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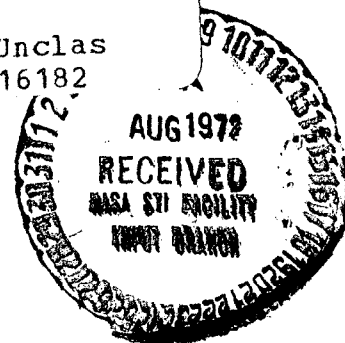
# TECHNOLOGY APPLICATIONS PROGRESS REPORT

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TECHNOLOGY APPLICATIONS  
PROGRESS REPORT

An Annual Review

*for*

THE TECHNOLOGY UTILIZATION OFFICE  
(CODE KT)  
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

*For the Period*

1 December 1971-31 May 1972

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by the

Technology Application Group

THE GEORGE WASHINGTON UNIVERSITY  
Medical Center  
Biological Sciences Communication Project  
Washington, D.C.

as the

Annual Report for NASA Contract NASw 2055

This report was written by Todd Anuskiewicz, John Johnston, William Leavitt, and Robert R. Zimmerman of the Technology Application Group.

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## **TO THE READER**

The NASA Technology Utilization Program embodies a broad range of activities designed to transfer aerospace technology to nonaerospace sectors. This annual review summarizes current activities of the Program intended to accelerate specific applications of space-related technology in major public sector problem areas.

The report focuses on those projects active during the period 1 December 1971 through 31 May 1972. An abbreviated description of the overall Technology Utilization Applications Program is provided as background for the specific applications examples. More detailed descriptions of the Technology Utilization Program are contained in other documents available from:

Director, Technology Utilization Office  
Office of Industry Affairs and Technology Utilization  
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## INTRODUCTION

The Technology Utilization Office of the National Aeronautics and Space Administration sponsors a variety of activities designed to facilitate the transfer of space-related technology to nonaerospace fields. Much of the technical capability developed in the course of aerospace research and development have been found applicable to nonaerospace needs. It is frequently possible through modest additional investment to capitalize on such new developments for the public benefit by expediting their transfer to nonaerospace contexts.

This report describes Technology Application projects designed to facilitate specific applications of NASA-related technology toward the solution of significant public sector problems. To accomplish such applications, the program:

- Identifies problems in conjunction with responsible mission-oriented agencies.
- Systematically seeks relevant NASA technology.
- Assists in effecting application of the technology.

In its efforts to facilitate applications of NASA-related technology to significant public sector problems, the Technology Utilization Office Applications Program had underway, as of May 31, 1972:

- Cooperative efforts with more than 150 public sector agencies, groups and institutions.
- Analyses of more than 400 public sector problems.
- More than 140 specific technology application projects.
- Specific projects at 11 NASA field installations.

NASA is now cooperating with other agencies in the fields of biomedicine, sensory aids for deaf and blind, air and water pollution control, criminalistics, law enforcement, mine safety, postal services, urban construction and transportation.

NASA is presently cooperating with:

- Department of Health, Education and Welfare
  - National Institutes of Health
  - National Center for Health Services R&D
  - Social and Rehabilitation Service
  - Health Services and Mental Health Administration
  - National Cancer Institute
  - National Heart and Lung Institute
- Department of Housing and Urban Development
- Department of Interior
  - Bureau of Mines
- Department of Justice
  - Law Enforcement Assistance Administration
- Department of Transportation
  - Federal Highway Administration
  - Federal Railroad Administration
  - Office of High Speed Ground Transportation
  - Urban Mass Transit Administration

- Environmental Protection Agency  
Office of Air Programs  
Water Quality Office
- Department of Commerce  
National Bureau of Standards  
National Oceanographic and Atmospheric Administration
- U.S. Postal Service
- Veterans Administration
- Over 75 Medical Schools and Health Care Institutions
- 25 Criminalistics Laboratories
- 6 State Highway Departments
- New York State Urban Development Corporation

Liaison with user groups and agencies and identification of technical requirements is a function performed primarily by interdisciplinary "Application Teams" under contract to the NASA Technology Utilization Office. There are seven NASA funded Application Teams currently in the program. Team locations and the special problem areas in which each team concentrates are shown in Table 1.

**TABLE 1**

**PROBLEM AREAS STUDIED BY NASA APPLICATION TEAMS**

<b>TEAM LOCATION</b>	<b>PROBLEM AREAS</b>
Abt Associates, Inc. Cambridge, Massachusetts	Urban Construction and Planning
IIT Research Institute Chicago, Illinois	Law Enforcement Mine Safety Water Pollution
Research Triangle Institute (2 Teams) Research Triangle Park North Carolina	Air Pollution & Environmental Sciences Biomedicine
Southwest Research Institute San Antonio, Texas	Biomedicine
Stanford University School of Medicine Palo Alto, California	Biomedicine
Stanford Research Institute Menlo Park, California	Criminalistics Transportation Postal Services

In addition to the specific projects described in the next section, a number of supporting activities are carried out in conjunction with the applications program. These supporting activities are described in another section.



## **CURRENT TECHNOLOGY APPLICATIONS PROJECTS**

This section describes specific applications projects active during the period covered by this report.

## CANCER: DETECTION, TREATMENT AND RESEARCH

**Detection of Eye Tumors Using Radiation Probes.** A valuable technique for diagnosis of eye tumors is based on the detection of beta-radiation emitted by a radioisotope. The isotope, which is selectively absorbed by tumor cells, is administered intravenously to the patient. It is then necessary to differentiate between different levels of radiated energy to detect tumors which are hidden from direct observations or are in such an early stage of development that they cannot be detected by any other means. A measuring technique currently being used requires insertion of a dime-sized Geiger counter probe between the eyeball and the eye socket. The Geiger probe is both excessively large and insufficiently directional to provide adequate readings. The large size and lack of directionality make it difficult to determine if the detected increased level of radiation is indeed a tumor within the eyeball or merely an area of increased blood flow in one of the eye muscles. Thus, readings from the probe could be falsely interpreted to indicate the presence of an eye tumor, when in fact, there is none.

To answer the need for greater diagnostic precision a semiconductor radiation detector developed for NASA has been adapted. It is sufficiently small to put in a 2 mm diameter probe; mounted at the tip of a catheter, it can be inserted into the area behind the eye with minimal trauma. The probe, incorporating a thick film preamplifier adjacent to the detector, has a signal-to-noise ratio that is amenable to recording equipment. It is highly sensitive, and provides a realistic measurement of the spatial and energy distributions of beta-radiation. From data gathered from several locations, differences in isotope concentration can then be used to identify and outline the area of increased isotope uptake by suspected tumor cells, if they are present.

Using such a device, the clinician can determine more accurately the distribution of the isotope, making his diagnosis more specific. This will reduce the present high percentage of false-positive tumor diagnoses, which results in unnecessary removal of the eye. Solid State Radiation Inc.—the firm which originally developed the semiconductor radiation probe under NASA contract—is planning to market the probe for diagnostic use in the near future.

**Method of Controlling Rate of Freezing of White Cells for Leukemia Treatment.** Leukemia is a form of cancer characterized by proliferation of white blood cells formed in bone marrow. It is treated by killing the cancerous white blood cells in the blood and bone marrow with drugs or radiation. This process can cause loss of all bone marrow, inhibiting or eliminating the reproduction of normal white cells, creating the need for a fresh supply of white cells. It would be desirable to have a white cell 'bank' or frozen storage facility to provide ample white cells for leukemia patients. But currently this is almost impossible because the white cells are destroyed by existing freezing and thawing procedures in which the rate of temperature change is not constant. A method of freezing that would assure a constant rate of temperature change should solve this white-cell destruction problem.

In cooperation with the National Cancer Institute, NASA's Goddard Space Flight Center has begun a program to analyze, design, fabricate and test a device with precise thermal-control capability. The major problem to be solved is to maintain a constant rate of change in the blood's temperature as it is cooled. This rate of freezing cannot at present be controlled because of the plateau in cooling rate when the latent heat is released at the freezing point.

Goddard is applying their thermal-analysis techniques, originally developed to maintain stable operating temperatures in space satellites, to studies necessary to define and specify the materials in the blood-cooling unit.

A preliminary design effort has been undertaken to conceptually define the system. The heater, LN<sub>2</sub> cooling system and interfacing and bonding requirements have already been defined. This conceptual design (Figure 1) has formed the basis for performing thermal analyses.

Thermal analyses included studies of the LN<sub>2</sub> flow channel dimensions, flow rates and flow control to show their relationship to system performance. Heater power requirements and control were included along with electrical and thermal insulation requirements. All system characteristics were integrated into the analysis to determine cooling rate limits and freezing time capabilities.

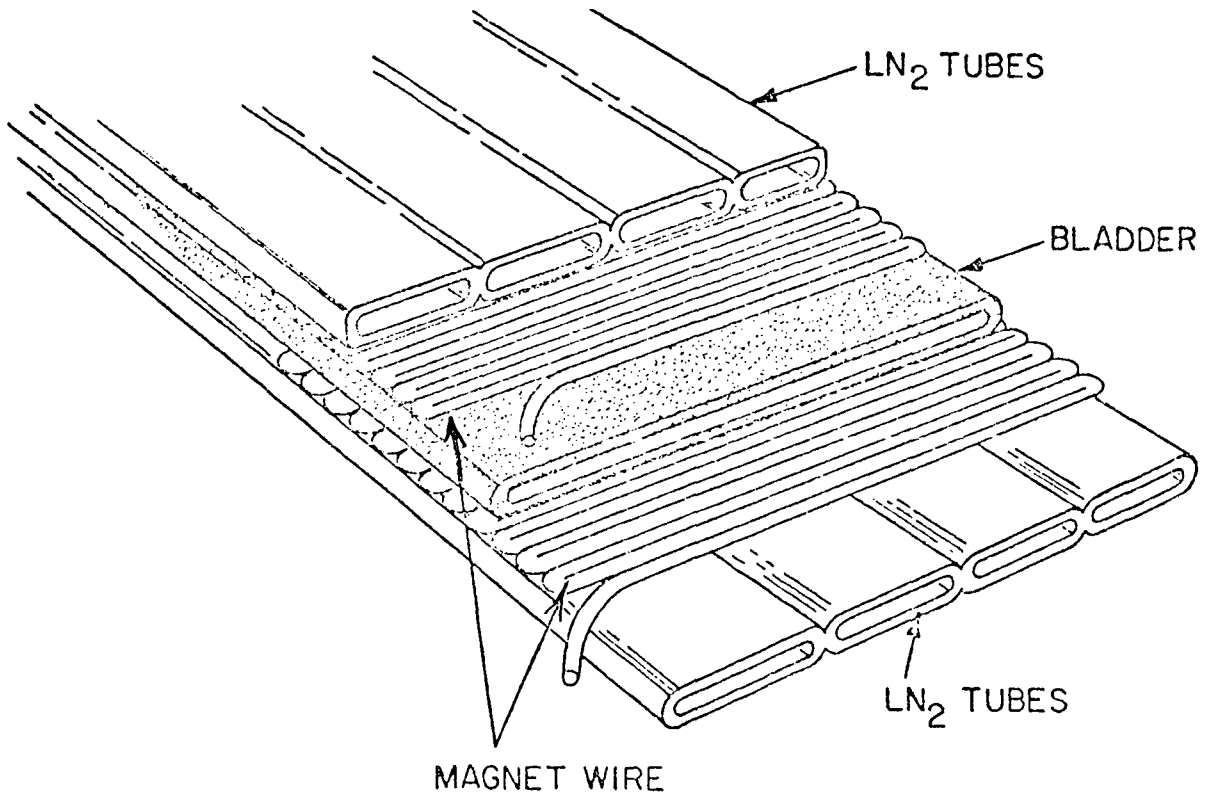


Figure 1. Controlled Freezing Unit

White blood cells, unlike red blood cells, are destroyed by present freezing and thawing methods. Experiments indicate that the maintenance of a constant rate of cooling is essential to cell survival. By detecting the onset of freezing and then increasing the heat transfer rate during the release of latent heat at the freezing point, a nearly constant rate of cooling can be maintained. Cooling is supplied by the liquid nitrogen tubes and is controlled by heating the magnet wire. When the freezing point is reached, heating is discontinued so that a sharp increase in thermal flow occurs.

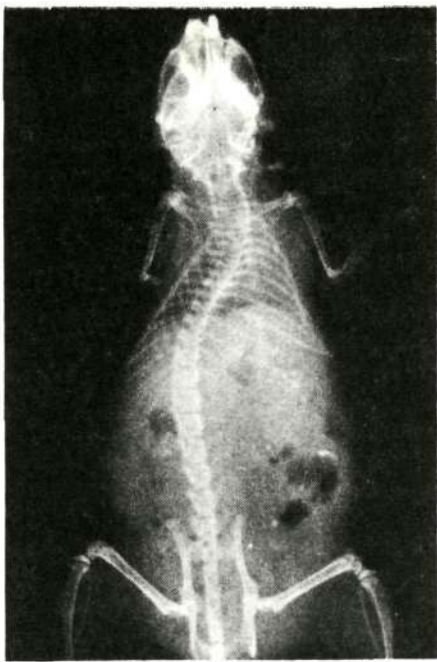
Concurrent with the thermal analysis, researchers are undertaking the design of the heater's thermal barrier between the  $LN_2$  and the blood bag. This part of the system has conflicting requirements. The heater must have good response and provide a large thermal resistance during the time cooling is being controlled. It should also have minimal thermal resistance during the quick-freezing process. The heater's thermal-barrier design is critical to the determination of system capabilities.

Following completion of the thermal analysis, a prototype unit will be constructed for further evaluation. Based on operating characteristics measured from the actual prototype, a programmable heater control and hardware for  $LN_2$  control will be added to the system. The working prototype will be delivered to NCI before the end of 1972.

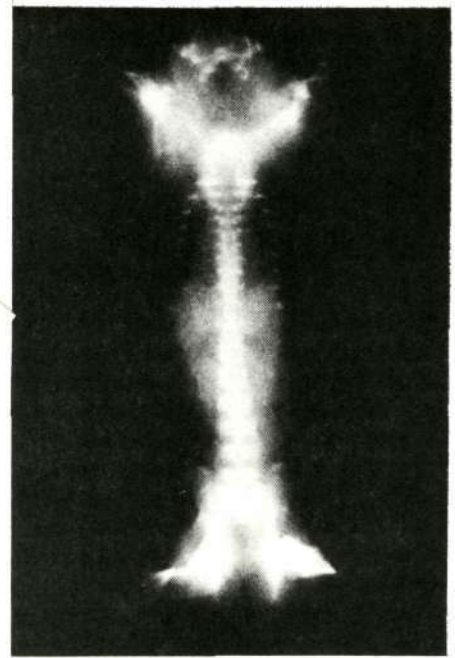
**X-Ray Microplanigraph.** An aerospace method used for analysis of printed circuit boards is being explored as a way of obtaining improved x-ray images for detection of deep seated tumors.

The common method for detecting tumors is by x ray. Unfortunately, when the entire body is x-rayed, small tumors frequently remain undetected because the background level of the x-ray signal is vastly increased by scattering within the thickness of the body. It is more desirable to x-ray laminar regions only. But present techniques still produce images of rather thick laminae.

The general technique of making x rays of thin laminae is called x-ray microplanigraphy. While this technique is theoretically applicable to tumor detection, it is not being used at present. It has been employed by NASA to



A. Conventional X-Ray Image of a Mouse



B. X-Ray Planigraphic Image of a Mouse

Figure 2. Comparison of Conventional and Planigraphic X-Ray Images

inspect multi-layer printed circuit boards, layer-by-layer, with a resolution of 0.001 inch. The technique, developed by a NASA contractor, involves moving the x-ray source and detector in a particular geometrical arrangement so that only thin laminae are measured. (An example of the use of the technique is shown in Figure 2).

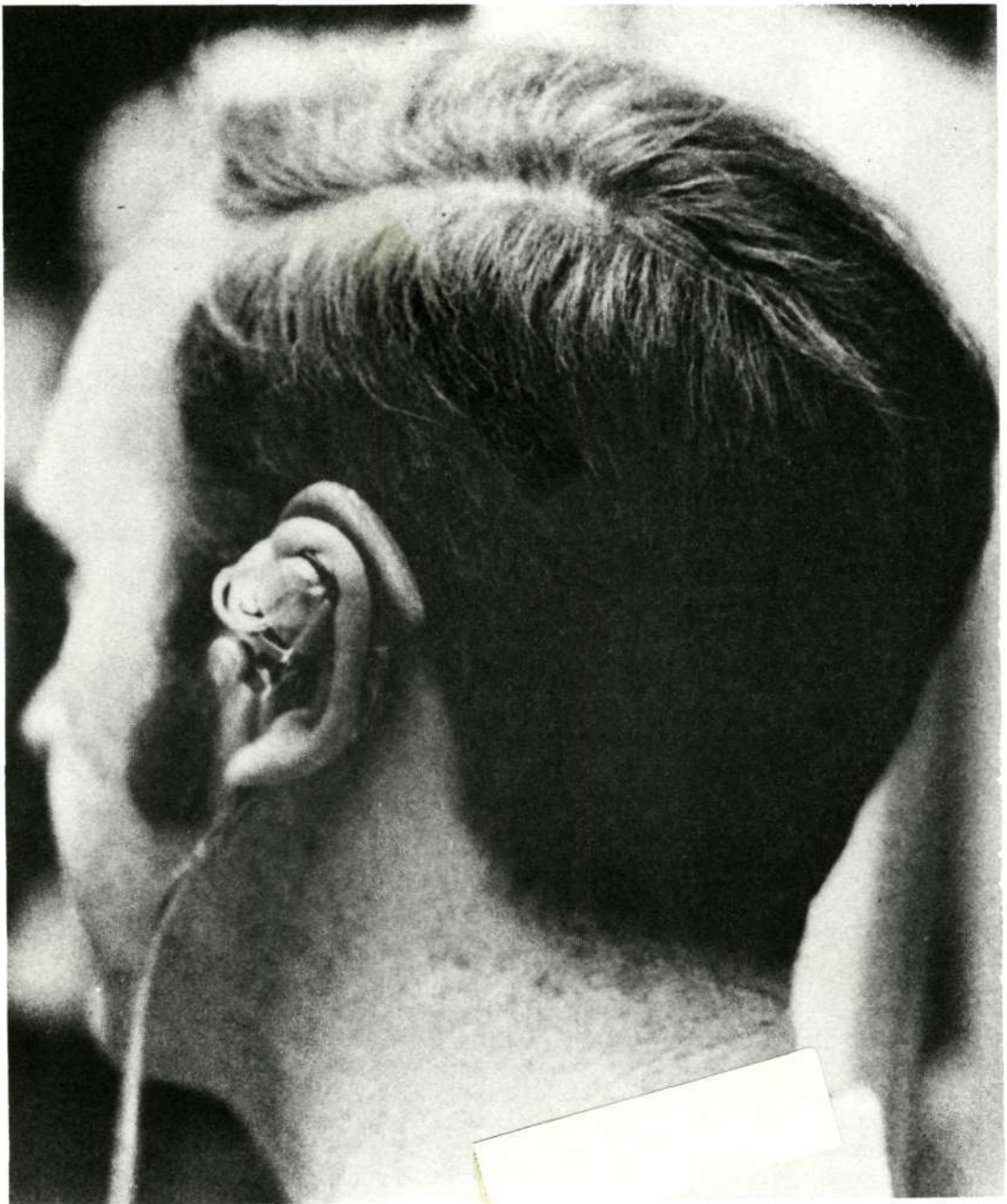
The Problem Originator has submitted a proposal to the National Cancer Institute (NCI) for adaptation of this technology to tumor detection. Some very promising preliminary x-ray studies have already been performed using this technique, which should be implemented more fully with the additional NCI funds. A paper on this technique was presented at the NASA/American College of Radiology Joint Conference in February 1972.

**Noninvasive Continuous Monitor Detects Onset of Shock.** Leukemia is a disease characterized by self-perpetuating proliferation of white blood cell-forming tissue. An extensive National Cancer Institute program is directed toward finding the causes and cures of leukemia. The clinical phase of this program is concerned with early detection of shock. Shock, defined as the sudden reduction in the volume of circulating blood, frequently results from hemorrhage, or infection, as well as other causes. If it is not recognized early, the damage is irreversible and rapidly becomes fatal. Thus, there is a need for an accurate indicator of the onset of shock, so that corrective measures can be taken in time.

An important measurement of the onset of shock is a reduction in blood pressure. The usual means of measuring blood pressure is with a sphygmomanometer. A cuff is placed around the arm which is then inflated to a higher than maximum blood pressure and slowly reduced. This conventional method is quite inadequate, uncomfortable and cumbersome for continuously measuring blood pressure of a critically ill patient.

NASA's Ames Research Center has lent the National Cancer Institute a device for measuring relative blood oxygen content—the ear oximeter (Figure 3), originally designed for use in the early astronaut program, fits the ear like a hearing aid and can detect the onset of shock without disturbing the patient.

The device includes a small sensor mounted on the ear and a small electronics package which can be placed at the patient's bedside. The absorption of infrared radiation by the blood is directly related to oxygen content of

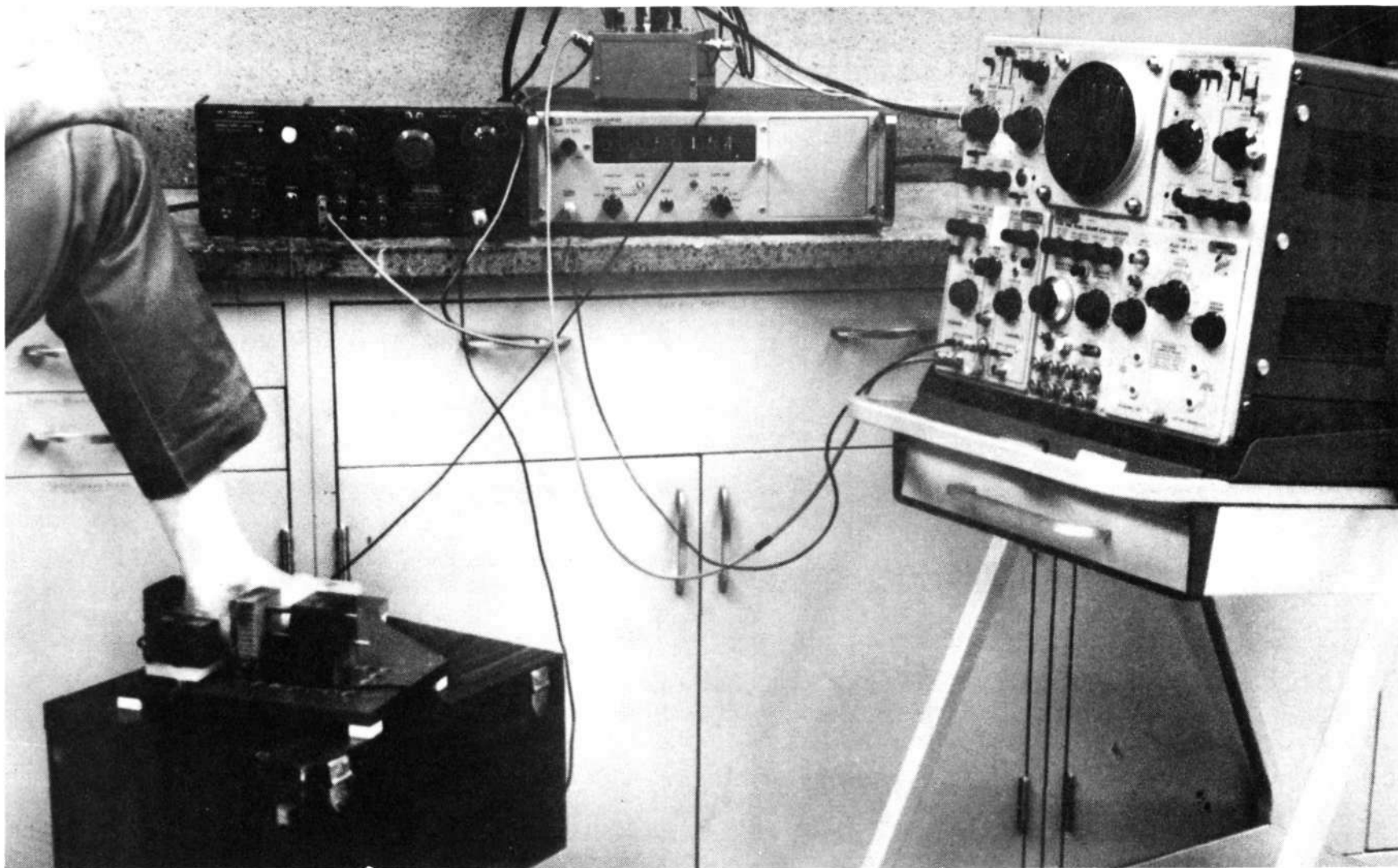


The ear oximeter was developed to clip on to the ear and measure blood oxygen by absorption of infrared radiation. The output is related to both blood oxygen and pressure so that it may be used to provide for early detection of shock in hospital patients.

Figure 3. Ear Oximeter

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Ultrasonic bone densitometer allows determination of changes in the calcium content of bones. By measuring the propagation time of an ultrasonic pulse across a section of bone, it is possible to determine changes in the density of the bone.

Figure 4. Ultrasonic Bone Densitometer

the blood. The onset of shock is accompanied by a reduction in the amount of blood and the oxygen content of the blood flowing through the earlobe. The oximeter detects change in the infrared absorption and sets off an alarm that warns medical personnel to take corrective action.

Clinical tests of the Ames device are underway at the National Cancer Institute. A technical paper on this device was presented at the International Conference of the Institute of Electrical and Electronics Engineers (IEEE) in March 1972.

**Bone-Density Measurement.** Neoplasms such as tumors often secrete hormones which leach calcium from the bone. This can produce hypercalcemia (excessive calcium in the blood) and can also produce a site in the leached bone that is vulnerable to cancerous cells. Hypercalcemia affects approximately 20 percent of lung-cancer patients and 40 percent of breast-cancer patients. Although hypercalcemia can be treated, its fundamental cause is not known. Present studies on experimental animals use x-ray absorption techniques to measure bone density as a means of following the progress of demineralization. This technique is not desirable for humans because it requires exposure to repeated numerous doses of x rays over long periods of time.

A researcher at the Ochsner Foundation in New Orleans studying the bone demineralization process, inquired whether NASA had developed any techniques for determining the decalcification of bone. The Marshall Space Flight Center had constructed a device (Figure 4) for just such a purpose for possible use in the NASA Skylab program. It measures the propagation time of an ultrasonic pulse across a section of bone. Since conduction velocity is a function of material density, the NASA techniques should provide a good indication of any changes in the composition of the bone. The technique merely requires accurate positioning of two transducers in good contact against the skin over-laying the bone being examined and is therefore noninvasive.

The researcher at Ochsner will perform measurements on rat tibias having bone dimensions similar to the phalange bones of the human hand. He hopes to extrapolate his data and findings to measurements made on the phalange bones of humans where hypercalcemia is suspected. If the technique proves fruitful, it will be important both as a diagnostic aid and to evaluate the efficacy and progress of therapy. As a result of early clinical tests several improvements are being incorporated in the device and further testing will continue in 1972.

**Improved Photographic Emulsion to be Used in Cancer Research.** Cancer study in experimental animals can be facilitated by labeling the tumor cells with radioactive tritium. The tritium attaches itself to the DNA molecule and the division of the tumor cell produces new labeled cells. Autoradiography is used to detect radioactive cells. A film sheet of photographic emulsion is placed over the cells and exposed by the radioactivity. But existing film emulsions require exposure of a month or more. Investigators at the National Cancer Institute needed a faster high resolution film so that the autoradiography technique could be used clinically to evaluate the progress of cancer in humans.

In response to this need, an improved photographic emulsion, developed at NASA's Goddard Space Flight Center for high-altitude cosmic-ray studies, is now being explored for use in the detection of radioactive cancer cells. Originally designed for use on board atmospheric sounding rockets, the resolution and sensitivity to low energy radiation seem ideally suited to the requirements of autoradiography. The National Cancer Institute has now let a contract for the further development of these emulsions under the guidance of the NASA scientist responsible for their initial development.

## **CARDIOVASCULAR DISEASE: DIAGNOSIS, TREATMENT AND RESEARCH**

**Rechargeable Cardiac Pacemaker.** Aerospace technology originally developed for rechargeable nickel-cadmium cells for spacecraft is now being directly applied to a NASA-supported effort by the Johns Hopkins Applied Physics Laboratory to develop a rechargeable cardiac pacemaker. Such a device would make unnecessary the present requirement for pacemaker wearers to have the devices surgically removed for replacement in the event of failure which is usually caused by depletion of the battery. The wearer would simply recharge his unit by donning a special vest for several hours. This is an especially useful feature for infants and the aged.

The new device would also offer other significant advantages: since a large battery is not required, the entire unit can be drastically reduced in size. The use of a hybrid circuit further reduces size and weight. Unlike the pacemakers presently manufactured in the U.S. which start to lose energy as soon as they are produced, the rechargeable pacemaker can be kept at a safe charge level until the time of implantation. Also, the rechargeable pacemaker has a telemetry system to measure battery voltage and charging current.

The space-developed, hermetically sealed nickel-cadium cell is the key to the unit's workability. Its power cell is essentially a miniature version of cells used in virtually all U.S. spacecraft. Hybrid circuitry, a technology to which Johns Hopkins Applied Physics Laboratory has made considerable contributions, offers great advantages since it improves circuit reliability while reducing size and weight.

Tests on animals will precede implantation in a human patient. In view of the large backlog of experience in power-cell and circuit technology available, researchers expect relatively rapid successful demonstration of the rechargeable pacemaker for human use.

**Electrodes for Low-Cost Emergency Personal Coronary Care Kits.** Flexible electrodes developed at NASA Ames Research Center are now being field-tested as significant components of emergency coronary-care units. Constructed of a conducting elastomer and shaped like a golf ball, these electrodes can be rapidly placed under the armpits of a heart-attack patient to rapidly provide an artifact-free EKG signal that can be sent by telephone to a physician. These electrodes are part of a new portable emergency coronary-care unit package being developed and studied by the National Heart and Lung Institute and recently dramatically demonstrated by Representative James W. Symington of Missouri before a congressional committee. Congressman Symington showed colleagues how a patient using the kit could send kit-gathered EKG data to his physician by telephone. The doctor then ordered the "patient" to administer appropriate medication to himself. The kit can be carried routinely by high-risk cardiac patients.

Designed for emergency use by ambulance, police, and even patients themselves, the portable package contains two drugs and a hand-held monitor. The electrodes of the hand-held monitor are placed under the armpits of the person experiencing the classic coronary symptom. Depending on the presence of either a low heart rate or a fast erratic heart beat, one of the two drugs is administered. The application of the drugs is quite easy since they are contained in automatic injector syringes like those originally used in the Apollo medical package. The simplicity and reliability of the hand-held monitor is a critical factor in determining which drug is appropriate. Early versions of the monitor worked well except that untrained personnel had difficulty properly attaching conventional electrodes. NASA cooperation was sought to provide electrodes which would be highly reliable yet would require little training for proper use.

The NASA conductive elastomer electrodes, aided by the moisture found under the arms, provide adequate contact with the body surface without the use of an electrode paste. Because of the high-impedance contact provided by the material, a high-impedance amplifier (FET) is built into the electrode and reduces the inherent noise problem.

Evaluation of the electrodes has been quite promising to date. They appear to solve a major problem in the operation of this system—which should provide a valuable technique for dealing with the problem of prompt medication of heart attack victims.

**Automated Measurement of Coronary Angiograms.** The volumes of the heart's chambers during various stages of the contractile cycle are now being measured with the use of techniques originally developed at NASA's Jet Propulsion Laboratory to enhance television images transmitted by the Mars probes. Researchers at Duke University had developed a technique using biplane cineangiography (x-ray movies taken at right angles to each other) to evaluate the heart's contractile action by tracking bifurcation points in arteries located on the external surface of the heart. By measuring the spatial distances between bifurcations in successive frames, the length of epicardial segments and changes in their dynamics could be determined. Thus, the technique could indicate whether an occlusion observed in a vessel also involved damage to the myocardial tissue. NASA's pattern recognition and image enhancement techniques enable a computer to recognize the bifurcation points in successive film frames and to measure the changes in spatial distance in successive film frames.



The investigators hope that computer analysis of biplane cineangiograms will be used routinely within the next two years for evaluating candidates for coronary bypass grafts or repair of ventricular aneurysms. The technique can also be used to check on the results of surgery. Prior to the use of the computer analysis techniques, this bifurcation measurement technique was impractical in terms of time and manpower. The cineangiograph takes 120 frames per second—60 in each plane—so two heart cycles produce about 240 frames. The distance between as many as twenty bifurcation points is measured on each frame, thus requiring nearly 5000 calculations. The computer searches each frame for the predesignated bifurcation points and measures the distances as they change position from frame to frame, presently reducing the analysis time to less than 1 hour.

Through a NASA fellowship, the Duke investigator was able to spend a summer at JPL where he studied the image-processing procedures which he has applied to this problem. The system is being used in a research capacity in conjunction with a Myocardial Infarct Research Unit, funded by the National Heart and Lung Institute.

**Bedside Biomedical Computer.** Special computer programming techniques developed for the Apollo Guidance Computer are being applied to the development of the Bedside Biomedical Computer (BBC). As part of a cooperative effort between NASA's Manned Spacecraft Center and the Massachusetts Institute of Technology, the BBC is intended to improve health care delivery to a wide population and to place emphasis on cardiovascular care as well as biomedical problems which involve the measurement, analysis, and display of subject data in real time.

The computer system will consist of a small digital central processor, a magnetic tape and disc unit, a display/keyboard terminal, and associated electronics. The program structure of the BBC will resemble that of the Apollo Guidance Computer. It is specialized to the tasks of real-time computation and multi-programming, in other words, the computation of several programs on a multi-task, priority-interrupt basis. The program coding will be in assembly language, a single-instruction format which uses mnemonics to describe the computer's basic instruction set and storage locations. In order to conserve core storage and to simplify coding, calculations common to many programs will be combined in macro-programs. These are sequences of instructions that define higher-order operations such as transcendental functions, digital filters, and input-output routines.

The five major phases of the BBC's operation are: initialization, background monitoring, running estimate, batch processing, and hypothetical diagnosis. During initialization, the patient history is taken (or reviewed) by the computer, the results of laboratory tests and pertinent off-line physical findings are entered, a preliminary identification of possible problem areas is made on the basis of history and laboratory data, the direct channels to be used during the analysis are defined, and the data channels are tested for open circuits, improperly placed leads, and noise artifacts. The background monitor detects and tallies arrhythmias and can provide, if desired, a continuous display of such frequently used parameters as average heart and respiration rates. This monitor continues independent of the major mode of the computer, i.e., the analytical program. Running-estimate programs can provide continuous output which is synchronous with the input. Examples of these programs include transformations of electrocardiogram (ECG) channels to form vectors, band-pass filtering of the phonocardiogram (PCG), and analysis of each carotid artery pulse as it occurs. Batch programs operate on a finite span of input data and do not necessarily produce an instantaneous result. These programs operate for a fixed time interval, providing answers after the fact. Examples include discrete Fourier transforms of large data arrays, multi-variate correlation, and estimation of indirectly measured parameters. The hypothetical diagnosis is made on the basis of the results of the previous programs.

The goal of the system's operation is the diagnosis of cardiovascular disease in the examination subject, with a confidence level equaling or exceeding that of an experienced cardiologist, and without the use of invasive techniques. To achieve this goal, the BBC will perform a sequence of quantitative steps, displaying intermediate results (as requested) to facilitate the skilled physician's own process of arriving at a diagnostic conclusion. In the hands of a medical technician, the machine will perform an independent statistical analysis of its verbal and objective input. When operated by an experienced physician, the BBC will have the capability to interact with the physician, incorporating his opinions in the diagnosis and supplying him with additional information beyond the technician's understanding.

