MEDICAL APPLICATIONS OF AEROSPACE SCIENCE AND TECHNOLOGY

QUARTERLY REPORT NO. 3
1 November 1967 - 31 January 1968

NASA Contract No. NASr-63(13)

MRI Project No. 3077-E

For

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

MRI

MIDWEST RESEARCH INSTITUTE

425 VOLKER BOULEVARD/KANSAS CITY, MISSOURI 64110/AC 816 LO 1-0202

MEDICAL APPLICATIONS OF AEROSPACE SCIENCE AND TECHNOLOGY

by

David Bendersky

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PREFACE

This report covers the activities of the Midwest Research Institute Biomedical Applications Team during November, December 1967, and January 1968. These activities were supported by NASA Contract No. NASr-63(13).

The work was directed by David Bendersky, under the general supervision of Paul C. Constant, Jr., Manager of Technology Utilization. Other MRI BA Team members who contributed to the reported activities are: Edward T. Fago, Wilbur E. Goll, and James K. West. Consultants and contacts at the participating medical and bioengineering schools are Dr. John W. Trank, University of Kansas Medical Center; Dr. William G. Kubicek, University of Minnesota Medical School; Mathew L. Petrovick, Northwestern University Medical School; Drs. Robert Schwarz and Harry Ludwig, University of Wisconsin Medical Center; Dr. James B. Reswick, Case Western Reserve University, and Blair A. Rowley, University of Missouri Medical Center.

Approved for:

MIDWEST RESEARCH INSTITUTE

Harold L. Stout

Harold L. Stout, Director
Engineering Division

15 February 1968

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I. INTRODUCTION

The objective of this project is to transfer aerospace generated technology to applications in the non-aerospace medical field. In the course of its concern with the well being and functional capabilities of man in aerospace environments, the National Aeronautics and Space Administration has generated an extensive amount of science and technology pertaining directly to the medical field. In addition, the aerospace program has led to the development of technical innovations which may be applicable to the solution of medical equipment problems.

To efficiently transfer applicable science and technology from the aerospace program to the medical field requires the establishment and conduct of an orderly and effective procedure. The procedure developed by the MRI Biomedical Applications Team consists of five basic steps. The first step is the definition of specific medical problems. These problems are obtained from the research staffs at participating medical and bioengineering schools. The second step is the identification of aerospace-generated technology which offers potential solutions to the medical problems. The identification is done through literature searches, circulation of abstracts of the problems to the NASA research centers and to aerospace contractors, and personal contacts. The third step is the modifications which may be required to adapt the original technology to the medical problem. The fourth step is the evaluation of the technology by the medical and bioengineering researchers who submitted the problem. The final step is the dissemination of the information on successful transfers.

Seven medical and bioengineering schools are presently associated with the MRI Biomedical Applications Team project. These schools are the University of Kansas Medical Center, Kansas City, Kansas; St. Louis University School of Medicine, St. Louis, Missouri; the University of Minnesota Medical School, Minneapolis, Minnesota; Northwestern University, Evanston, Illinois; the University of Wisconsin Medical Center, Madison, Wisconsin; Case Western Reserve University, Cleveland, Ohio; and the University of Missouri Medical Center, Columbia, Missouri.

The earlier activities under the present contract are reported in Quarterly Reports Nos. 1 and 2.

II. ACTIVITIES ON BIOMEDICAL PROBLEMS

The following biomedical problems were pursued during this report period.

A. University of Kansas Medical Center Biomedical Problems

Oxygen Consumption Measurement, Problem No. KU-2: The presence of water vapor in exhaled breath causes difficulties in obtaining accurate measurements of oxygen concentration. A potential solution to this problem is an instrument developed for the NASA Manned Spacecraft Center. This instrument determines the oxygen concentration in a gas mixture by measuring the absorption of ultraviolet radiation through a sampling cell at two different wavelengths in order to eliminate the effects of ultraviolet absorption by water vapor. A brief description of the instrument is given in NASA Tech Brief 67-10387, Appendix I.

Additional information on the NASA unit was obtained from John Wheeler, Technology Utilization Officer, NASA Manned Spacecraft Center. The information was given to Dr. R. M. Lauer, University of Kansas Medical Center, the problem originator. Dr. Lauer expressed an interest in evaluating the NASA unit for his problem. An inquiry has been sent to John Wheeler to determine the present status of this item and its availability.

Cardiac Output Measurement, Problem No. KU-24: An impedance cardiograph, developed at the University of Minnesota for NASA, is being evaluated by Dr. R. M. Lauer at the University of Kansas Medical Center. The electrical impedance between two special external electrodes placed around the neck and the chest is used to determine the amount of blood pumped by the heart. The system is being evaluated on children with heart defects. The results obtained with the impedance cardiograph system are being compared with results obtained with the standard Fick method.

Intracranial Pressure Measurement, Problem No. KU-26: Literature on a small commercial (Scientific Advances, Inc., Columbus, Ohio) pressure transducer was furnished to Dr. C. Brackett, University of Kansas Medical Center. These transducers, only 0.55 mm. thick x 6.35 mm. diameter, are coated with silastic rubber to prevent body fluids from contacting the metallic transducers. One of these transducers is being evaluated at the University of Kansas Medical Center.

B. St. Louis University School of Medicine Biomedical Problem

Tremors and Muscle Reflexes, Problem No. SLU-7: The application of the muscle accelerometer to the measurement of tremors and muscle reflexes was continued at the St. Louis University School of Medicine. Sister Agnita Clair reported that "it looks as if these records are going to be quite sensitive in picking up pathology." She cited a case in which abnormal tremors were detected on a girl, three weeks after she had suffered a moderate head injury in a bus accident. A copy of Sister Claire's report is given in Appendix II.

C. University of Minnesota Medical School Biomedical Problems

Bone Distortion Measurement, Problem No. UM-8: Jet Propulsion Laboratory Report No. 32-643, entitled, "On the Construction and Theory of a Miniature Stress Transducer to Measure Radial Stress in Propellant Grains," describes a small transducer which may be applicable to the measurement of bone distortion. A copy of this report was forwarded to Dr. M. Tascon, an orthopedic surgeon at the University of Minnesota Medical School. Dr. Tascon has undertaken a study of bone distortion as a result of previous information on the JPL transducer and other references furnished by the MRI Biomedical Applications Team. A request for one of these JPL stress transducers was sent to Mr. Wallis Tener, Technology Utilization Representative, Jet Propulsion Laboratory.

The paper, "Dynamic Response of Bone and Muscle Tissue," by James H. McElhaney, published in the July 1966 issue of the Journal of Applied Physiology, describes work done at West Virginia University on a study of the mechanical response of bone and muscle tissue to impacts of varying velocities. This work, supported in part by a NASA research grant, may be useful in connection with the University of Minnesota study of bone distortion. A copy of this paper was forwarded to Dr. Tascon. It was reported that the information in this paper is excellent and will be immediately incorporated in the bone research project at the University of Minnesota.

A new dimension has been added to this problem. Dr. Tascon is also interested in measuring bone density *in vivo* for determining bone healing following a fracture. An ultrasonic tool for diagnosing bone integrity, shown in Appendix III, was previously submitted by James B. Beal, NASA Marshall Spacecraft Center. Information on this device was forwarded to Dr. Tascon for evaluation. A copy of "Progress in Development of Methods in Bone Density," NASA publication No. SP-64, was also forwarded to Dr. Tascon for possible interest in connection with this problem.

Rotary Damping Device, Problem No. UM-15: This problem was submitted during this report period by Dr. W. G. Kubicek, University of Minnesota Medical School. There is a need, in the field of physical medicine and rehabilitation, for a small lightweight, bi-directional damping device for controlling the rate of rotation of a joint in certain prosthetic devices. An example is where an individual with a particular neurological disorder cannot control the rate of extension or flexion of his elbow.

A search of the NASA literature did not reveal any applicable technology. An abstract of this problem will be prepared and distributed to the NASA research centers.

D. Northwestern University Medical School Problems

Temporomandibular Joint Action, Problem No. NU-1: A device to measure jaw motion has been developed at the Case Western Reserve University. This device is described in "The Case Gnathic Replicator for the Investigation of Mandibular Movements," by Charles H. Gibbs, Case Institute of Technology, Engineering Design Center, 1966. A copy of this report was forwarded to Dr. R. Cole, Northwestern University Medical School, for evaluation in connection with Problem No. NU-1.

Electroencephalogram Telemetry System, Problem No. NU-3: Dr. H. R. Myklebust, Director of the Institute for Language Disorders, Northwestern University Medical School, is interested in obtaining a NASA EEG telemetry helmet, shown in Appendix IV, for evaluation in connection with a study of child brain dysfunctions. A request for one of these helmets has been sent to the NASA Biotechnology and Human Research Division, Washington, D. C.

Another EEG telemetry system is being developed at the University of California at Los Angeles (UCLA) for the NASA Manned Spacecraft Center. An inquiry into the status of this system indicated that this system is still under development and is not expected to be completed for approximately nine months.

Flexible Tether for Prosthetics and Orthotics, Problem No. NU-5: Dr. D. S. Childress, Head of Prosthetics, Northwestern University Medical School, submitted this problem during this report period. A flexible tether is needed for prosthetics and orthotics which can be made rigid or limp by manipulating a grip lever.

A tether design, which has been developed under partial NASA support, at the Missile and Space Division (GE-MSD), General Electric Company, Valley Forge, Pennsylvania, may be applicable to this problem.

Dr. T. Marton and A. Ruggieri, (GE-MSD), were contacted and arrangements were made to obtain details on these tethers for evaluation in connection with Dr. Childress' problem.

A computerized NASA literature search was conducted. No relevant reports were revealed in this search. (GE-MSD has not issued any reports on their work.)

E. University of Wisconsin Medical Center Problems

Eyeblink Measurement, Problem No. UW-2: Further attempts were made to obtain a NASA eyeswitch (Tech Brief 65-10059) from the Hayes International Company, developers of the device, for evaluation as a means for measuring eyeblink. A letter and several phone calls were made to Mr. R. Allen of the Hayes Company. Mr. Allen has been noncommittal about supplying a unit for this evaluation. James Wiggins, the Technology Utilization Officer, NASA Marshall Space Flight Center, was contacted and he is attempting to provide a test model of the eyeswitch for evaluation on this problem.

Learning Research Apparatus, Problem No. UW-5: A NASA literature search on learning machines was conducted. Although several related references were found in the search, no apparatus was found which would meet the requirements specified by Dr. R. Heber, University of Wisconsin. A proposal is being prepared to undertake the development of the required apparatus.

Temperature Telemetry System for Monkeys, Problems Nos. UW-10 and UW-11: Dr. R. K. Meyer, Department of Zoology, University of Wisconsin, requires telemetry equipment for determining temperatures of internal organs and muscles in experimental monkeys. A NASA literature search was conducted, which revealed work done at the NASA Ames Research Center on a small temperature telemetry system, which is described in Appendix V. This equipment has been recently commercialized by the Electro-Optical Company, Pasadena, California. Information on this NASA temperature telemetry system was forwarded to Dr. Meyer for his consideration. Dr. Meyer has ordered two of these units from the Electro-Optical Company for use in the monkey applications.

Infusion of Fluids into Animals, Problem No. UW-12: A comparatively sophisticated apparatus for infusing various fluids into the blood vessels of experimental animals is needed by Dr. R. K. Meyer, Department of Zoology, University of Wisconsin. The apparatus must automatically infuse up to four different fluids over a wide range of variable rates and automatically record the infusion history. A search of the NASA literature revealed an automatic microsyringe for metering small fluid volumes, developed at the Jet Propulsion Laboratory, which is briefly described in Tech Brief 67-10203, Appendix VI. However, this device does not provide variable rates and does not provide a record of the injection history. A proposal to develop the required apparatus is being prepared by MRI for Dr. Meyer.

Rotary Joints for Small Cannulas, Problem No. UW-17: A search of NASA literature did not reveal any reports related to small rotary joints. However, literature on a commercial (Lehigh Valley Electronics, Fogelsville, Pennsylvania) cannula feedthrough swivel was obtained and sent to Mr. Honeycutt, University of Wisconsin Medical Center, for evaluation.

Remote Manipulation of Brain Electrodes, Problem No. UW-18: A search of NASA literature revealed a report, "New Methodological Directions in Electrophysiology," by R. M. Mescherskiy, NASA No. N66-2690, which describes a system for remote control of microelectrodes which appears to be applicable to Problem UW-18. A copy of this report was sent to Dr. C. N. Woolsey, University of Wisconsin Medical Center, for evaluation.

