfers follow. It is noteworthy that six of these potential solutions were found in manual searches in the MRI-BAT document files. This is indicative of the growing accumulation of pertinent documents in the MRI-BAT files. Two of the solutions were found through computer searches, two were suggested by NASA Research Center personnel, and one was found by the medical investigator in the open literature. Transfers are expected during the next quarter on Problems Nos. KU-31, KU-37, MU-29, and UW-2.

ELECTROCARDIOGRAM ELECTRODES

Problem No. KU-31

Robert F. Hustead, Department of Anesthesiology
University of Kansas Medical Center

The Problem

Reliable ECG electrodes are required for use during surgery and anesthesia. The electrodes must function for several hours with no attention, must be independent of position, and must require no straps or bands to hold them in place. It is not practical to replace or adjust the electrodes even though a patient may be moved during the operation. A serious problem is the rectification of high voltage, high frequency electrical noise that is picked up by the electrodes from various sources in the operating room.

The Potential Solution

A potential solution is the spray-on electrodes developed by the NASA Flight Research Center.[7]

How Solution Was Found

The spray-on electrodes have been identified by the MRI-BA Team previously as a solution to an earlier problem (KU-1).

Status of Transfer

Dr. Hustead plans to evaluate the electrodes in clinical use. The problems of noise pickup and rectification will be of particular interest in his evaluation.

OXYGEN PARTIAL PRESSURE MONITOR

Problem No. KU-32

Robert F. Hustead, M.D., Department of Anesthesiology
University of Kansas Medical Center

The Problem

An oxygen partial pressure monitor is required for use during surgical anesthesia. The operating pressure range is 50 to 500 mm Hg. The sensor should be insensitive to nitrous oxides, carbon dioxide and halogenated hydrocarbons. A readout of rate of change as well as actual values of oxygen partial pressure is required.

The Potential Solution

The Perkin-Elmer Corporation has developed several instruments for sensing spacecraft cabin atmosphere and respiration gases. These instruments include a spacecraft cabin analyzer, rapid response metabolic sensor, and two-gas atmosphere sensors (photometric and mass spectrometer). All were developed under NASA contract for the space program.

How Solution Was Found

A computer literature search of aerospace literature cited two contractor reports[8,9] on the Perkin-Elmer two-gas atmosphere sensor. Preliminary specifications of the two-gas sensor and the other instruments were located in a file of commercial literature maintained by the MRI-BA Team.

Status of Transfer

The researcher desires to evaluate these instruments. Additional information including complete specifications, instrument costs, and possible demonstrations have been requested from the Perkin-Elmer Corporation.

RESPIRATION VOLUME FLOWMETER

Problem No. KU-35

Robert F. Hustead, M.D., Department of Anesthesiology
University of Kansas Medical Center

The Problem

During surgical anesthesia it is essential that the respiratory state of the patient by under continuous observation. The patient is connected to a closed circuit anesthesia machine in which the machine gas flow directly represents patient flow. The research needs a respiration volume flowmeter to be used during surgery and sensitive to flows as low as $\pm$ 5 liters/sec. The readout should indicate instantaneous flow, volume flow per breath and accumulated volume flow per minute. The measurement should be independent of gas temperature, humidity, and gas composition. Pressure drop should be on the order of 1 to 2 cm. H_2O. The instrument should be reliable and require no adjustments during use.

The Potential Solution

A possible solution to this problem is the use of a NASA modified Wright Spirometer, developed at Flight Research Center. NASA Technical Note TN D-4234 and NASA Case No. FRC-10039 describe the unit.

How Solution Was Found

Clinton Johnson, Technology Utilization Officer at NASA Flight Research Center, suggested the use of the modified spirometer in response to an abstract of this problem.

Status of Transfer

Mr. Johnson was contacted to obtain more details on the spirometer, and in hopes of borrowing a unit for evaluation. Unfortunately, there are no spirometers available. He promised to supply the BA Team with drawings and specifications for modifying a standard Wright spirometer in accordance with the NASA-FRC design.

ARTERIAL BLOOD PRESSURE MONITOR

Problem No. KU-36

Robert F. Hustead, M.D., Department of Anesthesiology
University of Kansas Medical Center

The Problem

During surgery only the patient's head is available to the anesthesiologist. A remote monitor of arterial blood pressure is needed to measure systolic, diastolic, and average pressure. Any equipment attached to the patient must be in place before the final drape is applied and must remain functional without additional attention for periods up to 6 hr. Either direct arterial catheterization or auscultation is acceptable, but simplicity, reliability, and a minimum of attention to the equipment is essential.

The Potential Solution

An ultraminiature manometer-tipped cardiac catheter developed at the NASA Ames Research Center (by Mr. G. Coon) may be the solution to this problem. This instrument is described in NASA Tech Brief B67-10669. Three alternate solutions are pressure sensors commercially available from the following companies: Kulite Semiconductor Products, Inc. (Model CPL-070); Statham Instruments, Inc. (Model P-866); and Whittaker Instrument Systems Division (Model 1007).

How Solution Was Found

A routine search of NASA Tech Briefs revealed Tech Brief B67-10669 (see Appendix) which describes the Coon manometer-tipped cardiac catheter. The Technology Utilization Officer at Ames Research Center, Mr. George Edwards, suggested the three alternate solutions of commercially available pressure sensors.