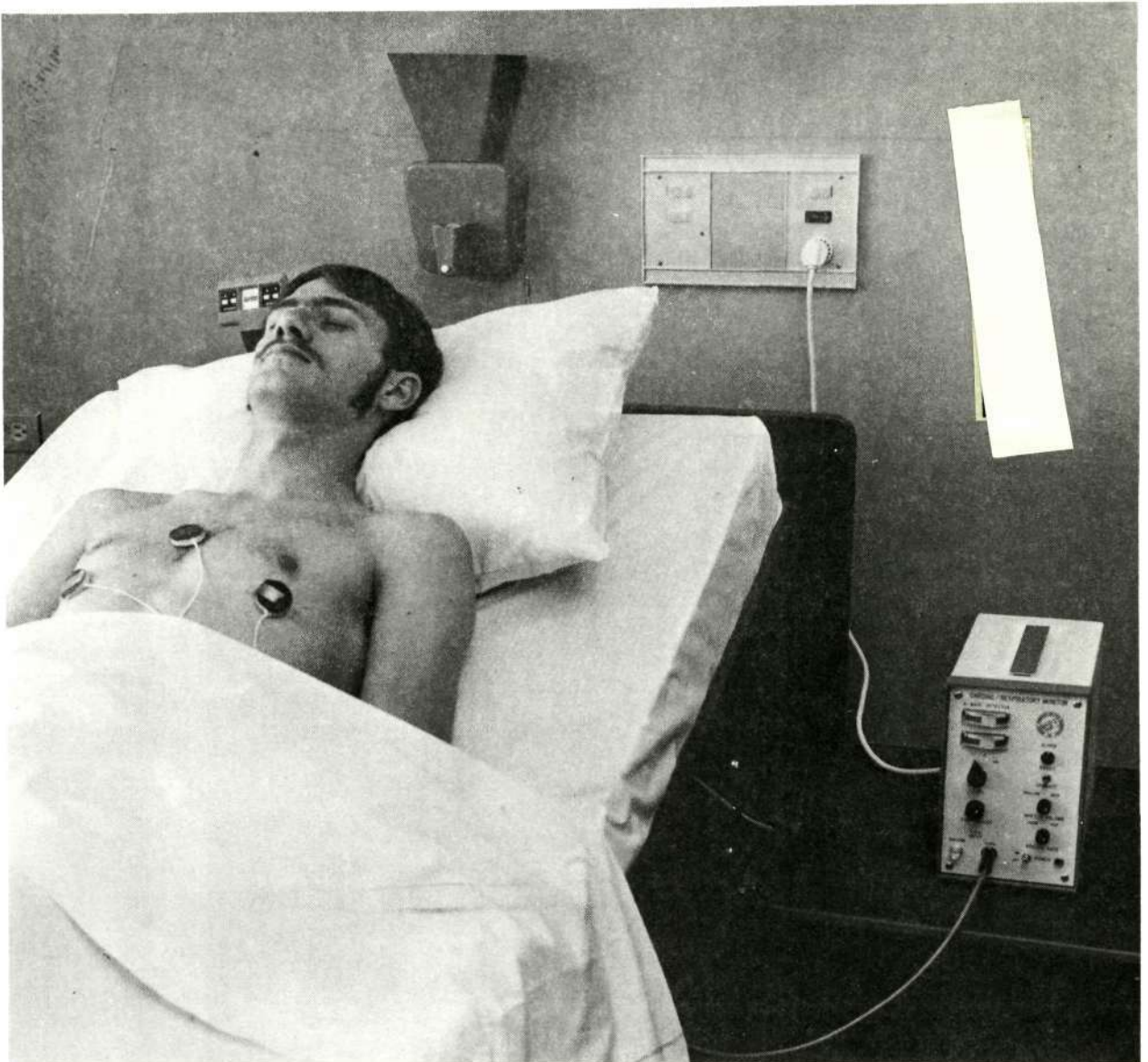


Figure 5. An Economical Vital Signs Monitor

**Economical Vital Signs Monitoring System for Use with Conventional Nurse Call Systems.** In response to a request from a major Southwestern Rehabilitation center, NASA has developed a prototype, an economical vital-sign monitoring system (Figure 5) for use in nursing homes and rehabilitation hospitals where high-risk patients are frequently found. Such an intensive care alarm system could alert patient care personnel when a high-risk patient's vital signs cease, so that immediate remedial action (e.g. external cardiac massage) could be taken to resuscitate the patient. Nursing homes and rehabilitation centers generally are not able to afford intensive care units featuring such alarms, due to high cost. A potentially economical, reliable and easy-to-operate alarm system which could be plugged into the existing outlet for the nurse-patient call system would be a valuable alternative to the more sophisticated intensive-care alarm system. It could be moved from location to location as needed.

The NASA system is based on a number of aerospace-related electronic physiological monitoring circuits which were applicable to this problem. Funds were provided by the Technology Utilization Program to fabricate a prototype of the cardiac/respiratory monitor for evaluation in the rehabilitation center. The device can monitor



the EKG signal and by proper placing of the electrodes, it can also monitor respiratory information. When either component of the signal exceeds prescribed bounds, the unit will give an alarm via the local nurse-call system installed in the institution.

The monitor consists of three sections: an EKG Signal Conditioner, an EKG/Respiration Signal Processor, and an Alarm Unit. The EKG Signal Conditioner receives the EKG signal via either leads placed on a subject or through the EKG Isolator. The latter is a device that provides electrical isolation of the subject from the monitor and other equipment. The level of the EKG signal is adjusted to permit proper operation of the processor circuitry. An output is provided for monitoring and recording of the EKG signal. The EKG/Respiration Signal Processor receives the EKG signal and continually adjusts itself to the amplitude of the R-wave of each cardiac cycle. With proper placement of the EKG electrodes, the baseline of the EKG signal varies with respiration and the processor will provide a signal dependent on the rate and depth of the subject's respiration. A change in the normal respiratory cycle or severe change in the EKG signal will be reflected in the output signal of the processor. The Alarm Unit will actuate an existing nurse-call system to give notice that some disturbance has taken place either with the equipment or the monitored functions of the subject. The unit will actuate the alarm relay as long as the signal from the Signal Processor exceeds certain predetermined limits. The Cardiac/Respiratory Monitor is portable and powered by 115 volts ac (available in all rooms of most hospitals or rehabilitation centers). An adapter can be provided easily to go from the output of the monitor to the input of the existing nurse call panel.

**Telemetry of Electrocardiograms (EKG).** Telemetry systems originally designed for monitoring the cardiac activity of astronauts and subjects under severe gravitational stress are now being widely used in civilian medicine. Researchers at Baylor College of Medicine requested NASA assistance in developing a nonencumbering device (Figure 6) for telemetering the EKG signals of cardiac transplant patients during convalescence. While excellent instrumentation for monitoring such patients' cardiac activity is available during the post-operative

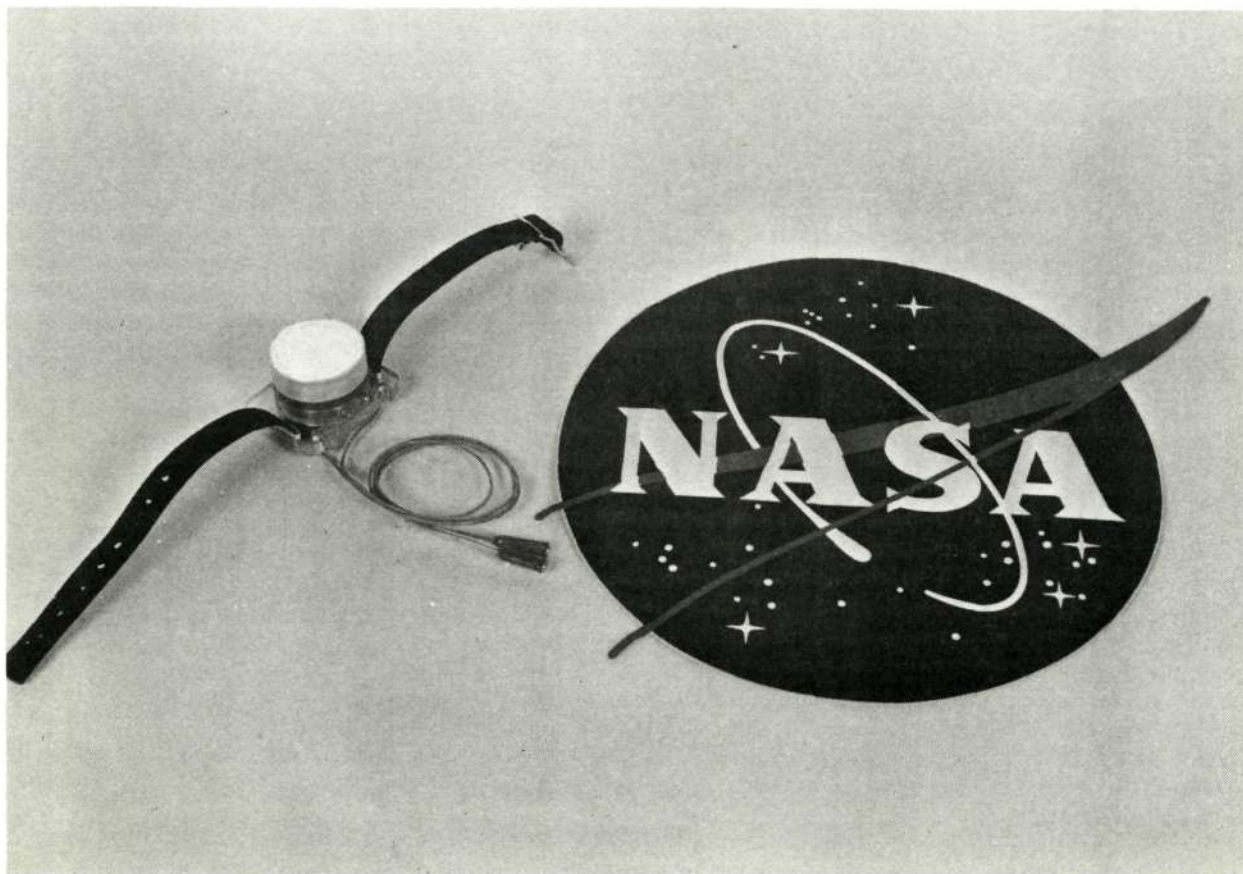


Figure 6. Wristwatch Size EKG Telemetry Transmitter

period in well-equipped coronary care units there was no adequate system for monitoring the patients during convalescence, when carefully controlled activity and stress was introduced. The researchers wanted a small nonencumbering device, similar in size and configuration to a wrist watch, that could be worn by the transplant patient as he pursued daily activities during convalescence—with the device accurately transmitting the EKG signals. Such information permits precise monitoring of cardiac activity under the controlled activity and stress conditions characterizing the convalescent period and can signal onset of the rejection phenomenon in heart-transplant cases.

Minor modification of the NASA technology used in several other monitoring systems produced the telemetry system required by the Baylor researchers.

The prototype was built with Baylor funds, successfully field tested, and forwarded to Baylor Medical School for clinical evaluation. The device is useful not only for monitoring cardiac activity for transplant patients, but also for other cardiac patients. The small size and convenience of wearing it on the wrist like a watch minimizes patient discomfort. Long-term application EKG electrodes developed at NASA Ames are also being evaluated as an additional component of the system.

The same circuit is now also being used in a cardiac rehabilitation program. Frequently patients have been conditioned into inactivity during the early recovery phase from cardiovascular disorders in order to avoid additional strain on the myocardium. Psychological rehabilitation and physiological rehabilitation is needed for a healthy myocardium and a healthy attitude. A planned exercise program fits these criteria.

The physician sought to monitor heart rate and the electrocardiogram waveform from his exercising cardiac patients. Commercially available units did not have adequate low-frequency response to provide the required accuracy of detail in the "S-T" segment readouts. The NASA unit has proven highly satisfactory.

The superior resolution of the NASA circuit enables the patient to be warned as changes in the "S-T" segment indicate the patient is reaching his fatigue limit. Thus, the patient can be maximally exercised, yet warned before he overexerts himself.

**Improved Instrument for External Recording of Arterial Pulse Waves.** A transducer developed at NASA's Goddard Space Flight Center to record arterial pulse pressure waves externally is now being evaluated at the Veterans Administration Hospital in Washington, D.C. It is anticipated that this device will allow physicians to non-invasively evaluate the functional status of the major arteries in atherosclerosis patients.

This transducer, basically a Pitran displacement pressure transducer, has both high-sensitivity and good low-frequency response. Although displacement-pressure measurements of the carotid artery do not replicate the pulse shape as measured by an intra-arterial catheter, these measurements do contain clinically useful information. Permanent records can be made quickly and without penetration of the skin or discomfort to the patient. Although previously available displacement pressure transducers gave satisfactory measurements, they were difficult to economically produce because of their mechanical complexity. The simpler design of the NASA transducer should provide a more clinically acceptable instrument.

The transducer is currently being used in a Hypertension Study Program at the Washington VA Hospital. The data acquired will be used to determine the relative elasticity of each patient's carotid artery and the responsiveness of his pulmonary system to injected sedatives. The effectiveness of the device will also be compared with a currently available system that costs approximately 10 times as much as the new NASA design.

**Accurate Determination of Arterial Pressure Pulse Transit Time.** A unique pressure generator system developed at NASA Ames Research Center eliminates the distortion present in conventional methods of measuring the arterial pulse-wave velocity. Such a measurement would be quite useful in accurately determining the extent of atherosclerotic disease.

The volume elasticity of blood vessels is an important parameter in the evaluation of total cardiovascular function. Knowledge of this parameter is necessary for formulating a meaningful model of the behavior of the cardiovascular system in a variety of states of health and disease. For example, atherosclerotic disease is known to change arterial elasticity or distensibility by changing the composition of the arterial wall. The velocity of the arterial pressure pulse wave is roughly proportional to the inverse of arterial distensibility. Therefore, changes in arterial distensibility will produce changes in arterial pulse-wave velocity.

A researcher involved in a project to establish a relationship between the extent of atherosclerotic disease as determined by conventional histo-pathological grading and changes in pulse-wave propagation velocity—which is potentially a non-invasive technique—queried NASA as to its work in this area. Conventional methods of determining arterial blood vessel elasticity yield only approximate results. Also, conventional techniques require a small section of the blood vessel to be removed in order to subject the vessel to pressure changes. The volume elasticity is computed from the rate at which the pressure changes in response to a change in vascular volume. Because of the relationship between arterial elasticity and arterial pulse-wave velocity, researchers believe that accurate measurement of pulse-wave propagation velocity in arteries will provide information related to the arterial blood vessel elasticity that is, in turn, related to the amount of atherosclerotic disease present.

As noted, conventional methods for determining arterial pulse-wave transmission are unsatisfactory because of the distortion of the pulse wave as it travels from the heart to the extremities. Distortion may occur (1) along the artery where a significant change in vessel wall composition occurs (such as severe aortic atherosclerosis), (2) at vessel bifurcations, or (3) at terminal arteriolar vascular beds where reflection of the pulse wave occurs. The process of wave reflection accounts for a major part of wave distortion and occurs when part of the energy imparted to the blood by the heart is actually reflected (bounced back) toward the heart. When this happens, the reflected wave adds to the actual wave transmitted by the heart and forms a third wave. Neither the reflected wave nor the actual pulse wave transmitted by the heart can be measured directly; what is measured appears to be a combination of the two. Generally, the closer to the reflection site blood pressure is measured, the greater the amount of reflection and distortion. Reflection of pulse waves appears to provide one explanation for the observation that systolic blood pressure is greater in the peripheral vessels than in the aorta because in the periphery one is nearer the sites of reflections.

In 1968 a unique pressure-generator system was designed at the NASA Ames Research Center and Stanford University. This pressure-generator system eliminated the distortion present in conventional methods of measuring pulse-wave velocity. The system now consists of two fundamental components: (1) a pressure-wave generator, and (2) a thin catheter on which is mounted two pressure transducers separated by a fixed distance (about 10-15 cm). The pressure-wave generator operates to produce a burst of sine waves that superimpose on the naturally-occurring pressure pulse. The superimposed sine waves are higher in frequency than the naturally-occurring pressure pulse (usually 40 to 100 hertz; the natural pulse is 1 to 3 hertz) and travel along with the pressure pulse. There is little difficulty in detecting the superimposed pulses. Because they are higher in frequency, their energy is dissipated in a much shorter distance. Consequently, little or no energy is available for reflections. This eliminates the distortion problems associated with measuring the natural pulse. The time relationship of a train of sine waves measured simultaneously at two sites provides information related to the pulse-wave velocity within the vessel segment under examination.

This method of superimposing a high-frequency, sinusoidal pressure oscillation of the naturally-occurring arterial pressure pulse for the purpose of examining quantitatively the elastic behavior of the cardiovascular system in health and disease appears unique. No such system is available commercially. The technique has proved to be useful in characterizing the elastic behavior of blood vessels in healthy dogs and it should be even more important in the same capacity for evaluating diseased sub-human primates. The application of the technique for identifying non-invasively the extensiveness of atherosclerotic disease in humans also appears to be practical and scientifically sound.

**Visual Presentation of the Heart's Electrical Activity.** A graphic three-dimensional model of the heart's electrical activity—based on aerospace modeling techniques—is now being developed which should provide a means for early detection of small areas of damaged heart muscle. Body surface mapping, using as many as 40 electrodes to simultaneously record the heart's electrical activity from various points on the chest surface, has been demonstrated as a potential means for early detection of damaged heart areas. Unlike traditional EKG's, body-surface mapping also allows for measurement of the size of the area which is damaged. Three-dimensional computer-based graphic models, originally developed at NASA's Ames Research Center to study air-flow characteristics of aircraft, will be used to develop a graphic three-dimensional model based on the body-surface map of the electrocardiogram.

Myocardial infarctions—heart attacks—account for the majority of heart-disease related death. Early diagnosis and treatment of heart disease has not been widely attained. A graphic display of the mapped body-surface potentials would provide a means for detecting the presence of small areas of infarction which previously might have been missed. By detecting such deterioration at an early stage, preventive measures could be taken to reduce

the possibilities of heart attacks. Precise measurement of the size of the damaged area would allow a physician to determine the efficacy of a treatment regimen and could lead to improvements in treatment techniques. A more accurate indication of the extent of damage would also allow a more realistic prediction of the amount of exercise and stress a cardiac patient could tolerate.

The availability to the physician of an easily interpreted physical model would be invaluable as a teaching device and might also be used for screening large numbers of patients in clinics and hospitals.

The recording of 40 electrode body-surface potentials is being performed by the Rancho Los Amigos Hospital in Downey, California under NASA contract. Records will be obtained from both normal patients and patients with varying types and degrees of heart disease. Those records will then form the basis for the development of a three-dimensional electrical model of the heart's electrical activity. The model will then be used to create a graphic image display in order to present changes in the data in a form that is easily identified and classified.

**Mechanical Stresses in Aortic Valves.** Close range stereophotogrammetry (precision stereo mapping) techniques used by NASA are now being used to study artificial aortic valves.

With the development of advanced fiber and composite-material knowledge and technology through the National Aeronautics and Space Administration programs and the advancements made in the blood-prosthetic surface interface research under the auspices of the Artificial Heart Program of the National Institutes of Health, the fundamental keystones have been laid for the development of a tri-leaflet prosthetic heart valve.

It is desirable to fabricate an artificial aortic valve for a human heart which duplicates the mechanics of the normal valve. The normal aortic valve is composed of three leaflets which come together to close a circular opening. The leaflets are flexible; they flap open and closed on each heartbeat, nearly 40 million times/year. To design and evaluate a prosthetic tri-leaflet valve which can withstand many years of complex flexure, the dynamic stress-strain relationship must be known. The leaflet motion will be photographed at various flow pressures and velocities. The record of the valve motion will then be put in computer format for further evaluation. This data will enable engineers to specify design changes intended both to strengthen the areas of the leaflet subject to the greatest stresses and to minimize the turbulence of the flow through the valve.

It is anticipated that about 30 molds or 90 leaflets should be mapped to provide a statistical range of information. Work is continuing on schedule; the data acquisition and reduction systems are now nearly complete. The complete systems should be operational by the fall of 1972.

**Quantization of Heart Tissue Hardness.** Post-mortem examinations of various organs of the human body reveal not only the cause of death. They also often show other conditions that were affecting the person at the time of death. Research at Tulane's School of Medicine, for example, has shown unusual softening of the heart tissue in some patients who did not die of heart disease. The cause of this unusual softening is not known but a number of factors have been considered significant. There seems to be a critical time period between the appearance of an infarction and a definite softness in the heart tissue. Reasons for this are being studied in experimental work, using rats whose blood is temporarily cut off from portions of the heart in order to determine changes in the heart tissue. Studies to determine whether this soft region can be attributed to any known condition in the human patient prior to death are also being conducted. But an accurate means of measuring softness of the heart tissue is needed. The use of a conventional eye tonometer for this purpose has not been successful because the results were not reproducible.

A computer search of the NASA data bank for Tulane turned up experiments and development work conducted at the Marshall Space Flight Center (MSFC) on a variety of hardness-testing techniques which appear to be applicable to the problem. A number of techniques in current use at MSFC were found to be applicable.

NASA personnel indicated the type of instrument required for hardness testing. They also outlined the procedures necessary to obtain reproducible results. This information was then provided to a researcher at Tulane's School of Medicine who incorporated the suggestions in his testing procedures. The researcher has also determined the need for a tester for small areas and a manufacturer has fabricated a special instrument according to his specifications to allow the testing of very soft, small regions. The results of this experiment are expected to add considerably to present knowledge of the effects of stress and physical trauma.

**Optical Studies of Cardiac Muscle Excitation-Contraction.** A laser-modulating system developed by NASA is now being used in cardiac-muscle contraction studies at the Stanford University School of Medicine.

Stanford has been conducting studies to further define the action mechanisms of numerous drugs used to treat heart failure. Researchers were particularly interested in these drugs' effects on the strength of contraction and on excitation-contraction coupling. In earlier studies, they had observed changes in the optical properties of nerve tissue and skeletal muscles during excitation and contraction. Although these earlier studies had involved rather large segments of cardiac muscle and an intense quartz-iodine light source, a ten-stage photoamplifier and a computer of average transients had been required to detect changes in the reflected light. The new series of studies required the use of smaller cardiac-muscle segments and a different light source and detector was needed.

In consultation with NASA's Ames Research Center, researchers determined that a helium-neon gas hose would provide the needed light in a beam no larger than 0.5 mm in diameter. Coupled with a laser-modulator system, the detecting system would meet the requirement of resolving changes of the order of  $10^{-3}$  to  $10^{-4}$  of the resting-light intensity.

The required laser has been purchased by Stanford and NASA has loaned them a laser-modulator system previously used in a hydrocarbon detector. It is anticipated that these optical studies of cardiac muscle will provide new information about the effects of various drugs on the excitation-contraction phenomenon.

**Bonding of Metal to Ceramic for Artificial Heart Energy Sources.** Ideally, a practical prosthetic heart system should be totally implantable, i.e., all its parts should be contained within the body. To satisfy the many physical and physiological requirements that must be met to realize a compatible, safe, and reliable system for long-term use, the artificial heart must exceed the stringent design and functional requirements demanded of high-performance aerospace systems.

An unanswered need in artificial-heart development is the proper bonding method for the energy-conversion system used to carry out the pumping function of the heart. A stack of piezoelectric disks with interspaced electrodes is a leading candidate for the energy-conversion task. Upon the application of an electric field across the stack, each disk lengthens axially. The net result is an additive linear movement in the axial direction of the stack. This force powers the blood pump.

An engineer at NASA's Langley Research Center suggested two bonding techniques. One employed epoxy. The other made use of mechanical loading. These techniques were evaluated by the National Heart and Lung Institute and the NHLI contractor who was investigating the piezoelectric stack concept. The epoxy bond appeared promising. Following the engineer's advice, the NHLI fabricated a piezoelectric stack. This stack has good mechanical, as well as electrical, properties and appears to meet the requirements for use as an energy conversion system in the artificial heart. The epoxy bonded piezoelectric stack has now become an integral part of the artificial heart program.

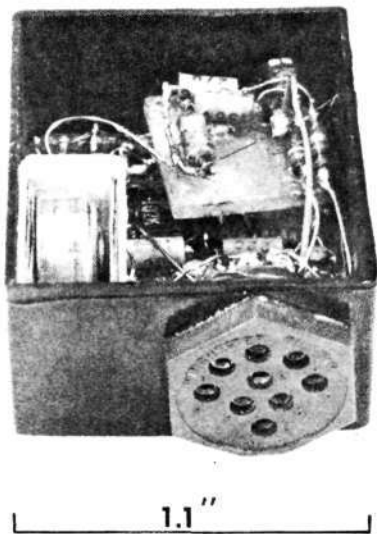
## **MEDICAL INSTRUMENTATION: MISCELLANEOUS**

**Intracranial Pressure Measurement System.** NASA is providing assistance in the development of an improved technique for continuous monitoring of the intracranial pressure, e.g. fluid pressure within the skull. The new technique will permit continuous telemetry of the required data without encumbering the patient with hardwire hookups to the monitoring instrumentation.

Injury to the brain as a result of head trauma results in swelling and increased intracranial pressure which reduces the perfusing blood flow to these delicate tissues. This can lead to inadequate oxygenation and cell death. Drugs are available to reduce intracranial pressure buildup by causing water to be drawn out of the brain into the circulatory system. But a quantitative guide is needed to indicate when to give the drugs and to assess their effects in terms of reducing intracranial pressure.

Conventionally, a pressure transducer, mounted through a burr hole drilled through the skull, is used to monitor pressure of the cerebrospinal fluid in such patients. The conventional transducer assembly is connected to the electronics and recording system via wires. The connection to the skull can serve as a path for infection, particularly when stress is inadvertently applied to the wires during routine care of the patient. The encumbering wires must be relatively short and the associated equipment, therefore, must be close to the patient.





Early prototype of an intracranial pressure transducer telemetry system.

Figure 7. Intracranial Pressure Measurement System

A medical researcher sought a telemetry system which would eliminate the problems caused by the hardwire connection. A computer search of the NASA aerospace data bank located a NASA Tech Brief (TB66-10624) that provided the kind of circuitry needed. A prototype of the device has been constructed. While the present prototype (Figure 7) occupies roughly 1 cubic inch, further miniaturization is easily possible. Laboratory tests conducted with the prototype thus far have been successful. The device will be delivered to the problem originator in July 1972.

**Beta-Radiation Catheter Probe to Monitor Cerebral Blood Flow.** Physicians need an improved method of continuously monitoring the cerebral blood flow of head-injury patients over long periods. Present techniques require inhalation of a radioisotope and the frequent withdrawal of many blood samples for analysis to determine arteriovenous concentrations of the isotope. The current technique produces patient discomfort and requires cumbersome equipment which must be maintained in a sterile condition. Also, there are few data points for assessing the blood flow.

NASA had developed a semiconductor radiation probe capable of continuously monitoring blood flow by detection of weak beta-radiation from the isotope. The device can be mounted in a small double lumen (channel) catheter, making it easy to insert at the proper point in the bloodstream. The probe (Figure 8) has a low signal-to-noise ratio and provides good measurement of the spatial and energy distributions of radiated electrons and protons. The use of this probe will enable the physician to continuously obtain data. One catheter-mounted probe can be placed in the carotid artery to monitor the isotope concentration in the blood being supplied to the cerebral area. (A lumen located near the tip of the radiation probe allows a blood sample to be taken for blood-gas analysis). A second catheter-mounted probe with appropriate lumen can be placed in the jugular vein to get a similar measurement on blood flowing from the cerebral area. From the data collected at these two points the cerebral blood flow can be determined. The blood-flow data gives information relative to the extent of head injuries, progress towards recovery, and effectiveness of therapy.

The radiation probes are being mounted in suitable catheters by the Southwest Research Institute which will also provide the investigator with the necessary electronic interfacing devices.

The detector element is delicate and must be handled with care. It may be necessary to develop a catheter-tip-mounted protective hood. However, several successful feasibility demonstrations have been performed with experimental animals. Additional prototype instruments will be fabricated for the researcher.



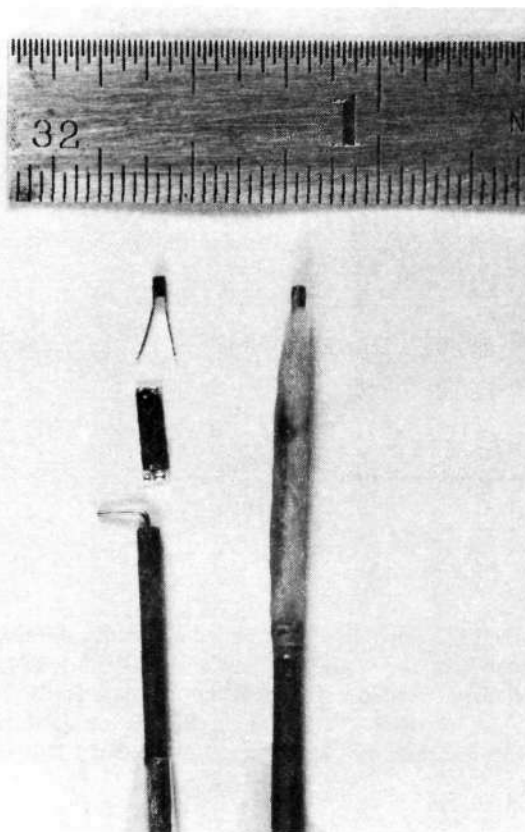
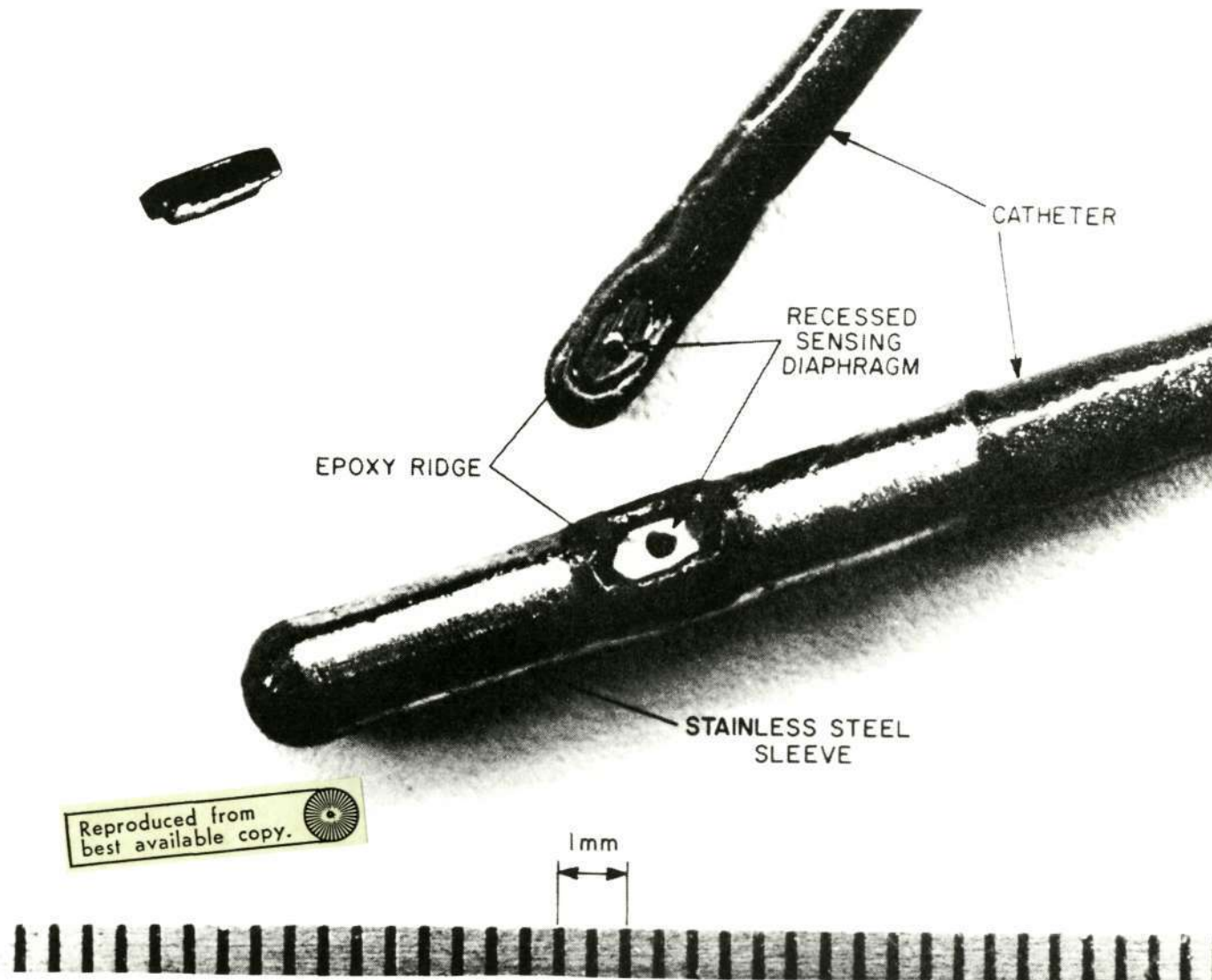


Figure 8. An Exploded View of the Beta-Radiation Catheter Probe

**Tunnel Diode Transducer Used as a Biomedical Sensor.** The human body is dependent on several fluid transport systems for moving nutrients, gas, enzymes, hormones, and wastes from one part of the body to another. Blockage or excessive pressure within one of the fluid transport systems can result in various pathological conditions. Diagnosis and determination of proper therapy could be improved by a small pressure transducer (diameter less than 1 mm) with the proper sensitivity and range. Inserted into a vein or artery, or any of the other fluid-transport systems, it would be valuable in assessing the condition of the circulatory, cerebrospinal, lymphatic and urinary systems. A NASA-developed pressure sensor (Figure 9) is being put to work on this task.

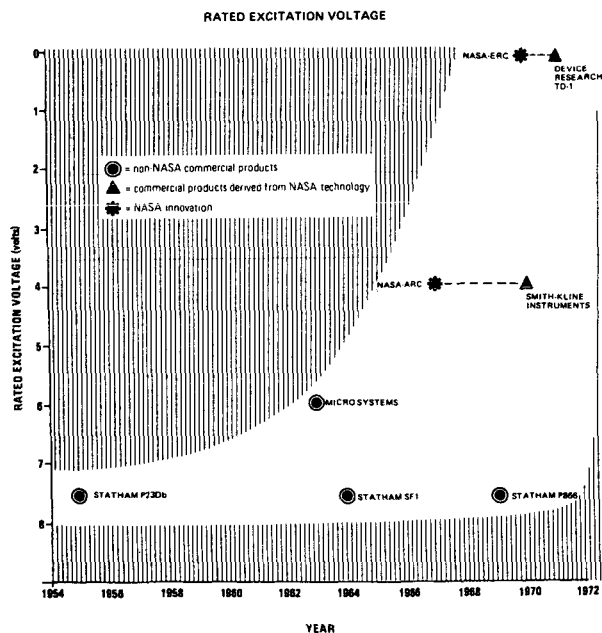
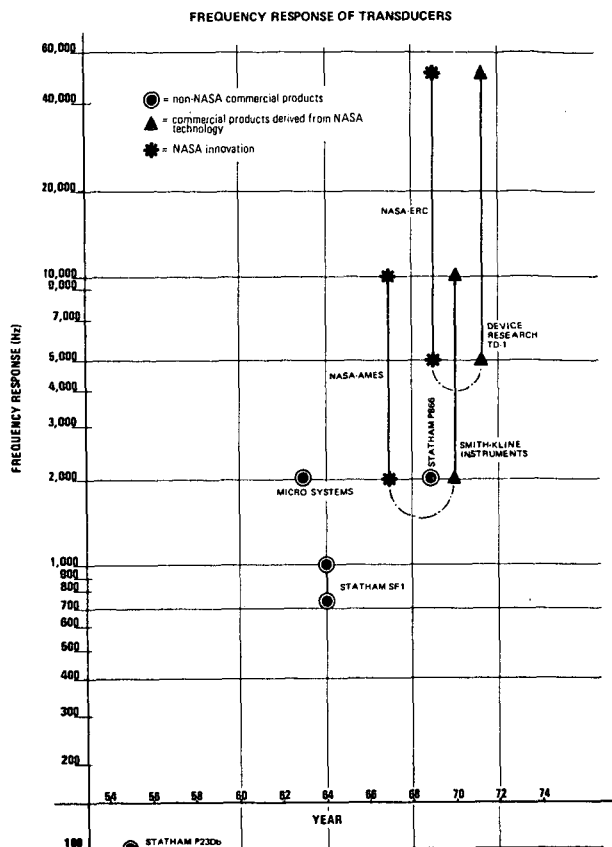
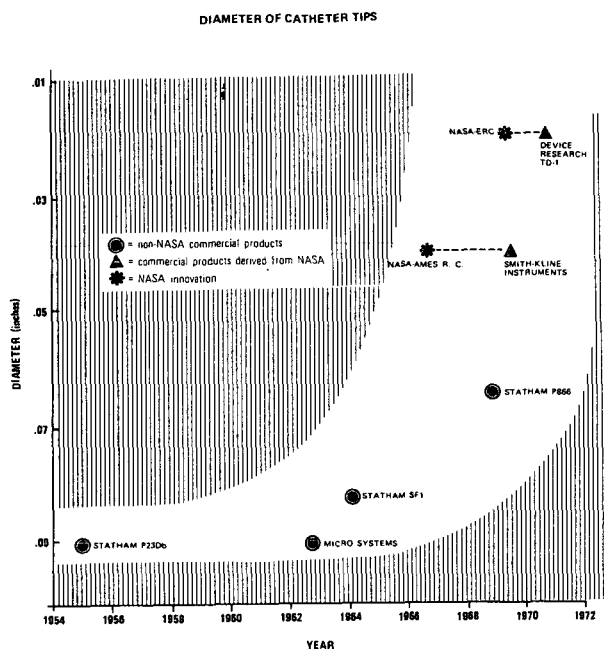
New semiconductor fabrication techniques were utilized for a transducer with resolution of greater than 0.1 mm Hg with an overall diameter of less than 1 mm and low power requirements. The device has been designed, fabricated and tested. Through Device Research, Inc. the transducer is available commercially. The frequency response of this device is flat to greater than 4,000 Hz.

The high-frequency response allows the detection of high-frequency heart and valve sounds and permits more accurate measurement of introvascular and intracardiac blood-pressure waveforms. Mounted on the tip of 100 cm catheters, the pressure transducer can be introduced into an artery or vein through a standard 17-gauge thin-wall needle (ID=1.1 mm), a size routinely used for humans. It will probably replace techniques which use fluid-filled catheters for measuring ventricular heart pressures and those procedures which require cutdowns on arteries for the insertion of the catheter. Measurement techniques currently in wide use employ a fluid-filled catheter to transmit internal pressures to external transducers. These are subject to distortion and error introduced by the long fluid column through which the pressure pulse must propagate before being measured. The improved device



The tunnel diode pressure transducer was originally developed by NASA/Electronics Research Center and is now commercially available.

Figure 9. Tunnel Diode Pressure Transducer



Tunnel diode pressure transducer developed by NASA Electronic Research Center represents a significant advance in the state-of-the-art. Its smaller diameter, high resolution (0.5 mm Hg), broad frequency response, low excitation voltage, and controlled thermal zero shift should improve the quality of data available to physicians and researchers in studies of the cardiovascular, cerebrospinal fluid, and urinary systems.