Enzyme Electrode Amplifier and Telemetry System, Problem No. UW-20: This is a new problem, submitted by Dr. S. J. Updike, Department of Medicine, University of Wisconsin Medical School. Dr. Updike needs a miniature animal implantable, high impedance, DC amplifier and a radio transmitter, for use with a special enzyme electrode developed by Dr. Updike. This system is to be used to measure tissue oxygen and glucose concentration.

A review of previously accumulated references on telemetry systems revealed two items which appear to be applicable to Dr. Updike's problem. A high impedance amplifier is described in, "A Progress Report on Radio Telemetry from Inside the Body," by R. S. Mackey, Space Sciences Laboratory, University of California. This work was aided by a NASA grant. A subminiature telemetry unit, developed at the NASA Ames Research Center, is described in Tech Brief 64-10171, Appendix VII. A combination of the Mackey amplifier and the Ames telemetry system looks like it should meet the requirements of the enzyme electrode. This information was sent to Dr. Updike for evaluation.

F. University of Missouri Medical Center Problems

Effects of Magnetic and Electric Field and Currents on Living Cells, Problem No. MU-1; Automatic Recording of Heart Sounds, Problem No. MU-2; Hemodynamic Impedance of the Vascular System, Problem No. MU-3;

Automatic Blood Pressure Measurement, Problem No. MU-4; Damping in Cardiac Catheters, Problem No. MU-5; Charges on Formed Elements of Blood, Problem No. MU-6; Differential Blood Pressure Measurements, Problem No. MU-7: NASA literature searches were conducted on Problems Nos. MU-1 through MU-7. These literature searches were reviewed by the MRI Biomedical Applications Team and pertinent reports were ordered for evaluation. The complete literature searches were sent to the problem originators at the University of Missouri for their review.

A blood pressure measuring system, described in Tech Brief 65-10365, Appendix VIII, may be applicable to Problem No. MU-4. The medical investigator, H. H. Purdy, Missouri Regional Medical Program, is interested in applying this technique to mass health screening. Construction details were requested by and sent to Mr. Purdy.

X-Ray Enhancement, Problem No. MU-8: Dr. Peter L. Reichertz, Director of Radiology Computer Research, University of Missouri Medical Center, is engaged in an investigation of equipment and computer programs to eliminate noise, correct distortions and enhance contrast in image processing. The ultimate goal of the program is to provide enhanced radiographs and computer processing of radiographs for diagnosis. A statement of the problem, as received, is given in Appendix X.

Copies of Tech Brief 67-10005, Appendix IX, and Jet Propulsion Laboratory Report No. 32-1028, "Digital Computer Processing of X-Ray Photographs," by R. H. Selzer, were sent to Dr. Reichertz for consideration. Arrangements were made for Dr. Reichertz and James West of the MRI BA Team to visit the Jet Propulsion Laboratory on February 1, to obtain further information on the JPL X-ray enhancement technique. Consideration is being given to setting up the JPL X-ray enhancement system at the University of Missouri Medical Center.

Electrocardiogram Electrodes, Problem No. MU-9: Dr. Reichertz is also interested in obtaining electrodes which can be used to collect electrocardiograms in hospital coronary care units, which are connected to a central computer network. The electrodes must be small, have constant impedance over long periods, must not be effected by movement of the patient, and must not cause decubities even when attached to the back of a motionless lying patient for long periods. A statement of the problem, as received, is given in Appendix X.

Information on the NASA spray electrodes was furnished to Dr. Reichertz for evaluation.

Indirect Monitoring of Animal Blood Pressure, Problem No. MU-10: This problem was submitted by personnel at the Department of Veterinary Medicine, University of Missouri. It is desired to monitor the blood pressure of animals without cannulations. A statement of the problem, as received, is given in Appendix X. This problem is similar to Problems Nos. MU-4 and KU-5. Information collected on Problmes MU-4 and KU-5 is being evaluated for this application.

Tracking of Large Animals, Problem No. MU-11: This problem was submitted by personnel at the Reactor Facility, University of Missouri. A method is desired to track or locate large animals by radio signals. A statement of the problem, as received, is given in Appendix X.

Cardiac Output Measurement, Problem No. MU-12: A method is needed to determine cardiac output in critically ill patients by peripheral measurements without catheterization. A statement of the problem, as received, is given in Appendix X. This problem is the same as Problem No. KU-24.

Information on the impedance cardiograph, system developed at the University of Minnesota for NASA and now being evaluated at the University of Kansas Medical Center for Problem No. KU-24, was sent to the medical investigator at the University of Missouri Medical Center. Blair Rowley, University of Missouri, and James West, visited the University of Kansas Medical Center on January 24 to obtain further information on the impedance cardiograph.

Pulmonary and Metabolic Monitoring Instrumentation, Problem No. MU-13: Medical investigators at the University of Missouri Medical Center have requested a survey of techniques for the measurement of pulmonary functions and metabolic rates under adverse environmental conditions. A statement of the problem, as received, is given in Appendix X. A computerized NASA literature search was conducted and the results are now being evaluated.

Storing of ECG Tracing Waveforms, Problem No. MU-14: A technique for condensing analog ECG waveforms to a limited number of digital parameters is required. A statement of the problem, as received, is given in Appendix X.

Two computer programs for processing bulk ECG data were developed at the NASA Flight Research Center (FRC). A request for information on these computer programs was sent to Clinton Johnson, TU Officer at FRC.

III. MISCELLANEOUS ACTIVITIES

A. Inquiries on Accomplished Transfers

Inquiries concerning the NASA spray electrodes were received from the Ames Research Center, Moffett Field, California; Karalinska Hospital, Stockholm, Sweden; State University, Utrecht, Netherlands; Karl Marx University, Leipsig, East Germany; Pegasus International Corporation, New York, New York; and Dr. J. H. Issacs, Beverly Hills, California.

Inquiries concerning the respirometer helmet were received from Childrens Research Center, University of Illinois, Champaign, Illinois; Hankscraft Company, Reedsburg, Wisconsin; Ames Research Center, Moffett Field, California; and Dr. J. H. Issacs, Beverly Hills, California. Dr. R. E. Herron, Childrens Research Center, University of Illinois, informed us that he plans to fabricate and use one of these respirometer helmets.

Inquiries concerning the muscle accelerometer were received from the Spring Grove Hospital, Baltimore, Maryland; and the Raytheon Company, Sudbury, Massachusetts. At the Spring Grove Hospital, they are interested in the possible application of the muscle accelerometer for early detection of tremors as a complication of psychotropic drug administration.

The requested information was sent to each inquirer. The replies to foreign countries were sent to NASA-TU Headquarters for transmittal.

B. Reports

Monthly letter progress reports covering the activities of the MRI Biomedical Applications Team during November and December 1967 were prepared and distributed.

Separate NASA Technology Transfer reports were prepared on nine actual and potential NASA technology transfers which have been accomplished by the MRI Biomedical Applications Team. These transfers include the electrocardiogram electrodes, muscle accelerometer, respirometer helmet, impedance cardiograph, electroencephalogram helmet, sterile operating rooms, bone elasticity measurement, eyelid closure measurement, and a system for delivering medication to the respiratory tract. These reports, given in Appendix XI, were sent to Dr. Q. Hartwig, NASA-TU Consultant.

C. Project Trips

On 28 November 1967, David Bendersky met with Dr. William G. Kubicek and Marshall W. Keith at the University of Minnesota, Minneapolis, Minnesota. Arrangements were made for Mr. Keith to acquaint the entire University medical research staff with the MRI Biomedical Applications Team activity and to encourage their participation in the program.

On 30 November 1967, David Bendersky visited the University of Wisconsin Medical School, Madison, Wisconsin, and met with the various medical investigators who have submitted problems and discussed the status of the problems. A discussion was held with Dr. Robert Schwarz concerning the SRS suggestion for appointing a technology utilization communicator. Dr. Schwarz indicated that they have initiated a request for such a person to be added to their staff.

On 30 November 1967, David Bendersky met with Dr. James Reswick and Mrs. June McCauley at Case Western Reserve University, Cleveland, Ohio. Mrs. McCauley will continue to act in the capacity of the contact person at the University for the BA Team activity.

David Bendersky attended the Biomedical Applications Team Conference held at Research Triangle Institute, Durham, North Carolina, on 30 October and 1 November 1967.

Dr. John Trank and James West attended the conference on Engineering in Medicine and Biology, Boston, Massachusetts, 13-16 November 1967.

On December 21, 1967, James West visited the University of Missouri Medical Center, Columbia, Missouri. Discussions were held with Blair Rowley and several medical investigators.

D. Literature Searches

Literature search strategies on 22 searches recently conducted by the MRI Biomedical Applications Team were sent to the directors of the RTI and the SwRI Biomedical Applications Teams for their information and file. The results of ten of these literature searches were requested by and sent to Dr. James Brown, director of the RTI Biomedical Applications Team.

E. Non-NASA Transfers

Dr. F. R. Kirchner, University of Kansas Medical Center, reported that a commercial sand blaster, suggested by Wilbur Goll of the MRI BA Team, has been successfully used in a study of ear specimens. A thesis on this work is being prepared by Dr. Kirchner for publication.

Information on a commercial device for mounting books for microfilming was furnished to Mr. M. Spangler, University of Missouri Regional Medical Program.

F. International Association of Chiefs of Police Problem

On January 30, 1968, Dr. Q. Hartwig instructed the MRI BA Team to undertake a problem for the International Association of Chiefs of Police, Washington, D. C. The problem is to provide lightweight clothing for policemen which will be comfortable during winter in northern U. S. cities. A search of NASA literature will initially be made in an attempt to solve this problem through the application of aerospace technology.

APPENDIX I

TECH BRIEF 67-10387

NASA TECH BRIEF

NASA Tech Briefs are issued to summarize specific innovations derived from the U.S. space program, to encourage their commercial application. Copies are available to the public at 15 cents each from the Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia 22151.

Lamp Enables Measurement of Oxygen Concentration in Presence of Water Vapor

The problem:

To design an ultraviolet source lamp that will radiate sufficient energy at 1800 angstroms and 1470 angstroms for use in a double-beam, dual-wavelength oxygen sensor. This instrument determines the oxygen concentration in a gas mixture by measuring the absorption of ultraviolet radiation through the gas sampling cell at the two different wavelengths in order to eliminate the effects of ultraviolet absorption by water vapor. The source lamp was required to have the characteristics of small size, low input power, low-temperature operation, inherent ruggedness, and long life.

The solution:

An open-electrode lamp filled with xenon at a pressure of 100 mm of Hg. At this pressure, the lamp gives optimum output at 1800 angstroms and a sharp peak at 1470 angstroms. This sharp peak is useful in aligning the slits of the optical system.

Note:

Inquiries concerning this development may be directed to:

Technology Utilization Officer
Manned Spacecraft Center
Houston, Texas 77058
Reference: B67-10387

Patent status:

Inquiries about obtaining rights for the commercial use of this invention may be made to NASA, Code GP, Washington, D.C. 20546.

Source: F. J. Brisco, J. E. Moorhead,
and W. S. Paige
of the Perkin-Elmer Corporation
under contract to
Manned Spacecraft Center
(MSC-10043)

Category 01

APPENDIX II

LETTER REPORT ON MUSCLE ACCELEROMETER
FROM SISTER AGNITA CLAIRE

C
O
P
Y

December 22, 1967

Dear Dave:

This time I am combining the season's greetings with business! May your Christmas be a happy one and may the New Year bring you many joys!

Now for the business - I have received your two requests to forward information about the use of the accelerometers. Miss Katz also wrote to me direct, since Dr. Hartwig apparently gave her my name also at the time he gave her yours. I got a letter out to her yesterday enclosing a couple of sample recordings.

It seems to me that the accelerometers would be an excellent tool for the project they have in mind, and I believe that the techniques I use would fit their project also. I described my setup with the Twin Viso Recorder in my letter with the specific technique I have been using. I told her, too, that almost any other kind of D.C. recorder could give her the same results, if the attenuation is adequate.

I have been running tremor recordings on the graduate students in my physiology class with some interesting results. I am hoping, in this way, to get a collection of "normals" that I can compare with my own "supposed" normal pet! I'm also doing my best to get them interested in research.