Status of Transfer

The Coon manometer-tipped catheter is not presently available. The U. S. Department of Health, Education, and Welfare has contracted with Corbin-Farnsworth, Inc., of Palo Alto, California, to construct 50 Coon catheter transducers for the purpose of initiating commercial manufacture and evaluation of these devices. Dr. Hustead may be able to make arrangements with HEW to evaluate one of these devices.

EGG MONITORING DURING ANESTHESIA AND SURGERY

Problem No. KU-37

Robert F. Hustead, M.D., Department of Anesthesiology
University of Kansas Medical Center

The Problem

A reliable technique for monitoring the electrocardiogram is needed for use during anesthesia and surgery. The primary requirement is for an amplifier with high differential gain, high common mode rejection, and a very high common mode dynamic range. Numerous sources of interference are present in the operating room; the most serious being the electrocautery unit which produces high voltage, high frequency damped oscillatory pulses at a 60 Hz repetition frequency. These pulse trains produce very large interference signals in the patient's EGG. With conventional equipment these extraneous potentials are large enough to produce electrical damage in the EGG amplifiers.

The Potential Solution

NASA Tech Brief B68-10233 describes a system for the transmission of electrocardiograms from an ambulance to a hospital. The system uses existing radio transmitter and receiving equipment, telephone lines, and NASA developed amplifiers, filters, and other signal conditioning electronics. The EGG amplifier and filters could be used as a partial solution to this problem.

How Solution Was Found

As the result of reading an MRI BA Team report the Technology Utilization Officer at NASA Flight Research Center, Clinton Johnson, suggested the use of the ambulance telemetry system outlined in Tech Brief B68-10233.

Status of Transfer

Mr. Clinton Johnson was contacted at FRC regarding additional information on the proposed solution. He informed the MRI BA Team that the entire ambulance system is being commercially produced by Electro-Biometrics in Lancaster, California, for about a $7,000 cost. Dr. Hustead is now looking into this system.

TELEMETRY SYSTEM TO IMPLANT IN THE OVARY DUCTS OF SMALL ANIMALS

Problem No. MU-23

Saul D. Larks, Ph.D.,
University of Missouri

The Problem

It is desired to implant a small telemetry package in the ovary ducts of miniature pigs to measure physiological cyclic changes. The package should contain transducers to measure pH, electrical potentials, pressure, and chemicals. Life span of the unit should be 60 to 90 days, be impervious to, and nonreactive with, the animal's fluids and body tissue.

The Potential Solution

NASA Tech Brief, B64-10171, describes a subminiature transmitter suitable for biopotential measurements. It will operate for 48 days at a 10-ft. range. Also, three implantable telemetry units developed at NASA Ames Research Center to sense temperature, pressure, and biopotential are commercially available from Electro-Optical Systems, Inc., as the BTI telemetry series.

How Solution Was Found

The NASA Tech Brief and commercial literature from Electro-Optical Systems, Inc., were contained in the MRI BA Team biomedical files.

Status of Transfer

Dr. Larks is evaluating the information supplied by the MRI BA Team.

DIGITAL SIGNAL ENHANCEMENT SOFTWARE

Problem No. MU-28

Alan H. Purdy, Bioengineer, Missouri Regional
Medical Program, University of Missouri

The Problem

A digital computer program is needed to filter out high- and low-frequency noise from pressure and flow data of the peripheral blood circulation in dogs. Analog signals representing pressure and flow data are being recorded by FM tape recording. The signals contain low-frequency noise (baseline drift) and high-frequency noise. The investigator is attempting to describe the data by analytical functions, and to demonstrate the direct relationship between flow and pressure, and hydraulic impedance in the peripheral blood circulation. Computer programs are needed to pre-process (filter) the data, apply curve-fitting and interpolation schemes, and plot the functions.

The Potential Solution

The following three digital computer subroutines offer a potential solution to this problem:

"A Subroutine to Determine the Conventional Fourier Spectrum of a Sampled Signal."

"A Subroutine to Generate, Using the Calcomp Plotter, Continuous Plots of 1,2, or 3 Signals, Given Arrays of Discrete Sample Points Taken at Equally Spaced Time Intervals."

"A Subroutine to Label Calcomp Plots Generated by Routine CPLOT."

How Solution Was Found

A computer search of NASA abstracted literature revealed 40 documents of applicable technology. The investigator selected 18 documents from the literature search abstracts for his personal review. One of these documents contained the three subroutines.[4]

Status of Transfer

Listings and punched cards were obtained from the Johns Hopkins University Computer Center, and were sent to Mr. Purdy. Mr. Purdy reported that he sent the plotting routines to the MU engineering computer center to be implemented into their program library. He will attempt to use the Fourier spectrum program to analyze his biomedical data. This work will be completed in September, and he will report on the usefulness of the computer programs at that time.

CATHETER BLOCKAGE DETECTOR

Problem No. MU-29

David M. Kachko, M.D., Assistant Professor of Medicine
University of Missouri Medical Center
Columbia, Missouri

The Problem

The investigator is conducting research on the treatment of diabetes which involves monitoring of blood sugar in diabetic and normal subjects during both rest and exercise. During continuous on-line monitoring of blood glucose, the catheter which draws the blood periodically blocks, interrupting the measurement. Because of the long line between the patient and the monitor, there is a considerable time lag (minutes) between the occurrence of a blockage and an indication at the output recorder. The investigator requires a simple and inexpensive means of detecting a catheter blockage during continuous blood glucose monitoring.