Figure 10. Characteristics of Miniature Pressure Transducers

will allow physicians to obtain a more accurate indication of the intracardiac pressure while reducing risk to the patient. Figure 10 illustrates comparative characteristics of the tunnel diode transducer and other commercially available transducers.

Three pressure transducer systems have been made available to medical researchers who have expressed interest in such a device. It is currently being used in studies on an artificial heart, pediatric cardiology and myocardial physiology.

The National Heart and Lung Institute has used the tunnel diode transducer to measure directional stresses within the myocardium (heart muscle) of a calf. The researchers have been able to obtain data which were never before measurable by recording hydrostatic pressure. The measured myocardial stresses are found to vary under conditions such as a local infarction and various drugs. Although these studies began only recently, the early results are quite promising. A paper describing the device and several of its applications was presented at the 1972 meeting of the Association for the Advancement of Medical Instrumentation.

**Fluidic Respiratory Flowmeter.** The continuous accurate measurement of respiratory air flow, still a difficult problem, would be useful for both clinical evaluation and physiological research. Currently, no economical air-flow measurement system is available that functions adequately for more than a few minutes at a time. Present systems are either quite sensitive to the moisture contained in respired air or they impose a significant load on the patient's respiratory system. While an ultrasonic flowmeter is now commercially available, it is sensitive to changes in gas composition and its cost is prohibitive for widespread use.

NASA is presently supporting the development of a fluidic respiratory flowmeter based on a NASA-designed fluidic air-speed sensor. It is anticipated that the device will be insensitive to the amount of moisture contained in expired air and will impose a relatively small load on the patient breathing through it. This fluidic respirometer will be compatible with a miniature mass-spectrometer, also described in this report, that will enable a physician to study both respiratory patterns and the gas-exchange characteristics of the lungs.

**Measurement of Respiratory Function of Free Moving Children.** Respiratory diseases are the major cause of illness in children from infancy through adolescence. Some of the more serious respiratory diseases are asthma, cystic fibrosis, and bronchitis. A great deal of research is presently being conducted into the causes, diagnosis, and cures of respiratory diseases.

One valuable index for diagnosing lung disease in children is their respiratory pattern while engaged in quiet play. If this rate is studied for the same patient over a period of months, much information can be gained about the condition and changes in condition of the patient's lung. The respiration pattern is important because it is directly related to lungs; the body will adjust to the disease by breathing more shallowly and more rapidly. In the case of asthma, a disease which restricts the airflow, the patient will breathe more slowly and more deeply.

A physician at a southern medical school was conducting a study of respiratory patients ranging in age from infancy to adolescence. It was necessary that the pattern-measurement method would not encumber the child so that he would be free to engage in quiet play. It was also desired that the data be transmitted to signal processing equipment by a small unit attached to the child. The respiration rates ranged from 12-80 breaths per minute, and precision and accuracy of 0.1 breaths per minute was required.

The physician posed the problem to the Manned Spacecraft Center (MSC). MSC personnel suggested the use of the Gemini impedance pneumograph (ZPN), which was available. The impedance pneumograph was designed by NASA to measure respiration rate and respiratory volume during a manned space flight. Although the unit had been slightly modified for the Apollo missions, the Gemini equipment appeared capable of solving the stated problem. A search of the commercial literature determined that, although certain commercial impedance pneumography equipment was available, none was as small as the NASA equipment.

The Gemini ZPN was obtained to test its suitability. When these tests proved satisfactory, it was decided to implement the telemetry portion of the problem with commercial telemetry equipment. During the preliminary tests it was determined that not only was respiration-rate information available, but also that the clean waveforms produced by the impedance pneumograph allowed both inspiratory and expiratory times to be determined.



This signal conditioner allows a physician to record a patient's respiratory rate, inspiratory and expiratory times while permitting the patient to move about freely and unimpaired.

Figure 11. Impedance Pneumograph Signal Conditioner

The impedance pneumograph was mated with a commercial telemetry system in a breadboard model. Initial tests on this system allowed the subject a range up to 40 feet from the antenna, and a multiple-antenna system was installed which allowed the children to roam freely throughout the clinic area. The unit has now been packaged into a small final unit that will facilitate clinical use (Figure 11).

This application of technology will enable the Problem Originator to obtain valuable clinical information on the respiratory patterns of children who are moving freely and unimpaired in a quiet play environment. This information can be used both for diagnostic purposes and for obtaining baseline information on respiratory rates of small children. Baseline information previously obtained is believed inaccurate because the act of taking the respiratory rate modified involuntary respiration. The Problem Originator intends to publish the results from his experiments so that they will be available to the medical community.

**Lung-Sound Detection.** A new method for studying respiratory diseases in children utilizes a technique that was originally developed to analyze sounds and vibrations of aircraft engines. It is being applied in the study of respiratory ailments.

The major illness in children from infancy through adolescence is respiratory disease. Serious forms include asthma, cystic fibrosis, and bronchitis. Significant research is being conducted in both the causes and cures of respiratory diseases. The search continues for better methods of diagnosis.

One useful and simple method to determine whether a portion of the lung is performing properly is to listen to the sounds made by the airflow inside the lungs. This is usually done with a stethoscope. But only one section of the lung can be heard at a time with that technique. To compare sections of the lung, it would be useful if the sounds generated by a section of the lung could be checked against sounds generated by the symmetrical counterpart in the other lung. The problem is to detect the sounds from two sections of the chest wall by microphones and to display the sounds graphically. Comparisons could then be made on the amplitude, frequency, and time interval between the appearance of the two sounds.

Using a pressure microphone attached to an amplification system, the aerospace-derived new instrumentation allows measurement of the intensity of respiratory sounds of the sound envelope for comparisons of homologous portions of each lung. This is accomplished by providing a dual channel sensing and amplifying system that integrates the sound information and displays only the intensity of the sound in each channel as a function of time (Figure 12). A stereo headphone assures the physician that he is recording artifact-free sound. The information is displayed on a strip-chart recorder or a storage oscilloscope. Using the relative intensity and phase



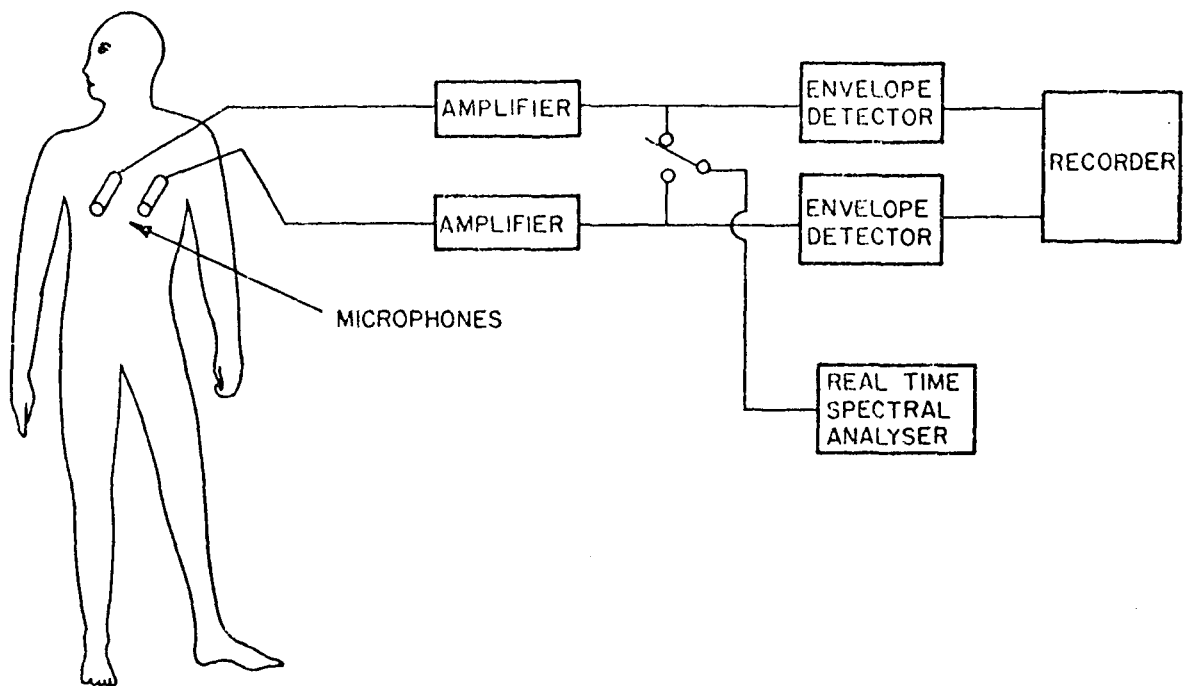


Figure 12. Block Diagram of Lung Sound Analysis System

relationship of the sound between homologous portions of the lung, it is possible to determine regions of local airflow obstruction with a precision greater than what is attainable with the conventional stethoscope. Preliminary data indicates that in normal children, homologous segments of both lungs transmit essentially the same respiratory sound-pressure levels (55-60 dB with moderately deep breaths). Peak sound is achieved early in inspiration, and expiration is relatively soundless (30-40 dB). Children with bronchitis, asthma, or cystic fibrosis may show transient or persistent sound-pressure differences between homologous segments. Also expiratory sound may increase. Rales can be identified by characteristic changes in the sound-envelope pattern. This part of the system is now being used clinically on a routine basis.

In the second part of the system, the sounds are presented to a real-time spectrum analyzer and averager combination. This allows both instantaneous and time-averaged analysis of the frequency content of sounds over the range of 10 to 10,000 Hz. An optional 300 Hz high-pass filter can be utilized to remove the low-frequency heart sound and reduce background noise. Respiratory sound-pressure levels in normal pediatric patients range from 30 to 60 dB over the frequency range of 10 to 1,000 Hz. Above 1,000 Hz, the sound pressure level is below 40 dB.

Using the sound-intensity apparatus and a pneumotachometer, the real-time relationship between respiratory sounds and flow rate has been studied. This real-time analysis has confirmed the results of earlier studies showing a linear relationship between sound intensity and air-flow rate.

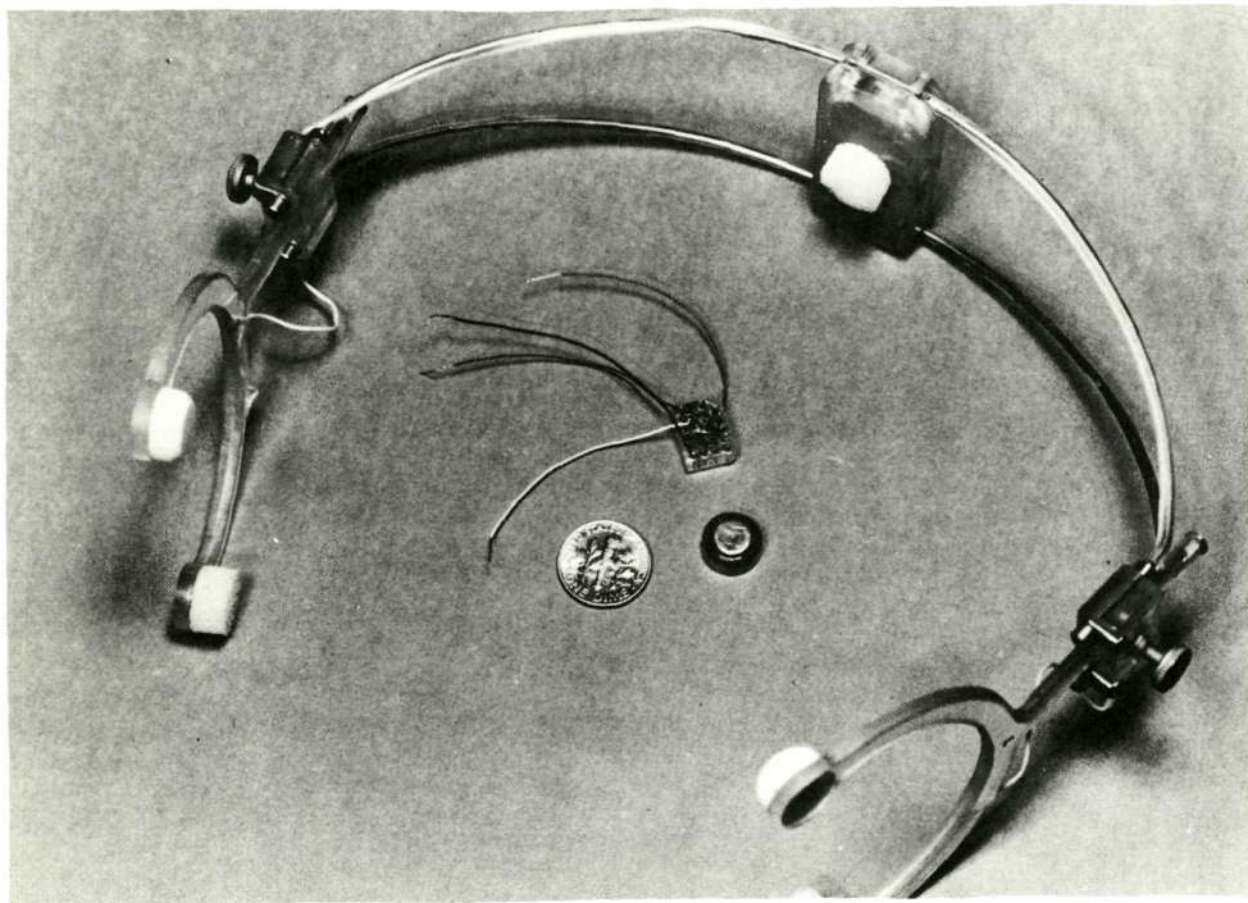
The NASA contractor supplying the spectral-analysis equipment is providing the physician with a spectral analyzer specifically configured for respiratory analysis. In return, the physician will provide the medical consultation necessary to develop this new product. This significant technology application will result in a new diagnostic tool of particular importance in the pediatric field for detection of asthma, cystic fibrosis, and bronchitis. The equipment has been delivered to the investigator and early results are quite promising. A paper on this project will be presented at the 1972 Annual Conference on Engineering in Biology and Medicine.

**Gastrointestinal Electrical Potentials Detected Using Ultra-Low Frequency Bandpass Amplifier.** NASA technology is being applied to studies of gastrointestinal disorders. There is reason to believe that electrical potentials generated by the smooth musculature of the gastrointestinal tract can be useful in diagnosis of gastrointestinal disease. Researchers at the University of Alabama Medical Center are engaged in a large-scale research program designed to investigate possible correlations between various gastrointestinal disease states and electrical potential phenomena centered in the gastrointestinal tract. To date, such potentials have been related clinically to such states as hypothyroidism, hyperthyroidism, and level of morphine ingestion.

Research had been hampered by the nonavailability of a suitable, economical ultra-low frequency bandpass amplifier. Commercially available instruments, having an excess range in filtering and gain, tend to be very costly. A device which provided appropriate signal conditioning in the specific area of interest was needed. A search by the NASA data bank revealed that NASA's Ames Research Center had developed for physiological research a tunable bandpass filter with variable selectivity. The basic circuits were obtained for use in fabricating a stable, active RC bandpass filter having continuously variable noninteracting control of center frequency, Q, and center frequency gain. It was capable of providing reliable signal conditioning for the special application described above. The device has been built and is now being used in an active research program.

**Brain-Wave Sensor as Diagnostic Aid.** A brain-wave [electroencephalograph (EEG)] sensor and radio transmitter system, developed for space medical research with test pilots, may lead to major improvements in diagnosis and treatment of schizophrenic mental patients. Scientists at NASA's Ames Research Center and at Agnews State Hospital, a mental hospital of the California Department of Mental Hygiene, are working together on the system. It is comprised of a radio-sensor system with a computer. The new method is under clinical test on mental patients at Agnews Hospital and has shown good preliminary results. Although advances in modern drugs have greatly improved the treatment of many emotionally disturbed individuals, there may be a subgroup of schizophrenics for whom nondrug therapy is better. The problem has been to distinguish these individuals from those for whom drugs are more appropriate.

The headset installed EEG radio-sensor system (Figure 13) is light and comfortable and does not frighten disturbed patients. The diagnostic method is based on research in patient brain-wave responses to light stimuli.



Headpiece with electronics module and battery removed, showing two paralleled mastoid electrodes, single vertex electrode, and two temple pads.

Figure 13. EEG Telemetry Headband

For diagnosis, the patient is fitted with the comfortable, wire-free headset and seated in a darkened isolation room. He watches light flashes of varying intensity, and his responses are then radioed to the computer for analysis. The technique uses differences between a patient's brain-wave responses to a series of light flashes as a way of distinguishing between various types of behavior disorders.

Because of the advantages of this system, doctors believe they can use it to distinguish between schizophrenics needing immediate large doses of tranquilizing drugs and those patients who can be treated without drugs. (M. Rappaport, J. Silverman, H.K. Hopkins and K. Hall. Phenothiazine Effects on Auditory Signal Detection in Paranoid and Non-Paranoid Schizophrenics, *Science*, vol. 174, 12 Nov., 1971. p. 723-725.)

Past diagnostic methods using brain-waves have required the insertion of needle electrodes under the scalp, or shaving of a portion of the scalp for electrode contact. With seriously disturbed schizophrenic patients, these disquieting procedures—required immediately on admission to the hospital—usually were not possible. The Ames-developed system, however, employs only a headset consisting of a light wire clip fitted with two small electrodes which sense brain-waves with no scalp preparation. The headset also carries a tiny battery-powered radio transmitter to broadcast the brain signals to the computer for analysis. Because data is radioed, the absence of wires prevents undue anxiety about shock therapy by some disturbed patients who have either undergone or fear such treatment. The allaying of such fears is important for good, early diagnostic work.

The 1.22 cubic centimeter, 1.0 milliwatt, high-performance transmitter has low internal noise and high sensitivity and works from a single aspirin-tablet-sized mercury battery. The sensors consist of a silver chloride pellet coated with electrode paste—in contact with a sponge wetted with saline solution. The brain's reaction patterns to the light signals are tiny, brief and mingled with the constant massive flow of other brain-wave signals. However, a computer program has been developed to filter out these tiny electric signals.

The radio-sensor system has promise for other uses too. Patients could wear the headsets in their wards. For patients who are unstable or in a very acute state, moment-to-moment monitoring and intensive care could be provided as is done with medical patients in intensive care units in general hospitals. The data on their EEG activity could be radioed to the computer as they engage in a variety of activities or are presented with different situations.

The NASA Technology Utilization Office has funded the fabrication of several additional EEG telemetry headsets and will make them available to qualified users for additional clinical trials.

**EEG Sleep-State Analyzer.** NASA is assisting the Veterans Administration on a large-scale program in the Antarctic, designed to investigate various psychophysiological phenomena manifested under extreme environmental conditions. An important phase of this research is the recording and analysis of sleep data to help advance existing knowledge on the processes of adaptability and inadaptability to extreme environmental conditions. Traditionally, efforts to study sleep and sleep patterns have relied largely on trained specialists for proper interpretation of EEG recordings. This is time-consuming and expensive. The Veterans Administration learned that NASA had developed an electronic sleep analyzer system, capable of automatically determining the stages of sleep in a human subject. The system had been originally developed to determine the effects of weightlessness on brain activity. It precludes the need for a professional to interpret hundreds of hours of EEG recordings. The NASA instrument uses selected aspects of the total available EEG signal to continually assess the subject's state of consciousness.

A soft, comfortable, EEG electrode cap (Figure 14), originally developed to measure brain-wave responses of astronauts in long-duration missions, will also be used in the Antarctic study. This cap eliminates the time-consuming scalp preparation required when conventional electrodes are used.

Although this newly developed sleep analyzer is still primarily a research tool, there are many possible future uses for the device in clinical medicine. Medical researchers have expressed an interest in using the device to study and treat insomniacs and other patients experiencing "sleep neuroses." The Federal Aviation Administration is considering studying the sleep patterns of air controllers and pilots after periods of unusually stressful duty. Other medical researchers are interested in evaluating the sleep patterns of drug addicts. Many pharmacologists believe that sleep analysis may be useful in identifying harmful side effects from drugs currently being developed for clinical use.



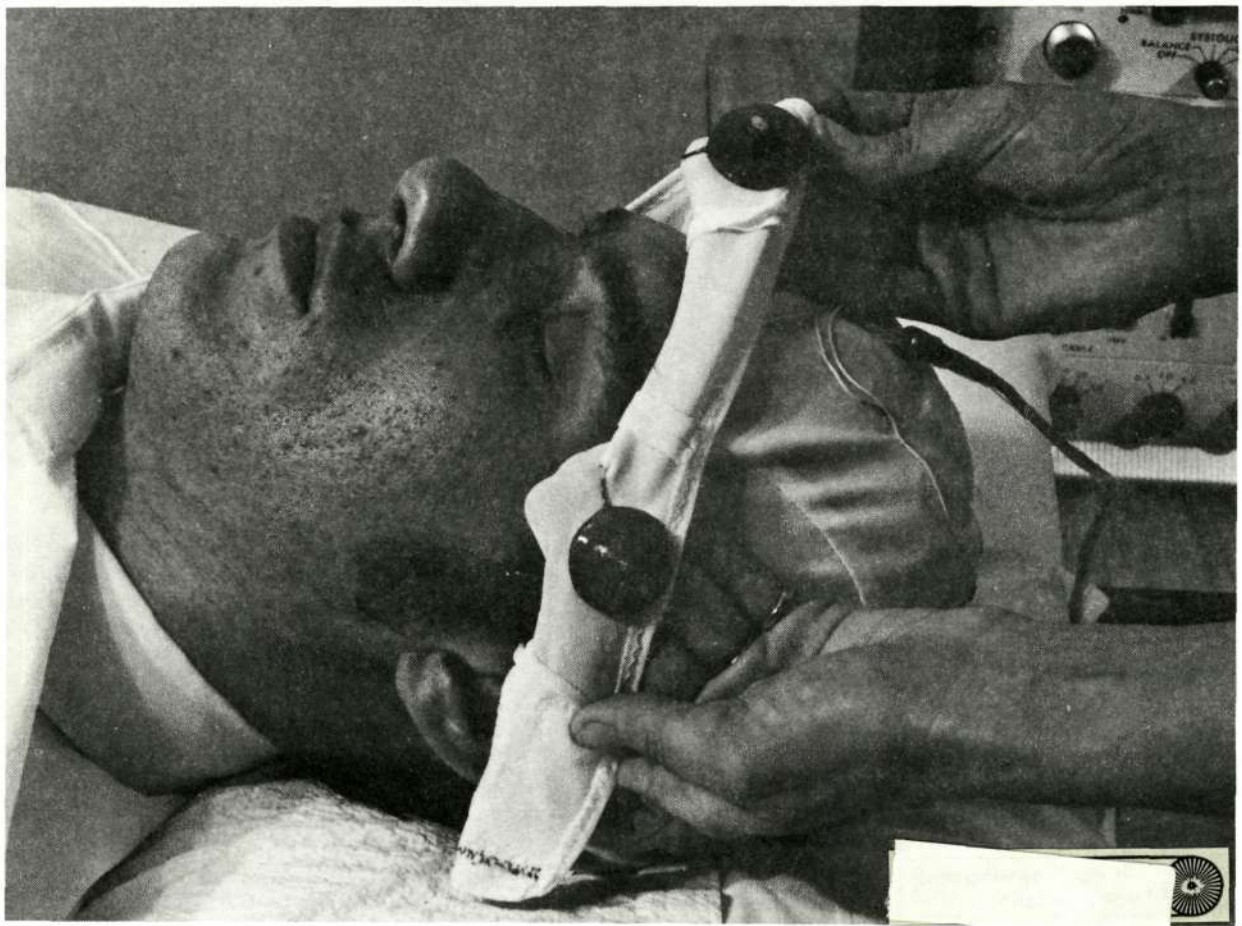


Figure 14. Soft Cap EEG Electrode Assembly

In addition to the prototype now on loan to the Veterans Administration, two other sleep-analyzer units are now in use. One is being used in sleep studies of burn patients at the University of South Carolina Medical School. The other, at the Galveston Medical branch of the University of Texas, is being used to study the sleep characteristics of victims of brain and head injuries.

**Direct Viewing Radiography.** Techniques developed to assess the quality of welds in spacecraft appear to have a high potential for clinical medical x-ray examinations. Solid-state image-amplifier panels developed for non-destructive testing of materials at NASA's Marshall Space Flight Center in Huntsville, Alabama, have many properties that make them appealing for clinical, diagnostic procedures.

Their high sensitivity to x rays permits the use of smaller doses. Thus, the patient is exposed to less radiation. Conventional fluorescent image amplifiers now in use require 50 times more radiation than the new solid-state screens. The contrast range on the new screens is claimed to be 4 times greater than on present devices. This may make certain types of interpretations and diagnosis far easier and more reliable. Originally intended for use in hazardous environments or for in-space inspection and checkout where film storage and development is difficult or unlikely, these panels could be easily used by physicians in remote locations. Radiographic examinations for bone fracture, internal organ damage or disease would be easily performed with future versions of the device, thus significantly broadening the capabilities of a physician's practicing in remote areas of the world.

A cooperative effort is now in progress between NASA and the Tulane University School of Medicine to evaluate more broadly the diagnostic utility of these solid-state image-amplifiers. Prototypes of the device have been demonstrated to the American College of Radiology which has expressed considerable interest in the further development of the device.

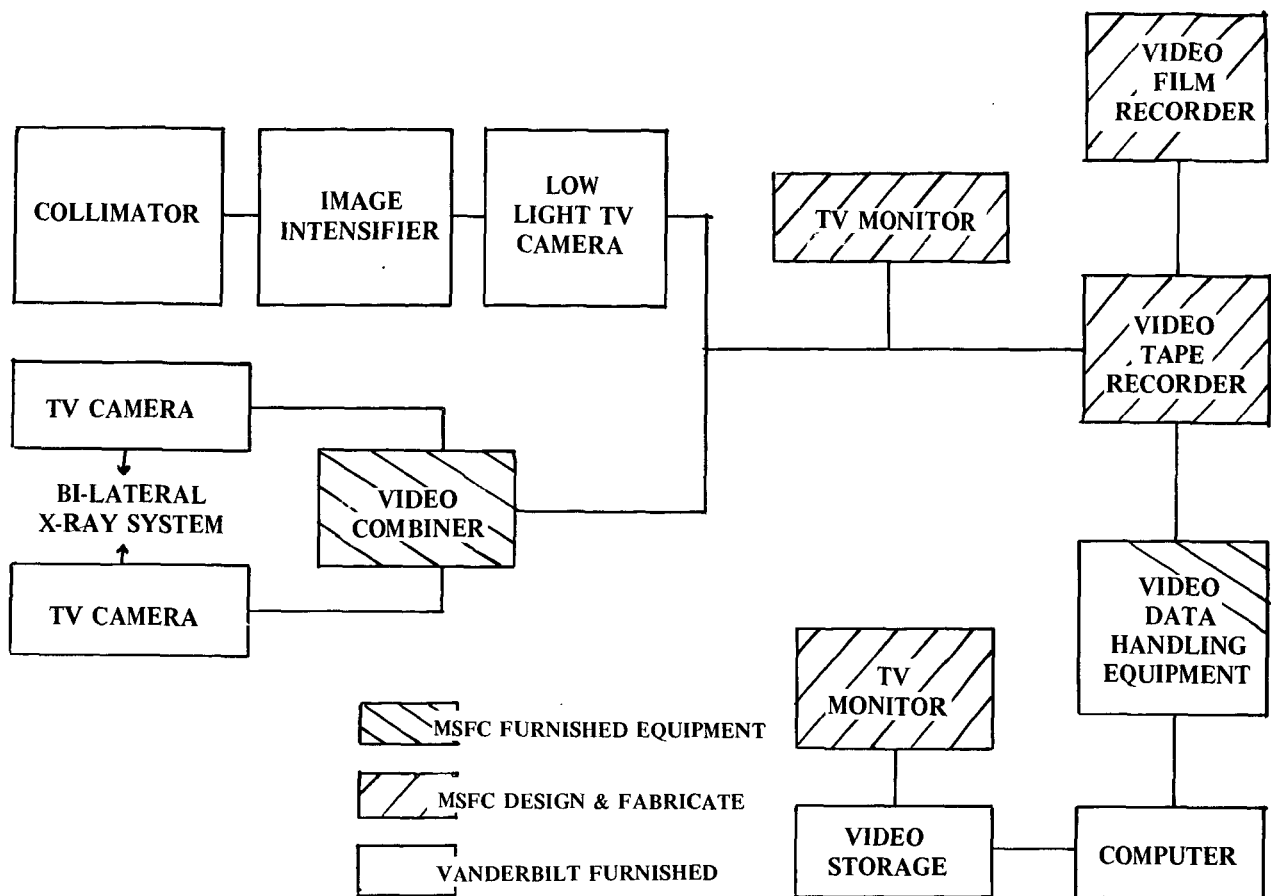


Figure 15. Gamma Ray Imaging System

**Improved Photographic System for X-Ray Image Intensifier.** NASA's Marshall Space Flight Center and Vanderbilt University have developed an adaptation of a neutron-radiography real-time weld inspection system for use in the diagnosis of tumors and cardiovascular problems. Using a gamma ray source rather than neutrons, it will display a patient's tumor(s) or cardiovascular flow in real-time. Image intensification, video data processing and display and a kinescopic photographic recording system have been added to extend the usefulness and utility of the system (Figure 15).

The image intensifier data-processing and kinescope-display system will initially be applied in the study at Vanderbilt of children with congenital heart disorders. The system will be used to visualize the site of the defect and to measure the amount of flow through the anomalous channels. This is important in determining which patients should have operations, and at what age.

Once the complete system is operational, researchers hope that it will also detect brain tumors at an early stage.

Conventional gamma ray sources will be used—for example Technetium ( $Tc^{99}$ )—which can be injected as a short-lived radioisotope.  $Tc^{99}$  is relatively available, has a half-life of approximately 6 hours and provides 140 kev gammas (the system can accept 100 kev to 550 kev gamma rays). Diagnostic scanning can be done approximately 20 minutes after the injection of the isotope.

A collimator must be used if an image of the tumor is required. Prior art involved 1-inch thick lead plates with perhaps 1/8-inch holes. NASA has developed a multiplate array of random pinhole-etched tungsten plates based upon microcircuit technology and photolithography to etch the computer-located random pinholes. The lightweight array is rotated to produce a truly random motion of the collimator and provides a significant increase in the resolving power of the imaging system.

The sensing system is based on photon-electron interchanges which are amplified in an image intensifier tube whose output may be fed directly to a high-resolution video display. The data may be recorded on magnetic tapes or digital-disc recorders. The quantum efficiency of present image systems is relatively low and must be improved in order to permit the use of high-resolution collimators. A pulse-height-analyzer may be added to the system to discriminate against stray radiation. The ultimate goal is to be able to perform real-time analysis of each patient.

The ability to share the results of the studies with others requires a high-quality photographic recording system to record and display the stored video images and the computer-processed images as motion picture sequences illustrating the rapidly changing information (30 frames/sec). The proposed kinescope photographic system will greatly increase the impact of the research because high quality motion pictures of the cardiovascular studies and of tumor detection will be available for use in diagnosis, medical education and conferences.

High-resolution motion pictures made directly from an image intensifier would require at least ten times the radiation exposure of the patient than does video recording of the same information. Since pictures can be made from the video system, a ten-fold reduction in radiation dosage can be achieved. This is significant since the patients are children in whom genetic-damage hazards must be minimized.

NASA had found it necessary on early Saturn flights to convert the video tapes of flight data to high-quality motion-picture film without loss of data or resolution in order to facilitate post-flight motion studies. A 16-mm camera, air driven at 30 frames per second, was used successfully. NASA funded the conversion of the camera from the normal 24 frames/sec to the required 30 frames/sec. During the evaluation, it was discovered that the use of a mechanical shutter caused a 50% reduction in vertical resolution. To overcome this difficulty, a camera was designed which used air and vacuum to move the film, instead of a mechanical shutter. This proved successful. Since the Vanderbilt problem was identical, researchers believe that the NASA technical experience can be easily applied.

**Remote Medical Diagnostic System via Television.** Telemedicine systems for providing physician-monitored medical services in rural areas and in inner-city ghettos are now under active study. A pilot program (not NASA related) under the direction of D. Kenneth Bird, at the Logan International Airport in Boston and the Massachusetts General Hospital (MGH), is now in operation. This system uses a three-mile closed-circuit television link between MGH and the airport to provide remote medical services. The federal health agencies are interested in expanding the telemedicine systems to offset the physician shortage and to extend health care facilities. However, a major technical problem is the lack of a television system that would meet the medical diagnostic needs yet also be compatible with existing telephone transmission lines.

In response to an inquiry from the NASA-funded National Academy of Engineering's Committee on the Interplay of Medicine and Biology and its subcommittee on Remote Diagnosis and Treatment, NASA's Manned Spacecraft Center personnel are investigating and defining the communication and medical requirements for a television system operating between a central medical facility (hospital) and remote clinics. The Health Services and Mental Health Administration is assisting in defining the medical requirements. A television system, compatible with existing transmission facilities and meeting the medical pictorial requirements, will be built and tested.

This research study will be divided into two phases: (1) television requirements will be ascertained through a coordinated program of medical doctors' rating and evaluating pictorial medical data. Such parameters as picture resolution, colorimetry, motion rendition and video bandwidths will be rated using a representative cross-section of medical patients. In addition, a systems study of the bandwidth capabilities of existing telephone lines, optimal modulation schemes, bandwidth compression techniques and financial cost tradeoffs will be performed. The results of these studies will define a television system designed for telemedicine systems. (2) The second phase of the program will be to build and laboratory-test the television system. Final testing of the television study would be in medical care facilities.

**Improved Reliability, Quality Assurance, and Safety of Hospital Bioinstrumentation.** Hospital medical administrators and other organizations evaluating hospital procedures have indicated that bioinstrumentation in hospitals is not as reliable as the needs of hospitals dictate nor as accurate as the medical profession requires. The potential for errors in data and the added potential for physical harm to patients dictate that instrumentation used in hospitals should be as reliable, accurate, and of as high a quality as the current state-of-the-art allows.

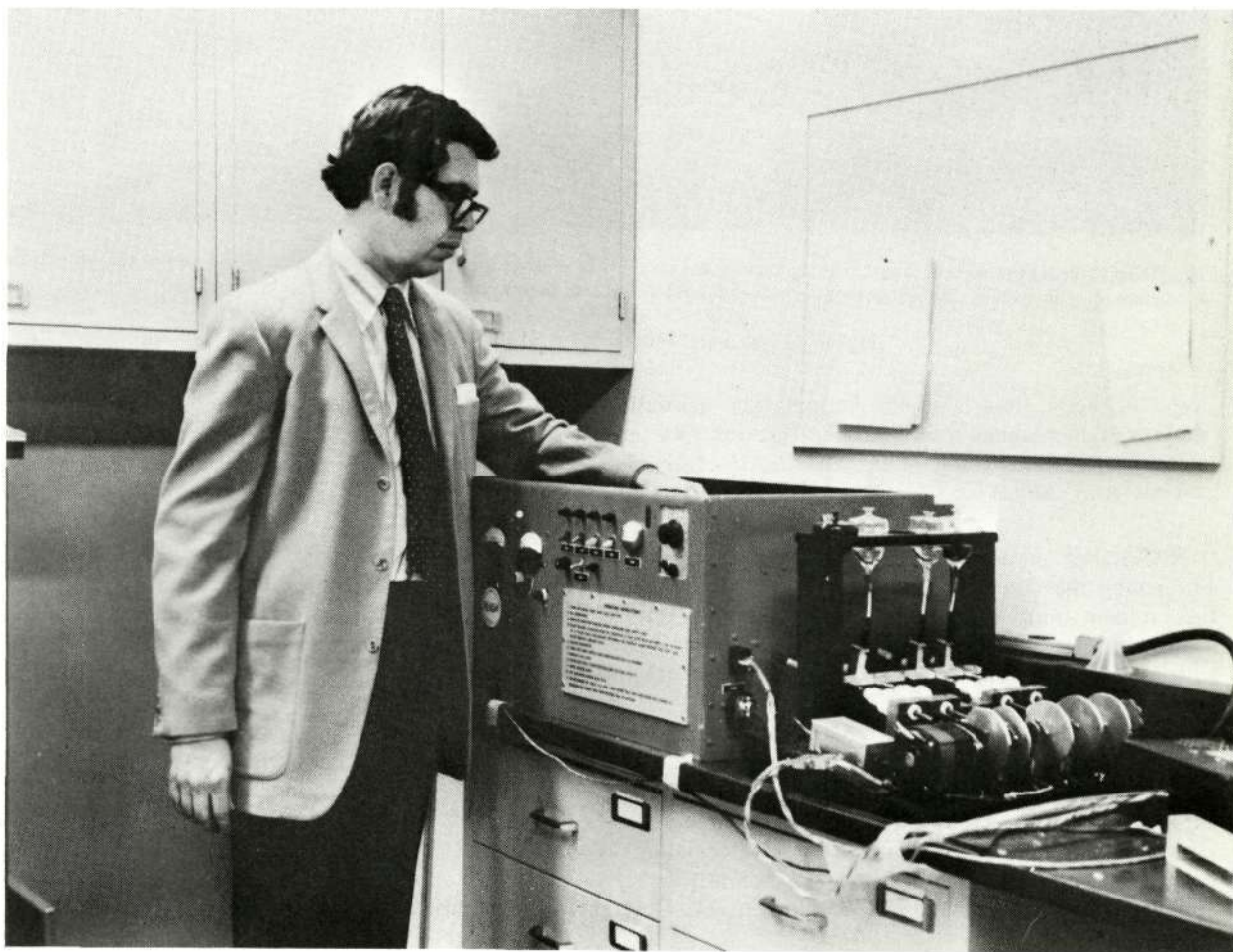


Exploring this problem, a subcommittee of the National Academy of Engineering reviewed the NASA reliability, quality and safety program technologies and was impressed with their potential application to the solution of hospital equipment deficiencies. The American Hospital Association and the Department of Health, Education and Welfare have expressed an interest in this project and will join in a joint cooperative study.