It looks as if these records are going to be quite sensitive in picking up pathology. One of our younger students suffered a moderate concussion over the Thanksgiving week-end. She was riding in a bus when a sudden swerve caused a suitcase full of books (not even <u>her</u> books) to fall off the rack above her seat on top of her head! The blow was hard enough that she was really mentally confused when she reached St. Louis, and said that about an hour later she found herself wandering around on the levee down at the riverfront! Of course, she was frightened and I don't blame her for apparently no one had made any effort to help her after they reached St. Louis. She said she finally became clear enough in her thinking to get out to St. Mary's and the emergency room. She was in bed about 10 days altogether. On the 15th (3 weeks from the accident) I was running some records and she came in to watch. Since she was interesting and willing I ran a set on her which definitely showed a residual even after the 3 weeks. Tremor amplitudes were higher than normal - and she showed some very definitely hyperactive labyrinthine reflexes - even after 3 weeks. I'm going to try to catch her again after the holidays and recheck her.

When we utilize the standard set of head positions it is not difficult to pick up abnormal reactions. I am very pleased with this fact, since it substantiates my other findings $\bar{c}$ the cyclic movement.

Must bring this to a close. The offices are closed now until after Christmas and I am playing "chauffeur" for our convent family today. I had to interrupt this once to make a trip and have another one coming up in about 15 minutes. It's a good thing I decided to get my driver's license or there wouldn't be anyone to run errands today! Will keep you posted on the correspondence. I still have to write to the ones at Raytheon but will try to get it done in the next day or two. Will send you a copy of what I write.

Greetings to you and to your family.

Sincerely,

Sister M. Agnita Claire
St. Louis University

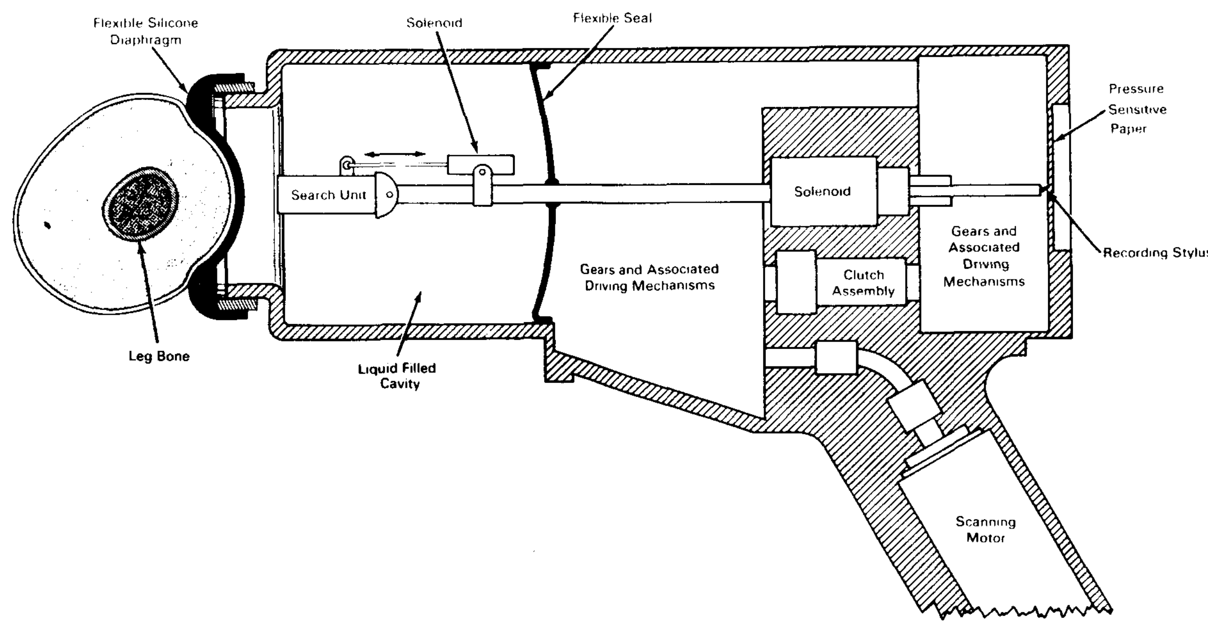
APPENDIX III

IDEA FOR NON-DESTRUCTIVE TESTING OF BONE

December 1967 Brief 67-10486

NASA TECH BRIEF

Ultrasonic Hand Tool Allows Convenient Diagnostic Scanning of Bone Integrity



The problem:

To devise a hand tool for the rapid and mechanical scanning of bone integrity and determination of density without the need for surgery or X-rays. Current ultrasonic techniques do not allow convenient scanning of areas that are not readily accessible to bulky equipment.

The solution:

A small, portable, electrically powered ultrasonic hand tool which, coupled with auxiliary ultrasonic equipment, can be used for scanning small areas and fracture sites conveniently. This Tech Brief is a modification of NASA Tech Brief 66-10289, "Ultrasonic Hand Tool Allows Convenient Scanning of Spot Welds." It should be noted that due to the pulse echo ultrasonic technique used (reflection from the bone surface), the use of this equipment is limited generally to bone surfaces not hidden behind other bones, i.e., arm, leg, skull.

How it's done:

The hand-held tool consists of an ultrasonic search unit that carries a housing assembly accommodating a solenoid. The solenoid plunger is fitted with an extension and a recording stylus which records upon the pressure sensitive paper located in the cavity at the rear of the unit. In operation, the front end of the scanner is fitted with the proper body-fitting silicone rubber diaphragm, a couplant of water or grease is applied, and the scanner is placed on the area to be

(continued overleaf)

examined. The spiral scanning motion of the ultrasonic search unit is recorded as a spiral pattern on the pressure sensitive paper. Discontinuities appear as breaks in the spiral pattern.

The scanning motor causes the mechanism to rotate about the centerline of the main cylindrical body. While rotating, the clutch assembly causes an outward translation in a radial direction, thus producing a spiral motion. The search unit is rotated a short distance back and forth by a solenoid as shown. This produces a curvilinear motion of the ultrasonic search unit, which enables the beam to hit the bone perpendicular to the bone surface, and thus reflect the maximum amount of signal and record the maximum area of the curved bone surface. This type of search unit motion is called "compound motion."

The best interrogation frequency for inspection of bone integrity is between 500 kHz and 1 MHz. To determine bone density, lower frequencies may be required.

Notes:

1. A variety of flexible silicone diaphragms will be required to form fit the hand tool to various portions of the body. It may prove more practical and time saving to have the equipment on a multiposition adjustable stand during the scanning operation with the patient's body member strapped rigidly in place.
2. Inquiries concerning this invention may be directed to:

   Technology Utilization Officer
   Marshall Space Flight Center
   Huntsville, Alabama 35812
   Reference: B67-10486

Patent status:

Inquiries about obtaining rights for the commercial use of this invention may be made to NASA, Code GP, Washington, D.C. 20546.

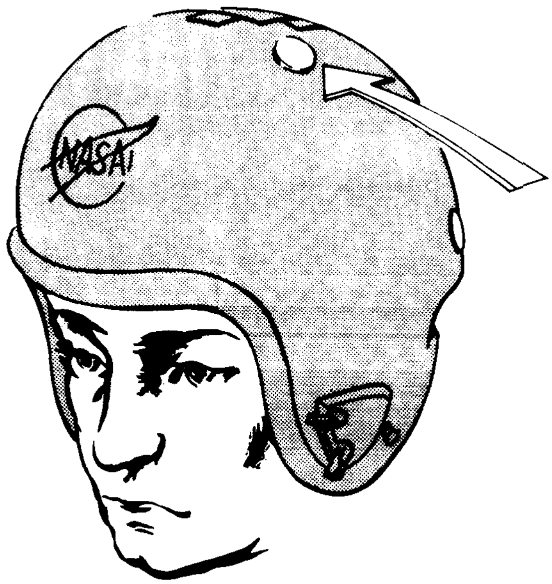
Source: James B. Beal
(MFS-14102)

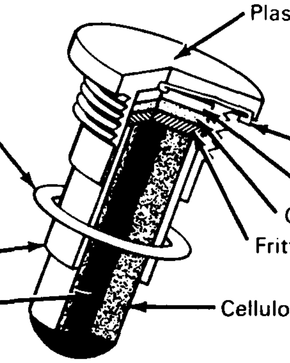
APPENDIX IV

NASA EEG TELEMETRY HELMET

NASA TECH BRIEF

Helmet System Broadcasts Electroencephalograms of Wearer





The problem:

To develop an improved system for obtaining electroencephalograms (EEG's) of pilots and astronauts performing tasks under stress. In the past, electrodes were cemented to the scalp and were uncomfortable, irritated the scalp, and took as long as an hour to attach. Furthermore, the wires to the readout equipment restricted the subject's motions.

The solution:

An EEG monitoring system consisting of non-irritating sponge-type electrodes, amplifiers, and a battery-powered wireless transmitter, all mounted in the subject's helmet. No preparation of the scalp is required. After a quick initial fitting, the helmet can be removed and replaced without further adjustment. There are no external wires.

How it's done:

A flight helmet is modified to contain the EEG electrodes and the electronic components. The elements of the system fit conveniently in the helmet and do not impair its usefulness as a protective device.

The key element in this system is the EEG electrode, which consists of a flexible portion that rests against the scalp and a rigid portion that fits securely in the helmet and is connected to the amplifier. The flexible portion consists of a hollow-core cellulose acetate sponge impregnated with an electrode paste. The rigid portion consists of the following: a disk of fritted glass wetted with a saline solution; a disk of compressed silver powder; a disk of Ag–AgCl; and a solid silver contact which connects with the amplifier.

Fitted to the subject, the sponge portion containing the electrode paste contacts the scalp with a light

(continued overleaf)

steady pressure. This member can accommodate a certain amount of relative motion between the scalp and the helmet without altering the electrical properties of the connection or distorting the signal.

The remaining elements of the system are a pair of miniature biomedical amplifiers, a pair of commercially available FM subcarrier oscillators, a miniature PM transmitter operating at 108 MHz, and standard miniature mercury cells that provide 90 hours of continuous operation.

Notes:

1. The helmet shell comes in three basic sizes, and by selection of liner size and length of replaceable sponge, the helmet can be adapted to any subject. Initial fitting requires only about five minutes.
2. Experiments with a variety of subjects (some with thick hair, with and without hairoil, and some bald) have been made in the laboratory, in flights of a T-33 airplane, and in centrifuge runs. The data obtained have been consistent with EEG records obtained with carefully applied metallic electrodes.
3. A related innovation is described in NASA Tech Brief B65-10203, July 1965.
4. Inquiries may also be directed to:

   Technology Utilization Officer
   Ames Research Center
   Moffett Field, California 94035
   Reference: B66-10536

Patent status:

Inquiries about obtaining rights for the commercial use of this invention may be made to NASA, Code GP, Washington, D.C. 20546.

Source: Richard M. Westbrook and
Joseph J. Zuccaro
(ARC-70)

APPENDIX V

TEMPERATURE TELEMETRY SYSTEM

-- Journal of Applied Physiology, Jan. 1966

Miniature long-life temperature telemetry system

THOMAS B. FRYER, GORDON J. DEBOO,
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Instrumentation Division, Environmental Biology Division, National Aeronautics and Space Administration, Ames Research Center, Moffett Field, California

FRYER, THOMAS B., GORDON J. DEBOO, AND CHARLES M. WINGET. *Miniature long-life temperature telemetry system*. J. Appl. Physiol. 21(1): 295–298. 1966.—A miniature telemetry system including transmitter and sensor suitable for implanting in small animals to measure their deep body temperature has been designed. A compensating bridge circuit is used to achieve a stable and accurate measurement system. The high performance, coupled with the small size and long battery life, makes the device valuable for long-term observation of an animal's temperature rhythms. The device has a self-contained miniature battery that provides approximately 3,600 hr operation.

radio telemetry; temperature measurement; implanted telemetry; long-term telemetry; small-animal telemetry; deep body temperature; high-performance animal telemetry

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AN IMPORTANT CONSIDERATION in the design of a temperature telemetry device is its ability to measure temperature changes accurately and reliably over extended periods. The approach most commonly taken has been to build a simple circuit with a large temperature coefficient and then to calibrate the temperature effect (2). Temperature-sensitive capacitors, thermistors, or transistors are the elements usually used as transducers. Unfortunately, factors other than temperature also affect the performance, causing inaccurate results. Body capacitance and sensitivity to changes in battery voltage, for example, are two factors that can cause serious difficulty in a simple circuit that would otherwise be desirable from the standpoint of small size and reliability (3, 4).