The present monitoring technique uses a manometer to measure pressure. A photocell on the manometer activates an alarm when a vacuum develops on the line. If the blockage is not relieved quickly, the salt-water solution separating the blood from the manometer fluid is drawn into the line and contaminates the sample. The blood sample is drawn at the rate of 10 ml/hr by a roller pump through 0.027 I.D. tubing.

The Potential Solution

The solution to this problem may be the modification of a differential pressure gauge developed at the Marshall Space Flight Center. The pressure gauge uses a strain gauged beam afixed to two pistons and pressure plates suspended by a bellows arrangement. NASA Tech Brief B65-10285 (see Appendix) describes the unit.

How Solution Was Found

The potential solution was found in the technology files of the MRI BA Team.

Status of Transfer

The pressure gauge must be redesigned to adapt it for vacuum pressure measurements and to reduce the size and cost.

MEDICAL DATA STORAGE AND RETRIEVAL SYSTEM

Problem No. MU-35

Dr. Fred Clayton, Missouri Regional Medical Program
University of Missouri

The Problem

As a part of the Missouri Regional Medical Program, the researcher wishes to establish an automated medical data storage, retrieval, and display system for use throughout the State of Missouri. The system would permit a physician in any part of the state to request the display of microfilmed documents, x-rays, diagnostic information, and pharmaceutical data. The investigation is to identify existing systems and their features.

The Potential Solution

A good potential solution to this problem is a system developed for NASA by Lockheed Aircraft Corporation, Palo Alto, California. The system consists of a central computer and mass storage facility; remote terminals having a CRT display, keyboard, and printer; and software permitting interrogation of the storage facility and conversation between the user and the central computer. NASA contractor report CR-1318 describes the system.[5]

How Solution Was Found

Dr. Clayton requested information on the NASA system which he had seen written up in a trade journal. The MRI BA Team contacted Mr. James Richards, NASA Technology Utilization Division, to obtain a full description of the system. Mr. Richards informed the BA Team that the system was being used by NASA personnel in several locations, and suggested that Mr. Dave Bendersky, MRI BA Team director, view the system at the Washington Headquarters. Mr. Bendersky received a demonstration and performed a sample literature search on the system. A description of the system, a contractor's report and user's manual obtained and given to Dr. Clayton.[6]

Status of Transfer

Dr. Clayton is circulating the contractor's report among his colleagues for their evaluation.

EYEBLINK MEASUREMENT

Problem No. UW-2

Professor Leanard E. Ross, Department of Psychology
University of Wisconsin

The Problem

The eyeblink response has been used extensively to study classical conditioning, or learning, in adult subjects. It offers many advantages for work with infants; in particular, the advantage of being a specific response which can be easily elicited by appropriate stimuli and can be studied developmentally with little basic change in procedure.

The usual procedure with adults and older children is to make a mechanical attachment from the subject's eyelid to a microtorque potentiometer, which forms the external arms of a polygraph strain gauge coupler. While this instrumentation gives a satisfactorily linear recording of eyelid movements, the size of the equipment, the necessity of using a headset, and the difficulty of maintaining the proper potentiometer arm-eyelid relationship through a mechanical connection make it very difficult, if not impossible, to use with newborns and other infants. The infant will not remain in a fixed position and movements of the head may produce artifacts and change the calibration of the mechanism for recording response. Further, the subject will not tolerate or will remove pick-up devices that are not secured. The small size of the subject requires that anything attached to him be lightweight; it must also be noninjurious to the skin and able to withstand cleaning with alcohol.

What is needed is a small sensing device which will provide signals that can be converted into a recording of the response form of the eyelid closure. The device must detect movements as small as 1 mm. and follow the lid closure, which covers 0.25-0.5 in. in about 0.05 sec.

The Potential Solution

A photoelectric sensor has been developed for the NASA Marshall Research Center by the Hayes International Corporation, Missile and Space Support Division. The device, designed to sense eye movements, incorporates an infrared (IR) source, consisting of a battery powered lamp and high pass IR filter and or radium selenide IR sensor. The IR source and sensor are mounted relative to one another so that when the eye is looking straight ahead all of the IR radiation from the source is incident on the white of the eye and the radiation on this area is reflected to the sensor. This is the normal or off condition of the device. When the eye is voluntarily turned toward the IR source a high percentage of the radiation is absorbed by the iris, and an external control relay converted to the sensor is actuated.

It is proposed to use the NASA eyeswitch to measure eyeblink. The eyelid will be coated with an infrared absorption material. The infrared sensor will be triggered by an eyeblink due to the difference in absorption of the eye and the coated eyelid.

How Solution Was Found

A manual search of the NASA literature revealed NASA Tech Brief 65-10079, which briefly describes the eyeswitch. Mr. James Wiggins, Technology Utilization officer at the Marshall Space Flight Center and the Hayes International Company provided the MRI BA Team with detailed information on the device. The MRI BA Team suggested the applications of the NASA eyeswitch to eyeblink measurement to the medical investigator, Professor L. E. Ross. Professor Ross agreed that the suggested solution looks promising.