The NASA Manned Spacecraft Center, with strong experience in the reliability, quality assurance, and safety checkout (R, QA, & S) of space bioinstrumentation, will work on ways to apply management and control techniques to hospital bioinstrumentation.

The program will be subdivided into several phases. The first phase will identify and study the basic problems to develop options for solving them. There will be coordination among Government agencies, equipment manufacturers, hospital administrators and other representatives of the medical community. The second phase will be to document the existing conditions to the medical community and their comparison with present aerospace practices. Site visits to a number of medical centers are now nearly complete and discussions are in progress as to the most effective form the recommendations might take, as voluntary guidelines or as government standards.

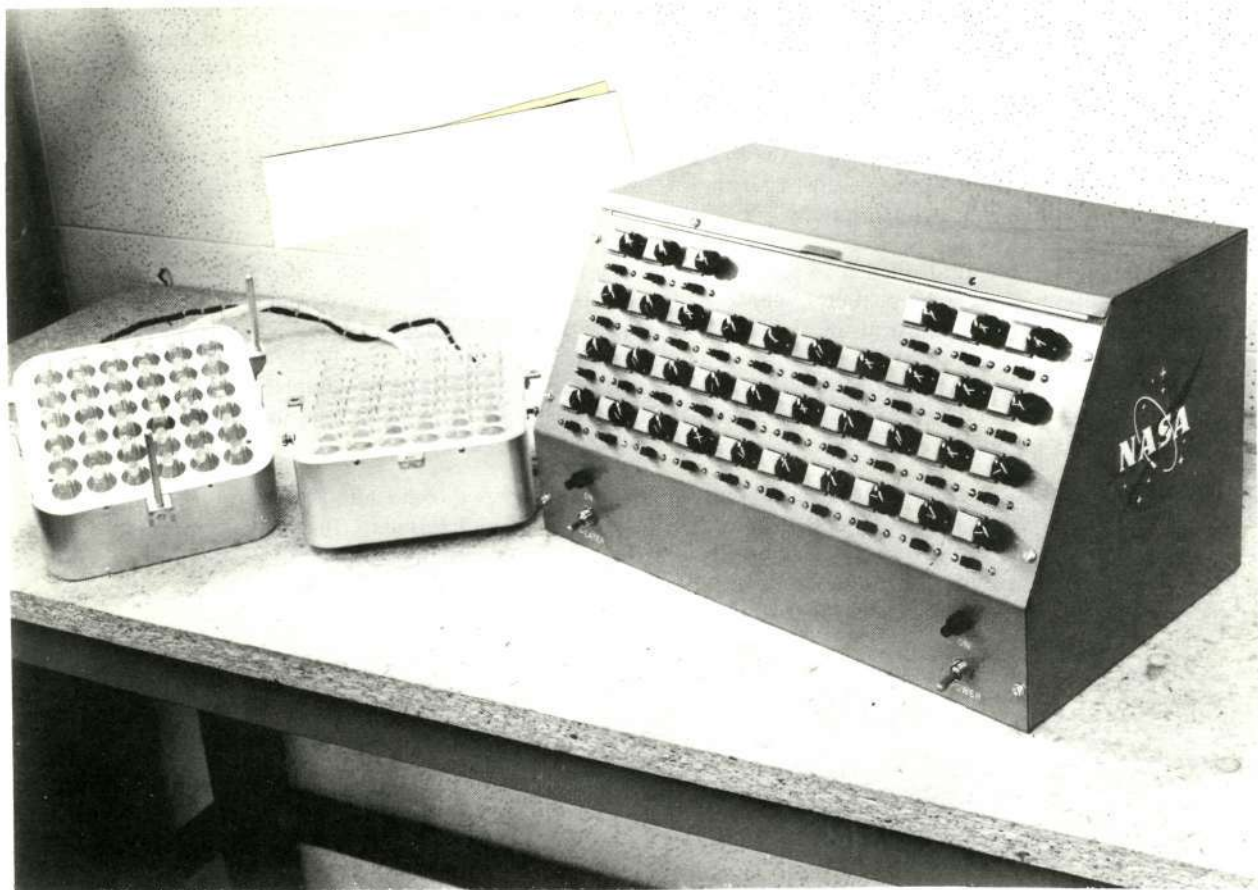
**Rapid Detection of Bacteria in Biological Fluids.** The true incidence of bacterial infections in human biologic fluids is enormous but unknown. Blood, urine, cerebrospinal fluid and serous effusions of the chest, abdomen and joints are commonly cultured to determine the presence and extent of bacterial infections. Techniques currently used to determine the presence of bacteria require a 24 to 72 hour incubation period. Consequently, a similar time is required to determine an antibiotic's effectiveness against a particular type of bacteria. Also, each



This automated urine bacteria detection system is based on the light flash produced when living bacteria encounter the substance luciferase obtained from firefly tails.

Figure 16. Automated Urine Bacteria Detection System





The REDOX potential measurement system detects the changes in electrical potential which varies as oxygen in the growth media is consumed. The system permits detection of living bacteria in less than one hour.

Figure 17. Bacterial Detection by REDOX Potential Change

type of body fluid contains factors that neutralize or delay rapid detection by currently available means. Improved techniques for rapid identification of bacterial presence would speed the process of specific bacterial identification and would reduce the time, tedium, and expense now required for the designation of negative (i.e. no bacteria) studies.

NASA has developed and refined two techniques which show considerable promise for speeding and automating the detection functions of bacteriology laboratories in hospitals or clinics. Each technique approaches the problem quite differently. One is based on the detection of ATP, a biochemical compound present in all living cells. The quantitative determination is made by measuring the light emitted in the reaction of the ATP with luciferase, an enzyme derived from fireflies (Figure 16). The other technique is based on changes that occur in the electrical potential of the growth medium as the oxygen in the medium is consumed by the growth of bacteria (Figure 17). Rapid determination of antibiotic effectiveness, in the long run, would reduce the damage caused by chronic bacterial infections. Accurate administration of the most appropriate antibiotic would also reduce the opportunity for bacteria to build strong immunities to various kinds of antibiotics. And the automation the new devices could bring to clinical bacteriology labs would enable the labs to provide the physician with better, more meaningful information at lower cost to the patient. Working prototypes of both devices have been constructed and are currently being field-tested in the bacteriology laboratories of the Johns Hopkins Medical Center and the Washington D.C. Veterans Administration Hospital.

**Determination of the Effect on Blood of Microwave Heaters.** A technique developed by NASA to measure the effect of high oxygen pressure on blood cells is now being used to study the effects of microwave heaters on blood. The warming of refrigerated blood banks ( $4^{\circ}\text{C}$  to  $6^{\circ}\text{C}$ ) has become a common clinical practice because of the difficulties of transfusing cold blood. Indeed, clinical studies leave little doubt that rapid transfusion of large quantities of blood at refrigerator temperatures may be a dangerous practice resulting in cardiac or general body

hypothermia. Warming of the blood before infusion reduces the morbidity and mortality rates. To avoid the effects of cardiac and general hypothermia during massive hemorrhage, cold bank blood should be warmed to body temperature when it is rapidly administered in large amounts.

Until very recently, the basic method of warming refrigerated blood involved using some sort of water-bath heat exchanger. Because human blood at 4°C is a highly viscous fluid, coil heating systems cannot attain sufficient flow because they must force the cold blood through a filter before warming. The method is relatively inexpensive, but the apparatus requires considerable warm-up time as well as some blood for priming. Also, precise temperature control is difficult to achieve and the unit must be placed close to the patient, which adds to the equipment clutter in an already crowded operating room.

Recently, the use of microwave blood warming has eliminated these problems by warming the blood in the bag before filtering—a technique that offers speed, economy and ease of use. The refrigerated blood can be heated to a desired temperature in only one minute. Blood is heated only when needed and there is no waste.

Microwave heating is unique in that it does not involve a hot object transferring heat through conduction, radiation, or convection. Instead, electromagnetic energy is generated at a very high frequency (2.5 gigahertz) by a special oscillator tube. This sets up an alternating electromagnetic field that causes the molecules in the blood to continually try to realign themselves electrically with each field reversal. The friction between these moving molecules generates heat, converting electromagnetic energy into thermal energy.

Although initial tests on the use of microwave-heated blood indicated that the method was basically safe, the rapidly increasing use of the new technique demands more subtle tests of blood damage to determine whether the method is safe in all circumstances. In response to the problem statement, an Ames Research Center scientist suggested the use of an enzymatic technique. The enzymatic technique is used at Ames for measuring the effect of high oxygen pressures on blood cells. The technique involves the use of a proteolytic enzyme which can be monitored in a simple manner and with very high sensitivity using a specific substrate. The enzyme is dipeptidyl aminopeptidase III, which was first purified and characterized from the pituitary gland and which can be specifically determined by means of the fluorogenic substrate, arg-arg-beta-naphthylamide.

The problem originator discussed the basic technique with the NASA scientist who then agreed to process some initial samples of microwave-warmed blood. Twelve units of blood were sent to Ames Research Center for analysis using the Ames enzymatic technique. The initial tests revealed that some of the microwave-warmed blood had, in fact, undergone significant changes. However, not all microwave-warmed blood gave the same response, which indicated that other factors may be obscuring the basic phenomenon. The problem originator plans to send additional samples to Ames for evaluation. In addition, arrangements are being made to duplicate the Ames technique at the Tulane School of Medicine to assure more complete studies.

**Evaluation of Plasticizers from PVC Plastic.** NASA's Goddard Space Flight Center is collaborating with the Johns Hopkins School of Hygiene and Public Health in a detailed toxicological evaluation of the presence of phthlate plasticizers in the blood and tissues of individuals who have received blood transfusions. Of particular concern, considering the almost universal use of polyvinylchloride (PVC) plastic blood-storage bags, is the effect of the plasticizer (DEHP) on the function of the cellular elements of the stored blood. Certain preliminary evidence suggests a deleterious effect on blood platelets involving increased adhesiveness of these cells and the formation of micro-aggregates during storage. Studies are planned to investigate whether these aggregated particles can clog the fine capillaries in the circulatory system of various organs following transfusion.

Polyvinylchloride (PVC) is one of the most widely used plastics. Because the molecular chains of PVC are relatively rigid and non-flexible, quantities of a compound, referred to as a plasticizer, must be added to the formulation to yield a pliable end product. The amount of plasticizer added varies from product to product but it is not a trivial amount and can hardly be considered a trace additive since it ranges in many applications up to 35% of the weight of the final product. The most commonly used plasticizers are the esters of phthalic acid, referred to as phthlate esters. Of this class of chemical additives, the most widely used ester is diethylhexyl phthlate (DEHP). Because the plasticizers are not bound chemically to the PVC but are only physically dissolved in the plastic, migration of the plasticizer from the plastic surface becomes a distinct possibility. NASA recognized the problem of plasticizer contamination and banned the use of plasticized PVC in the space program some time ago. Although NASA does not permit use of these plasticized polymers, the phthlate plasticizers continually appear along with others. As a result, technology has been developed to identify the sources of these materials and to analyze contamination associated with the plasticizers in clean rooms, vacuum chambers and

spacecraft. The decision to ban these materials was based on the demonstrated volatility of the plasticizer from PVC surfaces and the interference of the volatilized plasticizer with the performance of various optical devices in the spacecraft.

Although NASA had experienced various problems with plasticized PVC, until recently the biomedical community had very little appreciation of the volatilization and migration of the plasticizer from PVC surfaces. In 1970, papers were published that reported the migration of plasticizers from surgical plastic tubing, cardiac-bypass units used in open-chest surgery, kidney-dialysis units, and blood-storage bags. In these papers, the authors documented the presence of these plasticizers in tissues of individuals who had received transfusion of blood stored in PVC plastic bags. This form of blood storage is routinely used throughout the world.

Evidence has recently been obtained which suggests that the phthalate esters might be of importance to a broader segment of the public than the relatively small percentage of persons who receive blood transfusions or undergo some sort of surgical procedure involving direct contact of the blood with a plasticized device. Recently, plasticizers have been observed in individuals who have never received any blood transfusions. Consequently, in addition to the toxicological studies mentioned above, the source of plasticizers and their route of entry into the body—oral, percutaneous, and inhalation—will be investigated. Phthalate ester plasticizers have also now been identified in fish taken from the waters of several states. The presence of phthalate esters in the environment has potential widespread implications.

The majority of the work in the next two years will be performed at Johns Hopkins under NASA contract with the assistance of NASA's materials and analytical expertise.

## **URINARY SYSTEM DISORDERS: TREATMENT AND RESEARCH**

**Urine-Transport System for Postoperative Fluid Maintenance.** An aerospace-derived system to improve the postoperative maintenance of body-fluid levels is now being clinically tested. Based upon the urine-transport system developed for the NASA Biosatellite program, the new equipment will accurately record urine volume output versus time. The output of this system may then be used to control the rate at which additional fluids are administered to the patient.

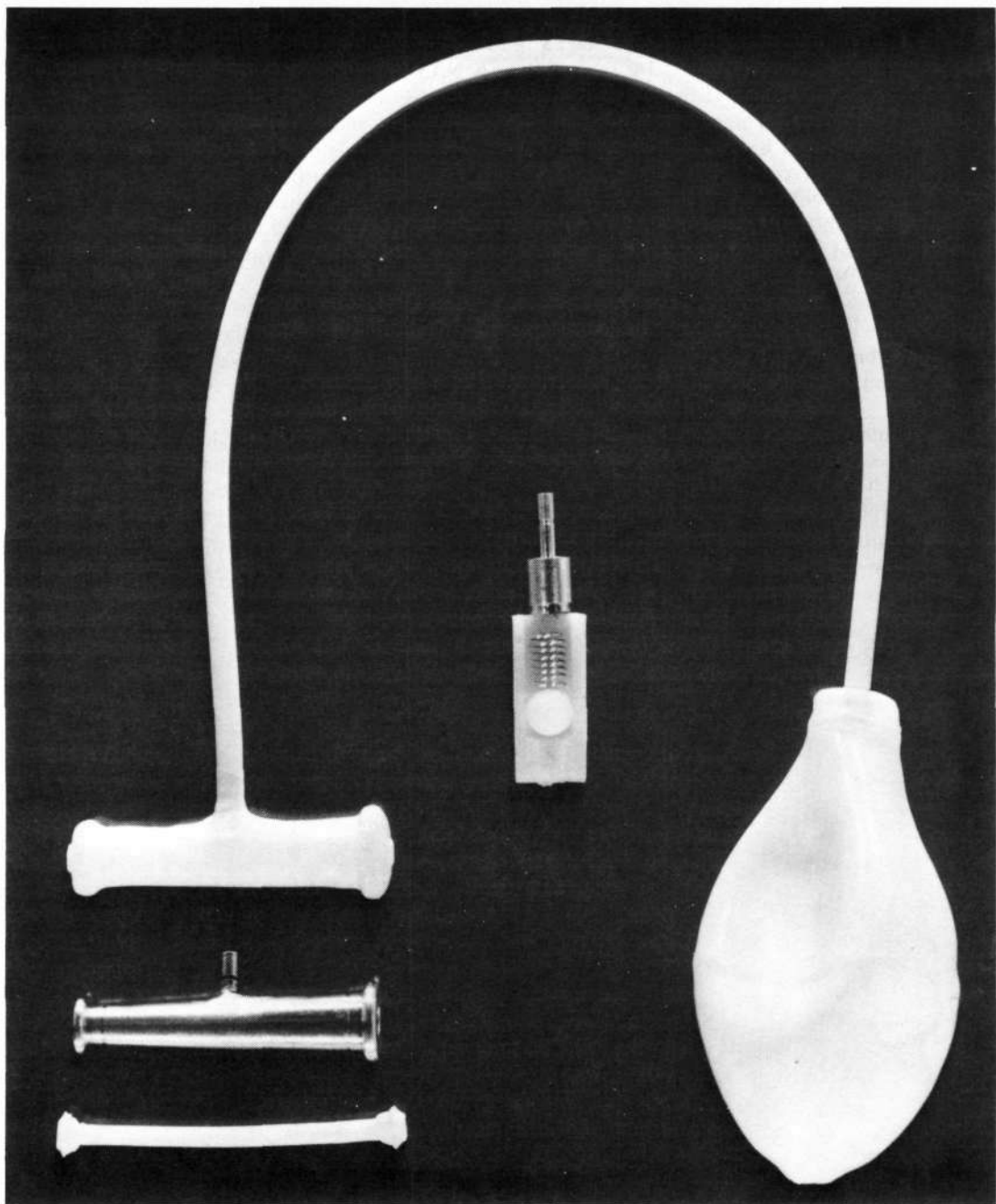
One of the essential indicators of a postoperative patient's condition is his fluid intake-output record. Additional fluids must be administered to a patient passing a large amount of urine in order to maintain a proper electrolyte balance. Excessive retention of urine or unusually high rates of urine output are indicators that specific action must be taken. The present practice is for a nurse to manually record the amount of urine in a calibrated container at specified intervals. This procedure is not completely satisfactory because patients can easily slip into electrolyte imbalance, with scant note made of increased urine output.

The urine-transport system originally developed for the monkey in the Biosatellite program provided a solid basis for further development leading to a clinical urine-transport system.

The new system works this way: The patient's urine is collected in a holding tank and accurately measured in 3 cc increments. It is then pumped into an analysis bag so that it may either be collected for further laboratory tests or discarded. The system provides a direct digital indication of the patient's urine output. Connected to a monitoring computer, it will provide information on the patient's rate of fluid output and will immediately notify nursing personnel of unusual conditions. Through the computer hookup, it may also be used to control the rate at which additional fluids are administered to the patient, thus permitting precise maintenance of body-fluid content.

A less sophisticated version of this device has already been in clinical use for over a year. Used to maintain the fluid levels of cardiac patients during the first 24 hours after surgery, it has proven to be of considerable value in patient care. Maintenance of constant fluid levels places less stress on the patient than the depletion-restoration cycle normally encountered and less time is required of medical personnel.

The two prototypes of the new Biosatellite-based system were delivered for clinical trials in February 1972. The bacteriological evaluation was satisfactory and the systems were then installed, one in a shock-trauma unit, the other in a post-surgical recovery area. Preliminary clinical trials uncovered some design difficulties which have since been corrected. Further clinical testing is now in progress. Following successful demonstration of these units, three additional prototypes will be released for further clinical evaluation.



Complications resulting from the loss of voluntary control of urinary function are the most common cause of death of paraplegic patients. Based on a NASA manometer tube valve, this prototype, consisting of a flow valve, a check valve, and a pressure bulb has been constructed and is being tested. Voluntary pressure applied to the bulb which is also implanted under the skin allows the bladder to drain completely in a normal fashion, thus preventing the development of bladder or kidney infection or the development of pathological high pressures within the urinary system.

Figure 18. Prosthetic Implantable Valve for Urinary Tract

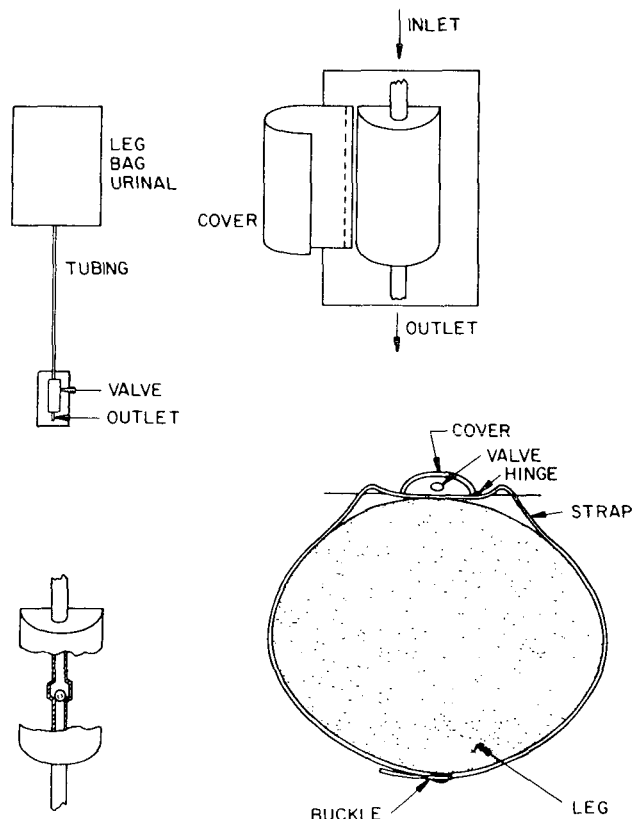
**Aerospace Valve for Urinary Control.** NASA is aiding in the development of an implantable urethral valve for use by incontinent patients. Certain injuries and diseases cause the loss of voluntary control of the urinary function. The inability to control urine flow can result in kidney-tissue deterioration, infection, and in some cases, kidney damage and death. Electrical stimulation of the flow-controlling muscles has not been wholly successful because of insufficient muscle response and painful bladder pressure.



A medical researcher treating paraplegics saw a need for a simple, reliable, and totally implantable urethral valve which could be easily controlled by the patient. A NASA engineer suggested that a valve similar to one used in manometer tubes might solve the problem. The valve has now been included in the design of an implantable control system. This system will enable the patient to mechanically control urination by applying pressure to a small air-filled bulb located under the skin. Biocompatible materials such as silastic, normally used for long-term implants, were unsuitable since they react adversely to continuous exposure to urine. A material has been found by the NASA Applications Engineering Project and preliminary tests indicate it is biocompatible and capable of withstanding constant exposure to urine. Difficulties were encountered in fabricating tubing and bulbs of the material but these techniques have been mastered. Five prototype urinary control systems (Figure 18) have been fabricated and delivered for laboratory testing.

These prototypes have been implanted in dogs to determine if there are any unfavorable long-term interactions of body tissue, tubing and valve material and urine. If the prototypes prove satisfactory, the design would be inexpensive to manufacture and could benefit as many as 15,000 patients per year.

The pressure-bulb-controlled valve may also be useful as a drainage valve for leg-bag urinals. Many spinal-cord-injury patients, who often wear a leg bag urinal, lack the muscular coordination to open and close a rotary valve to drain such a urinal. Their dependence on others to perform this task could be reduced by using a pressure-bulb-controlled valve to control drainage. Since the ability to make a fist and to push on an object are among the few controlled muscular actions these patients can perform, the bulb-controlled valve would appear to be an ideal solution to the problem. Since these valves will not be implanted, they could be manufactured at low cost using readily available materials. (see Figure 19).



Many neuropathic patients lack sufficient muscular control to operate a rotary valve, thus increasing their dependence. The NASA-designed valve merely requires that a force be exerted on the valve cover to operate it.

Figure 19. An Improved Drainage Valve for Leg-Bag Urinals

**Liquid Flowmeter for Use in Kidney Research.** A liquid flowmeter developed for the NASA Skylab project may help lead to better diagnosis and treatment of kidney disease which requires an improved understanding of the total urological system. Urine-flow measurement in the ureters, tubes that connect each kidney to the bladder, is complicated by the flow being pulsatile. Small gas bubbles are also present in the liquid. The bubbles make accurate volume measurement difficult. The existing measurement technique requires collecting urine samples at definite times and can only provide average flow-rate information.

The NASA system can measure instantaneous flow rates. The system uses a thermal dilution probe and two-phase flow-separation techniques to get accurate liquid-mass-flow measurements regardless of the air or gas trapped in the liquid. The ability to accurately measure the liquid-flow patterns from the kidneys will be particularly important to a better understanding both of kidney function and of the bodies response to specific clinical drugs. A joint proposal for NIH is being prepared for the development of this Skylab device for use in clinical medicine.

**Scanning Electron Microscope for Analysis of Surface Morphology of Kidney Stones.** A scanning electron microscope at NASA's Marshall Space Flight Center has been used to extract information on the structure of kidney stones. A researcher at Bowman Gray School of Medicine was engaged in a long-term study of kidney stones, their occurrence, causes, and related surgical techniques. The overall objective of his research was to prevent the formation of kidney stones. Specifically, he was seeking to understand the mechanisms that cause kidney stones to form in some people and not in others.

However, there is no precise theory for why kidney stones form in certain people and not in others. It appears that concentration of the chemical components in the urine may not be the critical factor, since stones develop in some patients with lower concentrations of the chemicals that seem to be the basic ingredients from which urinary calculi are formed. Tiny crystals often exist in the tubules of the kidneys but only in some people do they grow and form kidney stones. The researcher suspected differences in the surface structure or in the surface energy between those crystals which grow and form urinary calculi and those which remain in the tubules and do not grow.



Figure 20. Electron Micrograph of a Kidney Stone



The researcher sought a way to examine the surface morphology of renal calculi to yield more useful information on the surface structure than what is obtainable from light microscope techniques. He wished to determine whether or not surface morphology is a factor in kidney stone formation.

Four samples of representative kidney stones with identification numbers were sent to the MSFC. Forty scanning-electron micrographs were made of the surfaces of the kidney stones, and of the cross-sections obtained when the crystals were fractured. One of these electron micrographs is shown in Figure 20.

The immediate benefit of this effort is the availability of an analytical technique for the researcher to determine the applicability of his theoretical hypothesis. Neither the analytical technique nor the instrumentation required was available at Bowman Gray.

If the relationship between surface morphology and kidney stone formation is established, significant strides will be made in understanding the formation of human kidney stones. If a fundamental understanding of the mechanisms involved is obtained, methods to prevent kidney stone formation could soon follow.

**Liquid Crystal Sterilization.** NASA technology is providing techniques for greater precision in delicate kidney surgery. The kidney is supplied with blood by the renal artery which consists of at least two major branches. A large anterior branch supplies the anterior part of the kidney exclusively, and a smaller posterior branch supplies the posterior part exclusively. In a line, called Broedel's line, which passes between the two main arterial divisions, there are no large blood vessels. It is best to make an incision along this line when surgical opening of the kidney is necessary. But it is difficult to locate the boundary line visually. A researcher raised the question of using liquid crystals to determine the boundary. Samples of encapsulated liquid crystals were obtained from a commercial supplier by the researcher and from NASA's Marshall Space Flight Center. It was then necessary to establish sterilization methods which would not impair the effectiveness of the liquid-crystal films prior to their use in regular procedures.

MSFC has been using liquid crystals for nondestructive testing of metal structures. The encapsulated liquid crystals developed under NASA contract were considered ideal for use in renal surgery. Personnel at Marshall, experienced in work with liquid crystals, also suggested gas sterilization. Evaluation proved this to be the best solution to the sterilization problem. The researcher performed several surgical experiments on the kidneys of dogs, using the liquid crystal material obtained from MSFC and the technique proved to be very effective. After surgical exposure of the dog's kidney, one of the arteries leading to the kidney was ligated. The kidney was then placed in a cooling bath, and upon removal from the cooling bath, the artery not ligated furnished blood to the kidney, heating that portion of the kidney. Using small strips of liquid crystals, the researcher was then able to trace out the line of demarcation between the two arterial supplies (Figure 21). The juncture between the light and dark areas of the liquid crystal strips indicates the location of Broedel's line. This permitted incision into the kidney without severing any major arteries.

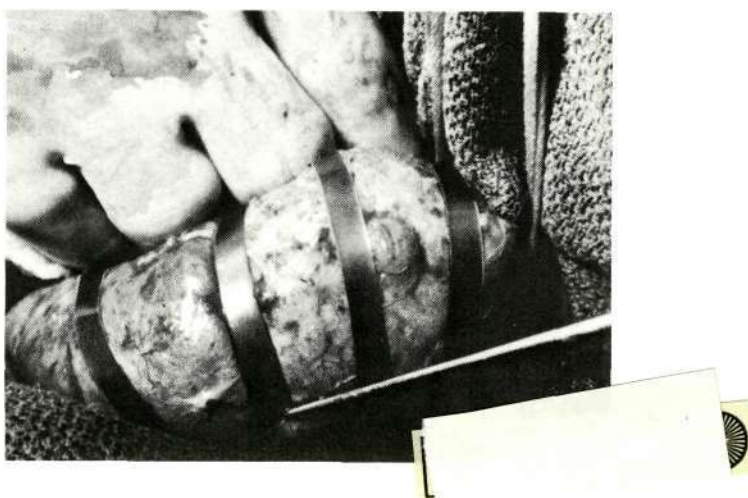


Figure 21. Liquid Crystal Tapes Aid Kidney Surgery

The advice on sterilization and the encapsulated liquid crystals supplied by the Marshall Space Flight Center were vital to the accomplishment of this transfer. The researcher and a commercial supplier are currently discussing the possibility of obtaining prepackaged sterile liquid crystal strips for general use in this surgical application. The crystals are being used frequently in animal experiments for complete evaluation.

## REHABILITATION MEDICINE: PATIENT TESTING, EVALUATION, AND TRAINING

**Mass Spectrometer for Exercise Stress Measurement.** Information on the workloads encountered by severely disabled patients in rehabilitation programs will be provided by instrumentation and techniques originally developed to monitor the metabolic activity of astronauts in the SKYLAB program. Information provided by this system will be valuable for improving the design of patient-assist devices and for assessing the efficacy of various treatment procedures.

The NASA instrumentation will provide accurate measurement of metabolic activity of both normal and severely disabled subjects during actual working conditions. It may also be used to follow the progress of severely disabled persons through the many phases of their rehabilitation training program. In the past, most metabolic measurement has been limited primarily to oxygen-consumption studies on young, healthy males, either during stationary activity or while walking on the standard treadmill. Studies of the severely disabled during actual conditioning or retraining programs is quite scant. Ambulation studies on patients whose disability involves a leg are nearly nonexistent. With only two exceptions, all energy-cost studies involving walking have been performed on a laboratory treadmill.

Treadmill performance does not adequately correspond to normal walking activity. And since only patients with relatively minor disorders are able to perform on a treadmill, the treadmill technique does little to provide data on patients with serious impairments.

In a cooperative effort between a Social and Rehabilitation Services Training Center and NASA, NASA will provide a special motorized cart and instrumentation system to enable physical therapists to gather accurate workload information. The instrumentation will consist primarily of a portable mass spectrometer to analyze respiratory gas exchange and an EKG recording system as well as devices for measuring patient velocity. The motorized cart will be used to accurately control the patient's velocity. The mass spectrometer will provide a continuous record of the amount of oxygen consumed, the carbon dioxide produced and the nitrogen and moisture exchange. Pulse rates and EKG tracings, as well as inspiratory and expiratory volumes, will also be recorded.

Accurate velocity data is essential to meaningful workload data. Coupled with accurate physiological data, velocity data will allow medical personnel to measure the actual stress being imposed on a patient. This will facilitate the design of assist devices and therapeutic techniques that will minimize the stress a patient experiences.

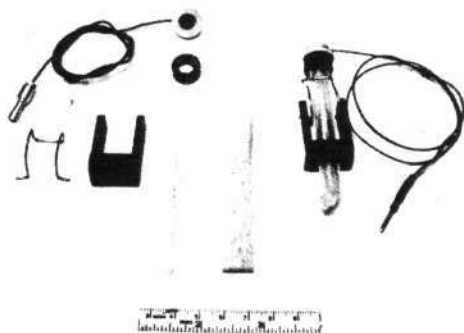
Construction of the cart is nearly complete and the instrumentation will be installed before the end of the summer of 1972. Studies of amputees will include both semi-stationary and ambulating activities involving the use of the parallel bars, walkerettes, crutches, and lower-extremity prostheses or braces. Further studies will include conditions such as cardiovascular disease, cerebral hemorrhage, spinal cord injury, diabetes hypertension, neurological diseases, peripheral neuropathies and peripheral nerve damage, peripheral vascular disease, and severe pulmonary diseases such as emphysema and asthma.

**EEG Helmet and Audiometric System for Early Detection of Hearing Defects.** Based on a system used originally to record changes in the brain waves (EEG) of astronauts and pilots while under gravitational stress, a NASA-devised EEG helmet (Figure 22) is now part of a system to test the hearing abilities of small children by recording their brain waves. Thousands of children classified as mentally retarded are believed to be suffering not from mental retardation but rather from hearing difficulties which have cut them off from the environmental interaction essential to the development of their intellect. If these hearing defects could be identified early in infancy and appropriate remedial measures taken, many youngsters could be prevented from becoming functional retardates. Thus, the entire system is intended to assist in identifying hearing defects in young children who cannot verbally communicate information as to whether, and to what degree, they hear an auditory stimulus.



The EEG audiometric helmet in position on the subject. The electrodes can be adjusted to a variety of head sizes, do not require shaving of the head, and do not require use of electrode paste. Used in a hearing testing program, evoked response audiometry uses changes in the brain waves to determine an individual's threshold of hearing. This makes it possible to determine hearing deficiency in infants and young children. By identifying and applying proper treatment to those children with a hearing problem, they may be prevented from becoming functionally retarded.

The NASA electrodes in place in the helmet, Audiometric signals are administered via the earphones.



The NASA EEG electrodes. (Note the threads which permit precise adjustment when placed in the helmet.)

Figure 22. NASA EEG Audiometric Helmet

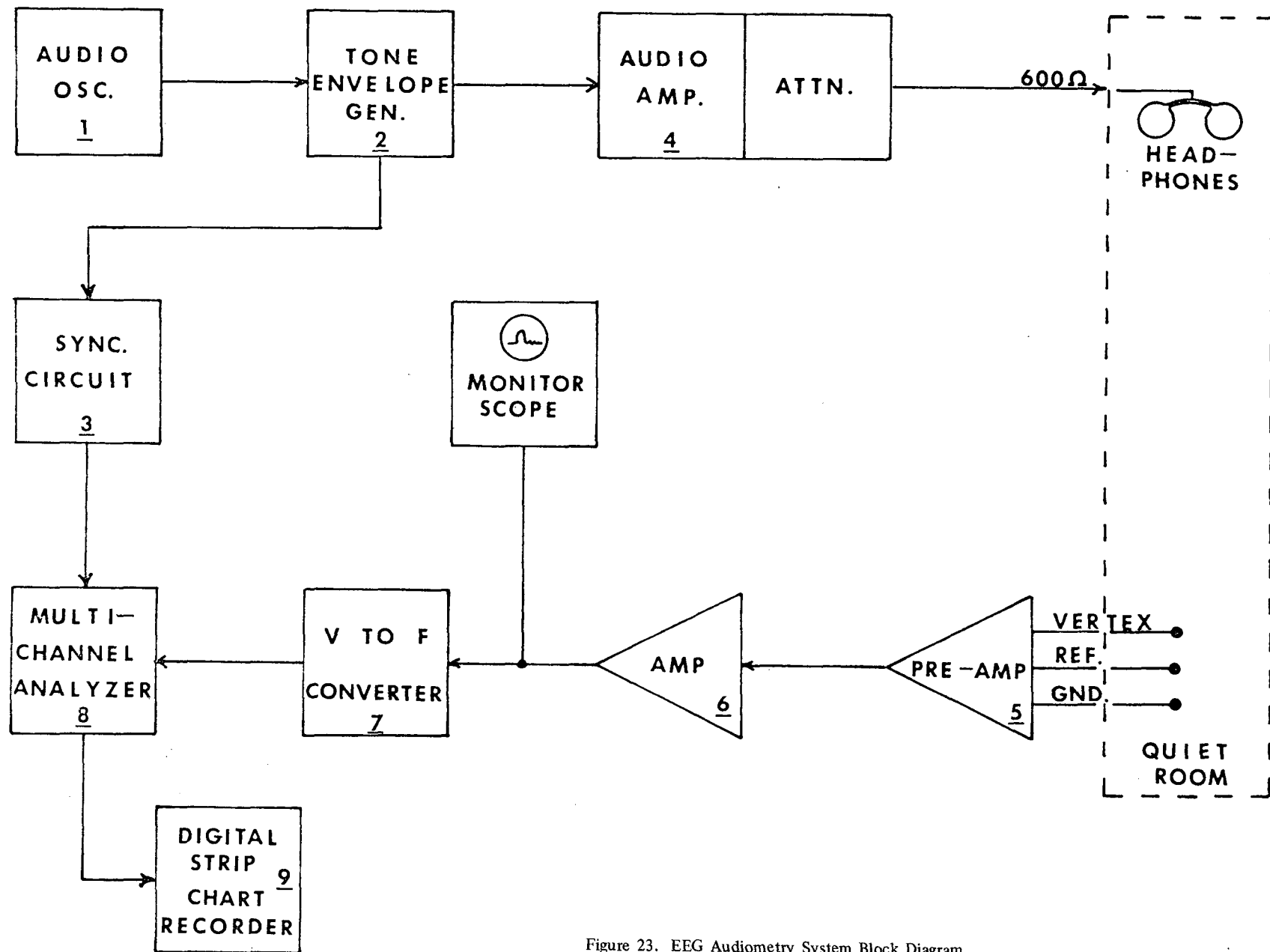


Figure 23. EEG Audiometry System Block Diagram

Mounted on the EEG helmet are three electrodes, a low-noise, high-gain amplifier, and a pair of earphones for administering the auditory stimulus. The helmet-mounted electrodes have several advantages over the more conventional, individually-attached type. No prior scalp preparation is required and, as all three electrodes are simultaneously placed, the time required to prepare a child for testing is significantly reduced. No special electrode paste need be applied to the child's scalp and later removed as in the conventional recording method. The electrodes and leads are held firmly in place by the helmet so that the child cannot tear off or dislodge electrodes by a mere swipe of his hand. All of these considerations would be quite valuable in terms of time and cost reduction in a large-scale screening program. The low noise amplifier (based on a NASA Ames Research Center design) built into the helmet amplifies the signal by a factor of 1000. By reducing the length of the wires carrying very small signals, the possibility of extraneous electrical noise pickup is significantly reduced.