The approach here was to design a somewhat more complex temperature-measuring circuit with a thermistor bridge and subcarrier system so that stable and accurate measurements of temperature may be achieved over extended periods. Small size is achieved by a circuit design which requires only microminiature components. The components are then assembled compactly. Figure 1*A* shows the complete sensor, transmitter, and power supply, and Fig. 1*B* shows a moisture-sealed unit ready for implanting. The moisture seal consists of a heat-sealed polyethylene container surrounding the circuitry, which is plotted in 85 C wax. The polyethylene case has a lip on the edge for sewing in place. The unit encapsuled for implanting is 0.73 inch in diameter by 0.2 inch thick and weighs 3.5 g. Results to date indicate that absolute temperature readings accurate to ±0.05 C can be made over extended periods.

SYSTEM DESIGN

Telemeter unit. The complete circuit diagram of the telemeter unit, including sensor, subcarrier oscillator, and transmitter, is shown in Fig. 2. The system uses a thermistor to sense the temperature to be measured, and the resistance change in the thermistor varies the pulse duration of a subcarrier oscillator. The oscillator is an astable multivibrator utilizing two transistors, Q_2 and Q_3. Figure 3 shows the significant multivibrator waveforms. The period T_2 is determined by the time constant R_3C_2 which is modulated by the temperature of thermistor R_3, while T_1 is a constant and determined by a precision resistor, R_4, and capacitor C_3. Each time the multivibrator switches, a pulse is coupled to the rf stage by Q_1 and Q_4.

Transistor Q_5 and its associated components form an rf oscillator that is tuned in the range of 88–108 Mc so that an inexpensive commercial FM tuner can be used as a receiver. Transistor Q_5 is pulsed on periodically by Q_1 and Q_4 in order to reduce power consumption and provide long life with a miniature battery. The 2N709 transistor used for Q_5 required a minimum collector current of 0.5 ma in order to oscillate reliably. Values gave typical collector currents of 0.5–2 ma.

The average current in the transmitter stage is reduced to 5 μa or less by the favorable duty cycle of approximately 20-μsec pulses spaced on the average 10 msec apart. The current could be further reduced by decreasing the multivibrator frequency, but physically larger capacitors would be required. Such considerations dictated the final circuit design and component selection. A different importance placed on any factors such as physical size, operating life, or reliability would have resulted in the possible use of other component values. The component selection was limited in this case to those available in miniature size having high reliability and suitable to minimize battery drain. The use of transistors with a very high beta at low collector currents makes reliable operation possible at collector currents of only 3 μa. Suitable resistors in small physical sizes were available for operation at this current level. The entire circuit as shown in Fig. 2 requires an average current of only 8–10 μa. This gives an operating life of at least 3,600 hr with the small 36-ma-hr battery used. The use of only a slightly larger battery should give approximately 15,000 hr of operation.

No provision is made in the circuit to distinguish between the pulse from Q_1 versus that from Q_4, so for identification it is necessary to maintain T_2 greater than T_1, or vice versa, at all times. The 6-megohm (25 C) thermistor and the 2-megohm resistor R_4 met this condition, T_2 becoming equal to T_1 at somewhat above 45 C, the maximum anticipated operating temperature. Table 1 shows a calibration of a typical thermistor. The percent change per °C is approximately 4%, and therefore a system accuracy of ±0.2% is required to maintain a ±0.05 C reading accuracy. Thermistors that are preaged and guaranteed by the manufacturer to ±0.1% for 1 year are available. Test results shown later indicate that the system will maintain this accuracy. An operating temperature range between 35 and 45 C was selected as adequate for all anticipated applications. The system, of course, is suitable for use

Received for publication 23 November 1964.

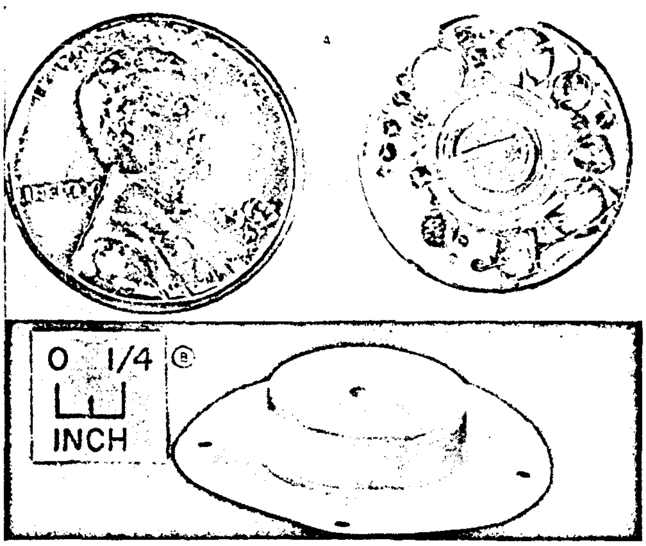


FIG. 1. Photographs of transmitter. *A*: temperature telemetry transmitter, *B*: transmitter sealed in a plastic container ready for implanting.

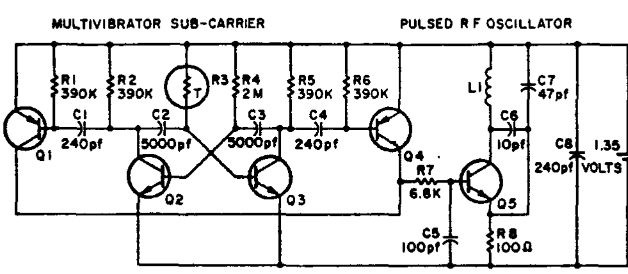


FIG. 2. Circuit diagram of the transmitter. R_3: thermistor to measure temperature (may be remotely located) 6 megohm at 25 C. All resistors in ohms, K = $\times 10^3$, M = $\times 10^6$. All capacitors in picofarads. Transistors: Q_1 and Q_4 FSP202 (2N1132 in a To51 case), Q_2 and Q_3 FSP8488 (2N2484 in a To51 case), and Q_5 FSP239-1 (2N709 in a To51 case). L_1: three turns no. 28 wire approximately 0.7 inch diameter.

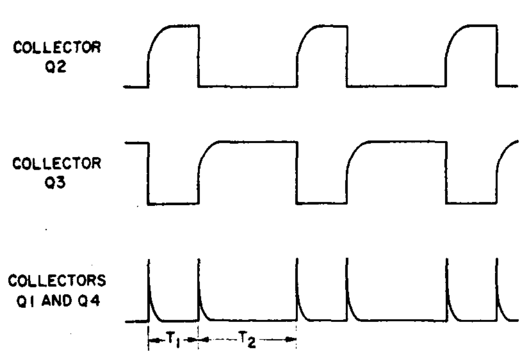


FIG. 3. Modulation waveforms.

in any other reasonable temperature range desired, limited only by thermistor selection.

Radio frequency operation. The inductor L_1 in Fig. 2 is used as the rf oscillator tank circuit and as the antenna for the transmitter. It is a three-turn coil approximately 0.7 inch in diameter. The receiving antenna is a three- or four-turn coil, 24 inches in diameter. The close relation between the two coils

TABLE 1. *Thermistor calibration*

Temp, °C	R_t, megohm	Temp, °C	R_t, megohm
35	4.12	41	2.99
36	3.90	42	2.84
37	3.69	43	2.70
38	3.50	44	2.57
39	3.32	45	2.45
40	3.14		

compared to a wavelength near 100 Mc means that the coupling is more like that of an air coil transformer than true rf transmission (1). A useful range up to 8 or 10 ft is possible, but there are many nulls depending upon location and orientation. An antenna other than L_1 could increase the useful range, but the device is primarily intended to be used with a cage of 4 or 5 ft^3 or less, and for this purpose L_1 is very satisfactory. Different receiving antenna shapes were tried, but the number of turns or the shape of the antenna did not significantly alter the signal strength.

The receiver used was a commercial FM tuner intended for the consumer Hi-Fi market. Any receiver that has a detection sensitivity of a few microvolts can be used. Communication-type receivers have also been used with insignificant differences in the reception. Since the amplitude of the signal is modulated rather than the frequency, it is necessary to detect the signal at the end of the last IF stage. The rectified IF signal gave a pulse amplitude of 5–30 v. A diode and cathode follower stage was used to provide low output impedance and the high-frequency response required for the microsecond-length pulses.

The demodulator is designed to handle pulses as low as 0.5 v so the 20-v signal can be greatly attenuated before the signal is lost. Under actual operating conditions, though, there are noise pulses that limit the ability to operate at this threshold level. A threshold level of 1.5–3 v eliminates most noise if strong FM stations are avoided. Radio-frequency interference noise from electrical equipment can also cause trouble, and proper shielding is the only correction for this. A nonmetallic animal cage with an antenna wrapped around it, which in turn is placed in a copper screen cage, is used for eliminating radio interference noise. The screen box should be at least 3 inches larger on all sides than the receiving antenna to avoid seriously reducing the signal strength.

Moving the transmitter to various locations in an 18 x 18 x 18 inch cage with a four-turn receiving antenna gave a signal range of 5–20 v. A particular orientation and position may give a more serious null, but such positions are so small in extent that they are difficult to locate. Holding the transmitter in the hand improves the signal, apparently because of capacitance coupling. This effect may help reduce the possibilities of nulls, but of course it is difficult to assess completely. Results to date have indicated no signal strength problem with transmitters implanted in chickens.

Demodulator. The telemetry circuit is symmetrical in design so that, except for the desired resistance change with temperature of the thermistor, changes in T_1 are accompanied by similar changes in T_2. The ratio of T_1/T_2 is therefore less affected by ambient temperature and voltage changes than are T_1 and T_2 individually. Hence, the ratio T_1/T_2 is the preferred system output. A counter is used to measure T_1 and T_2 after they are detected in the receiver, but digital readout of T_1 and T_2 and the calculation of T_1/T_2 do not lend themselves readily to continuous recording. Therefore, a demodulator was built to give an analog output. The counter measurements of T_1 and T_2 made at various temperatures are used as the basic calibration, since the counter is digital and not subject to drift. The analog demodulator readings, which may drift, are then cali-

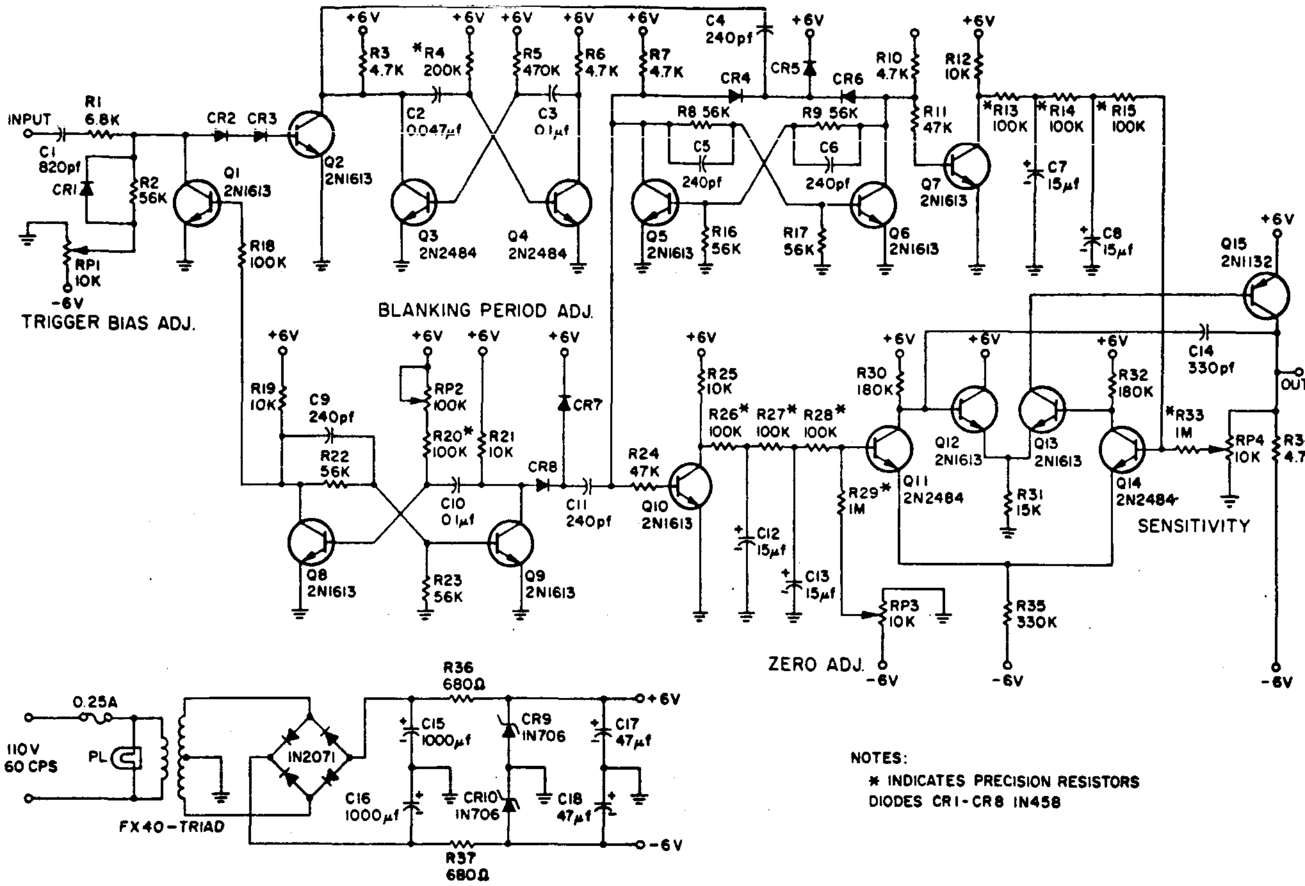


FIG. 4. Circuit diagram of the demodulator.