Status of Transfer

Professor Ross has requested a NASA eyeswitch for tests as a means for measuring eyeblink. A request for a quotation to provide one of these eyeswitches has been made to the Hayes International Corporation.

PHYSIOLOGICAL SENSORS FOR BABY INCUBATORS

Problem No. MP-1

Dr. William Andrews, Louisville University Hospital
Donald E. Snowden, Fenwall Company

The Problem

Premature babies and babies born with certain deficiencies are usually placed in incubators to assist them in proper recovery. The critical condition of many of these babies makes it imperative to maintain close watch on the condition of these infants. The shortage of professional personnel makes frequent manual monitoring difficult. Dr. Andrews has approached the Fenwall Comapny concerning the possibility of incorporating sensors in baby incubators so that the baby's physiological parameters such as temperature, respiration rate, etc., could be measured, transmitted and displayed at a central point. It is desired that no sensors be attached to the infants.

The Potential Solution

Under a NASA contract, the Philco-Ford Corporation, Palo Alto, California, developed techniques using unattached sensors for measuring electrocardiograms, respiration, blood pulse, thoracic sounds, galvanic skin response. The purpose of this development was to provide means for monitoring astronauts without the need to attach electrodes. A detailed description of the NASA sponsored development is given in a report entitled "Physiological Monitoring Technique Using Unattached Sensors." M. Fitzwater et al., Philco-Ford Corporation, NASA Contract No. NAS12-121, March 1968. The techniques described in this report appear to be applicable to baby incubators.

How Solution Was Found

James Richards, NASA-TU Division, sent a description of the problem to the MRI BA Team. The MRI BA Team made a manual search of the Team's technical documents file which revealed the Philco-Ford report.

Status of Transfer

The MRI BA Team sent information on the NASA-sponsored Philco-Ford work to Mr. Donald E. Snowden, representative of the Fenwall Company.

B. Active Problems

There were 53 biomedical problems that were active during this report period. The problem number, title, and status of these problems are given in the Appendix.

The status of the active problems are summarized in Table I, showing the number of problems and the percentages in each status category.

TABLE I

SUMMARY OF ACTIVE PROBLEMS

Status Category	Number of Problems	% of Total
A. Definition	5	9.4
B. Search	10	18.9
C. Problem Statement	1	1.8
D. Evaluation	20	37.8
E. Potential Transfer	13	24.5
F. Transfer Follow-up	4	7.6
Total	53	100.0

These data show that a majority of the activity is presently involved in searching the aerospace technology, evaluation of identified technology, and in potential transfers. The definition of new problems is comparatively low due primarily to the reduction in the number of participating medical institutions during the previous contract period. Action now under way to increase the number of participating medical institutions is expected to significantly increase the number of new problems.

Sixteen additional Biomedical Problem Statements were prepared, and 10 computer searches were conducted during this report period. The computer searches were conducted by ARAC. These new Problem Statements and the Computer Search Reports are contained in the monthly progress reports issued during this period.

III. DISCUSSION OF PARTICIPATING MEDICAL INSTITUTIONS AND METHODOLOGY

A. The Role of the Medical Institutions in the BAT Program

The participating medical institutions play a key role in the NASA-BAT Program. The basic functions of the medical institutions are: (1) to provide specific biomedical engineering problems that are hampering the progress of medicine; (2) to evaluate technology that is provided by the BA Team and that which offers potential solutions to the problems; and (3) to disseminate information on successful applications of new technology. The potential market for aerospace technology applied to the solution of biomedical problems includes practicing physicians, hospitals, medical schools, medical clinics, and medical industries. Initially, it was decided to concentrate the BA Team efforts on research-oriented medical institutions, such as medical schools, because of the potential large number of biomedical problems, and the fact that research-oriented people are in a good position to work with and evaluate new technology.

B. Selecting the Medical Institutions

The MRI BA Team experience indicates that there are five basic characteristics of the medical institutions that tend to enhance the chances of successful participation in the NASA BAT Program.

1. The institution should have an active group of medical researchers. The BAT Program depends upon the receipt of appropriate biomedical problems. These problems form the basis for a majority of the activities of the BA Team. To assure a good flow of biomedical problems it is essential that the medical institution have an active medical research staff. The staff should be at the forefront of medical research, where problems are constantly generated.

2. The medical institution must have a need for engineering talent. The BAT Program offers primarily engineering talent. Medical institutions vary with respect to the amount of engineering talent available to their medical research staff. Those institutions where adequate engineering talent is available are less in need of the BAT Program services because the engineering personnel tend to be familiar with the latest technology, including aerospace technology.

3. There must be funds available to pursue ideas submitted by the BA Team. In most cases, funds are required to procure the hardware recommended by the BA Team. Unfortunately, in many instances, funds for the procurement of hardware are not available. Many medical researchers are operating on budgets which do not allow for any significant amount of equipment purchase or development. In most cases, unless funds are available to pursue the procurement of hardware, technology transfers cannot be accomplished.

4. Effective contact with the institution must be readily maintained. One of the prime factors in assuring a successful application of aerospace technology to a medical problem is close personal contact of the BA Team with the medical researcher. This personal contact is required from the initial discussion of the medical problem to the final evaluation of the new technology. Close proximity of the medical institution to the location of the BA Team makes frequent visits easier and keeps travel costs down.