Auditory signals (tone bursts or clicks) are fed into the helmet via the built-in earphones. If the child "hears" the signal, it is indicated by a change in the brain wave pattern. The child does not have to tell the researcher that he hears. If he does in fact hear, his response will appear in the processed and displayed EEG tracing.

The NASA Marshall Space Flight Center Astrionics Laboratory has designed an appropriate signal-generating and processing unit. Design of the electronics instrumentation required to make this technique readily portable and economically practical is almost complete and four prototypes will be made available for clinical evaluation. The block diagram of the total system is shown in Figure 23.

**Diagnosing Gait Abnormalities.** A specially-instrumented suit developed at NASA's Langley Research Center (LRC) may prove quite valuable in studies of human locomotion for patient rehabilitation. Techniques for studying the motion of limbs during normal locomotion and for diagnosing gait abnormalities have been previously dependent on visual observation. Two and three dimensional information on limb motion has been acquired by using a system of grids and cameras. Data taken by these techniques is unsatisfactory because of the complexity of the installation, the fragmentary nature of the data and the difficulty of extracting position information from such visual data. In addition, visual techniques require that the desired position measurements be taken in a laboratory or other "artificial" environment in order to maintain the patient within the field of view of the camera and grid system.

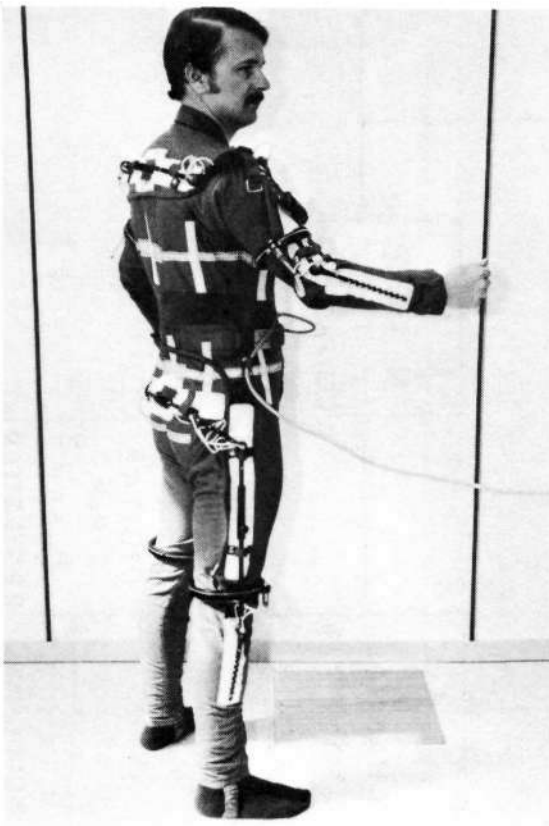


Figure 24.

Partial Exo-Skeleton for Locomotion Studies



A specially-instrumented suit for the Crew Vehicle Disturbances Study in the Skylab Mission was developed at the Langley Research Center. The suit (Figure 24) essentially consists of a partial exoskeleton which is fitted to the individual by means of a suit. Potentiometers are used at the various joints and also on rings located on the arms and legs to provide information on the angular relationships between the joints. This unit is lightweight and compatible with the overall requirements. The results at Langley indicate that precision of measurement of rotation of one member with respect to the other approaches plus or minus 1 percent. It is anticipated that some difficulty may be encountered in affixing the exoskeleton to the patient. However, this difficulty can be overcome as a result of the light weight and relatively small size of the exoskeleton. Researchers believe that for these preliminary studies only the lower half of the exoskeleton unit will be required since the studies are primarily concerned with gait analysis. The present suit uses an umbilical cable to transmit data from the potentiometers on the exoskeleton to the data-processing equipment. A study has been made at Langley of the requirements involved in instrumenting a telemetric system. The design of the telemetry apparatus has been completed. Should evaluation of the exoskeleton prove that this approach will provide the necessary data, it is expected that telemetric techniques will be required to obtain the greatest utility and versatility in the use of this technique. The suit has been loaned to the Rehabilitation Research Center at Emory University and it is now being evaluated by the Veterans Administration Hospital in Miami. Evaluations to date indicate that a modification of the device has significant potential in the clinical environment.

**Oculometer.** Visual performance and behavior studies are being helped by a device originally developed by NASA for pilot performance studies. The unit, called an "Oculometer," is an electro-optical instrument which measures eye-pointing direction, pupil position, pupil diameter, and blink occurrence. Unlike earlier devices developed for this purpose, the NASA oculometer does not require the subject to wear contact lenses or mirrors on his head nor does it require the subject's head to be firmly anchored in one place. It is small enough to be mounted in the dashboard of an automobile or in the instrument panel of an aircraft.

The oculometer seems ideally suited to studying the visual scanning difficulties in one side of the visual field that are often encountered in the hemiplegic patient. (These scanning difficulties interfere in the processing of visual information. They prevent the hemiplegic from singling out pertinent cues that are involved in visual-perception tasks). Some patients tend to ignore visual stimuli located on their impaired side. Others render false information in the impaired side. Still others compensate by turning their heads. These difficulties affect the patient's cognitive functioning and affect his reading, dressing and manipulation of his wheelchair. There is also a relationship between scanning difficulties and accidents in the hemiplegic population.

Rehabilitation specialists plan to explore the movements of the eye while the patient is viewing printed matter, geometric forms and pictures. This will permit comparison of hemiplegic patients with normals and it is hoped, permit characterization of hemiplegic eye movements. The apparatus or measuring technique should answer such questions, while the patient is reading or looking at a picture:

1. Is scanning initiated on the left or right side?
2. Is the upper or lower half preferred?
3. Does the eye perform horizontal or vertical excursions with greater frequency?
4. Is the excursion distance greater in the horizontal or vertical plane?
5. Is the number of fixations greater on the left or right side?

Since the apparatus will provide a graphic picture of the subject's eye movements as a function of time, it will aid in analyzing the specific visual-perceptual difficulties of each patient. It will also assist in devising an appropriate individual program of retraining, suitable for each patient's need.

The device is applicable to a broad range of problems in the testing of visual performance. It should also be useful for evaluating certain types of reading disorders and in the design of therapy regimen to correct these difficulties.

**Testing of Neuropathic Patients.** In the design of highly reliable aircraft and space systems which are to be operated under direct manual control, the problem of the man-machine interface becomes critical. Scientists at NASA's Langley Research Center have been working for many years on these problems. Of major importance is the understanding of the motor and perceptual characteristics of the human pilot. To measure limb-control

response time, rate of movement, etc., Langley researchers developed a variety of tests and testing apparatus. This research resulted in a mathematical model of the human pilot. The technique is under study for use with neuropathic patients.

Modern therapeutic treatment allows many thousands of neuropathic patients to improve the degree to which they can exercise voluntary control over their muscles. But therapeutic treatment, however, is presently hampered by the difficulty of measuring the improvement that individual patients make during the course of therapy. In one currently employed technique for measuring a patient's progress, the patient is presented with a drawing of a thin-lined geometrical pattern and is asked to trace the pattern with a pencil. From this experiment, a subjective judgement can be made regarding the degree to which a patient is able to control the movement of his hand. It was felt that more quantitative measurement of a patient's progress could lead to refined therapeutic techniques which, in turn, could bring about more rapid and more complete recovery for the many patients suffering from neuromuscular disorders.

The problem of testing neuropathic patients was discussed by medical researchers with two of the pioneers in pilot modeling at Langley. It became evident that the tests devised to determine pilot characteristics had much in common with the requirements for testing patients with motor disorders. In a demonstration tracking task given to aircraft pilots at Langley they were required to track a random disturbance by positioning a joystick so that an oscilloscope trace is maintained in the zero position. With this configuration, it was possible to record both pilot response and instantaneous error in tracing random disturbance. The task included model stick and aircraft dynamics. This configuration is illustrated in Figure 25 for a single axis tracking task. The Langley researchers suggested that the stick and aircraft dynamics be removed from the task, in order to acquire better motor performance measurement in neuromuscular patients.

The LRC tracking task with the suggested modifications, shown in Figure 26, was implemented and demonstrated to the Problem Originator to evaluate the technique. Evaluation indicated significant potential and a modified device is being designed and will be built during the fall of 1972.

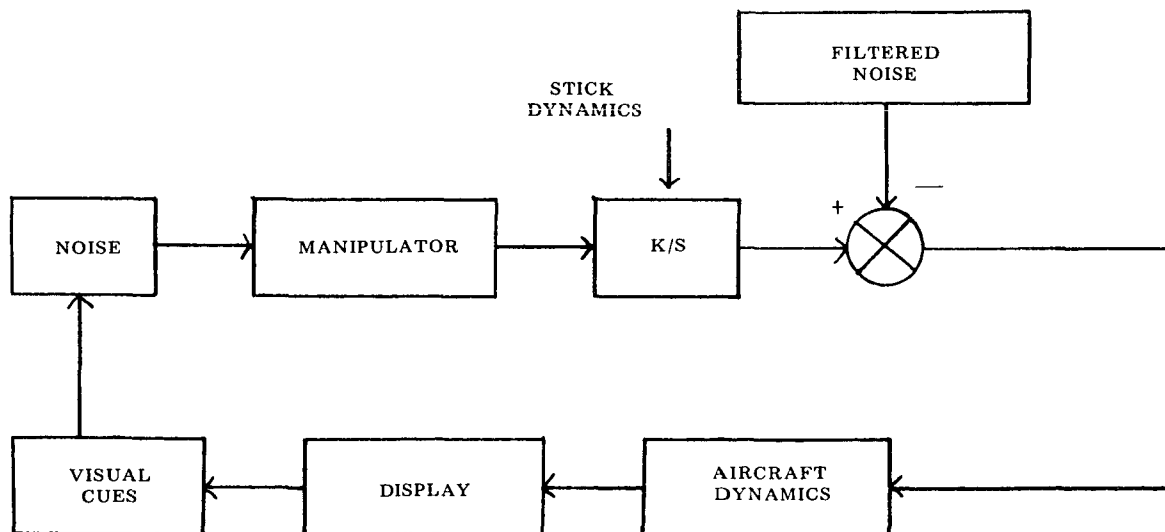


Figure 25. Single Axis LRC Tracking Task

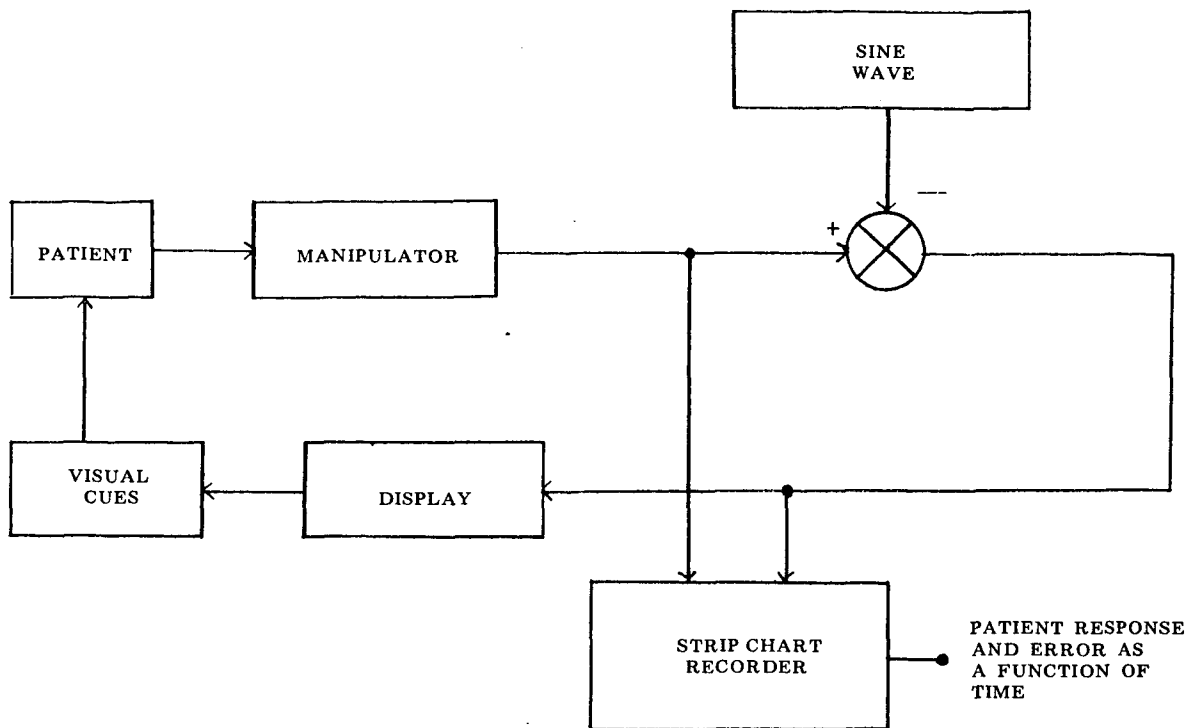


Figure 26. Single Axis Tracking Task for Testing Neuropathic Patients

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

Approximately 6 to 7 percent of the population is considered to be suffering either temporary or chronic speech defects. One such speech defect is characterized by pitch that is either too high or too low. The ailment can be caused by either contact ulcers, polyps, polypoid degeneration or chronic laryngitis. In chronic cases, inadequate understanding of the causes of speech defects hampers treatment.

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

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

NASA searched its data bank for potential solutions. Relevant documents dealt with the determination of spectral differences between several languages and with voice detection from a noisy environment (for example, spacecraft). The techniques discussed appeared to be directly applicable to speech therapy. The Problem Originator expressed strong interest in pursuing this approach. The use of the fast Fourier transform and a digital computer for analysis was of exceptional interest mainly because such a computer (capable of handling the fast Fourier transform analysis) was available at the Tulane University School of Medicine.

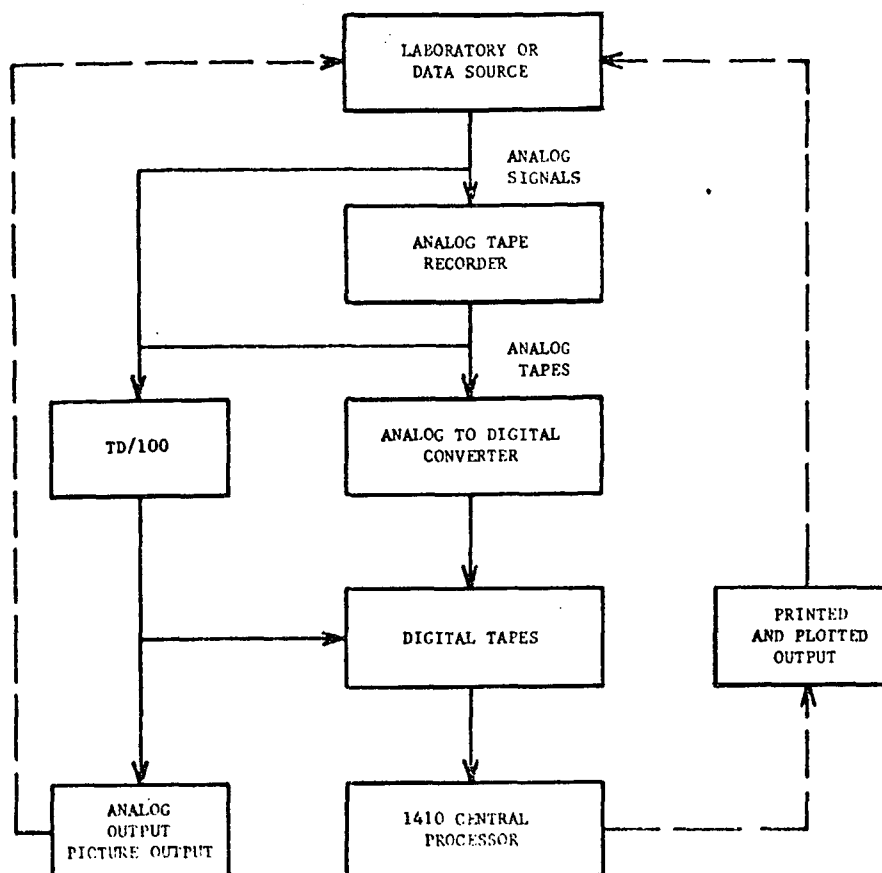


Figure 27. Block Diagram of Voice Analysis System

At present, the fast Fourier transform techniques, outlined in Figure 27, have been implemented on the digital computer for analysis of tape-recorded speech and for comparisons before and after therapy. The initial portion of the study is to establish a baseline of information from which changes can be documented. A specialized spectrum analyzer, providing less frequency resolution than the digital computer, will also be evaluated. If it provides adequate information, it may be more economical than the digital computer. The physician indicates that the initial results are favorable and that an advance in speech therapy can be anticipated.

**Electrodes for Hand Rehabilitation.** A NASA-developed "paint-on" electrode application technique is improving rehabilitative exercise programs for patients who have suffered hand damage.

An important aspect of the physical therapy of patients who have experienced damage to their hands involves the repetitious exercise of certain muscles. It is general practice in the treatment of hands in which muscles have been damaged or have become atrophied to implement a program of exercise and therapy aimed at permitting the patient to regain use of the hand. These therapy exercises are frequently prescribed following surgery to correct and improve hand function. In such therapy programs the patient must exercise specific muscles in the hand. It is frequently difficult for the therapist to determine if the patient is performing the exercise pattern by using the proper muscle instead of some other combination of muscles. This is especially true when a single therapist is working with a number of patients and the patient has to perform the exercises essentially unattended. The damaged muscle is frequently favored by bringing into play some other combination of muscles to produce the motions prescribed by the therapist. As a result, an EMG muscle trainer is employed to determine whether or not a specific muscle is being used by the patient. This muscle trainer consists of two electrodes, an EMG amplifier and a speaker to permit audible recognition of EMG signals. If the electrodes (Figure 28) are properly placed, the therapist can then determine audibly whether the desired muscle is being used by the patient in the exercise.

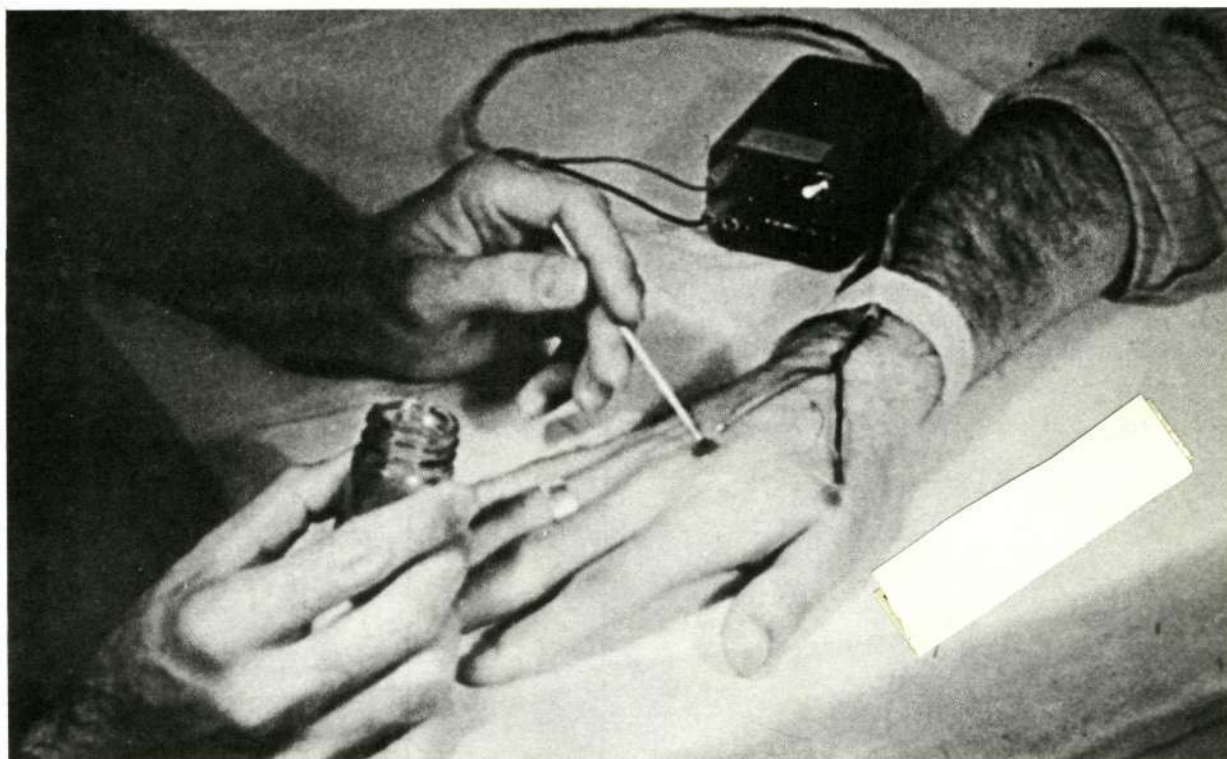


Figure 28. Paint-On Electrode for Hand Rehabilitation Training

Conventional electrodes used in this procedure consist of stainless steel cups approximately 5/16" in diameter which are filled with electrode paste and attached to the muscle with masking tape. There are some difficulties with these electrodes: they are too large and the attachment method along with the size of the electrodes obscures the muscle being exercised. Frequently it is desirable to perform other therapeutic procedures on the muscle while it is being exercised. The present electrodes and associated attachment tape prevent this because in most cases the muscle is completely covered. In addition, the masking tape does not maintain the electrodes in proper position during exercise which can result in artifact or complete loss of the EMG signal.

A search of the NASA data bank in response to medical researchers' requests had previously revealed a NASA technical note, TND-3414 (Dry Electrodes for Physiological Monitoring). This document discussed a dry electrode technique which used a spray-on method of application. The spray-on electrode application procedure was changed to "paint-on" so that very small electrodes could easily be attached to the surface of the skin. Preliminary tests made in the clinical environment using these small "paint-on" dry electrodes were completely satisfactory. The electrode could be made very small, no further attachment mechanism was needed for the wires and the electrodes provided extremely satisfactory input signals to the EMG muscle trainer. Motion artifact was no longer a problem and there was no tendency for the electrodes to become dislodged during exercise. Also, there was almost complete visual and physical access to the muscle being exercised, permitting the use of other therapeutic procedures during exercising, leading to an overall improvement in patient care. In addition, therapists have found that the "paint-on" electrodes are much easier to apply to the specific area on the skin, leading to increased convenience and more exact electrode placement. Since the paint-on electrodes are essentially a thin film, they are very flexible and remain in intimate contact with the skin as the muscles are being exercised. The paint-on electrodes have been evaluated for a number of months in the clinical environment and have been found to be satisfactory and effective solutions to the original problem. The paint-on electrode has been adopted by several other rehabilitation agencies and is now recommended by the designers of the EMG muscle trainer.

**A Simple Method of Obtaining Electrical Connection to 25-Micron Wire.** In EMG (electromyograph) studies of the spinal musculature, fine wire (25-micron) subcutaneous electrodes are placed through a hypodermic needle into the muscle whose EMG signal is to be monitored. The end of the electrode wire must be electrically connected to the input of an integrated circuit preamplifier strapped or taped nearby. Soldering, welding, or other bonding techniques which pose a real or psychological danger to the patient cannot be employed. The technique in use when this problem was defined employed a coil spring attached to the input terminal of the preamplifier as the connector. Connection was made by pulling the spring apart, inserting the bare electrode wire and allowing the spring to compress back down on the wire. Although handy and easy to use, electrical connection was accomplished by means of "smeared" point contacts with this method so that reliability difficulties have been frequently experienced. A better method of connecting the electrode lead to the preamplifier was desired. The new connection technique had to be easy to use with the fine wire, provide reliable and low impedance connection and not be hazardous or threatening to the patient.

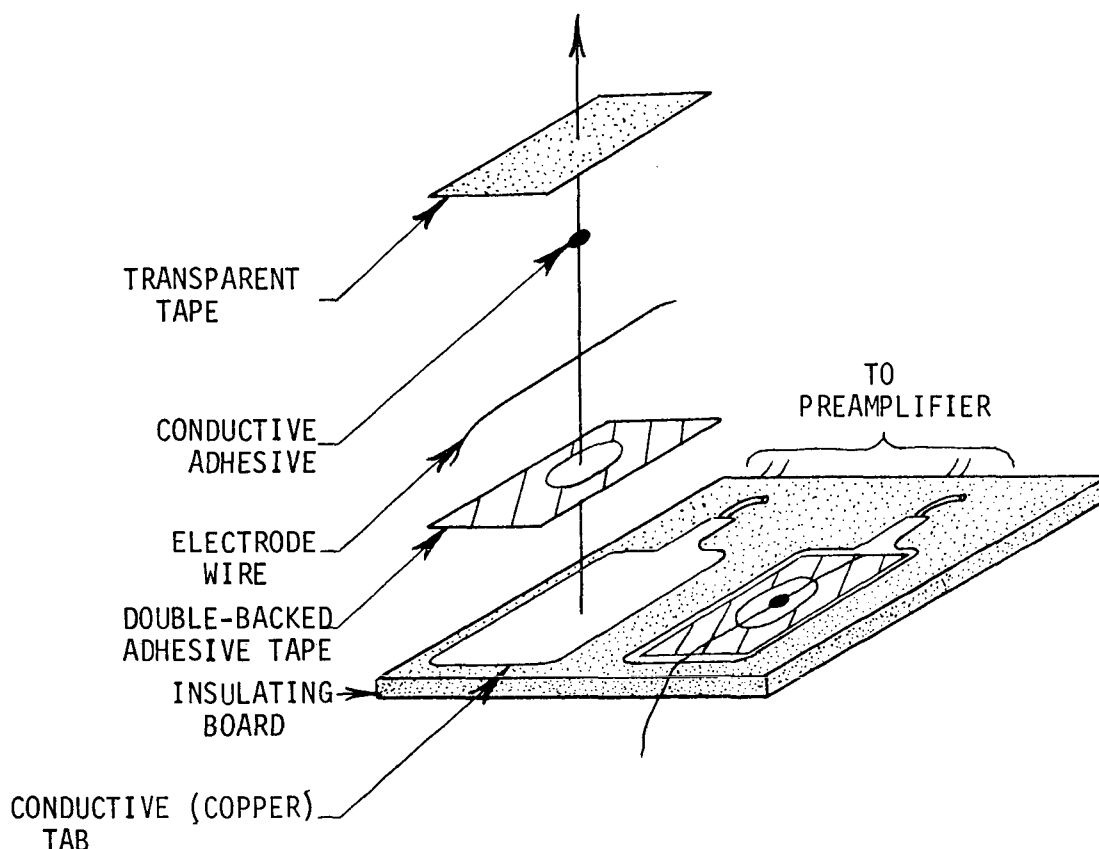


Figure 29. Connection Technique for 25-Micron Electromyograph Wire

A connection technique using a conductive adhesive based on NASA-developed dry electrode techniques was suggested as a potential solution to this problem. The terminals to the preamplifier are constructed by forming two tabs or "lands" of copper separated by a small distance on a chip of printed circuit board (see Figure 29). These terminals are attached to the preamplifier. Connection from the preamplifier to the terminals is accomplished by soldering. Because of the small size of the electrode wire and resulting difficulty in handling, it is necessary to fix the wire in place before the electrical connection can be made. To accomplish this, a small double-backed adhesive template shaped as shown in the illustration is applied to each terminal tab. Next, the electrode wire to be attached is stretched across the tab and pressed into the adhesive at each end of the tab. This holds the wire in a fixed position so that the conductive cement can be easily applied. The conductive adhesive is applied using a camel's hair brush, a Q-tip®, or other convenient applicator. Using a small hand-held hair dryer blower, the cement can be dried in less than 15 seconds. For additional mechanical strength, a piece



of transparent adhesive tape is applied over the terminal. This technique has provided excellent electrical connection between the preamplifier and the electrode wires and has been very reliable. Because of its ease of attachment, technicians have quickly learned the technique and become proficient in its application. Researchers have conducted clinical tests with both human subjects and gorillas. In both cases, this connection technique was highly successful. The researcher considered the connection problem completely solved and is now using this technique routinely as a part of his standard procedures. It has been demonstrated at several medical conferences and has been enthusiastically adopted by other rehabilitation centers.

**Ultra-Thin Electromyographic Needles.** Thinner electromyographic needle electrodes are being designed by materials scientists at NASA's Langley Research Center. Electromyographic studies frequently require repeated needle electrode insertions over extended time in a single session. When this time exceeds 30 minutes, the pain threshold of the patient lowers to the point of excessive pain generation. This pain is directly related to the gauge or thickness of the needle with thicker needles causing excessive pain sooner. The problem originator, a physician with the Rosewood Rehabilitation Center in Texas, requested NASA assistance to develop an ultra-thin, insulated needle. The presently available commercial needles are stainless steel and are not available in diameters less than 1 mm.

Four batches of new needles have been made of precious metal alloys and have been treated to resist warpages or breakage during insertions through the skin. Their electrical properties are similar to conventional electrodes—and they are biocompatible and may be sterilized by conventional techniques. Conventional stainless electrodes are insulated with teflon so that electrical signals are only recorded from the tip of the needle. This coating also contributes significantly to the thickness of the needle. NASA-developed techniques for applying this teflon coating will allow a reduction of the thickness of the coating by a factor of ten. Clinical trials with these new needles will begin in July 1972.

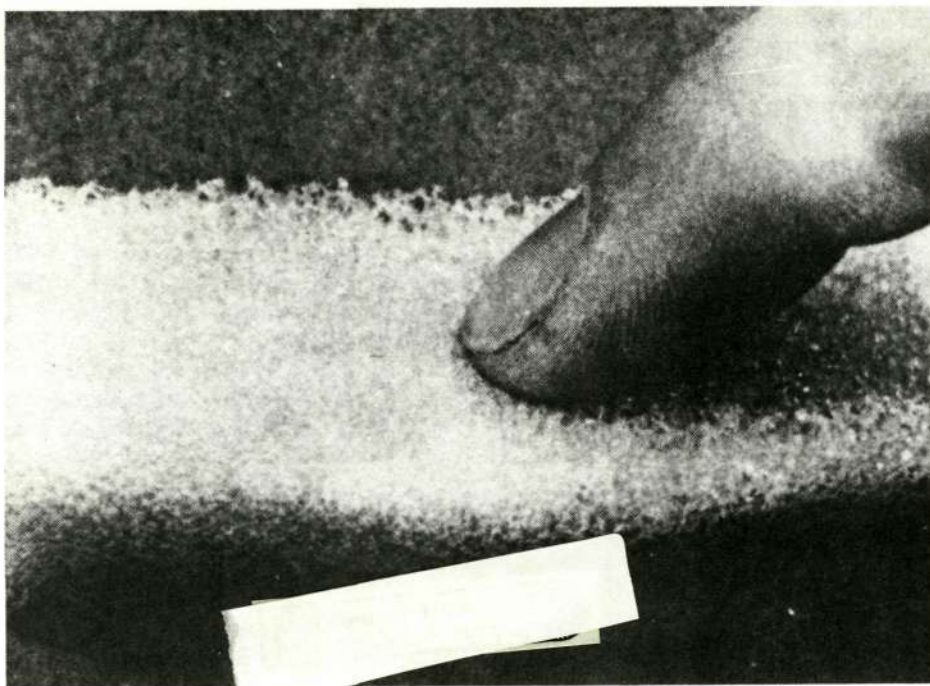
## REHABILITATION MEDICINE: MATERIALS AND TECHNIQUES FOR REHABILITATION

**Polyurethane Foam as a Padding Material.** NASA-developed foam material is being used to enhance the comfort of bedridden patients. Patients with spinal cord injury frequently develop decubitus ulcers (open bed sores) caused by continuous pressure applied to weight-bearing points of the body. Easily infected, these sores often become quite serious, exposing muscle tissue and occasionally bone. Surgery is often required to close the wounds. High-pressure points are more common in these patients, since their musculature and other padding tissues atrophy from lack of use. Sensory deficiencies prevent the patients from feeling pain; a person in normal health would reposition himself before an ulcer would form. Also, motor paralysis prevents injured patients from moving. Pressure sores cause much suffering and are difficult and expensive to cure. The high cost (up to \$15,000 per case) is attributed to hospital-staff time which must be devoted to the patient, to special medication, surgical correction, and postoperative care.

In response to a request from rehabilitation specialists, a group at NASA's Ames Research Center reviewed a number of padding materials developed for use in space vehicle couches to absorb vibration and shock. For the medical problem, the Ames group suggested the use of a NASA-developed polyurethane foam. This foam (Figure 30) has unique viscous and elastic properties, as well as temperature and compression-rate sensitivities. It absorbs mechanical energy, cushions to a comfortable, flow-fitted support and distributes high-pressure areas into uniform lower pressures. It can be easily formed while maintaining stiffness and it functions as rigid foam at low temperatures or as elastic foam at high temperatures. It is now commercially manufactured.

The material is available in several densities and has proven useful in many rehabilitation applications. Its use as a wheelchair pad has led to relief of pain and considerable increase in comfort. Although no ulcers have developed with the use of the polyurethane foam, this cannot be stated as an established fact because of insufficient experience. Patients using these pads previously had hip pains while sitting and feel that the polyurethane-foam pads are preferable to others. Sweating or heat problems have been reduced with the polymethane foam.

When polyurethane foam was used as padding for below-knee prosthesis, the results were excellent. The below-knee amputee usually has discomfort on the anterior distal end of the stump, because of clapper action against the prosthesis on extension of the knee. Rehabilitation specialists report that the use of ¼-inch strips of



Decubitus ulcers tend to develop over the bony areas of the bodies of spinal cord injury patients who experience sensory loss. The average estimated cost for treatment of a decubitus ulcer is \$15,000. Researchers have been seeking a cushion material which will prevent formation of these ulcers. A polyurethane foam developed for space vehicle seat cushions may result in a significant improvement in bedding for these patients. It may also be used as an improved padding material for wheelchairs and prosthetic or orthotic devices.

Figure 30. Polyurethane Foam

this foam has relieved this pain immediately. In one case, the foam was placed on the distal of a stump on which a blister had already formed. The patient continued to walk and to use the stump, bearing weight on the foam. The blister healed without complication.

When conventional felt padding on knuckle-bender splints of patients with burns was replaced with polyurethane foam, it provided adequate support without damaging the thin scar tissue as the felt padding had done.

The polyurethane foam has also been used to pad 4-post neck braces and various prosthetic devices. Patients report far more comfort and experience far less pain.

The results of these early applications of polyurethane foam have been highly encouraging and it is currently being evaluated for other uses in the medical area.

**On-Line Fabrication of Orthotic Support Devices.** Physicians at rehabilitation centers believe that patients could be relieved from a certain amount of pain and discomfort by means of rapid custom-fabricated orthotic devices, such as arch supports. Since most rehabilitation centers do not have in-house fabrication facilities, the usual procedure is to measure the patient for the device and then order it from a commercial source. This results in loss of much therapeutic time, since it usually takes two weeks from order to delivery.

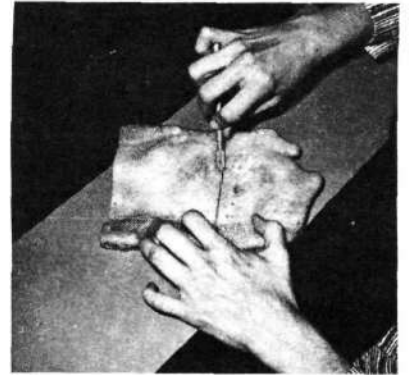
NASA responded to a request from a Southwest rehabilitation center for a lightweight material, that would be both resilient and tough and could readily be poured "in-house" to form a suitable temporary orthotic support.

A search of the NASA data bank revealed several alternatives. The most promising was the foam-in-place technique developed at Wright-Patterson Air Force Base for use in customized, form-fitting helmet liners. The technique appears very promising (Figure 31) as an effective, economical means for providing immediate custom-fitted temporary orthotic support aids.

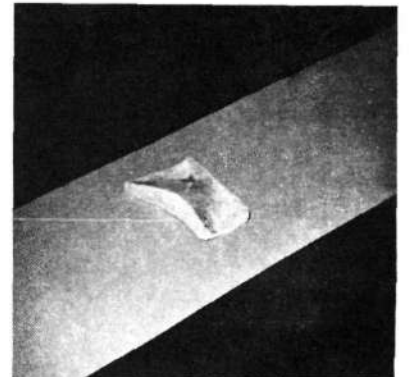
In place foaming of arch support provides the patient with a custom-fitted support device which can be used immediately. Shown here is the arch support foamed to the contour of the foot.



Trimming free foam arch support to fit patient's shoe.



Arch support trimmed and ready for insertion into patient's shoe. The entire process from foaming the arch support to placing it in shoe takes only ten to fifteen minutes.



Temporary arch support in place in shoe, ready for immediate use.



Figure 31. Helmet Liner Foam for Rapid Fabrication of Support Devices

There has also been interest in using this material to form molds for positioning and immobilizing patients during radiation therapy. Accurate repositioning of a patient is essential for effective therapy and the casting techniques currently used are both time-consuming and expensive.

Effective radiation therapy requires that a patient be accurately repositioned each time to receive a specifically directed radiation dose. For this accurate repositioning, as well as immobilization of limbs or a hand, casts must often be made to withstand months of repeated handling. The foam-in-place mold-making technique is being evaluated for this purpose since its rapid fabrication and curing properties are quite favorable.

**Biocarbon Implants.** Technology Utilization funds have been made available through the Marshall Space Flight Center for a special project at Rancho Los Amigos Hospital in California to further develop and test biocarbon materials in cooperation with interested medical specialists. High-purity, high-strength forms of carbon, developed for space capsule heat shields, are being tested and evaluated for the fabrication of implantable prosthetic devices. Devices such as bone substitutes, teeth and replacement heart valves intended for long-term implantation in the human body must be highly compatible with body fluids and tissues. Until recently, however, the available carbon was not sufficiently strong for prosthetics use. Materials of lesser biocompatibility had to be used.