TABLE 2. *Temperature calibration of telemetry unit prior to deep body implantation*

Temp, °C	T_1, msec	T_2, msec	T_1/T_2	Demodulator Output, v
45	6.653	9.523	.6986	0
44	6.656	10.058	.6618	.53
43	6.657	10.589	.6287	1.03
42	6.660	11.167	.5964	1.55
41	6.658	11.785	.5649	2.07
40	6.657	12.430	.5356	2.57
39	6.656	13.118	.5074	3.06
38	6.653	13.865	.4798	3.56
37	6.650	14.630	.4545	4.04
36	6.637	15.496	.4283	4.54
35	6.633	16.305	.4068	4.96

brated against these readings at any time desired. The demodulator is designed to be adjusted to read, 0 v at 45 C and 5 v at 35 C to give a convenient direct reading scale.

Figure 4 is the circuit diagram of the demodulator. An astable multivibrator is synchronized with each pulse. A trigger bias adjustment is provided to set the threshold level for noise discrimination. The first multivibrator triggers a bistable multivibrator. In order to force T_1 to be represented by one side and T_2 the other, a monostable multivibrator is provided. The period of this multivibrator is set greater than T_1 and less than T_2 at the highest operating temperature, 45 C, and is applied as a blanking signal to the input through a switching transistor in order to orient T_1 and T_2 properly.

The average d-c voltages on the two sides of the binary are proportional to $T_1/(T_1 + T_2)$ and $T_2/(T_1 + T_2)$, respectively. A differential amplifier measures the difference between these two d-c voltages. This gives $(T_2 - T_1)/(T_2 + T_1) = [1 - (T_1/T_2)]/[1 + (T_1/T_2)]$ which is a function of the stable parameter T_1/T_2. The function $(T_2 - T_1)/(T_2 + T_1)$ is a slightly nonlinear function of the variable T_2 over a limited range, but since T_2 is also a slightly nonlinear function of temperature due to the thermistor characteristics, the calibration is nearly linear as shown in Table 2. The analog voltage can be adjusted at two points by a gain and zero adjustment to provide a nearly linear direct reading scale over the range from 35 to 45 C.

Tests. Table 2 shows the calibration of a temperature telemetry system that was implanted in a chicken. Rectal temperatures taken with a thermometer agreed closely with those taken with the telemetry system. The unit measured the deep body temperature of the chicken successfully for a period in excess of 2 weeks. Figure 5 shows a typical short-term record, while Fig. 6 gives a typical curve of the daily temperature cycle over a 1-week period. This particular unit failed after about 2 weeks as a result of a change in the value of resistor R_4. With improvements in manufacturing and sealing techniques later units have been implanted for 6 weeks with no sign of deterioration.

Table 3 shows the effects of voltage and temperature changes on one of the telemeter units when the thermistor was replaced with a precision resistor. These tests cover extreme voltage and temperature variations to show how insensitive T_1/T_2 is to the variables that normally cause errors. Only the thermistor causes a significant change in the ratio of T_1/T_2. The results of a 4-month test on a model circuit are shown in Table 4 and further

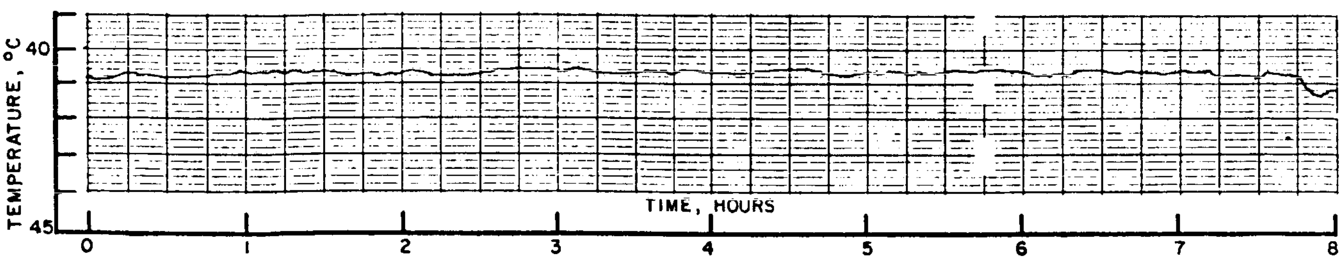


FIG. 5. Typical short-term record.

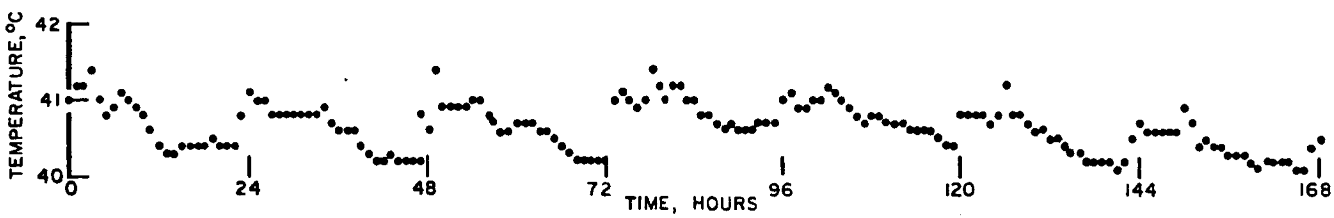


FIG. 6. Temperature curve for 1 week plotted at hourly intervals.

TABLE 3. *Effect of voltage and temperature on the circuit with R_t held constant at 2.4 megohms*

Temp, °C	Power Supply, v	T_1, msec	T_2, msec	T_1/T_2
26	1.1	8.668	10.015	.8655
26	1.2	8.535	9.915	.8608
26	1.3	8.435	9.820	.8589
26	1.4	8.355	9.750	.8569
26	1.5	8.278	9.685	.8574
26	1.34	8.416	9.807	.8582
30	1.34	8.394	9.785	.8578
35	1.34	8.315	9.689	.8582
40	1.34	8.216	9.569	.8586
45	1.34	8.114	9.444	.8591
50	1.34	7.965	9.259	.8602

TABLE 4. *Results of long term tests on a circuit with a fixed resistor for R_t**

Time, day	T_1, msec	T_2, msec	T_1/T_2
0	2.815	3.009	.9355
4	2.803	2.994	.9362
5	2.812	3.004	.9361
7	2.812	3.004	.9361
8	2.803	2.995	.9358
15	2.812	3.004	.9361
45	2.778	2.970	.9353
82	2.744	2.936	.9346
112	2.765	2.959	.9344

* T_1 and T_2 differ from Table 3 because of different circuit values used in an early design.

confirm the excellent accuracy of the system over an extended operating period. The slight variations in the actual values of T_1 and T_2 were caused by variations in the room temperature when readings were made.

Concluding remarks. The subcarrier system used should provide long-term, accurate data free of rf detuning effects. Although more complex, the system has been made smaller than many past circuits by microminiaturization techniques. The design of a circuit requiring only one battery contributed considerably to the small size since this component is an order of magnitude larger than any others used. The pulsed operation of a high-frequency rf carrier has proved to be a very satisfactory method of reducing battery drain.

The FM frequency band was selected because of the availability of inexpensive receivers. The lower rf frequencies give better transmission through the tissue and so have been most commonly used in the past, but difficulties with nulls have been a problem. Three crossed-axis antennas have often been used to solve this problem. Use of the FM band of 88–108 Mc has given no detection problem and, with only one antenna, has proved remarkably free of serious nulls.

The system as described has been completely satisfactory for the existing experiments and it will also be applicable to some more difficult future requirements. It will be possible to make temperature measurements at specific points by locating the thermistor remote from the transmitter. A fast response limited only by the thermistor will be possible and temperature changes on the transmitter will not affect the readout. The sealing problem is somewhat more difficult when a remote probe is used and the present applications have not required this refinement. The circuit may also be used to measure differential temperatures by replacing R_4 with a second matched thermistor. One possible application for differential temperature measurement would be between skin temperature and deep body as a blood flow index.

REFERENCES

1. ADAMS, R. M., G. L. FROMME, D. DIZON, AND G. L. AUSTADT. A microwatt VHF telemetry system for implantation in animals. *Proc. 1963 Natl. Telemetry Conf., Session 5-2, May 20–22, Albuquerque, N. Mex.*
2. EASLER, W. O. Radio telemetry of electrocardiogram and body temperatures from surgically implanted transmitters. In: *State University of Iowa Studies in Natural History*, vol. xx, 1961.
3. KO, W. H., AND E. YON. Micro-miniature, high impedance FM telemetering transmitter for bio-medical research. *Proc. 1964 Natl. Telemetry Conf., Session 2-2, June 2–4, Los Angeles, Calif.*
4. McKAY, R. S. Radio telemetry of physiological information from within the body. *Proc. 1963 Natl. Telemetry Conf., Session 5-1, May 20–22, Albuquerque, N. Mex.*

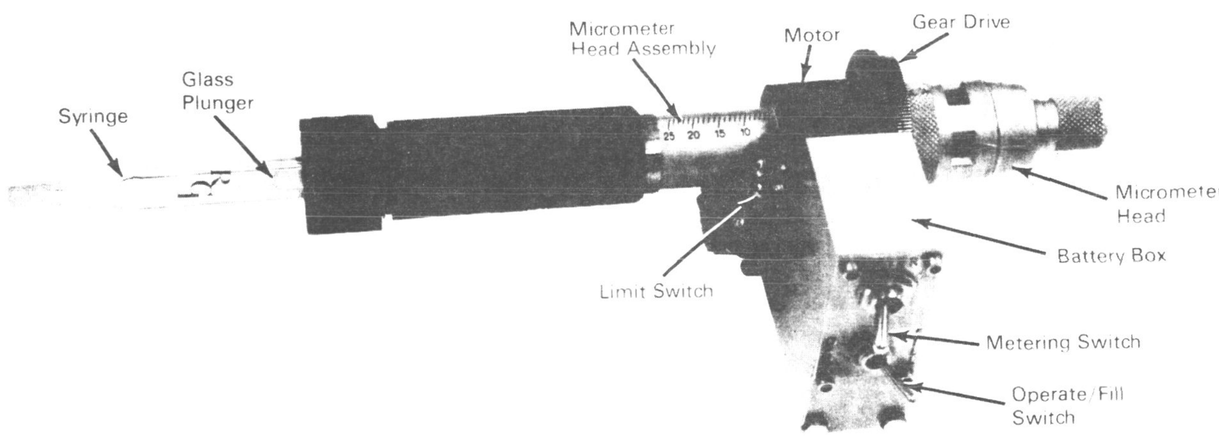
APPENDIX VI

TECH BRIEF 67-10203

NASA TECH BRIEF

NASA Tech Briefs are issued to summarize specific innovations derived from the U.S. space program, to encourage their commercial application. Copies are available to the public at 15 cents each from the Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia 22151.

Automated Microsyringe Is Highly Accurate and Reliable



The problem:

To develop a device that will meter small (microliter) volumes of fluid. In performing chemical analysis with extremely small volumes of fluids (microchemistry) a simple, reliable and convenient metering device was needed.

The solution:

A standard syringe body and plunger that has been adapted to fit with a motor driven micrometer.

How it's done:

A miniature electric motor and self-contained battery drive the micrometer. The contents of the syringe can be metered very precisely since there is a proportional relationship between the amount of fluid drawn into or expelled from the syringe and the relative reading of the micrometer. The micrometer is a standard depth-type micrometer that has been mechanized by the addition of gears and a motor drive.