5. The medical institution must be able to furnish a contact man who is willing and able to serve the BAT Program. A good contact man will: (1) acquaint the individual members of the institution staff with the BAT Program; (2) encourage the staff to participate in the program; (3) assist the staff in preparing appropriate problem statements; (4) transmit the problem to the BA Team; (5) set up appointments for the BA Team to discuss the problems with the staff members; and (6) see that the staff furnishes feedback to the BA Team.

The ratings in each of the above categories of eight medical institutions which have been served by the MRI-BA Team are shown in Table II. Institutions B, D, F and H are no longer participating in the BAT Program. At Institution B, the original contact man left the institution and no replacement could be arranged, due to lack of interest on the part of the administration. At Institutions D and F, there are a large amount of in-house engineering talent available, so that they preferred to develop their own solutions to their problems. Furthermore, at Institution D, the investigators were graduate bioengineering students with little time or resources to apply new technology.

TABLE II

RATINGS OF PARTICIPATING MEDICAL INSTITUTIONS

	Medical Institutions							
	A	B	C	D	E	F	G	H
1. Research Staff	F	F	G	G	F	P	G	P
2. Need Engineering	G	F	P	P	G	P	F	G
3. Funds	P	P	F	F	F	F	G	P
4. Effective Contact	G	F	F	F	F	P	G	F
5. Contact Man	G	P	F	G	P	P	G	P

G = Good
F = Fair
P = Poor

C. Optimum Number of Medical Institutions

The number of medical institutions served by the MRI BA Team during the last contract period (June 1968 - June 1969) was purposely kept small to determine whether better results would be obtained by concentrating the effort on fewer schools. The results of the MRI BA Team's activities during the last two contract periods are summarized in Table III. These data indicate that the number of new problems, potentially useful technology identified and actual useful technology are in direct proportion to the number of institutions served.

TABLE III

EFFECT OF NUMBER OF INSTITUTIONS

	Period	
	(May 1967-May 1968)	(June 1968-June 1969)
Number of Institutions	8	4
Number of New Problems	67	34
Total Active Problems	94	70
Potentially Useful Technology Identified	46	30
Actual Useful Technology	21	10

There is a general tendency for the number of problems submitted by a medical institution to come in cycles. Figure 1 shows this cyclic tendency at three of the medical institutions being served by the MRI-BA Team. A sufficient number of participating medical institutions are required to maintain an adequate flow of new problems.

It is evident that it is desirable for the BA Teams to serve as many institutions as possible.

D. New Institutions to be Served by the MRI BA Team

To expand the number of participating medical institutions, the MRI BA Team assembled a list of the accredited medical schools in the middle west. Four medical schools (Creighton University School of Medicine, Omaha, Nebraska; University of Nebraska Medical School, Omaha, Nebraska; Iowa University School of Medicine, Iowa City, Iowa; and Washington University Medical School, St. Louis, Missouri) have been tentatively selected from this list for addition to the medical schools being served by the MRI BA Team. In addition to medical schools, it has been decided to serve one or two major medical clinics, as an experiment. Arrangements are now in progress with the Mayo Clinic, Rochester, Minnesota, and the Menninger Clinic, Topeka, Kansas.

E. Selection of Biomedical Problems

The MRI BA Team found that the chances of attaining successful transfers depends significantly on the proper selection of the biomedical problems. Some of the important factors in the selection of the problems are:

1. The problem should be one that is high on the investigators list of priorities. If the problem is not of importance to the investigator, he usually will not take the time and effort to properly evaluate ideas submitted by the BA Team.

2. The problem should be specific and defineable in engineering terms. Our experience indicates that requests for background information on broad problems are designed to increase the investigator's knowledge. but have little chance of becoming transfers.