Studies have shown that vitreous carbon developed for aerospace use is now sufficiently strong to be fabricated into prosthetic devices (Figure 32) and pure enough to be biocompatible. Vitreous carbon combines strength with chemical inertness. In comparison with other materials used for implantation, it is notably light and hard enough to permit low-mass implants and has a low coefficient of linear thermal expansion. Being a pure carbon, it is highly resistant to body fluids since it cannot corrode at body temperature. The nonmetallic composition offers the prospect that vitreous carbon should be free of adverse tissue responses such as inflammation, swelling, pain, sepsis and body resorption initiated by the release of metallic ions and particles. Vitreous carbon also has an advantage over polymers such as acrylic, PVC, Teflon, and nylon, in that it contains no impurities or additives, such as stabilizers, antioxidants and low molecular weight components. With polymers, adverse tissue reactions arise from leaching of these various constituents. Also, although polymers offer high resistance to industrial chemicals, they are often metabolized by the body, resulting in a loss of strength. Studies to date indicate that vitreous carbon exhibits excellent chemical resistance and high strength and rigidity.

The interface between artificial and living material is the most demanding challenge in skeletal attachment of a limb prosthesis—that is, the attachment of an artificial limb to an extension device attached through the skin to the bone. This program will evaluate the suitability of currently available, high-purity biocarbons for the



High-purity, high-strength forms of vitreous carbon, form prosthetic devices intended for long-term implantation in the human body. Vitreous carbon is the material originally developed as an ablative heat shield for reentering space capsules.

Figure 32. Biocarbon Implants



fabrication of transcutaneous implants. The first state of the program calls for the evaluation of a device which can be attached to a bone, fixed in place by a pin, while allowing a bacteria-free transcutaneous passage. This would allow a skeletal fixation pin (Steinman pin, pelvic traction pin, etc.) to extend through the skin indefinitely without infection. To date, six Steinman pins have been implanted. These pins are installed through a bone so that traction may be applied to the two exposed ends of the pin. To provide meaningful test results, special pins have been fabricated so that one protruding end is made of the biocarbon while the other end of the pin is the conventional metal alloy. No infection or drainage problems have yet been encountered at the biocarbon penetration site.

The second phase of the study calls for the design of a transcutaneous electrical connector. This could be used to acquire myoelectric signals from implanted electrodes as well as for long-term electrical stimulation.

Although the transcutaneous problem as identified and the anticipated solution described above would have significant interest in a wide range of medical applications, one of the most serious clinical problems facing the orthopedic surgeon is the skeletal bond to prosthetic tissues. In spite of the use of a large number of prosthetic joints and devices attached to the bone, little basic understanding is available as to the optimum configuration and materials of attachment. Currently, a plastic filler—methyl methacrylate—is the most successful cement method to achieve fixation of prosthetic material associated with bone. Exactly what is happening to this material under dynamic mechanical and biological stresses is essentially unknown as is, indeed, the case in the use of titanium and vitallium at the interface between bone and prosthesis under functional circumstances. Considerable basic information could be provided if one could study the interface after a period in which functional stresses have been applied.

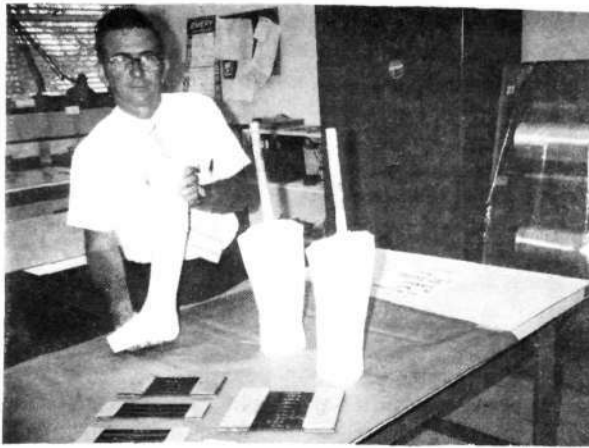
Wherein the first two phases of this project require human study for appropriate evaluation, the third phase will use animals. In this phase a bone bridge, constructed in the form of an intramedullary device, will be placed in a gap created midshaft of the femur or humerus of a dog. The implant device will have a disconnect section in the middle and a wide flange to prevent bony union of the gap between the bone ends. Using the two stems of the implant, differences of bone bond between carbon and various traditional materials would become apparent under functional circumstances. It must be pointed out that a wide range of materials, both polymer and metal, are well accepted by living tissue before functional stresses are applied to them; but under the impact of mechanical stresses, the previously benign, biologic response becomes more severe, and, thus, a source of failure eventually develops. By comparing one material with another under similar mechanical stresses in the same limb of an animal, a highly-controlled, basic study could be accomplished. The results of this study would have considerable impact on the scientific community and give credence to the claim of unusual biocompatible properties of medical-grade carbons.

The design and fabrication of a skeletal attachment device will only be a general problem following the successful conclusion of the first three phases establishing the design of a rational device. On the basis of data developed from the skeletal-stress study and from the skin-implant study, a rational design for skeletal attachments will be constructed. There is every reason to believe that the information developed out of the three preliminary phases would define the ultimate design of the NASA Skeletal Attachment System.

**Lightweight Prosthesis and Orthosis Materials.** A NASA-developed variety of hybrid composites consisting of fibers of boron-graphite-glass embedded in a matrix of epoxy resins offers potential for use in the building of lighter-weight orthotic and prosthetic devices (Figure 33). Such cured composites produced excellent structural materials to satisfy aerospace needs for lightweight materials to be used in airplanes and capsules. The composites are equal or superior to steel in stiffness and strength characteristics and their weight is about one-half that of aluminum. They have another advantage in contouring and shaping since they are cloth-like in the precured state. Adjustments in the epoxy resin components provide a wide range of curing temperatures, to include curing at room temperatures.

While present prosthetic and orthotic devices have been improved and refined by incorporating new ideas and materials in highly sophisticated developments, orthopaedists almost uniformly have standardized on using stainless steel as the preferred supportive material for its characteristics of durability, dependability and stress resistance.

Steel-reinforced artificial hands, feet, arms and legs have been extremely helpful in rehabilitating the amputee, the paralyzed, the neuromuscularly weak, and the patient who has birth-defect anomalies. But the stainless steel supports also introduced substantial weight and bulk factors for these devices.



Molds of the patient's lower extremity which will be used to custom-fit the composite (graphite) material orthotic device. The bars in the foreground are samples of various thicknesses of composite, which are being tested for strength. The laminate chosen for use will be the one lightest in terms of weight, which at the same time possesses adequate strength to withstand the considerable stress placed on the brace in use.

Sample of uncured graphite composite material being folded over to demonstrate its capability of being formed and handled with relative ease.



After conclusion of the stress tests on the composite samples shown in Photo A, the actual braces will be constructed. Composite brace components will be custom-molded on the cast so that when cured, the finished composite brace will conform precisely to the patient's limb.

Figure 33. Composite Material Orthotic Device



Men, women, and children with neuromuscular weakness have experienced considerable difficulty when they tried to manage the weight and bulk of their devices while adjusting during rehabilitation and in later activities. The physical difficulties and aesthetic objections affected a large segment of those receiving rehabilitation-medicine treatment.

The NASA composites appear to hold great promise for solving the weight and bulkiness problems without sacrificing durability, dependability, and stress-resistance requirements for orthotic/prosthetic devices. Fabrication design and feasibility testing of the materials is presently in progress.

**Motor for Powering Prosthetic Unit.** DC brushless motors designed under NASA contract to position satellite solar panels and to unfurl antennas now appear ideally suited as a motive source for prosthetic devices. The Rancho Los Amigos Hospital is working with NASA's Jet Propulsion Laboratory to define specifications and design compact, lightweight motors specifically for powering artificial limbs.

In a separate instance, a rehabilitation physician working with a four-year-old boy, born without legs and arms, approached NASA for assistance. With prostheses and intensive training the boy had been able to stand up and walk independently at the age of 19 months. At four years he was using both leg and arm prostheses. In addition to walking, he could eat, drink, and draw using his prostheses. The basic problem was to design a prosthesis that would permit the boy to go up and down stairs.

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

Needed for the design was a motor, small and lightweight enough to fit into the prosthetic leg yet powerful enough to lift the entire weight of the boy. Hard and fast specifications on the motor performance were somewhat difficult to assign. There followed a search for the smallest and most lightweight motors that could be obtained and which could provide the power to lift approximately 50 pounds a distance of eight to ten inches within five to ten seconds.

Brushless DC motors designed under NASA contract to provide motive power in positioning satellite solar panels and unfurling antennas were the most likely to fit this particular application. Information on the motors was obtained and forwarded to the Problem Originator. It appears that these motors are well suited for the prosthesis for the young boy. As soon as detailed motor requirements are completed a motor will be requested from the manufacturer.

**Electronic Peroneal Nerve Stimulation via Flexible Electrodes.** Ultraflexible electrodes being developed at NASA's Ames Research Center for long-term monitoring during prolonged space flight are suitable for many rehabilitation and patient-monitoring problems. The electrodes are made of an elastomeric material saturated with a fine suspension of conductive metallic particles. The material may be formed to any shape and can be stretched to 40% greater than its original length while maintaining excellent conductive properties.

In the patient with hemiparesis or hemiplegia (partial or complete paralysis of the muscles of one side of the body following damage to the upper motoneurons from any of a variety of causes such as brain injury, inflammation or tumor, and most frequently, cerebral occlusive disease) functional electrical stimulation of the peroneal nerve may be indicated, rather than the mechanical peroneal brace or splint, to achieve effective dorsal flexion and eversion of "drop foot." The impairment of the peroneal muscle group, resulting in "drop foot," appears to be the most common permanent residual. This produces a major interference with walking. Marked improvement of the impaired gait of the hemiparetic patient may be achieved by electrical stimulation applied to the peroneal nerve. This stimulation can be applied by surface electrodes connected to a stimulator triggered by a heel switch in the last third of the walking cycle. The stimulator affords adjustable frequency, duration, pulse width and intensity of the train of stimuli.

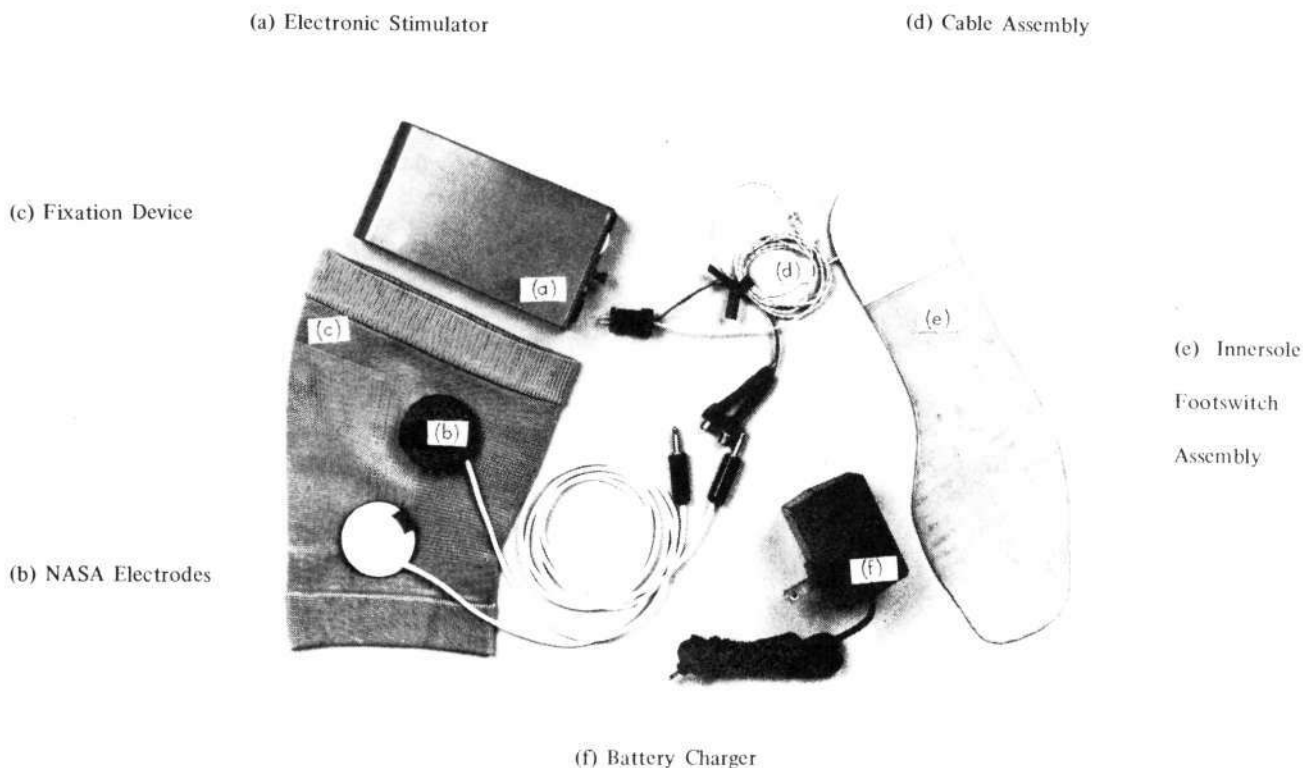
With the use of functional electrical stimulation, it is not only possible to prevent "drop foot"—the goal of classical mechanical peroneal braces—but also to control dorsal flexion and/or eversion of the foot in specific phases of the walking cycle. At the same time, the active processes of nervous activity involving related muscle groups (i.e., excitation and inhibition of them) which are necessary for any organized movement can be influenced. The technique described represents a useful aid for the hemiplegic patient in the control of simple defects of locomotion and other stereotyped, semi-automatic motor activities. However, a limiting factor has been the nonavailability of suitable electrodes. Since the area of attachment for the electrodes undergoes considerable adjustment during movement, ordinary electrodes and attachment methods were inadequate.

A rehabilitation-center researcher facing this problem contacted NASA's Ames Research Center researchers working on advanced ultraflexible electrode and wire technology. The Ames researchers fabricated specially shaped flexible electrodes (Figure 34) for external attachment to the leg. The Problem Originator has evaluated them and has expressed his satisfaction with the electrodes.

Interest has also been shown in evaluating these electrodes for use in a fully implantable nerve stimulation system. A conductive cuff of elastomeric material will provide a soft, nonabrasive contact with the peroneal nerve.

**Tendon Mender.** A NASA-developed technique for butt-welding fine-gage wire (NASA Tech Brief 70-10136) is being evaluated at the University of Utah for placing barbs on fine wire pins (Figure 35) used to hold the severed ends of tendons together while they are healing. The technique was originally developed by the NASA Langley Research Center for welding thermocouple junctions using fine-gage wire 0.001 inches in diameter.

Surgical restorations are required to regain mobility functions after tendons have been severed by accidents and injuries. Wire and other suturing materials have been employed to bind the tendon ends in close proximity to permit healing to anatomically join them again. These procedures required followup surgery in many instances for the purpose of exposing and removing the suture materials following the healing. Cosmetic and plastic surgery frequently was necessary to repair the area as a result of the scarring.



The use of special ultraflexible electrodes developed at NASA's Ames Research Center permits more effective functioning of this device which can control the flexion and eversion of "drop foot."

Figure 34. Electronic Peroneal Nerve Stimulator

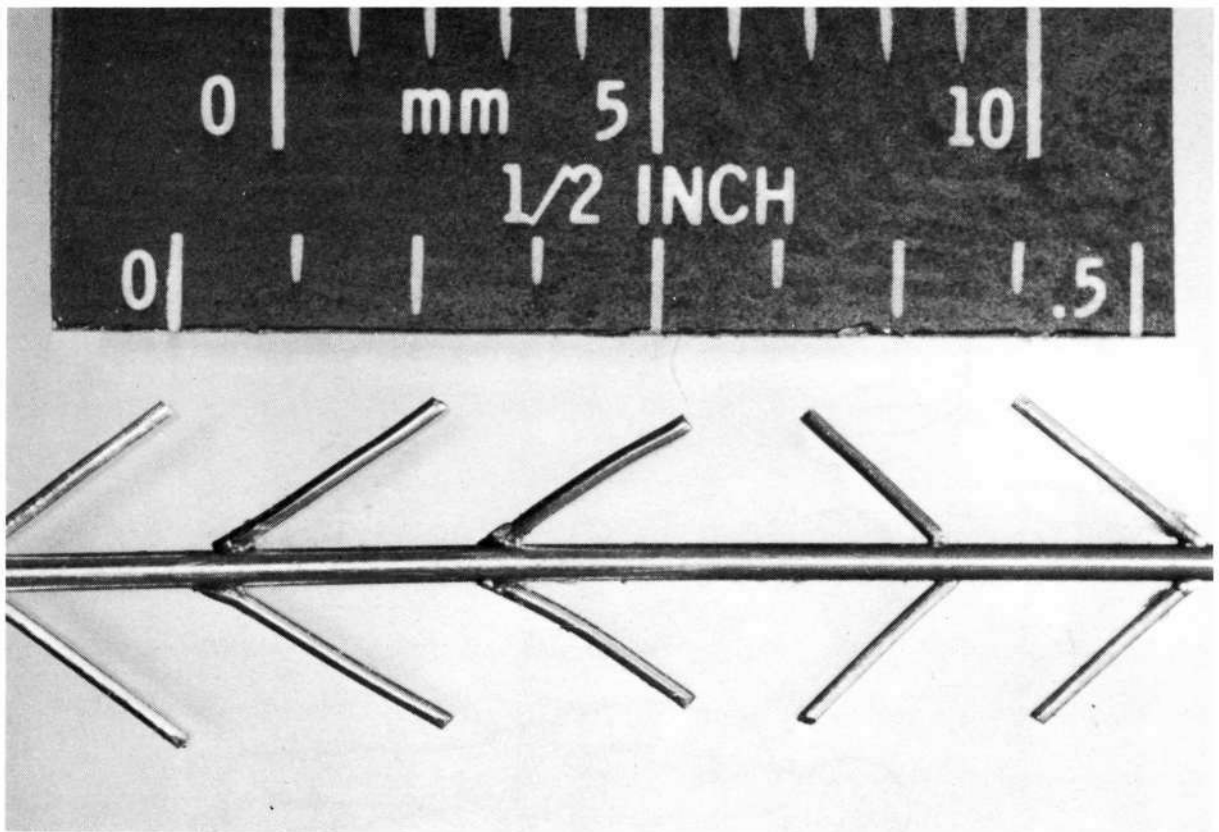


Figure 35. Tendon Mender Pin

The University of Utah Problem Originator sought the means to butt-weld barbs along the shaft of a fine-gage wire so that it could be inserted as a pin into both of the cut ends of the severed tendon. His idea was to angle and place the barbs so that they would present minimum resistance by flexing as the pin is inserted. Any outward pull by either cut end could cause the barbs to catch into the tendon material without inverting to present maximum resistance to pullout. The pin could remain in place after healing since it would resist any tendency to migrate in the tissue and would present no biocompatibility problems.

A number of these pins have been fabricated at Langley Research Center and are being tested in dogs.

## REHABILITATION MEDICINE: PATIENT ASSISTANCE DEVICES

**Survey of Teleoperator Technology for Use by the Handicapped.** Following up on its extensive experience in teleoperator technology—many aspects of which have already been put to work in equipment used by handicapped persons—NASA is presently engaged in an in-depth analysis of existing equipment and techniques. The purposes of the study are to discover additional applications based on state-of-the-art technology and to search out potential applications that would be based on advanced technology when it becomes available.

The state of current technology, as it applies to aids to the handicapped, will be determined in all principal areas of teleoperator technology through reviews of existing literature and through discussions with manufacturers and specialists involved in research and development at private and government institutions. This will be followed by analysis of current problems in prosthetics, orthotics and sensory aids for which required teleoperatory technology is not available, is ineffective or is being inadequately applied.

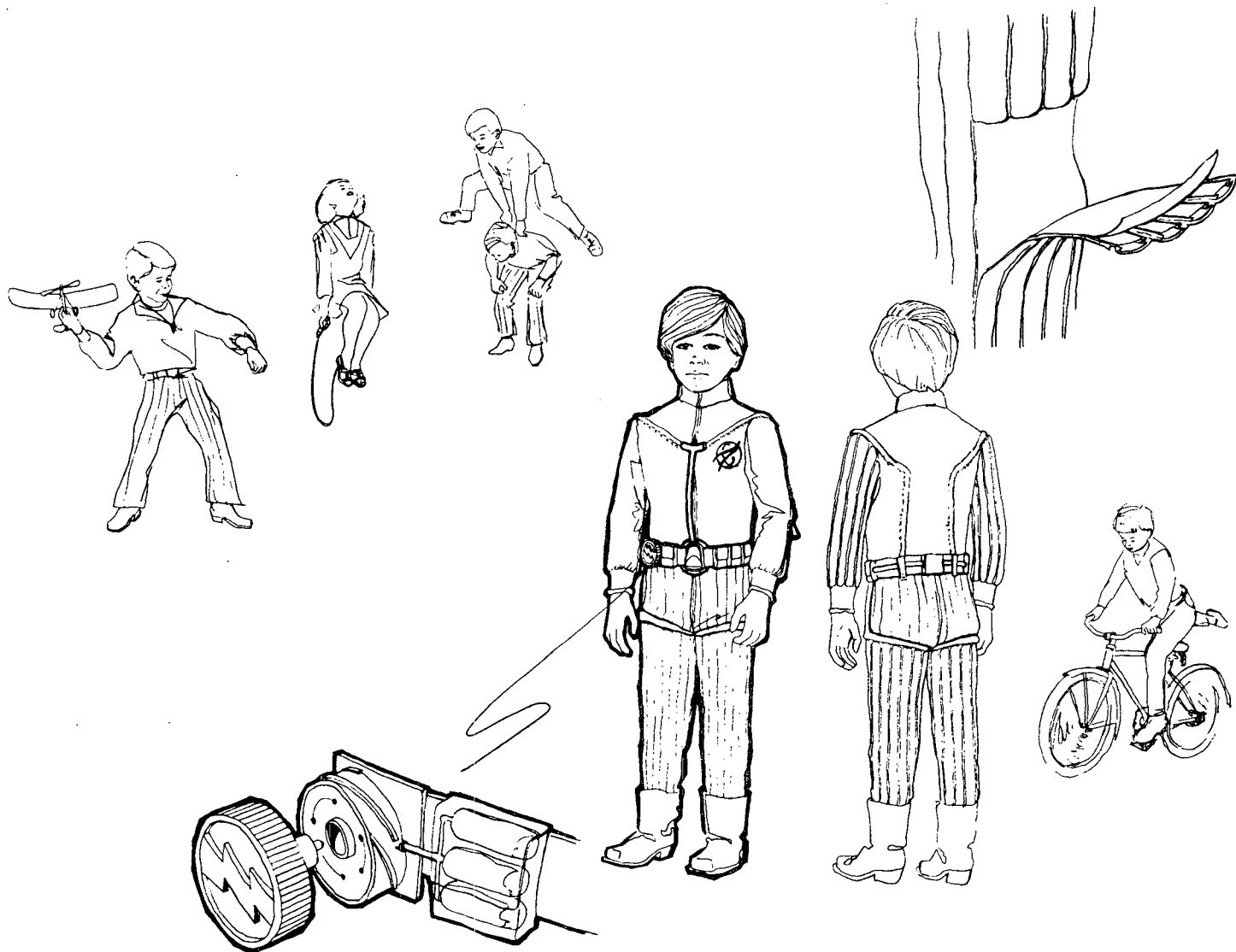


Figure 36. Concept for Application of Anti-G Suit to Hemophiliacs

Specialists will interview users of the available technology—the handicapped patients—and will confer with personnel involved in technology development at Veterans Administration facilities, private hospitals, the National Institutes of Health and industry. As new problem areas are identified through discussions with handicapped users, NASA follow-up contacts with developers may be indicated.

The review and classification of teleoperator development, current and future, and the description of the state of the art in prosthetics, orthotics and sensory-aid technology, is expected to produce a number of potential new “matchings” of technology and needs—with useful data on the degree of new technology development required, rough order-of-magnitude costs plus information on the best sources, in and out of NASA, of technology to solve identified problems. The study is expected to take about eight months. Its findings will be recorded in a NASA report.

**Anti-G Suit to Control Hemophiliac Bleeding.** NASA is presently funding the fabrication of a prototype “antihemophilia g-suit” for evaluation on suitable patients in a controlled clinical setting. Two suits have been built and are presently being worn by children who are patients at the Kaiser Hospital in Santa Clara, California (Figure 36).

Hemophilia is a physically and psychologically crippling disease which, according to National Hemophilia Foundation figures, affects more than 60,000 Americans. Afflicted children rarely reach adulthood without disabling joint deformity, contractures, and muscle atrophy due to recurrent hemorrhages following even minor trauma. Maternal over-protection, fear of injury and recurrent hospitalizations isolate the hemophiliac child from his peer groups and often lead to severe psychoneurosis. Employers are reluctant to hire the adult hemophiliac because of exaggerated fear of work-related injury and excessive sick leave.

The current treatment of hemophilia consists of the administration of fresh blood or plasma to replace the deficient antihemophilic globulin factor (AHG). The use of AHG concentrates and cryoglobulins gives promise of prevention but is limited by the development of neutralizing antibodies in 10 percent of the patients, frequency of injections required and excessive cost. Clearly, any technique or procedure which could prevent or minimize initial bleeding into the muscle or joint (which can sometimes exceed one quart) would be a valuable adjunct in the treatment of hemophilia. Not only would the subsequent crippling effects be reduced, but equally important, the afflicted child or adult could relate more normally with his peers.

The use of external body counter pressure, as exemplified in the modern anti-g suit, seems ideally applicable for use by the hemophiliac. A garment containing a system of inflatable bladders can be worn as an outer coverall which appeals to a child or as an undergarment under regular clothing. Immediately after a fall or suspected injury, the child can inflate the suit by simply blowing into a plastic tube attached to the bladder. This results in immediate immobilization of the injured limb and, by forced extension of the joint, effects a reduction in the size of the joint space into which potential bleeding can occur. In the current design concept the bladders are inflated to prevent pooling of blood in the extremities. The bladders can be removed to permit laundering or interchanging of garments.

The use of the anti-g suit in clinical medicine is not without precedent. Physicians and researchers at NASA's Ames Research Center and Stanford University Medical Center recently reported a case in which an anti-g suit arrested life-threatening hemorrhage in a young woman on whom standard techniques had been unsuccessful. The dramatic response in this case prompted the researchers to consider the possible application of the g-suit concept in hemophilia. Their report contains a theoretical discussion of possible mechanisms by which external counter pressure can control internal hemorrhage.

**Assist Device for Totally Paralyzed Patients.** The Vietnam conflict, plus the increasing incidence of serious automobile accidents on the Nation's highways, have resulted in a large number of totally paralyzed (quadriplegic) patients. These patients are confined to hospitals and extended care facilities. Depending upon the level of spinal cord injury sustained, some may have limited use of, for example, the fingers. Others, however, cannot even move their little fingers or move their heads. Obviously, such patients must of necessity depend upon others for everything that is done for them—from feeding and bathing to turning off the lights when they wish to sleep. Rendering the matter even more difficult is that such patients—having no control over their extremities—cannot activate the call system to summon the nurse for assistance when needed. The result for those quadriplegics who survive (many do not for extended periods) is an unending succession of long hours at the complete mercy of others.



Patients who are paralyzed in all four limbs (quadriplegics), multiple amputee patients, and patients with severe neurological disorders are almost totally dependent upon support from patient-care personnel for any activities or interests in which they can participate. The morale of such patients is markedly improved and the demands on patient-care personnel are greatly relieved by any device or procedure which enhances a patient's self-sufficiency.

The Veterans Administration Regional Office in San Antonio had placed a quadriplegic veteran in one of the local nursing homes and, having learned of the NASA efforts in rehabilitation during a recent state-wide rehabilitation conference, solicited help in devising some means for helping the veteran perform such simple functions as turning the page of a book or magazine, or turning on a radio or television set—to help add more meaning to his daily life. The veteran, despite the severity of his affliction, remained exceedingly alert and desperately wanted to do something other than continually watch the television set in his room, unable to change the station or turn the set off. He particularly wanted to be able to read books and magazines. This presented quite a problem, because, even with the utmost effort, the individual could not move his arms or hands to activate a control mechanism. The matter was complicated even more by his inability to move his head, which could perhaps have been used to activate a control device.

It appeared that an ideal solution might well be provided by using the NASA-developed sight switch, presently being evaluated as a control mechanism for electric wheelchairs. Accordingly, arrangements were made to obtain one of the sight switches for trial. The sight switch was found to work exceedingly well with a standard mechanical page turner and required only a modest adaptation to put into use (Figure 37). This adaptation involved designing a circuit that could complete the page turning (or other action) sequence—without the patient having to keep his eyes turned towards the switch while the action sequence was underway. With the modification, one brief glance activates the page turning mechanism which completes its cycle automatically, allowing the patient to return his eyes to the normal forward position, thus avoiding undesirable eye strain.

For this particular patient, the eye switch was considered superior to possible alternative control methods, such as intra-oral switches. These are subject to deterioration in saliva and, in addition, present sanitation problems. A further advantage of the eye switch is that it can, by adding simple logic components, control other functions designed to help give the totally paralyzed patient some measure of control over simple daily functions. The activities include turning on or off his room lights, calling the nurse or attendant when he needs help, turning on a special "talking book" phonograph when he tires of reading and—if interaction with the Southwestern Bell Telephone Company proves successful in adapting a telephone instrument—being able to call family and friends when he wishes, without the intercession of a nurse or attendant to place the call for him.

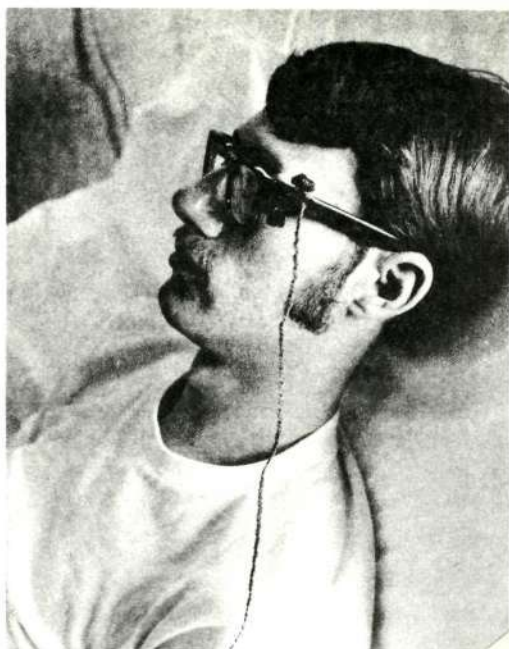
NASA's Marshall Space Flight Center is designing a fully instrumented room (Figure 38) which will enable patients such as paraplegics, paralysis patients or amputees, to control all of the equipment and devices in the room. To be installed and evaluated in the rehabilitation center at the Huntsville Hospital, the system will enable a patient to control room lights, a page turner, a radio or TV, message panels and a variety of servos capable of controlling appliances, the bed positioning and even a telephone.

A variety of patient-control switches (Figure 39) will be available, so that the control switches will be carefully matched to the patient's physical abilities. Some patients are able to turn their head and neck to either side. Others may be able to control the movement of a finger or toe. Even patients with extreme disabilities can usually produce a directed puff of air which may then be used to actuate a microswitch.

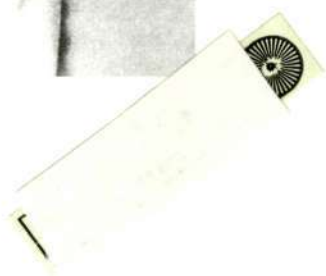
Extensive testing has proven the feasibility and operational capacity for each of the alternative actuating control devices and the coupling to selectively control the activating switches, within the capabilities of the patients who would use them.

Installation of the system is now in progress and the completed room will be ready for use by September 1972.

**Patient Assist Devices Controlled by Eye Motion.** Paralyzed patients and amputees are now using the NASA-developed sight switch to control electrically operated assist devices. Originally developed to allow astronauts to perform various control functions while immobilized by high gravitational forces, the device uses sensors mounted on eyeglass frames to sense eye motion. The signals generated by the sight switch system may then be used to control a wide variety of devices.



The Sight Switch Set is a unique switching device, which requires only movement of the eyes to actuate, and provides a "hands free" mode of control. It is small and suitable for mounting on a normal pair of eyeglasses or eyeglass frames. It consists of a low intensity light source and a photodetector to sense variations in light reflected from the sclera of the cornea of the eye, which can then be used to actuate control mechanism.



The NASA switch (with amplifier) interfaced with a mechanical page turner. To turn the page, the paralyzed patient need only turn his eye slightly towards the eye switch. Light reflected from the eye is picked up by the sensing unit built into the switch. In turn this energy, upon amplification, actuates the page turner. This eye-operated switch can also be used to control a television set, a radio, the room lights or other devices.

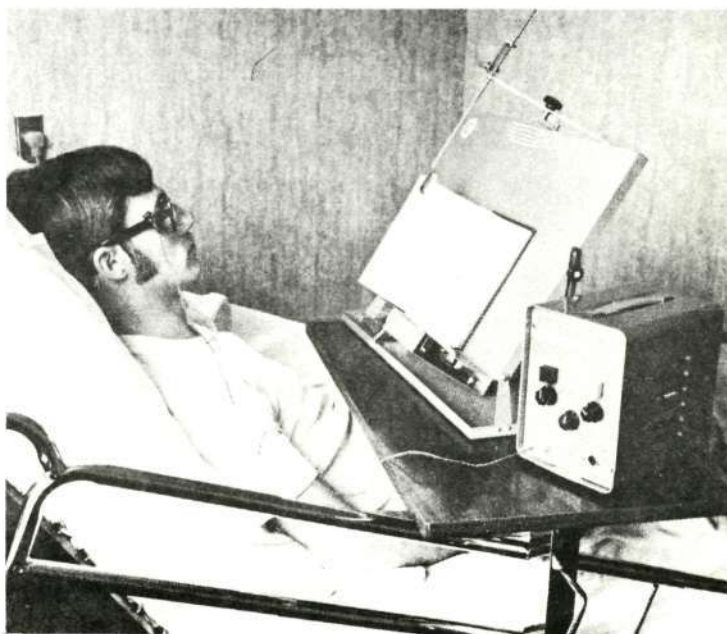
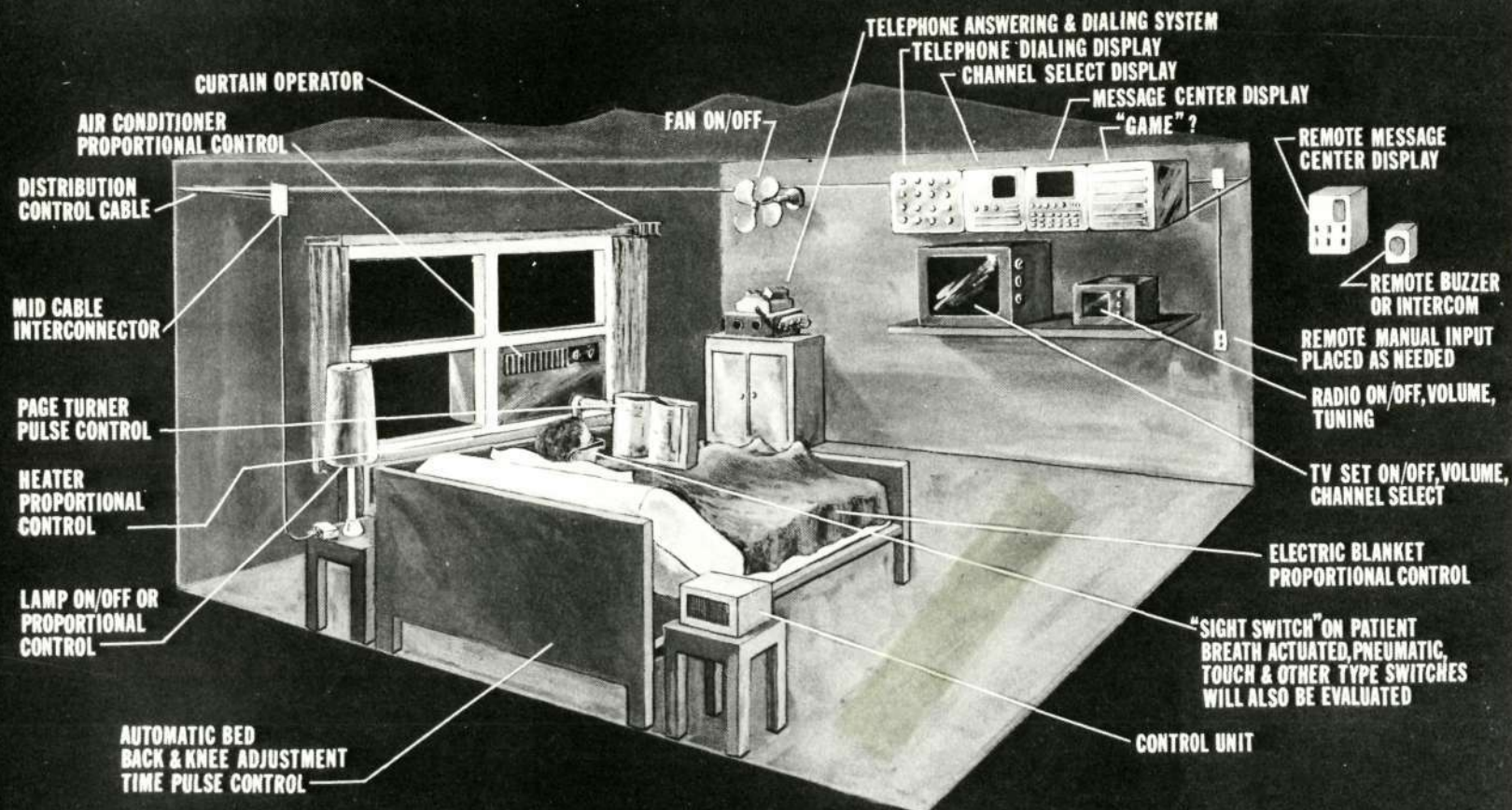


Figure 37. The NASA Eye-Operated Switch in Use



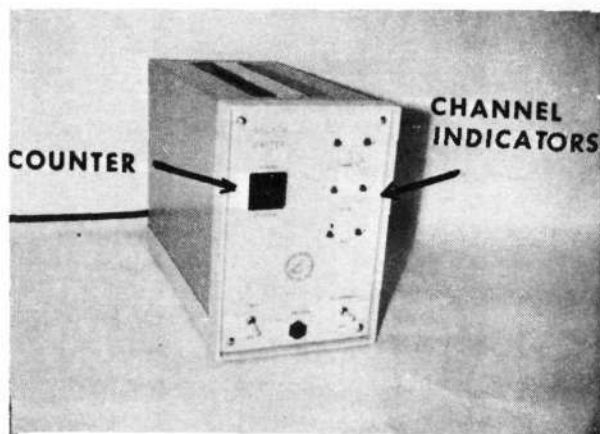
## CONTROL SYSTEM FOR SEVERELY HANDICAPPED

MSFC-72-A&TS-TU-114

Control mechanisms and logic switching devices will enable a paralyzed patient to control various devices in his room, such as lights, radio or TV, telephone, page-turner, bed or other patient assist devices.