To meter one sample of solution, the metering switch is toggled from the normally open position, and the motor is energized. The cycle proceeds automatically until one unit volume of fluid has been metered out of the syringe. At the end of the cycle, the motor drives the stop cam and, in turn, the stop switch to its normally closed position. This process may be repeated as many times as there are samples of fluid within the syringe. On the last delivery sample, the limit switch will move to the opposite position to prevent any further fluid from being delivered by the syringe through manipulation of the metering switch.

One feature of the normally closed position of the stop switch is to provide dynamic braking on the motor when the cam lifts the stop switch and de-energizes the motor. This makes a short circuit across the motor, thus providing dynamic braking which permits accurate metering of fluids.

(continued overleaf)

Notes:

1. This syringe can be used in automated wet chemical instrumentation. It is a highly adaptable device which can be used in a variety of applications where manually operated syringes are now used.
2. Commercial use of this instrument in automatic and semiautomatic chemical apparatus could be extensive. It may also find application in biomedical areas such as pathology laboratories in hospitals, or where extremely small and exact quantities of drugs or chemicals must be extracted or dispensed.
3. Simple packaging modifications would permit timed and metered medication dosage, while allowing the patient to have ambulatory freedom or outpatient status.
4. Other possibilities for this instrument are:
   (a) it can be operated by electrical signals;
   (b) it may be used in a chemical or electromechanical servo loop as a feedback element;
   (c) optical or electrical readout is possible.
5. Inquiries concerning this invention may be directed to:

   Technology Utilization Officer
   NASA Pasadena Office
   4800 Oak Grove Drive
   Pasadena, California 91103
   Reference: B67-10203

Patent status:

Inquiries about obtaining rights for the commercial use of this invention may be made to NASA, Code GP, Washington, D.C. 20546.

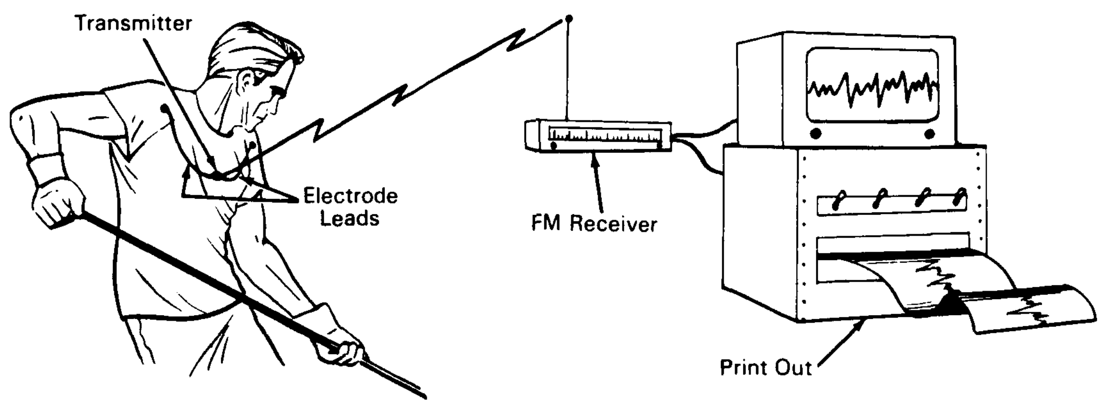
Source: J. L. Stuart
Jet Propulsion Laboratory
(NPO-10142)

APPENDIX VII

TECH BRIEF 64-10171

NASA TECH BRIEF

Subminiature Biotelemetry Unit Permits Remote Physiological Investigations



The problem: The measurement of biopotential response in humans or animals to controlled environmental stimuli has traditionally been impaired by encumbering electrical leads or bulky amplifying and transmitting equipment.

The solution: A subminiature, high-performance, biopotential telemetry transmitter operating in the standard 88- to 108-megacycle FM band.

How it's done: The transmitter was designed using standard, inexpensive, commercially available components and assembly techniques which permit easy and repeatable assembly with no sacrifice of performance or reliability. The transmitter is 0.74 inch in diameter by 0.20-inch thick and weighs two grams. A mercury cell provides power for operation in two modes, selected by the interchange of three components in the basic circuit. In one mode the transmitter has a two-day operating life with a 100-foot range; in the other, the transmitter has a 48-day operating life with a 10-foot range. Conventional biomedical electrodes are used to connect the transmitter to the subject.

Notes:

1. In tests, humans have worn the unit for four or five days without discomfort and have generated useful data while engaged in normal activities.
2. Further information concerning this innovation is described in NASA-TM-X-54068, "A Miniature Biopotential Telemetry System" by Gordon J. Deboo and Thomas B. Fryer, May 1964.
3. A related innovation is described in NASA Tech Brief 64-10025, May 1964.
4. Inquiries may also be directed to:

   Technology Utilization Officer
   Ames Research Center
   Moffett Field, California, 94035
   Reference: B64-10171

Patent status: NASA encourages commercial use of this innovation. No patent action is contemplated.

Source: Ames Research Center (ARC-39)

APPENDIX VIII

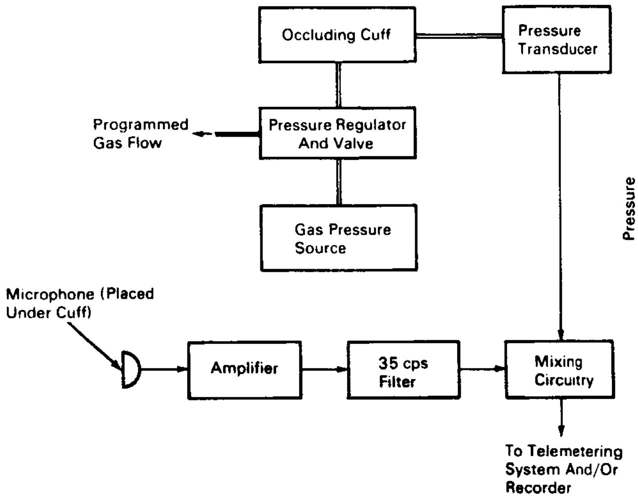
TECH BRIEF 65-10365

ASTRA

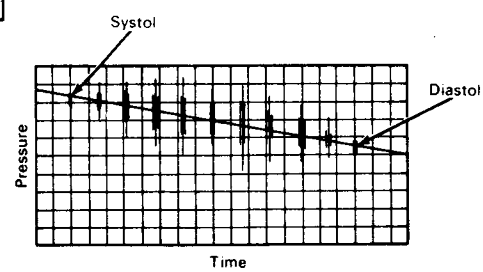
NASA TECH BRIEF

NASA Tech Briefs are issued by the Technology Utilization Division to summarize specific technical innovations derived from the space program. Copies are available to the public from the Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia, 22151.

Blood-Pressure Measuring System Gives Accurate Graphic Output



SYSTEM SCHEMATIC



TYPICAL OUTPUT TRACE

The problem: To develop an instrument that will provide an external (indirect) measurement of arterial blood pressure in the form of an easily interpreted graphic trace that can be correlated with standard clinical blood-pressure measurements. From sphygmograms produced by conventional sphygmographs, it is very difficult to differentiate the systolic and diastolic blood-pressure pulses and to correlate these indices with the standard clinical values. It is nearly impossible to determine these indices when the subject is under physical or emotional stress.

The solution: An electronic blood-pressure system, basically similar to conventional ausculatory sphygmomanometers, employing a standard occluding cuff, a gas-pressure source, and a gas-pressure regulator and valve. An electrical output transducer senses cuff pressure, and a microphone positioned on the brachial artery under the occluding cuff monitors the Korotkoff sounds from this artery. The output signals present the conventional systolic and diastolic indices in a clear, graphical display. The complete system also includes an electronic timer and cycle-control circuit.

How it's done: The output of the microphone is fed through a solid-state amplifier and a 35-cps filter into the mixing circuitry where it is superimposed on the signal from the pressure transducer. The output of the mixing circuitry is fed to a continuous chart recorder which gives a plot of cuff pressure versus time. The first signal pulse appearing on the graph as the cuff pressure is slowly reduced indicates the systolic pressure and the last pulse corresponds to the diastolic pressure.

(continued overleaf)

Notes:

1. The occluding cuff must be of a minimum width in order to ensure correlation of the measured systolic and diastolic values with the accepted indices. A narrow cuff is highly desirable for comfort and mobility of the subject.
2. Over 2,000 blood pressure measurements have been taken using this system on various individuals, and many of the readings have been compared with those taken with a conventional sphygmomanometer and stethoscope. In only a few instances were the readings off by more than a few millimeters of mercury.
3. A small amount of additional development would be required to make the system completely automatic. Such a system should be of considerable value for monitoring the blood pressure of hospitalized patients and as a clinical diagnostic aid.
4. Inquiries concerning this invention may be directed to:

   Technology Utilization Officer
   Manned Spacecraft Center
   P. O. Box 1537
   Houston, Texas, 77001
   Reference: B65-10365

Patent status: NASA encourages the immediate commercial use of this invention. It is owned by NASA and inquiries about obtaining royalty-free rights for its commercial use may be made to NASA, Code AGP, Washington, D.C., 20546.

Source: The Garrett Corporation under contract to Manned Spacecraft Center
(MSC-191)

APPENDIX IX

TECH BRIEF 67-10005

NASA TECH BRIEF

NASA Tech Briefs are issued to summarize specific innovations derived from the U.S. space program, to encourage their commercial application. Copies are available to the public at 15 cents each from the Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia 22151.

Digital Computer Processing of X-Ray Photos

The problem:

The interpretation of medical and biological pictures such as X-ray photographs could be made easier if selected portions of the image were first enhanced by means of a digital computer.

The solution:

For a number of years, digital computers have been used at Jet Propulsion Laboratory to correct various photometric, geometric, and frequency response distortions in the pictures received from the television cameras of the Ranger, Mariner, and Surveyor spacecraft. These methods have now been applied to the study of medical and biological photographs.

How it's done:

The first step in the process is to convert the picture into a form suitable for input to the computer. This is accomplished by means of a cathode-ray tube device that scans the film with a light beam on a line-by-line basis and converts each point of the picture to a number proportional to the film optical density. Each sample (typically 500,000 samples for a 1-in.-sq. transparency) is recorded on magnetic tape which is subsequently fed into a computer.

One of the principal methods of computer enhancement involves the use of a two-dimensional digital filter to modify the frequency spectrum of the picture.

(continued overleaf)

This filtering, in one case, is used to restore high-frequency losses (loss of fine detail) which result from the use of fluorescent X-ray intensifying screens. In other cases, the filtering is used to deliberately distort the frequency spectrum to bring out specific types of information. The figure on the left shows the sharpening of the image of a skull angiogram, and the figure on the right shows a distortion of the image which brought out the blood vessels in the front of the skull.

Another computer processing method is image subtraction. Two pictures of the same location of the body, perhaps taken at different times are subtracted from one another on a point-by-point basis. The resultant difference picture will tend to emphasize changes such as tumor growth. Subtraction is currently accomplished by optical methods but it is generally not applicable unless the areas photographed are rigid, such as the skull. The computer, however, is not so restricted and can force a match even on chest X-rays by arbitrarily shifting around different parts of the picture.

Preliminary efforts have been made using a pair of chest X-rays separated in time by six months. The rib cage of one picture was shifted by the computer to match the second and then subtracted. The results are sufficiently encouraging, but these results are not yet at a clinically useful stage.

In addition to medical X-ray photographs these methods have been applied to infrared photographs, photomicrograph scintillation, scanner displays, and standard light photographs.

Notes:

1. Further research is being conducted in this area at the Jet Propulsion Laboratory. In particular, emphasis is being placed on enhancement of pictures with specific medical value.
2. This innovation is the subject of Jet Propulsion Laboratory Technical Report No. 32-1028 and 32-877.
3. Inquiries concerning this innovation may be directed to:

   Technology Utilization Officer
   Jet Propulsion Laboratory
   4800 Oak Grove Drive
   Pasadena, California 91103
   Reference: B67-10005

Patent status:

No patent action is contemplated by NASA.

Source: Dr. Robert Nathan and R. H. Selzer (JPL-792)

APPENDIX X

MEDICAL PROBLEM STATEMENTS SUBMITTED BY
THE UNIVERSITY OF MISSOURI MEDICAL CENTER
(Problems MU-8 through MU-14)

University of Missouri Request for NASA Technology

TO: Biomedical Applications Team
Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri

DATE: December 5, 1967 NO: MU-8

X-RAY PHOTOGRAPH COMPUTER ENHANCEMENT

What is Needed: A literature review is desired which reflects the state of art of processing video-data.