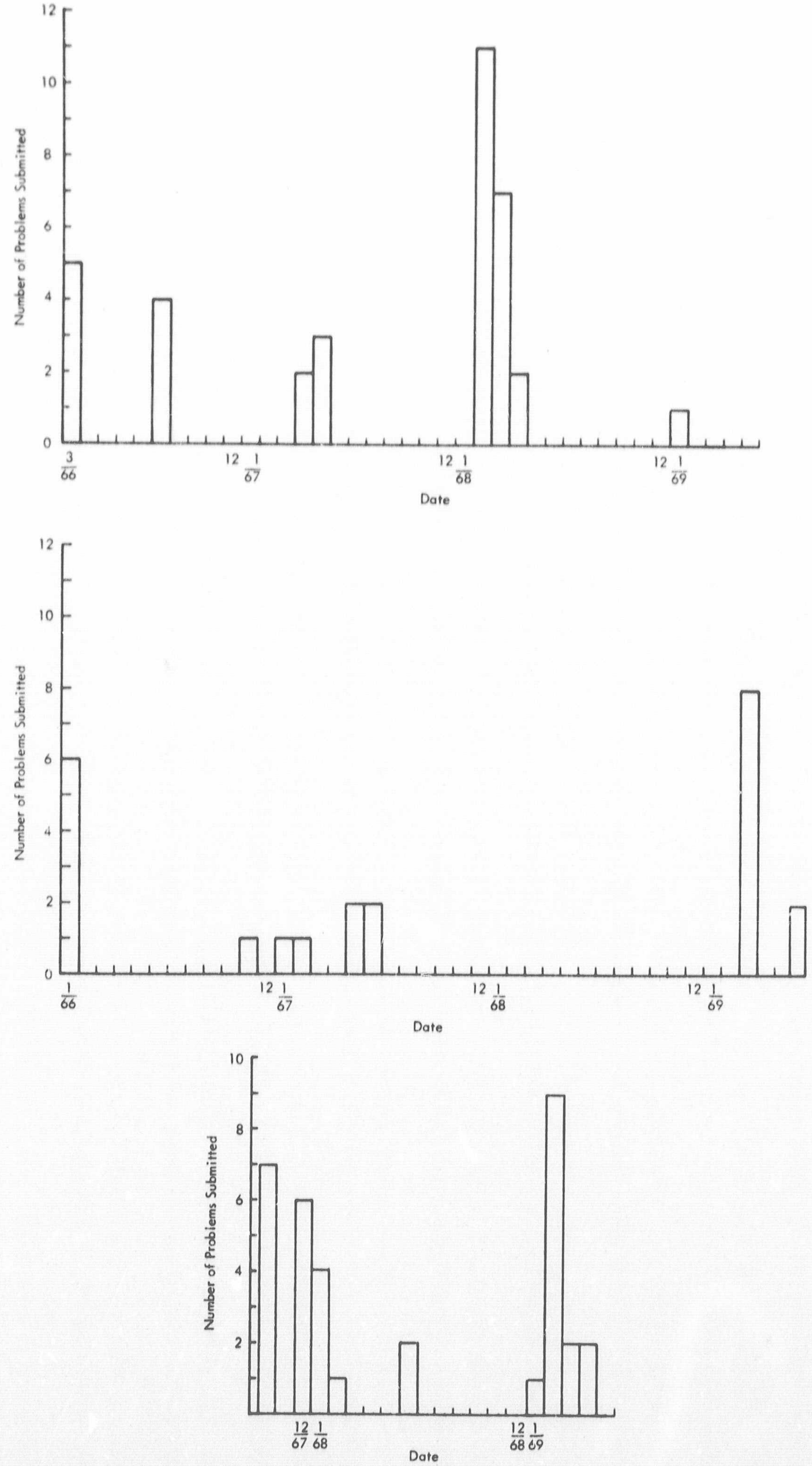

Figure 1 - Problems Submitted by Three Medical Institutions

3. The problem should lend itself to a reasonable probability of formulating a productive literature search. A brief review of the NASA Thesauris, the NASA Subject Authority List, and the Annual STAR subject index will normally allow a BA Team member to make this judgment.

4. Problems in which cost reduction is a significant factor should be avoided. Aerospace technology is not usually characterized by low costs.

5. The problem should not be short-lived. If the investigator must have a solution in a short time (within a few weeks), it is unlikely that an appropriate solution will be located and fully developed in such a short time. Experience indicates that on the average it takes in the order six months for the technology transfer process to be completed. Table IV shows the time it took the MRI BA Team to accomplish individual transfers.

6. Problems should be accepted only from investigators who are willing and able to corporate with the BA Team. Cooperation requires a willingness and ability to talk to the BA Team member about his problem in depth, evaluate literature supplied by the BA Team, utilize applicable technology, and provide adequate feedback to the BA Team. Any deficiencies in these areas creates serious handicaps in the technology transfer process.

F. Sources of Solutions

The MRI BA Team has used six different sources of technology to find solutions to the biomedical problems, which are:

1. Computer searches of the NASA literature tapes;

2. Manual literature searches;

3. Personal knowledge of a BA Team member of existing technology;

4. Suggestions by NASA Research Center personnel;

5. Tours of NASA Research Centers; and

6. Suggestions from other BA Teams.

TABLE IV

TIME TO ACCOMPLISH TECHNOLOGY TRANSFERS

Problem No.	Date Problem Received (month/year)	Transfer Date (month/year)	Elapsed Time (months)
KU-1	1/66	3/66	2
KU-5	1/66	11/66	10
KU-21	6/66	10/66	4
KU-24	1/67	5/68	4
KU-29	11/67	2/68	3
SLU-7	1/66	4/67	16
UW-1	12/66	6/68	18
UW-5	8/67	4/68	8
UW-10	8/67	6/68	10
UW-11	8/67	6/68	10
UW-12	8/67	8/68	12
UM-1	3/66	3/67	12
UM-10	5/67	9/67	4
UM-11	5/67	9/67	4
MU-1	10/67	4/68	6
MU-2	10/67	1/68	3
MU-5	10/67	1/68	3
MU-7	10/67	1/68	3
MU-8	12/67	1/68	2
MU-19	6/68	5/69	11
CI-1	1/67	10/67	9
MU-20	6/68	7/68	1
MU-22	2/69	4/69	2
MU-33	3/69	4/69	1
		Average Elapsed Time	6.6

Table V shows the sources of solutions to the problems solved by the MRI BA Team. These data indicate that the computerized search of the NASA literature tapes is the most fruitful source of solutions to the biomedical problems. However, it is believed that some of the other sources have not been fully exploited. For example, tours of the BA Team members to NASA Research Centers have been very limited in the past. It is believed desirable that more tours of the NASA Centers should be instituted to provide an opportunity for the BA Teams to become more familiar with the current activities at each of the NASA Research Centers.