Figure 38. Control Systems for Paralyzed Patient

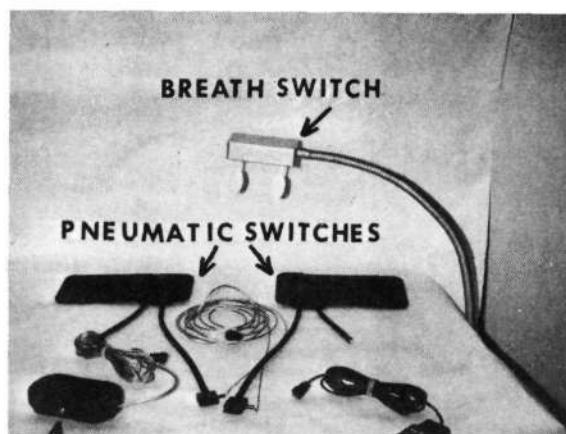




Logic unit for the automated patient environment control unit. The channel indicators light up when a given channel is activated, permitting the patient to know at any given instant which channels are activated. The counter (or digital display unit) permits the patient to follow the channel selection sequence so that he knows precisely what channel he is on at any given time during the channel selection operation.



Rear view of the logic unit showing the outlet where patient assist/control items are plugged in (such as lights, radios, television, page turner, electric bed adjustor, etc.). Each outlet corresponds to a particular channel on the logic unit.

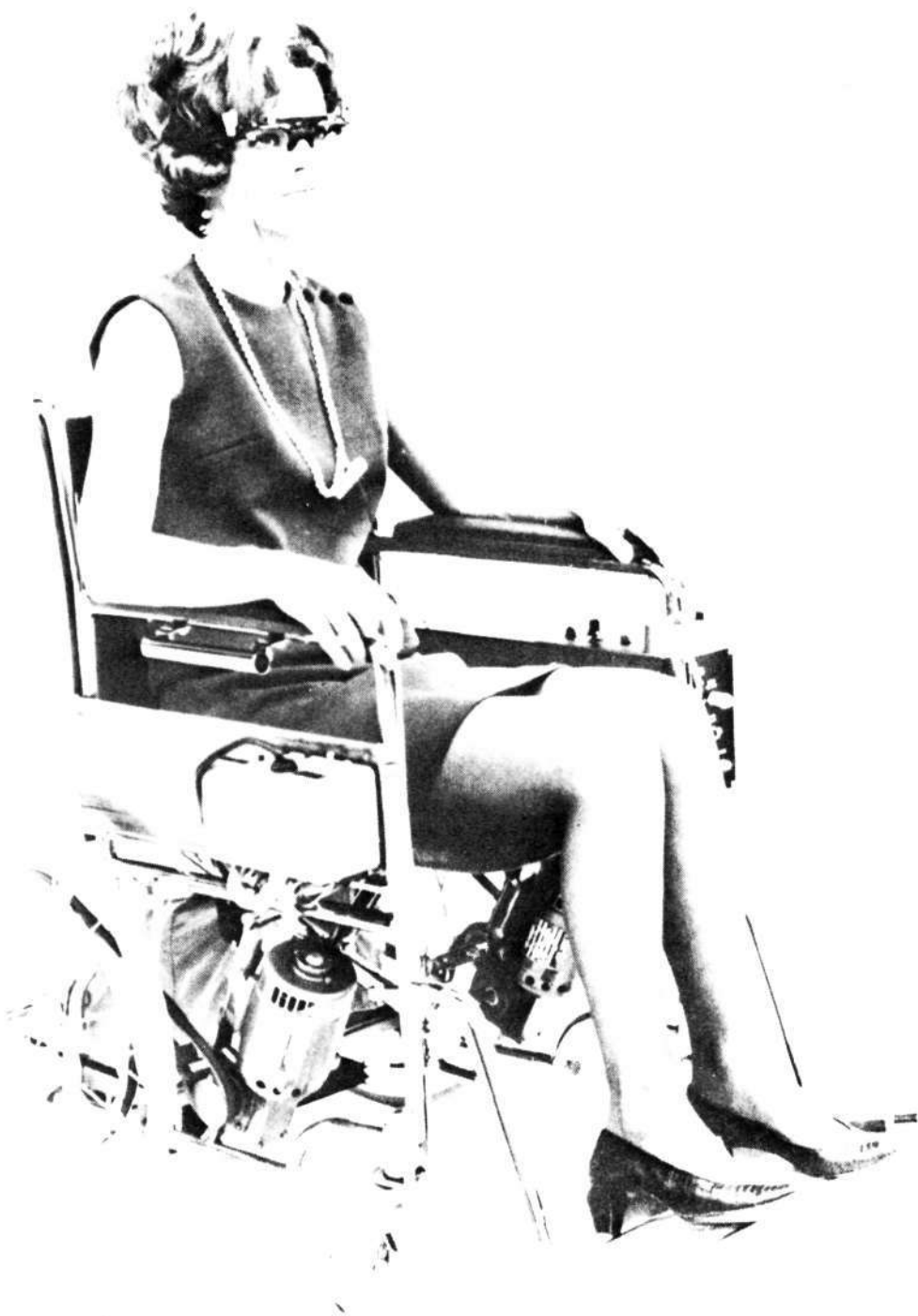


Various types of switches available for use with the logic unit. Not shown is the NASA-developed eye switch, which can also be used. The pneumatic switches are placed adjacent to the patient's head. A slight pressure activates the logic unit. One switch functions as a channel selector; the other functions to turn the channel on or off.



The automated patient environmental control unit in use with the breath-actuated switch. The innovation permits totally paralyzed patients to control assist/control devices merely by gently blowing on the breath-actuated switch. For the lesser disabled patients, other types of control mechanisms (see illustrations to the left) can be utilized as inputs into the logic unit.

Figure 39. A Patient Assist System Featuring a Variety of Control Switch Capabilities



The sight switch, originally developed to permit astronauts to control space vehicle flight under high gravitational force by the movement of their eyes, has been adopted to permit paralyzed patients to control the motion of the wheelchair.

Figure 40. Eyeswitch Operated Wheelchair



The sight switch has been used to enable a patient to control various orthotic devices as well as a wheelchair (Figure 40). When used to control a wheelchair, the sight switch allows a person to start, stop, reverse, and turn the wheelchair by eye motion alone. By enabling a patient to control orthotic and prehension devices it enables the individual to perform many daily functions for which they would otherwise be dependent on others. Thus it can considerably affect the degree to which a person can care for himself as well as the scope of productive work which he can perform. As the prehension and orthotic devices become more sophisticated it will be possible to restore many functions and capabilities which these persons have lost due to their injury or disease.

Traditionally, these persons have used the movements of various muscle or body parts to activate the drives and linkages which might be used to control an artificial grasping device or hand. Some persons, particularly those affected with the complications of spasticity or muscle tremor have considerable difficulty operating the conventional mechanical control devices. The sight switch therefore provides a basic on-off, all or nothing switch which is not likely to be inadvertently operated. It should now facilitate the training of patients to operate various assist and support devices.

The sight switch has been evaluated and compared with several alternative control devices and has been found well suited to certain device-control requirements. It is anticipated that the device will be applied throughout the nation in hospitals and in facilities providing extended care for quadriplegic patients. By restoring various control capabilities to persons previously unable to perform even simple functions for themselves, the impact on the daily lives of totally paralyzed persons will be considerable. To make others aware of what can be done, several special publications and demonstration projects are being prepared.

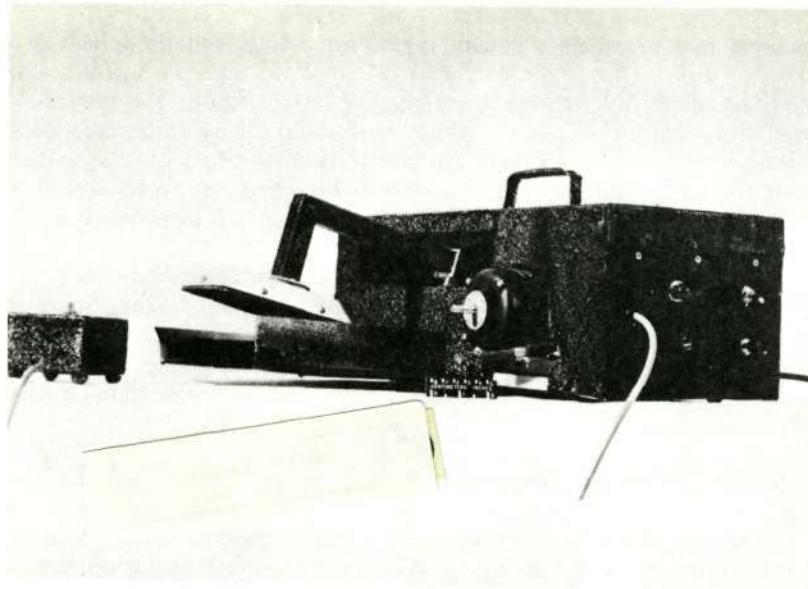
**Pressure-Sensitive Device for Use in Tongue-Operated Control Systems for Assist Devices and Wheelchairs.** Researchers at the Rancho Los Amigos Hospital with long experience in developing a variety of specialized new orthopedic methodologies and devices have worked with severely disabled neuromuscular and amputee patients to develop self-sufficiency through added mobility. A basic wheelchair, for example, has been modified through the addition of an electric motor, switches, and other attachments. It can now be operated to move forward and backward, to turn and to go up and down inclines or stairs. The researchers have also been successful in refining chair control and operations so that it can be used by paralyzed or amputee patients whose muscular use is limited to control of the eyes, mouth, and head. Such chairs have now become commercially available.

They have also made considerable progress in developing control systems for externally powered orthotic devices. Extra-oral, tongue-operated switch controls provide sequential off-on control of the orthosis, and show promise as a means of providing control. One researcher at the Rancho Los Amigos Hospital requested assistance from NASA personnel for technology adaptable to incorporation in a reliable, saliva-resistant switch small enough to fit the lingual area of the mandible and sensitive to tongue-pressure operation. A pressure-sensitive semiconductor device, identified in a NASA Tech Brief, appeared promising. The device is an insulated-gate field effect transistor that performs strain-sensing and amplification functions in one hermetically-sealed, integral package.

The researcher plans to incorporate the device into a switching unit to vastly improve the control devices currently in use. It will, for instance, permit the chair operator to achieve controlled gradual accelerations (and decelerations), a feat not possible with current on-off control systems. NASA has funded the custom fabrication of several of these devices for clinical evaluation. Device fabrication has been completed and the devices have been successfully listed in the laboratory. The sensors are now being evaluated in use at the Rancho Los Amigos Hospital.

**Paper Transport for Vocational Rehabilitation.** At the request of the Woodrow Wilson Rehabilitation Center in Virginia, an engineer at NASA's Langley Research Center has developed a device (Figure 41) which may enable a severely disabled quadriplegic to be financially self-sufficient. The number of vocations available to severely disabled quadriplegics is extremely limited. Many such patients have so little control of their musculature that the only basic proficiency they can manage is punching pegs or depressing keys on a keyboard. The Training Division of the Woodrow Wilson Rehabilitation Center is constantly seeking vocations for which these patients can be trained.

Quadriplegics can operate a specially designed bookkeeping machine, that is, they can enter the data. But generally the data is not in a form readily visible to them. In most instances, businesses which would employ a quadriplegic for this kind of work (perhaps in his home) would bring a stack of tickets to the quadriplegic for him to enter into the machine. This poses a difficulty since the quadriplegic cannot reach over and remove the



The first prototype of a paper transport system which would permit disabled patients to perform bookkeeping and clerical tasks.

Figure 41. Paper Transport.

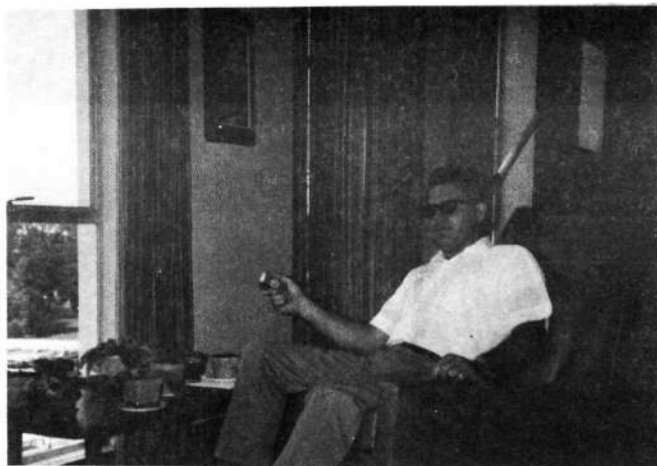
tickets from the stack. He cannot gain access to the tickets underneath the top ticket unless someone also transports the top ticket off the pile and into another pile as he enters the data. A simple device which could be remotely controlled by means of a single button was required to pick up or attach to the top ticket on a stack and remove that ticket to another location nearby. Stacking from one tray to another was desirable. The person who delivers the tickets would be able to stack them in the tray as needed by the pick-up device.

The device uses a vacuum pick-up with a transport mechanism operated by an electric motor. A working prototype has been fabricated and has been evaluated at the rehabilitation center. It is expected that a refinement of this model to reduce size and mechanical complexity will be undertaken. The cost of the design is quite low so acquisition of the machine would not impose an economic burden on quadriplegics wishing to use such a device.

**Portable Light Indicator for Use by Blind Persons.** Although lights are of no intrinsic value to blind people, they still play a role in their lives, particularly during visits by the sighted. Knowing when lights are on or off presents a problem for the blind—particularly in the case of ceiling lights which cannot be touched to feel the heat. Lights unnecessarily left on are not only wasteful but also are safety hazards and tend to alarm neighbors. Also, it is important for the blind persons to know when lights are on in areas presenting safety hazards to visitors—such as stairways during darkness hours. The Texas Commission for the Blind requested NASA assistance in developing a small handheld device which would activate an acoustic signal when it was pointed towards a source emitting light. A search of the NASA data bank revealed technology directly applicable to the problem. Four prototype light indicators (Figure 42) were fabricated under NASA sponsorship and are now undergoing testing in conjunction with the Texas Commission for the Blind. This device also is useful to blind persons operating house appliances or an office telephone. Blind persons working in an office can use the device to determine which button on an office phone is flashing or in use. It can also indicate whether the pilot lamp on an appliance such as a coffee pot is on or off. Presently, a manufacturer is being sought so as to make the device more widely available.

**Portable Sound Meter for Use by Deaf Persons.** The person with normal hearing has little difficulty with the values of ambient sound and the amplitude of his own voice output in learning to speak, because they are automatically assessed by his hearing abilities. The deaf person can be taught to speak effectively although unusual difficulties are encountered because he cannot realistically gauge the levels of sound. He has no way to estimate the noise level in any surroundings and can only estimate the acceptable level of his own speech amplitude by observing reactions of other people. Deaf persons are very sensitive about offending others with extraordinarily loud or unusual speech sounds, and therefore encounter many psychological problems. The

The light detector can indicate to the blind whether it is daylight or dark outside, or if interior lights are on.



Portable light detector emits an audible tone which varies in amplitude and frequency to indicate to the blind the presence or intensity of a light.

It can also indicate when automatic cooking devices (coffee pot with pilot light) have completed a cycle.



Figure 42. Light Detector Unit for the Blind



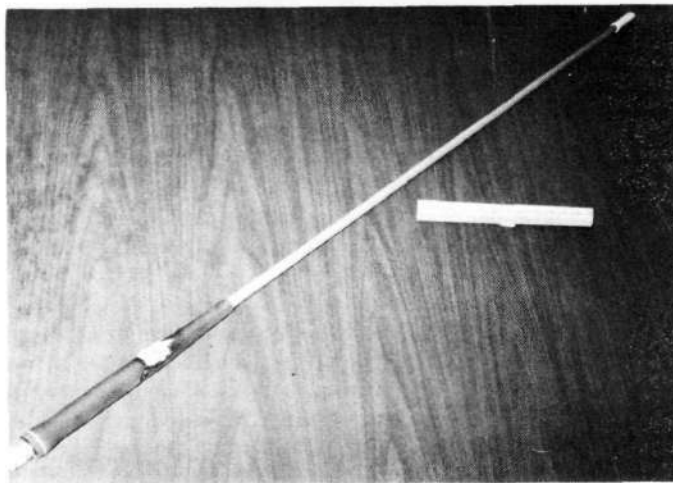
problems are severe in the process of teaching deaf persons to speak. Deaf persons need a simple and portable means for assessing amplitudes of sound. A solution to this problem, posed by the Texas Rehabilitation Commission, has been designed by an engineer at the NASA Kennedy Space Center. The solution involved a battery-operated device containing a microphone, amplifier, potentiometer, and meter.

The problem was nominated as an applications-engineering candidate and a prototype unit developed. By observing the meter (Figure 43) as he speaks, the deaf person can maintain his voice within calibrated ranges. Future plans call for the miniaturization of this device so that it may be worn like a wristwatch.



The NASA-developed miniature portable sound meter (on the right) compared to the conventional portable sound meter. The miniature unit will enable a deaf person to gauge the surrounding noise level and the loudness of his own voice so that he may speak loudly enough to be heard yet not be shouting.

Figure 43. Portable Sound Meter



An optical sensor built into the tip of the cane permits a blind person to follow a track marked on the floor with paint or tape. Installed in rehabilitation centers or homes for the blind, the track can contain coded information warning of turns or hazards, enabling a visually handicapped person to move around more easily in unfamiliar areas.

Figure 44. Tracking Cane for the Blind

**New Type of Tracking Cane for the Blind.** Most blind people do not have at their disposal an economical cane to "track" a previously laid course, as a means of providing a greater measure of self-sufficiency. The more sophisticated canes developed as aids to the blind (laser canes, ultrasonic devices, etc.) are not within the economic reach of the typical visually handicapped individual. A more economical, but effective alternative is needed, particularly for use in homes for the blind, dangerous industrial areas and in locations and situations where the number of blind persons present make it worthwhile to lay out a guidance track. A flash sheet prepared at NASA's Marshall Space Flight Center (ATTS-TU MSFC October 9, 1970) described a new type of cane (Figure 44) for tracking. This concept involved a grooved track which was not very practical to lay down due to cost. However, by adapting the MSFC cane to include the optical sensor used in the NASA sight switch, it is possible to have an effective tracking-sensing system which meets the needs described above. Use of the optical system permits a track to be laid down quite readily with paint, a durable adhesive tape, inlaid tile, or conventional carpet. The system allows incorporation of coded information such as right or left turn, stairs ahead, or other hazards, thereby permitting the visually handicapped person to negotiate the track with greater speed and assurance.

The system has been successfully tested in the laboratory and has been delivered to the Texas Commission for the Blind for actual field tests.

**Improved Powered Prosthetic Device with Proportional Control.** Most people equipped with presently available artificial-hand prostheses have trouble handling a power tool. Rehabilitation researchers have been seeking improvements in manipulating capabilities to expand the possibilities for self-help and job performance.

NASA had developed several powered terminal devices and appropriate control systems to operate a manipulator device in outer space and to remotely control vehicles. Spinoffs from those programs were combined to produce an upgraded, proportional control system which vastly increases the range of dexterity and the ease with which a totally paralyzed or amputee patient can use a prosthesis, arm or hand.

Using this powered, prosthetic, terminal hook device, a patient can single-handedly operate power tools such as electric drills, soldering guns, etc. Control of the device is positive and delicate enough to avoid danger even when picking up and drinking from a hot cup of coffee. Another version permits the individual to write and perform many complex tasks.



Progress to date consists of the design and fabrication of six prototype hooks with a trigger-finger device that is actuated by a preset closure force of the hook jaws. The design uses parallel strips of ¼-inch aluminum shaped to conform to the contour of Dorrance Hook jaws. This design provides strength, is lightweight, and provides space between the jaws for the trigger mechanism. These jaws are powered by a permanent magnet DC motor through a spur-gear reducer. The pinch force available on this model is approximately 20 pounds.

A prototype hook was fitted to a male below-elbow amputee for demonstration and evaluation. The results of this fitting indicate that an amputee can unilaterally operate a powered tool that has conventional pistol trigger-type actuation.

An interagency meeting was held to review this project. Representatives from Rancho, NASA-Huntsville, the local NASA Technology Utilization Office, U.S. Army Biomedical Engineering Department, Walter Reed Hospital, the Department of Defense, USC School of Engineering, and local components manufacturers attended the meeting. The consensus of this meeting was that the project is ahead of schedule and that the project can be successfully completed, provided that sufficient clinical evaluation can be done in the future. It was the unanimous recommendation of this group that efforts be made to clinically evaluate the powered hook using at least 15 patients. It was also recommended that this additional work on the project include a control system that would be adequate for evaluation. The controls that will be developed include a dual channel myoelectric system and also a unidirectional dual-channel displacement-type control. This control will be a force/proportional device based on the design concept employed in the NASA-developed remote manipulator controls.

**Proportional-Control System for Paralyzed Patients.** Patients suffering from disease or injuries causing paralysis may be aided by multi-channel proportional-control systems developed by NASA. Originally developed to control remotely-operated mechanical hands and manipulator devices they may restore a large degree of independence by enabling a patient to voluntarily control his paralyzed arms. Presently, externally-powered orthotic arm braces are controlled by simple on-off switches. As some braces have up to seven joints—and thus seven reversible motors—it is difficult to achieve smooth, accurate, motion control.

An early attempt to adapt the NASA proportional-control device to the control of an externally-powered orthotic arm brace has been quite successful. The proportional-control system provides both velocity and position proportional-control signals to regulate the operation of small direct-current motors. In this early trial, the totally paralyzed patient was able to perform tasks requiring considerable accuracy and dexterity. The control was sufficiently "fine" that many routine tasks could be readily performed—self-feeding, drinking from a cup, turning pages, dialing a telephone and writing legibly.

Through NASA's Technology Utilization Program, six control units will be made available for further clinical evaluation. These evaluations will be performed at key rehabilitation research centers throughout the country.

## AIR AND WATER POLLUTION

**Current Velocity Meter.** An improved instrument to measure water flows in lakes, rivers, and streams is needed by the Federal Water Quality Office and similar organizations. Water-velocity measurements at several points in a stream provide data used to calculate the volume flow of water at a particular time. Flow information is needed to design power generating stations, sanitation systems, to determine the suitability of a stream for municipal water supply and to assess the value of a stream for navigation and irrigation.

A strain gage force meter originally developed by NASA's Langley Research Center for wind tunnel monitoring, appears to offer a solution. It was developed to satisfy the need of the Virginia Institute of Marine Sciences for a relatively simple, inexpensive means to measure generally steady flows characterizing certain near-shore waters. The meter indicates the direction of current flow as well as its speed. The current meter is compatible with commercially available data-acquisition systems and several meters can be monitored simultaneously over long periods of time.

The water-current meter uses a strain gauge force balance to generate electrical signals that are related to water speed and direction. The primary components of the meter are: a drag sphere, a two-component strain-gauge-force balance, a power supply, a voltage measuring device and a mounting rod. A schematic representation of the meter is shown in Figure 45.

NASA contracted with researchers at the University of Chicago to build two of the water velocity meters which were completed in March of 1972. The meters will be available to water quality officials for testing and to industrial companies interested in commercial application.

Also, a market research report describing the technical significance of this innovation, identifying industrial applications for the new technology and assessing the commercial potential for water velocity meters has been prepared and offered for sale. Seventy-seven copies of this report have been sold through June 1, indicating substantial industrial interest in this technology.

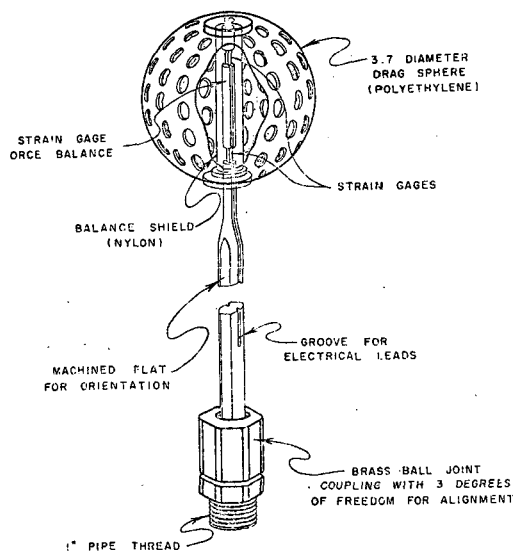


Figure 45.- Schematic of drag-sphere current meter.

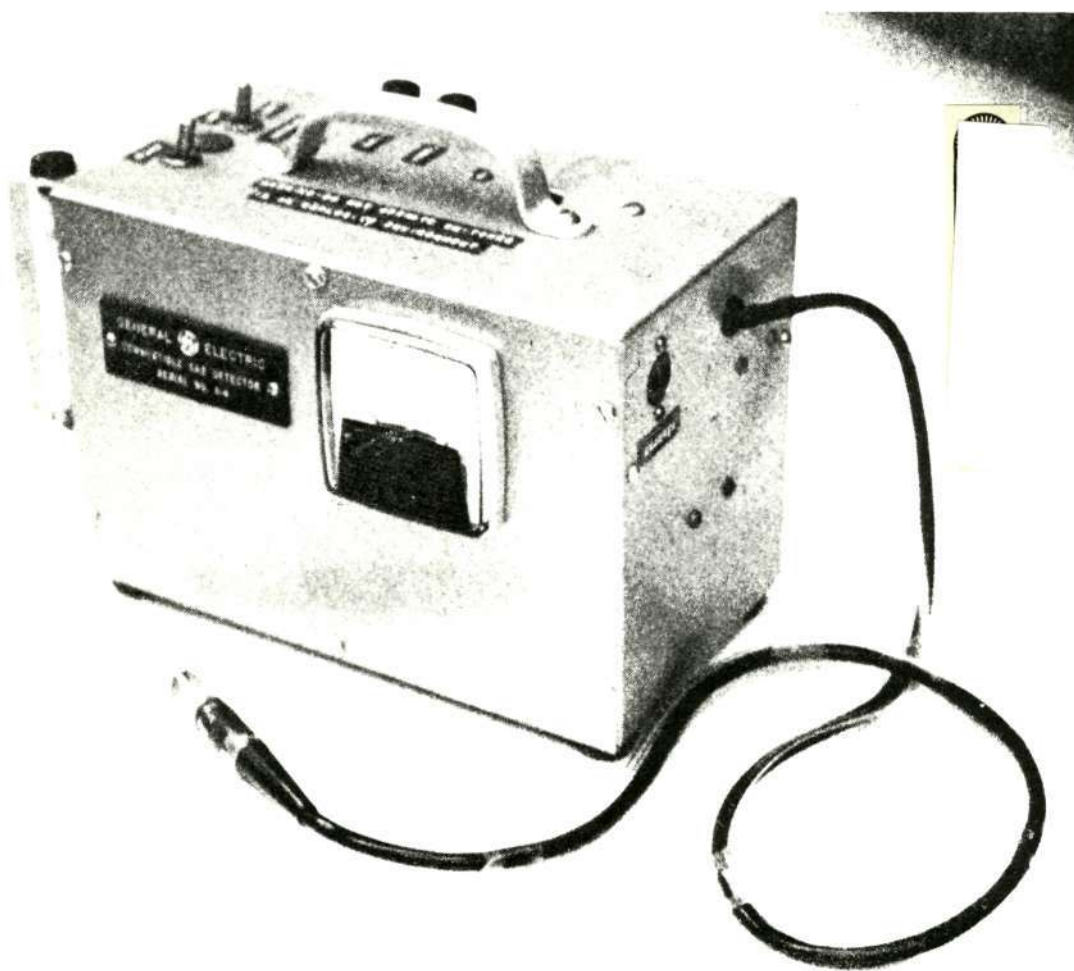
A schematic of an improved instrument to measure water flows in lakes, rivers and streams.

Figure 45. Current Velocity Meter

**Development of Advanced Pollutant Sensor for Total Hydrocarbons.** An inexpensive, advanced sensor capable of measuring total hydrocarbons in ambient air, auto exhaust and stack effluents is needed by the Environmental Protection Agency for its field monitoring program. The instrument would be of great value since it would facilitate field monitoring as a substitute for the costly process of sample collection and subsequent laboratory analysis. At present, instrumentation using a flame ionization detector and gas chromatographic techniques are being used in the environments mentioned above. But a lack of knowledge about flame chemistry and inadequacies of sample introduction have impaired progress in this area. In addition, such equipment is expensive, presents a potential safety hazard and requires the services of an operator who is a skilled technician.

The Bureau of Mines is also interested in improved detectors of methane for its mine safety programs.

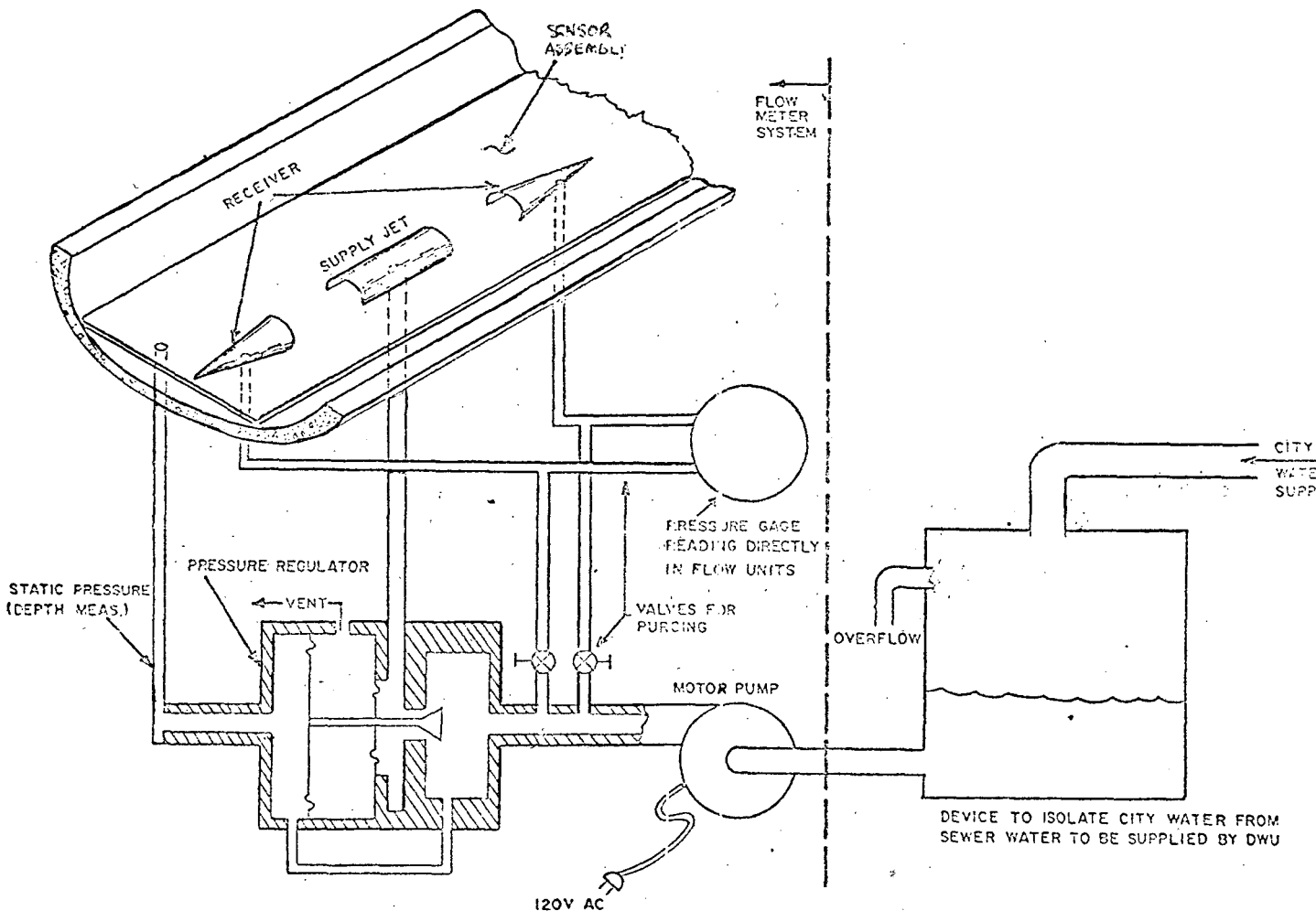
A device which would simplify and substantially reduce the cost of monitoring equipment for hydrocarbons is an indium-oxide, thin-film, combustible gas detector developed for NASA by the General Electric Research Laboratory (Figure 46). The indium-sesquioxide thin-film undergoes a change in electrical resistance when it is exposed to various concentrations of a combustible gas. The detector is maintained at 200° to 400°C, has a response time of about 1 second, and is currently designed to measure concentrations above 500 ppm. The device was originally designed to detect hydrogen but demonstrations have shown that it will also respond to hydrocarbons and methane. Successful application of the indium-sesquioxide thin-film sensor to the measurement of methane in mines, and of methane and total hydrocarbons in ambient air, auto exhaust and stack effluents would enable simpler, less expensive and more accurate measurements to be taken.



Advanced sensor for measurement of total hydrocarbons in ambient air, auto exhaust and stack effluents.

Figure 46. Indium Oxide Thin-Film Combustible Gas Detector

In September of 1971 NASA and Environmental Protection Agency representatives met at NASA's Marshall Space Flight Center (MSFC) to define requirements for a device suitable for air pollution and mine safety application. MSFC agreed to test the thin-film sensors to determine their sensitivity to methane and other hydrocarbons. A determination will be made as to the accuracy, sensitivity, stability, response time and specificity of the sensors. The test data will be evaluated and a determination made as to the feasibility of the sensors for the required applications. This test program will be completed in the summer of 1972. If successful, development of a complete instrument will be explored with the Environmental Protection Agency and the Bureau of Mines.



Modification of airspeed sensor adapted for use to measure flow in sewer lines.

Figure 47. Fluidic Flow Sensor for Use in Sewer Lines

**Fluidic Flow Sensor for Use in Sewer Lines.** A significant urban problem is the collection and treatment of sewage. Proper distribution of sewage flow is necessary to avoid backup and potential sanitation hazard and to avoid overloading sewage treatment plants. Beyond these needs, accurate information of actual sewage volumes is useful in the projection of urban development and growth.

These requirements could be served by a system that would monitor sewage flow in the collection network, relay the information to a central control facility and manually or automatically redistribute, store or treat sewage. A first step towards such a system is being taken by the Dallas Water Utilities which is conducting a program to monitor sewage flow with the immediate objective of identifying infiltration.

Accurate and reliable flow meters are essential to the safe and efficient operation of such systems. A usable sewer flow meter must operate unaffected by foreign bodies as diverse as rags, tree branches, dirt, scum, and oil. It must also withstand abrasive and corrosive conditions. Because of these problems, conventional flow meters have limited accuracy and applicability.

To solve this problem the capability of a fluidic air sensor developed by Bowles Fluidics Corporation for NASA's Electronics Research Center has been extended to measuring water flow (Figure 47). The device was originally designed as an airspeed sensor for V/STOL aircraft.

The pressure differential between two of the device's receivers, one upstream and one downstream of a supply nozzle, is measured and correlated with flow velocity. Among the features that make this unit especially suited for measuring sewage flow rates are: (1) it has no moving parts; (2) it is self-cleaning; (3) it is rugged; and (4) it provides no obstruction to flow.

A technical description of a proposed sewage flow meter was sent to the director of the Dallas Water Utilities who agreed to provide a test site if a suitable instrument could be developed. NASA then provided the necessary funds for Bowles Fluidics to design and build a breadboard unit. The unit was tested in water and found to work satisfactorily. It was delivered to Dallas in April of 1972 for an extensive series of tests to demonstrate its technical feasibility. In parallel with the testing program NASA has provided some preliminary assistance in examining alternate methods for penetrating the municipal market with a sewage flow meter manufactured by Bowles Fluidics.