Background: The possibilities to be explored are, what future research work in medicine can be based on the achievement of image processing. The project includes the investigation of equipment (in regard to cost and accomplishments) and programs developed in order to eliminate noise, correct distortions and enhance contrast. The ultimate goal of the project will be to investigate the possibilities of not only enhancing given radiographs, but also directing computer processing of the film to obtain a diagnosis.

Source of Problem: Peter L. Reichertz, M.D., PD
Associate Professor and Director
Radiology Computer Research

University of Missouri Request for NASA Technology

TO: Biomedical Applications Team
Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri

DATE: December 5, 1967 NO: MU-9

ELECTROCARDIOGRAMS ELECTRODES

What is Needed: Small electrodes are needed that have a constant impedance when being attached over longer periods and are not affected by movements of the patients. The attachment must not affect the skin and must not cause decubitus even when attached to the back of a motionless lying patient.

Background: The method is desired for coronary care units to be connected with a central computer network.

Source of Problem: Peter L. Reichertz, M.D., PD
Associate Professor and Director
Radiology Computer Research

University of Missouri Request for NASA Technology

TO: Biomedical Applications Team
Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri

DATE: December 5, 1967

NO: MU-10 - (MU-4) - (KU-25)

INDIRECT MONITORING OF ARTERIAL BLOOD PRESSURES

What is Needed: A method for indirect monitoring of arterial blood pressures in animals to avoid the trauma of intra-arterial cannulation.

Background: Due to size and location of arterial sources for direct monitoring of animal surgical patients, the additional knowledge of the physiological condition of the animal during surgery has been neglected. The anatomical relationships are such that these cannulations must be made with considerable effort or with the risk of permanent damage to the vessels involved. Ideally, a method with accuracy which could monitor arterial pressures through the skin is desired.

Source of Problem: Charles E. Short, D.V.M.
Research Associate
Dept. of Veterinary Med. and Surgery
University of Missouri
Columbia, Missouri

University of Missouri Request for NASA Technology

TO: Biomedical Applications Team
Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri

DATE: December 6, 1967

NO: MU-11

TRACKING OF LARGE ANIMALS

What is Needed: A method for tracking and locating large animals from an airbourne unit or on land.

Background: A method is desired to track or locate large animals by a radio transmission signal. This can be in the FM or CB band. The transmission line of sight preferred is to be approximately 5 miles. Ideally, the system should be able to operate for a period of 3-5 years without a change in the power source.

Source of Problem: Vince W. Zager
Chief Electronics Technician
282 Reactor Facility

University of Missouri Request for NASA Technology

TO: Biomedical Applications Team
Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri

DATE: December 8, 1967 NO: MU-12

CARDIAC OUTPUT MEASUREMENT

What is Needed: A method is needed to evaluate a cardiac output by computing peripheral measurements in a critically ill patient.

Background: A survey of the state of the art is desired in order to evaluate the possibilities of computing cardiac output from peripheral measurements in a critically ill patient (coronary care.unit). These measurements should not be obtained by catheterization, or dye-injection.

It is not sure, whether such a possibility exists. Information is desired about correlation studies of peripheral measurements such as blood pressure, pressure wave-velocity, BCG-parameters and cardiac output. It is desired to obtain information about multiple regression studies including these and other parameters to calculate cardiac output continuously.

Besides this information is desired about the available analogue data computers to calculate cardiac output from dye-dilution curves. The computation must not be based on the measurement of 2 pre-defined areas of the downward slope alone.

Source of Problem: Peter L. Reichertz, M.D., PD
Associate Professor & Director
Radiology Computer Research

University of Missouri Request for NASA Technology

TO: Biomedical Applications Team
Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri

DATE: December 18, 1967 NO: MU-13

PULMONARY AND METABOLIC MONITORING INSTRUMENTATION

What is Needed: A survey of all techniques that have evolved in the measurement of pulmonary functions under adverse environmental conditions and/or in the field for mass screening, and the same for measurements or inferences of metabolic rates.

This should cover the general field of spirometry, employing various types of transducers and methods of signal conditioning. It should also cover methods of deriving the respiratory quotient by expired gas analysis, by calorimetry, and by any other means.

Background: It is the considered opinion of the writer that no completely satisfactory instrumentation exists for obtaining the conventional pulmonary function measurements, much less the more refined parameters, for the purpose of mass screening in public health programs, and for aerospace and similar research applications. The spirometer is too bulky, is limited in rise time by its own inertia, and lacks the flexibility to accommodate novel parameters.

Considerable work has been done in recent years within both fields, attempting to up-date instrumentation. Heat-exchange and isothermal transducers, transducers utilizing the Bernouli principle (Fleish approach), ultrasonic transducers, and others have emerged, but all possess unique problems. All transducers which sense velocity or volumetric flow must feed some kind of integrating device. Liquid-state integrators, large capacitors, operational amplifiers, FET circuits, and even elaborate digital techniques have been attempted, with varying degrees of success.

Efforts have also been made to develop means of assessing metabolic rates and changes in them in real time, through breath analysis by mass spectrometry or infra-red absorption, chemical assays, calorimetry, and other approaches, in simulated aerospace environments. Results of these efforts are needed for examination, to assess the feasibility of their clinical extension.

A crude working model of an ultrasonic transducer, plus a breadboard signal-conditioning circuit has been developed. It produces an output which is an exceptionally good analog of volumetric flow rate of an unchanging gas, plus a change in composition of a stationary gas, and it is believed that this device may be refined to accommodate respiratory flows. Before undertaking this work, a survey of prior attempts, using all methods, is needed to minimize duplication of effort and to assess the practicability of the approach.

Source of Problem:

David W. Douglas
Bioengineer and Research Associate
Missouri Regional Medical Program

Earl M. Simmons, M.D.
Associate Director
Missouri Regional Medical Program

University of Missouri Request for NASA Technology

TO: Biomedical Applications Team
Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri

DATE: January 8, 1968 NO: MU-14

STORING OF EKG TRACING WAVE FORMS

What is Needed: A technique for condensing an analog EKG wave form to a limited number of digital parameters.

Background: We desire to store, using a digital computer, the wave form of EKG tracings. This information may be used to reproduce the original wave form and to compare with future tracings for significant changes. Due to limitations in storage capacity it is necessary to condense this information to 100 characters of (hexadecimal) digital information for 5 seconds of one EKG lead.

Source of Problem: Charles Buck
Manager of Systems
Computer Program
Medical Center

APPENDIX XI

TRANSFER REPORTS

NASA TECHNOLOGY TRANSFER

Title: Muscle Accelerometer

The Problem: A study of arm muscle reflexes and tremors is being conducted at the Saint Louis University School of Medicine. The effect of the neck and labyrinth on the arm muscle reactions is being studied in detail. These reactions were being studied by means of motion pictures and direct visual observation. These techniques were unsatisfactory because of the difficulty in obtaining accurate quantitative data. For example, the accurate determination of the time cycle of the arm movements required tedious examination of many frames of the motion picture. Furthermore, low amplitude tremors could not be detected with these techniques.

The Solution: A special muscle accelerometer has been developed which has solved this problem. This instrument operates on the same principle as a very sensitive micrometeorite detector* developed at the NASA Ames Research Center. Changes in acceleration of the instrument causes the deflection of a sensitive piezoelectric crystal which generates an electrical signal. The instrument is attached to the patient's hand and provides an accurate record of the arm muscle reflexes and tremors.

Method of Transfer: The medical investigators at St. Louis University requested the MRI Biomedical Applications Team to find a solution to the problem. The BA Team searched the aerospace literature and found a report which described the micrometeorite detector developed at the NASA Ames Research Center. Based on the principle used in the NASA micrometeorite detector, a special muscle accelerometer was developed by the BA Team. Experimental models of this muscle accelerometer were given to the medical investigators at St. Louis University for evaluation in connection with their problem.

Status of Transfer: The special muscle accelerometer is being successfully used at the St. Louis University School of medicine to measure muscle reflexes and tremors. The data are expected to be helpful in the diagnosis and rehabilitation of neurological conditions. This work was presented at

* "Micrometeorite Transducer," Ames Research Center, NASA Technology Utilization Report No. SP-5007.

the meeting of the Aerospace Medical Association, Washington, D.C., April 1967, and at the International Conference on Medical and Biological Engineering, Stockholm, Sweden, August 1967. Numerous inquiries have been received from medical investigators both in the U.S.A. and foreign countries.

D. Bendersky, Director
Biomedical Applications Team
Midwest Research Institute

December 14, 1967

NASA TECHNOLOGY TRANSFER

Title: Electrocardiogram Electrodes

The Problem: Medical researchers at the University of Kansas Medical Center were having difficulty obtaining electrocardiograms (ECG's) on children under exercise conditions. During exercise, the conventional metal plate electrode tends to move about causing variations in the electrical contact, which has a detrimental effect on the ECG signal. Furthermore, during vigorous exercise tests, such as riding bicycle ergometers or running on treadmills, the conventional electrodes tend to come loose, resulting in complete loss of the ECG signal.

The Solution: A solution to this problem is a spray-on electrode technique,* developed at the NASA Flight Research Center for instrumenting test pilots. The technique consists of spraying an electrically conductive mixture over the end of the electrocardiograph lead wire and onto the skin. A solvent in the mixture evaporates quickly, leaving a thin, flexible layer of conductive material which firmly holds the lead wire in contact with the skin. The electrodes are readily removed with a solvent.

Method of Transfer: The spray-on electrodes were initially identified as a potential solution to the problem by a member of the MRI Biomedical Applications Team during a visit to the NASA Flight Research Center (FRC). Additional information was obtained from reports supplied by FRC. A simple spray device was assembled at MRI for evaluation of the technique. The technique was evaluated by the medical researchers at the University of Kansas Medical Center.

Status of Transfer: The NASA spray-on electrodes have been successfully used at the University of Kansas Medical Center on over 1,000 children in connection with a study of exercise tolerance for normal children and children with heart defects. The children rode bicycle ergometers and ran on treadmills while their electrocardiograms were taken without difficulty.

* "Dry Electrodes for Physiological Monitoring," by Patten, Ramme and Roman, Spacelabs, Inc., and NASA Flight Research Center, NASA Technical Note D-3414, May 1966.

A paper describing this work has been prepared by the medical researchers at the University of Kansas Medical Center, which has been accepted for publication in the Journal of Applied Physiology. A presentation of these electrodes was made at the International Conference on Medical and Biological Engineering, Stockholm, Sweden, August 1967. A number of newspaper and magazine articles on these electrodes have been published.

Numerous inquiries on these NASA electrodes have been received from both U.S. and foreign medical groups. A commercial version of these electrodes is now on the market.

D. Bendersky, Director
Biomedical Applications Team
Midwest Research Institute

December 14, 1967

NASA TECHNOLOGY TRANSFER

Title: Delivery of Water and Medication to the Respiratory Tract

The Problem: The use of water and water-soluble medical compounds is a relatively common approach to the treatment of infections of the respiratory tract. Such respiratory infections are a particular problem in children with cystic fibrosis. The current method for introducing water and medicants to the respiratory tract is to place the child in a tent into which the vapors are introduced. This technique has the disadvantages of (1) being inconvenient due to the bulky structure of the tent, (2) unnecessary exposure of the entire body to the vapors, and (3) the traumatic effect on the child of being placed in the vapor-filled tent.

The Potential Solution: A potential solution to this problem is a system which is based on a modification of the NASA space helmet.* The helmet is equipped with an air inlet, an air outlet and a neck seal. A suction pump, attached by a flexible hose to the air outlet, draws a continuous flow of fresh air and the vapors through the helmet and continuously discharges the exhaled breath. This system has the advantages of being small and lightweight, exposes only the head to the vapors, and the children enjoy wearing a "space helmet."

Method of Transfer: Medical personnel at the University of Wisconsin Medical Center submitted the problem to the MRI Biomedical Applications Team. The MRI BA Team had previously developed the modified space helmet for collecting exhaled breath for oxygen consumption analysis. A member of the MRI BA Team conceived the system using this helmet for delivering water and medication to the respiratory tract. The idea was submitted to the medical investigators at the University of Wisconsin Medical Center.

Status of Transfer: The suggested helmet system was reviewed by the medical investigators at the University of Wisconsin Medical Center. They plan to assemble and test the system. An experimental helmet has been furnished for this evaluation.

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* "Space Suit Development Status," by R. S. Johnson et al., Manned Spacecraft Center, NASA Technical Note No. D-3291, February 1966.