TABLE V

SOURCES OF SOLUTIONS

Source of Solution	Number of Solutions	Percentage
Computer Searches	14	42.5
Manual Searches	9	27.3
Knowledge of BAT Member	5	15.1
NASA Personnel	3	9.1
Visits to NASA Center	1	3.0
Other BA Teams	1	3.0
Totals	33	100.0

IV. MANAGEMENT ACTIVITIES

1. James Richards, NASA-Technology Utilization Division, Paul Constant, Jr., and David Bendersky, Midwest Research Institute, met with Dr. R. E. Egan, Dean at Omaha, Nebraska, and other members of the staff of the Creighton University School of Medicine, on July 24, 1969. The purpose of the meeting was to discuss the possible participation of Creighton University in the BAT Program. After a presentation of the BAT Program and a discussion, it was agreed that Creighton University will participate in the Program. Dr. I. C. Wells, Chairman of the Department of Biological Chemistry, was assigned to be the BA Team contact.

2. James Richards, Paul Constant, Jr., and David Bendersky met with Dr. Harold Shipton and other members of the Iowa University College of Medicine, at Iowa City, Iowa, on August 4, 1969. The purpose of the meeting was to discuss the possible participation of Iowa University in the BAT Program. It was agreed that Iowa University will participate in the Program. Dr. Shipton, Director of the University's Bioengineering Resource Facility, was assigned to be the BA Team contact.

3. Meetings have been arranged at three additional medical institutions to discuss their possible participation in the MRI BAT Program as follows:

September 3, 1969 - University of Nebraska College of Medicine
Omaha, Nebraska

September 22, 1969 - Mayo Clinic
Rochester, Minnesota

September , 1969 - Washington University School of Medicine
(Day not yet established) St. Louis, Missouri

4. Dr. Charles Kimball, President of MRI, and Dr. Tom Bath, Manager of the MRI Washington Office, visited NASA-Technology Utilization Division on 17-18 June 1969, and discussed the NASA-Technology Utilization Program with Mel Day, Assistant Administrator for Technology Utilization; Ron Philips, Director of the Technology Utilization Division; James Richards, and Roy Bivins. Dr. Kimball suggested that the BA Team services be expanded to include medical clinics, such as the Mayo Clinic, Rochester, Minnesota. Ron Philips indicated that MRI should pursue this idea. Dr. Kimball initiated contact with the Mayo Clinic and the Menninger Clinic.

5. A meeting was held 23 July 1969, at the NASA-Technology Utilization Division, Washington, D. C., to discuss the activities of the MRI BA Team during the previous contract period (1 June 1968 - 3 May 1969). It was decided that an addendum to the Final Report should be prepared concerning the administrative and methodological experience of the MRI BA Team. This report was prepared and a draft was sent to the NASA-Technology Utilization Division for review.

6. Paul Constant, Jr., and David Bendersky attended the NASA-BAT Meeting held at the Lewis Research Center, Cleveland, Ohio, 5-7 August 1969.

V. MISCELLANEOUS ACTIVITIES

1. T. D. Brown, Denver Research Institute, requested information concerning NASA Tech Brief 68-10365, "Automatic Patent Respiration Failure Detection System with Wireless Transmission." The information was prepared and sent to Mr. Brown.

2. Four articles obtained by the MRI BA Team in connection with Problem No. MU-21 (Effect of Body Position on Electrocardiogram) were sent to Dr. F. T. Wooten, RTI BA Team, at his request.

3. Information on Problem KU-8 (Nondestructive Testing of Bone) was gathered and sent to John Johnson, George Washington University, at his request.

4. Information on Problems Nos. KU-5, KU-21, KU-24, KU-29, MU-7, MU-12, UM-1, UM-4, UM-10, UW-12, and UW-20 requested by Dr. Q. Hartwig, George Washington University, was assembled and sent to Dr. Hartwig.

5. An up-to-date list of the active problems and transfers accomplished by the MRI BA Team were requested by and furnished to J. Johnson, GWU.

6. Information on the NASA sight switch was sent to J. Richards, NASA-TUD, for transmittal to the Solvex Sales Corporation, Deptford, New Jersey.

7. Information on the respirometer helmet and the NASA spray-on electrodes was requested by and furnished to H. W. Agnew, University of Florida, Department of Physiology, Gainesville, Florida.

8. A copy of the literature search made for Problem No. MU-1 was sent to Dr. T. Wooten, RTI BA Team, at his request.

9. An inquiry was received from Swenson Research, Inc., Bedford Heights, Ohio, concerning means of sensing respiration in premature infants. Information on the automatic respiration detection system developed at Ames Research Center (Tech Brief 68-10365) and the respiration rate counter developed at the Manned Spacecraft Center (Tech Brief 64-10259) were sent to Swenson Research.

10. Requests for information on the NASA spray-on electrodes were received from Dr. Harold L. Karpman, Beverly Hills, California, and Dr. Bernard Sandler, Kingsbrook Jewish Medical Center, Brooklyn, New York. The requested information was sent.

VI. PLANS FOR FOLLOWING QUARTER

In addition to the routine activities of the Biomedical Application Team as outlined in the Introduction, the team will direct its efforts towards the following specific tasks during the next quarter.