D. Bendersky, Director
Biomedical Applications Team
Midwest Research Institute

December 14, 1967

NASA TECHNOLOGY TRANSFER

Title: Electroencephalogram Helmet

The Problem: Medical researchers at the Northwestern University Medical School are conducting a long-range study of psychosensory learning disorders in children. Data are being obtained which permit studies of the interrelationship of psychic with physiological functions. For example, while a child is in the act of learning an intraneurosensory task (auditory-auditory) the electrical output from the brain is recorded by electroencephalograms (EEG). Similarly, while the child is in the act of interneurosensory (visual-auditory) learning, the EEG is recorded as well as other physiological outputs such as his respiration and tongue motion. These studies indicate that it is possible to reveal brain dysfunctions that are otherwise undetected by more standard EEG procedures, and these data have a direct bearing on planning remedial educational procedures.

In this study there is a need for a convenient method for telemetering the EEG signals. The child's EEG is to be transmitted to a remote recorder, while the child is engaged in a normal learning environment such as in a classroom. This procedure would be effective for more accurately determining the ways in which brain dysfunctions relate to classroom learning. Furthermore, they expect to learn the limits of learning stimulation that a child with brain dysfunction can tolerate.

The Potential Solution: A potential solution to this problem is an electroencephalogram helmet system* developed at the NASA Ames Research Center. This helmet was developed to provide an improved system for obtaining EEG's of pilots and astronauts. The system consists of sponge-type electrodes, amplifiers and a battery-powered wireless transmitter, all mounted in the subject's helmet. No preparation of the scalp is required. After initial fitting, the helmet can be removed and replaced without further adjustment.

Method of Transfer: The medical investigators at Northwestern University Medical School presented the problem to the MRI Biomedical Applications Team. A search of the NASA technology by the MRI BA Team revealed the NASA Ames EEG helmet. Detailed information on the helmet was obtained by the MRI BA Team from the TU Officer at the Ames Research Center. This information was transmitted to the medical investigators at Northwestern University.

---

* "Helmet System Broadcasts Electroencephalogram of Wearer," Ames Research Center, NASA Tech Brief 66-10536, November 1966.

Status of Transfer: The medical investigators at Northwestern University Medical School believe that the NASA Ames EEG helmet system is applicable to their problem. Arrangements are now being made to evaluate one of these NASA helmets at Northwestern University Medical School in connection with this problem.

D. Bendersky, Director
Biomedical Applications Team
Midwest Research Institute

December 14, 1967

NASA TECHNOLOGY TRANSFER

Title: Eyelid Closure

The Problem: Medical researchers at the University of Wisconsin Medical Center are interested in measuring eyeblink response in infants, in connection with a study of mental retardation. The usual procedure for measuring eyeblink in older children and adults involves a mechanical attachment from the subject's eyelid to a microtorque potentiometer. Although this instrument gives satisfactory results on older children and adults, it is not applicable to infants. The infant will not remain in a fixed position, which causes artifacts in the records and changes the calibration of the system. Furthermore, infants will not tolerate any attachments to the eyelid. What is needed, therefore, is a method for measuring eyeblink which will not be affected by head movements and which does not require attachment to the eyelid.

The Potential Solution: The photoelectric eye switch*, developed by the NASA Marshall Space Flight Center, may be a solution to this problem. This device was developed to utilize signals from self-controlled movement of the human eye. A small infrared source and detector are mounted relative to each other so that when the eye is looking straight ahead all of the infrared radiation is reflected to the detector. When the iris is voluntarily turned toward the infrared source a high percentage of the radiation is absorbed by the iris. The difference in absorption of the iris and the white of the eye is used to actuate a switch. For measuring eyeblink, it is proposed to coat the eyelid with an infrared absorption material. The infrared source will be focused on the eye. When the eyelid covers the eye, during an eyeblink, the difference in infrared absorption between the eye and the coated eyelid will be detected and used as a measure of eyeblink.

Method of Transfer: The medical investigators at the University of Wisconsin Medical Center submitted the problem to the MRI Biomedical Applications Team for solution. A search of aerospace technology by the MRI BA Team revealed the NASA photoelectric sensor. The technique for employing the NASA sensor to detect eyeblink was conceived by a member of the MRI BA Team and the idea was submitted to the medical investigators at the University of Wisconsin.

---

* "Photoelectric Sensor Output Controlled by Eyeball Movement," Marshall Space Flight Center, NASA Tech Brief 65-10059, March 1965.

Status of Transfer: The medical investigators at the University of Wisconsin Medical Center are interested in testing this technique for measuring eyeblink. Arrangements are now being made to procure one of these NASA eyeswitches for evaluation.

D. Bendersky, Director
Biomedical Applications Team
Midwest Research Institute

December 14, 1967

NASA TECHNOLOGY TRANSFER

Title: Impedance Cardiograph

The Problem: There is a need for a method to measure cardiac output (the amount of blood being pumped by the heart) without surgical procedures or placing anything into the bloodstream. In many studies, such as the monitoring of astronauts and hospital studies involving volunteer subjects, it is undesirable to puncture or otherwise introduce instruments into the body of the subjects. The present techniques for measuring cardiac output (including electromagnetic flow meters, the dye dilution method, and the Fick method) require surgical procedures or the introduction of instruments into the blood stream.

The Potential Solution: A potential solution to this problem is an electrical impedance system* developed by the University of Minnesota for the NASA Manned Spacecraft Center. Four special external electrodes are placed around the neck and chest. A small electrical current is introduced through two of these electrodes. The electrical impedance across the other two electrodes is measured and used to calculate cardiac output. No instruments are required inside the body. Tests conducted at the University of Minnesota show a direct correlation between the impedance measured across the external electrodes and the amount of blood pumped by the heart.

Method of Transfer: Medical investigators at the University of Kansas Medical Center requested the MRI Biomedical Applications Team to find a solution to this problem. Through personal contacts at the University of Minnesota, the MRI BA Team learned of the impedance cardiograph system being developed for NASA. Detailed information on the system was obtained and arrangements were made to have these units evaluated at the University of Kansas Medical Center.

Status of Transfer: The NASA impedance cardiograph system is now being evaluated at the University of Kansas Medical Center as a means for measuring cardiac output.

---

* Development and Application of an Impednace Cardiograph System to Measure Cardiac Output," by W. G. Kubicek et al., University of Minnesota, Contract No. NAS9-4500, July 1967.

D. Bendersky, Director
Biomedical Applications Team
Midwest Research Institute

December 14, 1967

NASA TECHNOLOGY TRANSFER

Title: Bone Elasticity

The Problem: One of known difficulties encountered by the aged is the deterioration of the bones of the body. It is known that bones become more brittle with age and certain bone diseases. Some data have been collected on the elasticity of bones *in vitro* (not in the living state). However, little has been done to study bone elasticity *in vivo* (in the living state) because of the difficulty in conducting such nondestructive tests.

An *in vivo* study of bone elasticity in animals has recently been undertaken at the University of Minnesota Medical School. For this study, there is a need for special instrumentation which will permit the measurement of bone stresses under various test conditions.

The Potential Solution: A miniature stress transducer,* developed at the NASA Jet Propulsion Laboratory (JPL) to measure stresses in the propellant grain of solid propellant rockets, offers a potential solution to the measurement of bone stresses. This transducer employs a semiconductive piezoresistive element that is stress sensitive. The piezoresistive element is embedded in a high density polyethylene cylinder filled with an epoxy adhesive. The transducer leads are welded to end plates for connection to a recorder. The entire assembly is only five-hundredths of an inch in diameter and one-tenth of an inch long. These miniature transducers will be imbedded in the bone to measure the stresses in the bone.

Method of Transfer: The problem of measuring bone elasticity *in vivo* was presented to the MRI Biomedical Applications Team by the medical investigators at the University of Minnesota Medical School. A search of the NASA technology revealed the JPL stress transducer. Detailed information on this transducer was obtained from JPL by the MRI BA Team and forwarded to the University of Minnesota Medical School.

* "Miniature Stress Transducer," NASA Tech Brief 65-10023.

Status of Transfer: The medical investigators at the University of Minnesota Medical School are planning to use the JPL stress transducer in their study of bone elasticity. A request for one or more of these transducers has been sent to the Jet Propulsion Laboratory for use in this study.

D. Bendersky, Director
Biomedical Applications Team
Midwest Research Institute

December 14, 1967

NASA TECHNOLOGY TRANSFER

Title: Sterile Operating Rooms

The Problem: Extreme care must be taken in surgical procedures and post surgical patient care to avoid infection due to contamination. Yet most hospital operating rooms and post surgical patient care rooms do not have facilities for maintaining a clean and sterile atmosphere in these critical areas. Tests of operating room ventilating systems have revealed contaminated air being sucked into operating rooms from other parts of the hospital. Room air can also be contaminated by the personnel within the room.

At the University of Minnesota Medical School Hospital, consideration is being given to the construction of sterile operating and post operating rooms. Techniques for designing and constructing sterile rooms are, therefore, of interest in connection with this program.

The Potential Solution: NASA has developed a considerable amount of know-how related to the design and construction of "clean rooms" which is applicable to the design of sterile operating rooms. Under a NASA contract, the Sandia Corporation conducted tests on clean rooms which showed the extreme efficiency of these systems in reducing airborne viable particles.[1/] A NASA supported study of clean rooms was conducted by the School of Public Health at the University of Minnesota.[2/] Also, personnel at the NASA Ames Research Center furnished a list of reports pertinent to the design and construction of clean rooms.[3/] A system for providing sterile operating rooms, based on the Gemini spacecraft system, was submitted by the NASA Marshall Space Flight Center.[4/]

Method of Transfer: A request for information on techniques which could be applied to the design and construction of sterile operation and post operation rooms was submitted to the MRI Biomedical Applications Team by medical personnel at the University of Minnesota Medical School. An abstract of the problem was prepared and circulated to the NASA Centers. The suggestion from the Marshall Space Flight Center and the list of pertinent reports from the Ames Research Center resulted from the circulation of the problem abstract. The other NASA clean room technology was revealed in a literature search of aerospace technology.

Status of Transfer: The pertinent reports and other information of the NASA technology related to the design and construction of clean rooms were obtained by the MRI Biomedical Applications Team and forwarded to the interested people at the University of Minnesota Medical School. It was reported that this information will be extremely useful in the design and construction of the sterile operating and post operation rooms which are planned at the University Hospital.

D. Bendersky, Director
Biomedical Applications Team
Midwest Research Institute

December 14, 1967

References:

1. "Microbiological Studies in a Laminar Down-Flow Clean Room," V. E. Arnold et al., NASA Document No. 65-19646, January 1965.

2. "The Bacteriology of Clean Rooms," Progress Report, NASA Document No. N66-13553, September 1965.

3. Personal communication, from Dr. S. N. Stein, NASA Ames Research Center, August 5, 1966.

4. Personal communication from A. Ignatonis, NASA Marshall Space Flight Center, September 13, 1967.

Title: Respirometer Helmet

The Problem: Medical researchers at the University of Kansas are conducting a study of the oxygen consumption of normal children and children with heart defects. Difficulties were being experienced with the conventional rubber mouthpiece used to collect the exhaled breath. Under heavy breathing conditions the mouthpieces offer comparatively high resistance to gas flow so that an extra work load is imposed on the subject. This extra work load makes the subject consume extra oxygen, which limits the accuracy of the oxygen consumption data. Furthermore, the mouthpiece and required noseclip are uncomfortable and annoying for children.

The Solution: A solution to this problem is a modified NASA space helmet,* normally worn by astronauts. The modified helmet is equipped with an air inlet and an air outlet. A rubber neckpiece is used to seal around the neck. A suction pump continuously draws fresh air through the helmet picking up the exhaled breath and drawing the combined fresh air and exhaled breath into an oxygen analyzer.

Method of Transfer: The NASA Gemini space helmet was used by the MRI Biomedical Applications Team as a basis for designing an experimental respirometer helmet. The helmet was assembled at MRI and given to the medical researchers at the University of Kansas Medical Center for evaluation.

Status of Transfer: The respirometer helmet has been successfully used at the University of Kansas Medical Center on over 400 children to date to collect oxygen consumption data on normal children and children with heart defects. The results of this work were presented by the University of Kansas medical researchers at a meeting of the Midwest Society for Pediatric Research, and the paper was published in the Journal of Pediatrics.

* "Space Suit Development Status," by R. S. Johnson et al., Manned Spacecraft Center, NASA Technical Note No. D-329, February 1966

A considerable number of inquiries on this respirometer helmet have been received from other medical investigators. Several have indicated that they plan to build and use similar helmets.

D. Bendersky, Director
Biomedical Applications Team
Midwest Research Institute

December 14, 1967

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