1. Special efforts will be made to obtain the identified aerospace hardware required to convert the potential transfers into actual transfers on Problems Nos. KU-32, KU-35, KU-36, and KU-37.

2. Meetings will be held at the University of Nebraska School of Medicine, Mayo Clinic, and Washington University School of Medicine, to discuss their possible participation in the BAT Program.

3. Two additional MRI staff members will be added to the MRI Biomedical Applications Team. Ralph Fritz will be assigned to serve Creighton University, University of Wisconsin, and Nebraska University. C. Kenneth Doll will be assigned to serve Iowa University and the Mayo Clinic (if they decide to participate in the program).

4. Conferences will be held with the BA Team consultants at Creighton University, Iowa University, University of Kansas and the University of Wisconsin to discuss the solicitation of new problems from the staff at these institutions.

5. Detailed data records on the activities of the MRI BA Team will be assembled and maintained to permit analysis of the team's operations. These data will include such items as: the number and type of problems submitted by the participating medical institutions, time required to obtain and analyze computer searches, time required to identify potential solutions, time required for the investigators to evaluate identified technology, total elapsed time for transfers, handicaps in accomplishing transfers, and characterization of the participating medical institutions. It is anticipated that the analysis of this type of data will be helpful in improving the operation of the NASA BAT Program.

APPENDIX

STATUS OF ACTIVE PROBLEMS

The problem numbers are coded as follows:

MU = University of Missouri Medical Center

KU = University of Kansas Medical Center

UM = University of Minnesota Medical School

UW = University of Wisconsin

CU = Creighton University School of Medicine

MP = Miscellaneous

The status of each problem is given in the following letter code:

A = The problem is being defined.

B = The aerospace literature is being searched in an attempt to find applicable technology.

C = A problem statement is being circulated in an attempt to find applicable technology.

D = Identified technology is being evaluated.

E = A potential solution has been found.

F = Follow-up activity after a solution has been found.

STATUS OF ACTIVE PROBLEMS

Number	Title	Status
MU-23	Telemetry System for pH, Electrical Potentials, Pressure and Chemicals	A
MU-24	Measurement of Embryonic Heart Movement	A
MU-25	Relationship of Magnetic Fields with ECGs	A
MU-27	Telephone Signal System	A
MU-28	Digital Signal Enhancement	F
MU-29	Fluid Pressure Monitor System	E
MU-30	Method to Avoid Catheter Tip Obstructions	B
MU-31	Transducer for Glucose Detection in Blood	C
MU-35	Medical Data Storage and Retrieval	D
KU-31	ECG Electrodes for Use During Surgery	D
KU-32	Monitor for Oxygen Partial Pressure	E
KU-33	Water Partial Pressure in a Gas Anesthetic Mixture	B
KU-34	Thoracic Volume Measurement	B
KU-35	Flowmeter for Respiration Measurement	E
KU-36	Radial Artery Blood Pressure Monitor	E
KU-37	Electrocardiogram Monitor for Surgery	E
KU-38	Simulator for Training in Speech Pathology	B
KU-39	Observation of Inner Ear Blood Circulation	B
KU-40	Volume Measurement of the Inner Ear	B

Number	Title	Status
UW-2	Eyelid Closure Recording	E
UW-5	Apparatus for Learning Research	F
UW-9	Detector for Respiration Cycle	B
UW-10	Temperature Telemetry for Organs	F
UW-11	Temperature Telemetry for Muscles	F
UW-12	Apparatus for Infusion of Fluids into Vessels of Small Animals	F
UW-13	Small Sound Receiver for Ear	B
UW-14	Electric Shock Apparatus	B
UW-15	Small Sound Receiver	B
UW-16	Urination and Defecation Detector	D
UW-22	Attention Measurement Mechanisms	D
UM-2	A Pump for an Artificial Implantable Heart	D
UM-3	A Device to Store Electrical Energy with the Lowest Weight Per Unit of Stored Electrical Energy that is Possible	D
UM-5	Multichannel Telemetry System for Biomedical Applications. The unit should be small and lightweight.	E
UM-8	A Method to Measure Bone Distortion	E
UM-16	Determination of Optimum Response Conditions	D
UM-18	Pressure Measurement Between Teeth	D
UM-19	Transducer for Intercardiac Heart Sounds	E
UM-21	Remotely Controlled Bile Duct Valve	D
UM-23	Chemo-Sensors for Body Functions	D

Number	Title	Status
UM-24	Analysis of Translation Criteria of Digitized Scope Tracers	D
UM-25	Digital Conversion of Scope Traces Into Punch Card Data	D
UM-26	Portable Viewing Box for Visual Perception Tests	D
UM-27	Remote Examination of Patients	D
UM-28	Electrical Sensor for Bacteria Detection	E
UM-29	Rapid Playback ECG Recorder	E
UM-30	Detection and Correction of Disturbed Heart Rythms	D
UM-31	Continuous Measurement of pH, pO_2, and pCO_2	D
UM-32	Air Velocity/Resistance Measurements in Nose	D
UM-33	Pulmonary Function Instrumentation	D
UM-34	Detection of Protein Compounds in Body Fluids	D
UM-35	Cool Suit for Metabolic Studies	E
CU-1	Cryogenic System for Cat's Brains	D
MP-1	Physiological Sensors for Body Incubators	E