**Instrumental Techniques for Analysis of Formaldehyde in Ambient Air and Automobile Exhaust.** Formaldehyde is an eye irritant and plays a role in the photochemical reactions in the atmosphere. The exposure hazard from this gas is increasing, since a primary source of the gas is automobile exhaust. Ironically, the catalytic processes which have been developed to decrease nitrogen oxide and hydrocarbon emissions may actually increase formaldehyde emission. The role of formaldehyde in smog formation is also being studied but it is not sufficiently understood to set emission limits. Research in this field is hampered by lack of satisfactory measurement techniques. The Environmental Protection Agency (EPA) has the responsibility of specifying a measurement method for formaldehyde by the end of 1972. Currently, manual or automated wet-chemical techniques are used to monitor formaldehyde in ambient air and automobile exhaust. These methods are cumbersome, time-consuming, and subject to interference.

At EPA's request, NASA agreed to search for aerospace technology which might be relevant to the problem. A scientist at Langley proposed that microwave spectroscopy, used for the measurement of formaldehyde and/or other pollutants in space stations, might be applicable to this problem.

EPA agreed and Langley microwave spectrometry work has served as the basis for a jointly funded EPA/NASA project for the development of miniaturized gas analyzers. It is necessary to adapt the aerospace spectrometers into a smaller, single-frequency device and make the size price suitable for general use in air pollution monitoring. Toward this end, a contract has been let to the Lawrence Radiation Laboratory to develop an economical, practical instrument utilizing solid-state devices. It is anticipated that a prototype instrument will be completed and delivered to the EPA in March of 1973.

**Liquid Metal MHD Technology for Utility Power Generation.** The use of liquid-metal magnetohydrodynamics (LMMHD) technology as a candidate peak power source in utility power generation shows merit. It could help to alleviate problems stemming from rapidly growing power requirements and the resulting increased concern about environmental pollution. LMMHD is a relatively new technology which is not yet fully developed. The degree of development it has reached merits investigation of its application to full scale utility power generation. With the potential to improve power plant efficiency, LMMHD is being studied as a topping cycle for central-station power generation.



LMMHD power systems offer a prospect of savings over conventional steam plants in both fuel costs and capital costs for utility power-generation applications. Fuel consumption, and hence emission products and waste heat, are reduced by increased plant efficiency through utilization of higher source temperatures. Capital costs are potentially lower because the need for turbomachinery is eliminated. Most of the emphasis in LMMHD evaluation to date has been on plasma MHD. Liquid-metal MHD has several additional advantages warranting its consideration but the concept has yet to be subjected to a utility power application analysis.

The NASA Jet Propulsion Laboratory (JPL) has become a leading authority in the United States on liquid-metal MHD. This is the result of a 10-year program and \$5 million of NASA funding for space-power development. JPL was funded in February of 1972 to analyze the application of liquid-metal MHD to utility power. The study is expected to be completed by December of 1972. Applications for liquid-metal MHD will be defined, liquid-metal MHD will be compared with competing systems for each alternative application and applications will be selected for which liquid metal MHD appears to be superior.

A User Review Board made up of representatives of utility companies and manufacturers has been established to provide realistic inputs to the JPL study and to review its progress. Their initial meeting will be in June of 1972 to review progress to date.

**Sand Height Gage.** A problem common to studies of coastal erosion and sedimentation caused by natural hydraulic action is the movement of sand masses. Measurements are now performed with graduated rods, a technique which presents difficulties, particularly when divers are required for underwater tests. An alternate approach suggested by a Langley Research Center engineer incorporates transducer technology that was initially used to measure wind-tunnel pressures. An initial bread-board unit has been successfully tested by Old Dominion University in rivers and in the Atlantic Ocean. As a result of these tests, a second less complex unit has been funded and will be ready for testing in the summer of 1972. Old Dominion University will also test this unit and will include laboratory static loadings, laboratory flume tests and natural offshore tests.

Organizations interested in the sand height gage include the Army Corps of Engineers, the Virginia Institute of Marine Sciences and the Coastal Engineering Research Center.

**Automated Sewage Treatment Control.** In late 1971 NASA requested proposals from the aerospace community for solving important public-sector problems using space-related technology. Southwest Research Institute of San Antonio, Texas responded with an idea to apply NASA technology to the automatic-process control and operation of sewage-treatment plants. This application could answer several of the most difficult problems of sewage-treatment plant operation. It could also greatly improve effluent-water quality from such plants while cutting operational costs.

The program will be aimed at two major problems in process control of municipal sewage-treatment plants, the control of sludge recycle rate and of the sludge wastage rate. Improper control of these two processes has important effects on the overall treatment process and the quality of the finished effluent. At present, these two parameters are controlled manually. This requires two to three hours lag time for data feedback, making it difficult to produce consistently high-quality effluent.

The first control problem is in the proper proportioning of return-activated sludge to the incoming raw wastewater so that a constant ratio of food to recycled culture can be maintained. The second control problem is in the proper wastage from the sludge recycle system of excess activated sludge.

A contract is now being negotiated with Southwest Research Institute. The effort will be co-monitored with the Environmental Protection Agency. It is anticipated that the control system design will be complete in April of 1973. Assuming initial success, two additional tasks are projected—installation of the process control system in an existing activated sludge type sewage-treatment plant for testing and evaluation (the city of San Antonio has expressed interest in being a test site) and evaluation of the completed control system operation for possible widespread use.

**Nickel-Zinc Battery Development.** The NASA Lewis Research Center has developed battery-type sources of power for various space applications. Specialists at Lewis believe that changes in the technology of nickel-zinc batteries could make significant improvements in their performance leading to industrial and commercial applications. The basic problems which need to be solved are zinc electrode deterioration and inadequate separator performance. Solution of these problems should result in a highly rechargeable, high-energy density battery. Nickel-zinc energy density, for example, is approximately three times that of the present-day nickel-cadmium cell. Further, it is expected that the nickel-zinc battery will be less costly than nickel-cadmium. A good, highly rechargeable nickel-zinc battery should find a number of industrial-commercial applications in such items as power tools and appliances. Furthermore, in the event that a hybrid automobile power plant (heat or engine-generator-battery system) becomes feasible, the highly rechargeable nickel-zinc battery would be a strong candidate for this important application.

A developmental project was funded in February of 1972. By May 1973 it is proposed to demonstrate the improvements in nickel-zinc cell performance which can be realized. If this is successful, an additional two years of prototype development and testing will be needed. Proposals were received from industry to perform the work under NASA direction in May 1972. These proposals are now being reviewed with a tentative July 1 contract start date planned.

The United States Postal Service has reviewed the NASA efforts and will be kept informed of progress to aid in their nonpolluting vehicle work.

## HOUSING AND URBAN CONSTRUCTION

**Fire Retardant Coatings.** Intumescent paints, which swell when heated to form an insulating carbon char, have been commercially available for some time. NASA's Ames Research Center had developed a new class of intumescent paints (Figures 48 and 49) essentially for use on the interiors of aircraft and spacecraft.

Significant advantages of the NASA paints are their hydrolytic stability, superior optical and mechanical properties and greater heat stability of their char. Disadvantages of NASA's coatings include a toxicity problem resulting from  $\text{SO}_2$  given off from the film upon expansion and ultraviolet degradation of the binder after exterior exposure.

The intumescent agents developed by NASA are monomers based on p-nitroaniline and sulfuric acid, which undergo a complex series of condensation reactions when they are heated to temperatures above  $300^\circ\text{F}$ . Gaseous products are produced ( $\text{H}_2$ ,  $\text{SO}_2$ ,  $\text{N}_2$ ) along with a black, char-like, heterocyclic oxidation-resistant polymer. The polymer is blown into a low-density surface foam by the escaping gases. This char is stable to temperatures of  $1000^\circ\text{F}$ . Its low density (0.1 to 0.3 lb/ft<sup>3</sup>) results in a closed cell structure. The resultant very low thermal conductivities provide excellent heat protection.

The National Association of Home Builders identified a new use for these paints. Fiber Reinforced Plastic (FRP) shower stalls and tubs have been sources of fires in buildings under construction. Plumbers, accustomed to working with metal fixtures have, on occasion, inadvertently set fire to the FRP with pipe-soldering torches. The manufacturers of the FRP fixtures saw a need for protecting such areas. And the International Association of Plumbing and Mechanical Officials and the National Association of Home Builders (NAHB) Research Foundation developed a test procedure for these fixtures. The test involves placing a 1-inch flame from a propane torch on the FRP for 30 seconds and timing the duration of the resulting burn, waiting 2 minutes, then repeating the test at the same spot. In no instance may the FRP continue burning more than 30 seconds after removing the flame and pass the test.

The New York State Urban Development Corporation is considering using these paints to replace a requirement for a masonry fire wall between prefabricated units in a modular construction project.

The AVCO Corporation is producing intumescent paint under a NASA license to determine its commercial applications. When samples of FRP fixtures were coated with the intumescent paint and tested at the NAHB Research Foundation Laboratories, durations of burns were under 10 seconds with indications that less than 5 mil thicknesses of the paint would provide adequate protection. The company is currently surveying other potential markets and applications for the intumescent paint. AVCO has received 2,200 inquiries about the paint as a result of ads placed in trade magazines; however at present the paints are too expensive for nonspecialty commercial application.

new from AVCO

## a paint that buys you time when every minute counts



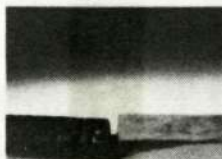
Reproduced from  
best available copy.



From the people who made the Apollo Heat Shield now comes an exotic new paint that can prevent fire damage to metal, wood, plastic, and other materials.

Called FLAMESHIELD, it expands 150 times in thickness when exposed to fire. The expanded coating keeps damaging heat and flames away from the base material. FLAMESHIELD doesn't put the fire out, but it does buy time — time to prevent costly damage, or maybe save a life.

Extra minutes of protection can save: valuable manufacturing equipment, files, storerooms, hazardous areas, and critical parts of trains, planes, boats — broad protection for both home and industry. FLAMESHIELD — an all-weather paint — can be applied inside or outside with brush or standard spray equipment. It dries quickly, resists humidity and other environmental conditions. And, it's available in quantities from quarts to 55-gallon drums.



Obtain more information on this new line of protective paints by phoning or writing: FLAMESHIELD, Avco Systems Division, Lowell Industrial Park, Lowell, Massachusetts 01851, Tel. (617) 452-8961.

*Test shows dramatic results from FLAMESHIELD paint protection.*

*One wood block is painted; another unpainted (photo No. 1).*

*Torch triggers action as paint forms thick, tough layer of insulating foam on painted block (photo No. 2).*

*Minutes later, painted wood shows virtually no effect after foam is scraped away; unpainted wood is damaged and would show even further deterioration if fire continued (photo No. 3).*



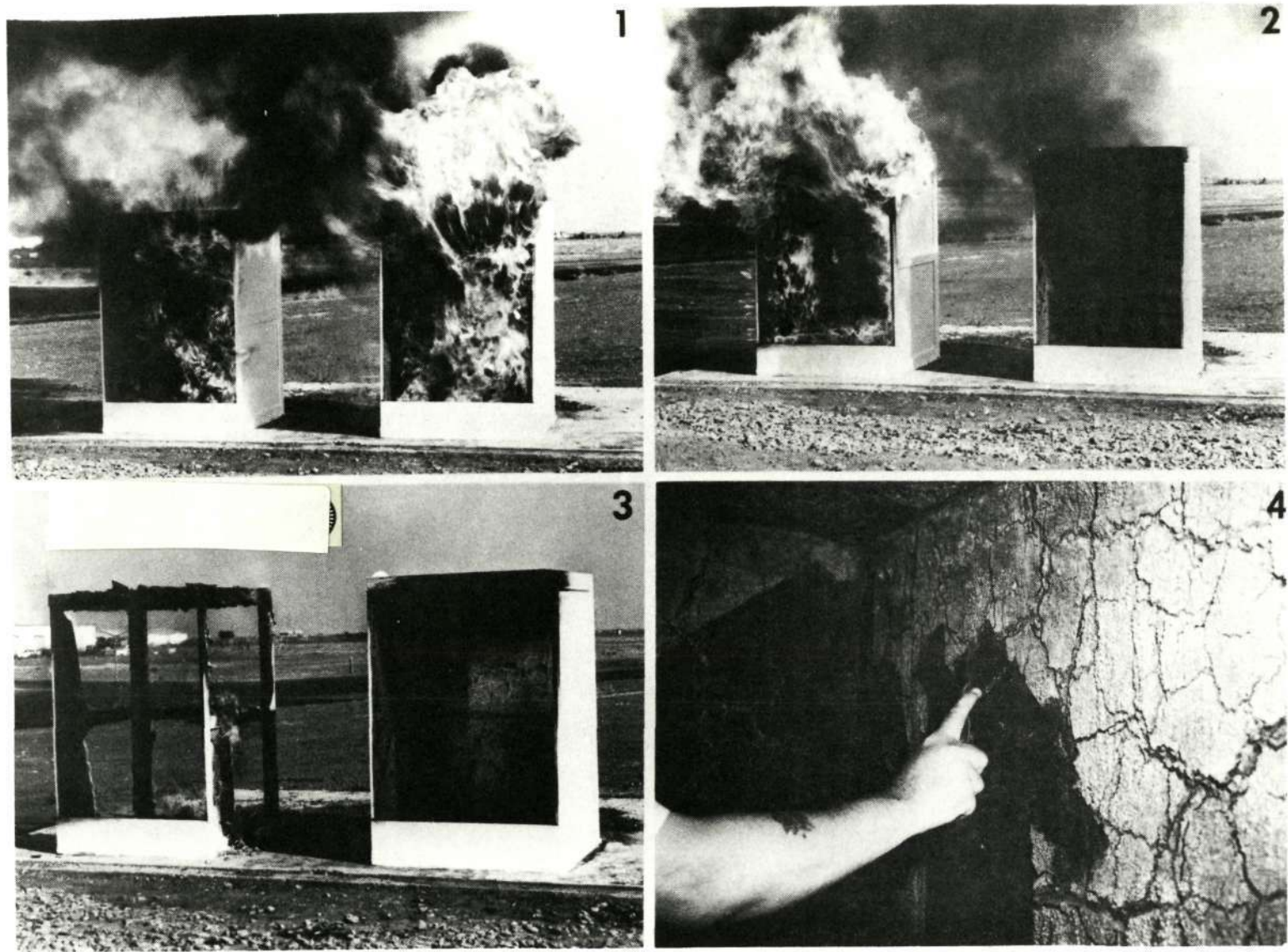
**AVCO SYSTEMS DIVISION**

LOWELL INDUSTRIAL PARK LOWELL, MASSACHUSETTS 01851

NASA-developed fire retardant coating, recently advertised in technical magazines, exhibits improved weathering properties.

Figure 48. Intumescent Paints





Test of fire retardant intumescent paints, showing coated and uncoated structures. Photograph 4 shows the heavy layer of char which acted as insulation.

Figure 49. Intumescent Paints

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In addition to the paints, NASA, as a result of its interest in heat ablation, has developed a new, highly stable class of intumescent materials which can be formulated as mastics by the addition of short fibers of glass. Mastics are high-viscosity pasty materials used as protective coatings or cements. Because steel loses its structural strength early in a fire (strength of structural steel at 950°F is 40% of strength at 70°F), some building codes require compensating protection. For example, the State of Michigan requires 1-hour protection for structural steel in school buildings. New Jersey requires 30 minutes. Mastics are generally applied with spray equipment to a one-half inch thickness. Concrete is a commonly used mastic material.

To expedite the utilization of these fire-retardant materials NASA specialists met in April 1972 to formulate plans for a fire-safety materials program involving three action phases: (1) obtaining industry acceptance of NASA materials standards; (2) testing NASA materials against industry standards; and (3) development of a low-cost intumescent adhesive material. A project plan for support of this program is now being prepared.

**Fire-Retardant Foams.** Fire-retardant foams are needed in the construction industry for use in thermal insulation and fire-resistant paneling for buildings. NASA's Ames Research Center has developed a class of fire-retardant foams which might meet this need. The NASA foams are based on isocyanurate (ICU) chemistry, and were developed principally for use in military aircraft.

Isocyanurates, formed by the trimerization of isocyanates, are flame-retardant because their molecular bonds have been modified to become inherently more temperature-stable. The performance of ICU foam in the presence of fire has been tested in a NASA fire-simulation facility designed to reproduce the radiative and convective heat fluxes in large fires. The time taken for a thermocouple to reach 200°F when it is located 2 inches below the heated specimen surface is a measure of the fire performance of commercial foams with which the ICU foam was compared. ICU is available from the AVCO Corporation in containers up to 55-gallon capacity.

**Low-Voltage Switching and Flat Conductor Cable.** The switching circuit commonly used in conventional electrical wiring of residences and buildings is expensive. Standard wiring practice uses a switch in series with the fixture to be switched. This necessitates bringing the power circuit from the fixture to the switch location.

Several problems are associated with switching circuits installed in walls. In some new systems of construction, walls are very thin, leaving little room for conduit and switch boxes. In panelized and prefabricated construction there is still significant on-site labor associated with fishing wires through conduit. And, of course, if there is a malfunction it is very difficult to repair embedded wires. Also, rewiring can be a significant cost in the rehabilitation of older buildings.

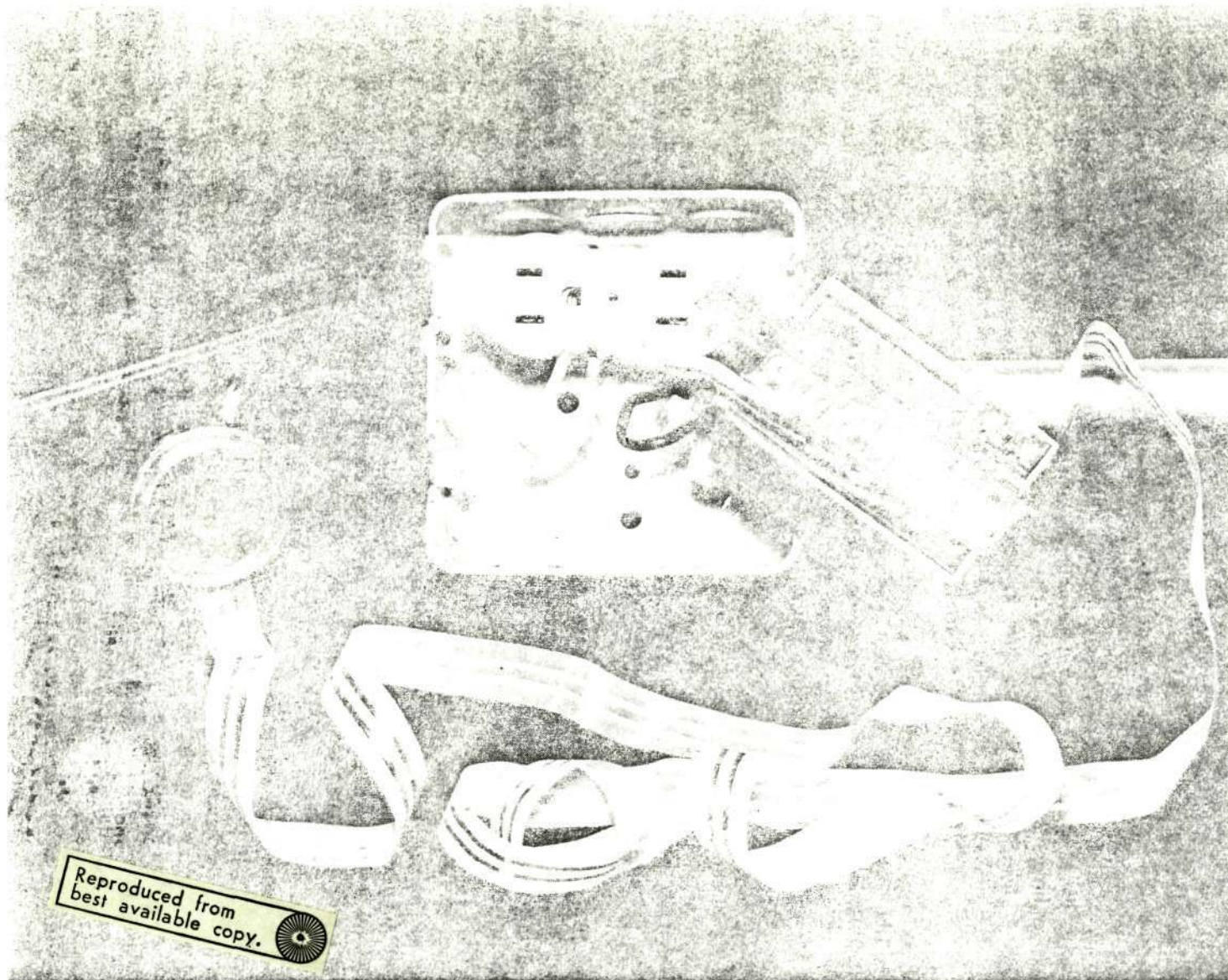
An investigation of alternative (and less costly) methods for the installation of electrical switches on walls was requested from NASA by the New York State Urban Development Corporation (UDC). The low-cost solution includes a low-voltage switching device developed with NASA technology and flat conductor cable developed at Marshall Space Flight Center (MSFC). The system, called "Switchpack" (Figure 50), will realize savings by eliminating the conduit network required for the switch leg of conventional circuits and by surface-mounting the switching circuits. The flat cable is adhesive-backed, mounted to effect a low profile (only 4 mils thick) and is obscured by paint. The simple, inexpensive switch that accepts the flat cable can also be glued to the wall. New buildings designed to accommodate Switchpack need only provide "in situ" horizontal power runs, going up or down for outlets and/or fixtures.

Several meetings were held with large manufacturers to interest them in adapting low-voltage switching devices to the flat conductor cable. A small innovative manufacturer, Non-Linear Systems, that produces electronic parts and equipment for the aerospace industry, expressed strong interest in this adaptation and developed with its own funds the necessary low-voltage solid-state switching device.

Because of the innovative nature of this device it was chosen by *Industrial Research* magazine as one of the most significant 100 new products of 1971. It was later included in *Industrial Research's* list of the top ten new products.

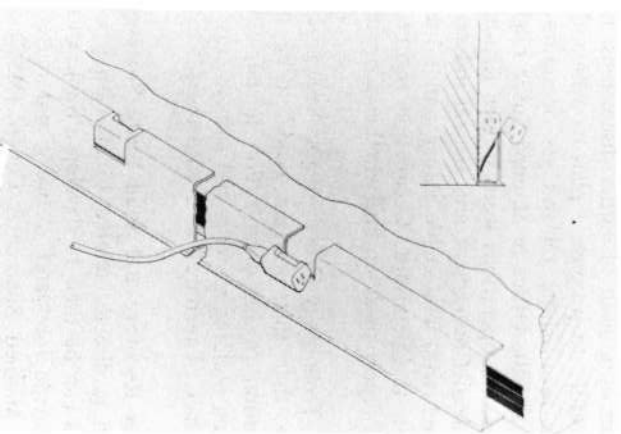
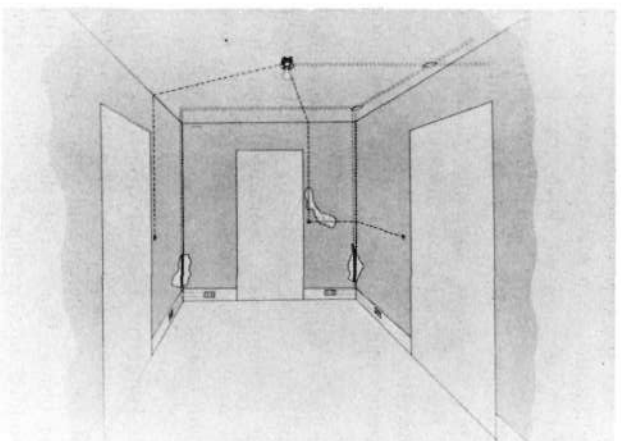
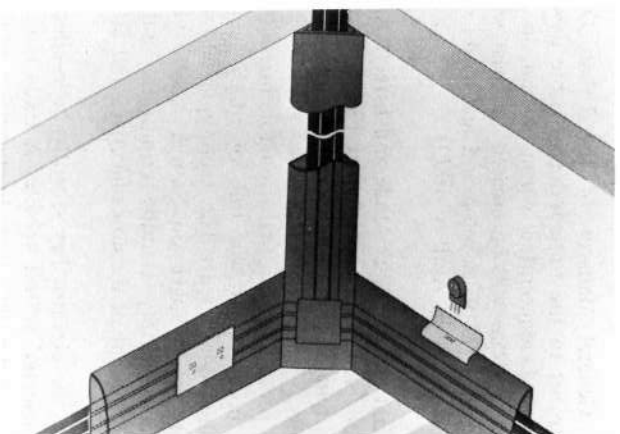
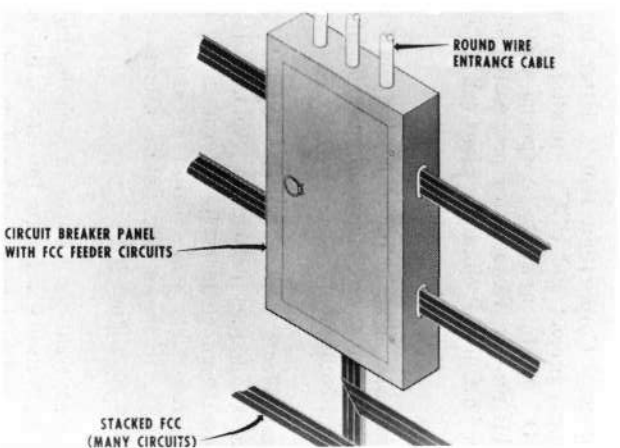
Switchpack received its UL approval in May, 1972. It's first application will be in UDC housing projects. It is estimated that the cost of installing electrical switches will be reduced by \$15 to \$35 per switched fixture in new construction. Even greater potential savings in rehabilitation and renovation projects are expected.





Photograph of switching device shows the thinness of the flat wire.

Figure 50. Switchpack and Flat Wire



Possible configurations of flat conductor cable to carry power circuits in residences.  
Figure 51. Flat Conductor Cable

In December 1971, the MSFC was funded to develop a flat conductor cable to carry power circuits for residences (Figure 51). This is another application of previously used aircraft and spacecraft technology. The aims of the program are to bring about a revision of electrical standards and to provide the building industry and UDC in particular with a totally new and planned electrical system. Problems to be resolved during development include connection and termination techniques, wiring system hardware development, installation, routing and attachment techniques and safety techniques.

The General Manager of the Urban Development Corporation sent a letter to MSFC affirming UDC's commitment to the flat-conductor cable development project and UDC's intention to install on an experimental basis, a surface-mounted wiring system in 10 UDC apartment units. A special UDC Advisory Committee on electrical systems will be created to assist with this project. Request for proposals will be released in the early summer of 1972 to develop and test hardware for UDC use. Preliminary plans call for installation and evaluation of the hardware in April of 1973.

**Utilization of Failure Mode and Effects Analysis.** Specialists at the Marshall Space Flight Center (MSFC) have suggested that NASA developed Failure Mode and Effects Analysis techniques might be appropriate to assure quality, reliability and safety of dwelling systems and equipment.

The procedure for performing failure-mode and effects analysis was developed by MSFC during the Saturn engine program. It was one of many analytical techniques needed to evaluate design performance against established equipment. The technique allowed the design engineer to determine the effect that failure of his hardware would have on Saturn Apollo vehicle crew-safety and mission. Provisions were made for redesign, redundancy, safety standby condition, and the like, whenever the failure effect became a factor affecting accomplishment of mission objectives and crew-safety requirements.

Since the elevator has recently been cited as a significant contributor to high-rise building fire-safety hazards, it was selected as test vehicle. A trade organization, National Elevator Industries, has responded favorably to the idea of applying failure-mode and effect analysis to a major elevator system. This lead is now being pursued.

As an outgrowth of earlier discussions, in May 1971 the U.S. Geological Survey requested NASA's Mississippi Test Facility to propose a plan by which the applicability of NASA procedures for quality control and hazard analysis to offshore oil and gas operations might be determined. With cooperation of Marshall Space Flight Center and the Office of Manned Space Flight, a study was carried out and a report written. Offshore oil and gas facilities and operations were studied first-hand. The report describes preliminary recommendations for action by the Federal Government and the oil industry to provide greater assurance that offshore energy resources can be produced with reasonable safety and protection from pollution of the marine and coastal environment. The Director of Operations, Occupation Safety and Health, Department of Labor is now studying this offshore-oil and gas report to determine whether a similar approach might be used for problems under his purview.

The Technology Officer of the New York State Urban Development Corporation has written to NASA that he believes that this program could make a significant contribution to building technology and offered the cooperation of his organization in pursuing this program. He commented that the present safety factors in designing building systems and sub-systems are so large as to substantially raise the cost of construction because of the lack of technical data with respect to ultimate failures.

**Water Recovery and Solid Waste Processing for Domestic Applications.** The problem of water and solid-waste disposal is directly related to increasing urban expansion. A technology resulting from NASA work on space stations can be used to develop a home treatment system which would remove potential pollutants at the source and provide for water recovery and reuse in the home. Because of the great potential of such a system, the NASA Manned Spacecraft Center (MSC) was funded in December of 1971 to develop a system design for residential use. It will utilize aerospace-oriented low-water appliances and waste-collection equipment designs, coupled with water recovery, sterilization, and recycle concepts.

The goals of the system are: (1) reduction of the quantity of water used for each function, and (2) reclamation and reuse of waste water. The program will consist of three phases leading to demonstration of the water/waste management technology in a pilot operation. Phase I will involve design analysis to select subsystems and to prepare a preliminary system design. The functions to be analyzed include clothes washing, use of bathroom wash water, dishwashing and food preparation and the use of the commode. Phase II will entail design and fabrication of a water-recovery/solid-waste handling module with associated collection/distribution

equipment in a size to support a single-family dwelling. Phase III may be the installation and demonstration of the hardware module in a mobile home or residence.

Three contracts have been let to aerospace companies for Phase I by MSC with a start date of February 10, 1972 for Martin-Marietta and Grumman and March 1, 1972 for General Electric. Concept review meetings will be conducted with each of these organizations in July of 1972.

## **FIRE SAFETY**

**Firemen's Breathing Apparatus.** NASA's attention to the problem of developing a new type of Firemen's Breathing Apparatus originated from the need of municipal fire departments for an improved breathing device for firefighters. While conventional breathing apparatus have been available for some years, many fire fighters neglect to use them because they tend to restrict mobility and vision, a fact which has led to a discouraging rate of smoke-inhalation injuries.

In cooperation with the National Bureau of Standards (NBS) Office of Fire Research and Safety and Public Technology, Inc. (PTI), NASA initiated an effort in the spring of 1971 to develop an improved breathing apparatus. PTI polled its member cities on their breathing apparatus needs, then organized a User Design Panel. The User Design Panel includes fire chiefs, city managers and a representative of the NBS Office of Fire Research and Safety. PTI has compiled the requested needs of the various cities to indicate what improvements in breathing apparatus are required.

At the first Panel meeting, held at NASA's Manned Spacecraft Center in June 1971, principal problems in currently used breathing apparatus were further identified. The main deficiencies were: insufficient duration, excess weight and size, protrusions, and lack of an adequate air-depletion alarm. In response, NASA funded a program to apply its background and expertise in life-support systems to the task of developing an efficient breathing apparatus.

Currently available firemen's breathing apparatus were reviewed. NASA and the fire department oriented User Design Committee determined that the current compressed air breathing apparatus could be improved significantly by developing a lightweight (4000 PSIG) design pressure vessel. This would have a potential 30 percent reduction in system weight. Other improvements included making the system more compact and changing the shoulder mounting of the device to a more comfortable hip position. The PTI Panel agreed that such a development program was required.

A second User Design meeting was held in October 1971 to review NASA developments on the pressure vessel and balance of the system. As a result of this meeting NASA decided to procure two lightweight pressure vessels: one for a longer duration system than now commonly used and one for slightly less duration. Contracts were awarded to two manufacturers in early 1972 with the last scheduled completion in December 1972.

Proposals were received from industry in April 1972 for the balance of the breathing apparatus effort. It is anticipated that a contract will be signed in the summer with the contract completion in mid-1973. The breathing apparatus will be extensively tested by NASA and then released for field tests in a number of cities in October of 1973.

Because of the requirement for a higher pressure air compressor system than is now being used, NASA has completed an engineering study of compressors, purification systems and cascade reservoirs. As a result of this study NASA will purchase a compressor system similar to that which could be purchased by the cities. Delivery is expected in December of 1972.

In a complementary program a breathing apparatus (Figure 52) developed at the Kennedy Space Center has been demonstrated at the Chicago Fire Academy. As a result of the demonstration the Fire Academy requested two units for a testing and evaluation program. The standard Kennedy unit contains approximately 20 SCF of air at 2550 PSI while a modified unit contains twice that amount which is slightly less than that contained in the standard commercial "half-hour" compressed-gas breathing apparatus. While the weight difference between the modified Kennedy unit and the standard 30-minute unit is insignificant, the low profile and low center of gravity of the former unit permit easier movement during some tasks than the standard back mounted unit. It is anticipated that two of the modified units will be delivered to the Chicago Fire Academy for testing the summer of 1972.





Breathing apparatus developed at Kennedy Space Center has superior human factor features incorporated in its design. Note pressure vessels mounted at the hips of the rescue team member.

Figure 52. Fireman's Breathing Apparatus



**A Low-Cost Reliable Fire-Warning System for Residential Structures.** Early smoke detection is one of the top priority technological requirements of the Operation Breakthrough Program of the Department of Housing and Urban Development (HUD) and of the National Commission on Fire Prevention and Control. The requirement was underscored in HUD's Guide Criteria for Operation Breakthrough, which requires that smoke detection and alarm systems be installed in multilevel dwellings under the program's sponsorship and by the new State of Ohio Building Code for Industrialized Housing.

Alternate technological approaches for a solution were reviewed which include infrared, ultrasonic, and ultraviolet detection methods. A new polymeric material, polyphenylacetylene, was specified which has electrical properties that change as it absorbs gases or particulates. The polymer acts as an effective contaminant-detection device when used as a coating on a field-effect transistor (FET). The FET can detect the polymer's changing electrical properties and actuate an alarm device. McDonnell-Douglas Corporation synthesized a polymer and developed a detection device for use on the NASA Voyager mission. Meetings with the Federal Housing Administration, McDonnell-Douglas, the Massachusetts Institute of Technology and the National Bureau of Standards have determined the criteria by which this early-warning system would be designed using this technology.

As a result of this meeting, McDonnell-Douglas and MIT submitted proposals to NASA for development of the device for application to residential structures. These were reviewed with NASA specialists in May of 1972. A possible program was outlined. Funding alternatives are now being reviewed.

In a complementary program pyroelectric polymer development activities now underway at the Bureau of Standards will be supported to June 30, 1972. This work appears to offer good potential for sensing the heat from an incipient fire. At the end of June the work accomplished will be evaluated to determine the feasibility of developing this material into a practical fire detector.

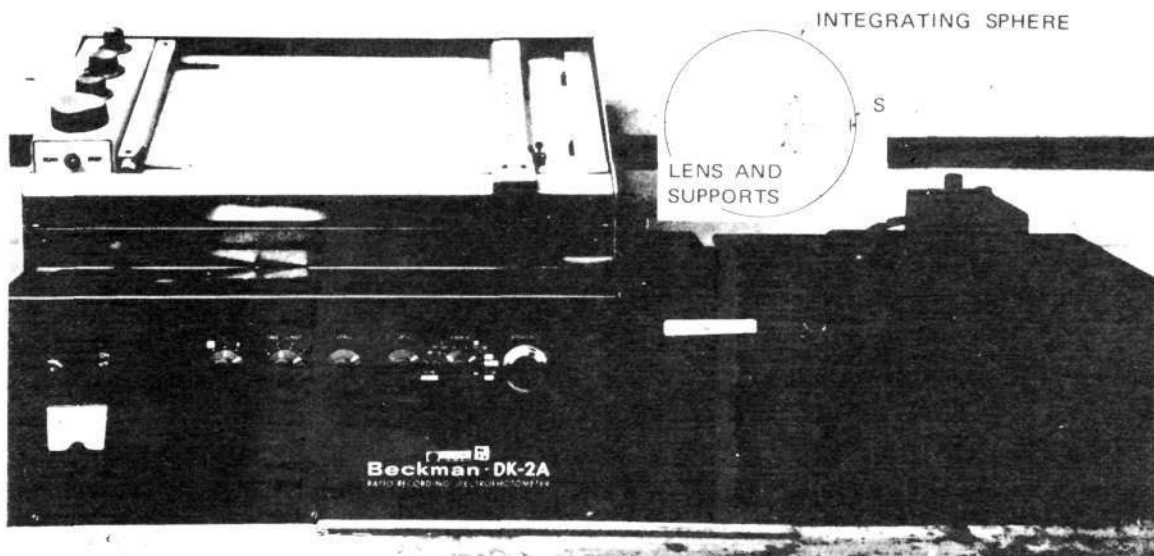
**Full Scale Fire Tests.** To further evaluate the relative merits of NASA fireproof and fire retardant materials in a nonaerospace environment NASA is sponsoring several tests utilizing full scale rooms in cooperation with the Department of Housing and Urban Development, the National Bureau of Standards, the National Fire Protection Association and the Canadian Research Council. After a draft work statement was prepared a meeting was held in May at Battelle Columbus Laboratories with an Advisory Committee of fire safety experts from across the United States and Canada to complete plans for the tests.

The room chosen to be tested will be representative of most domiciliary settings of public or institutional concern. It will be fully instrumented. The room will be built in cooperation with the Columbus Fire Department inside the Columbus, Ohio fire tower to help assure repeatability of the tests. Tentatively, a series of three tests are planned. The first room burned will contain an amount of flammable material normally found in such a room. The second test will be in a room containing the best commercially available fireproof and fire-retardant materials. The third test will include aerospace-developed fireproof and fire-retardant materials. Also, a fourth test may be run using only a limited number of aerospace materials. The purpose is to evaluate aerospace materials for such parameters as flame spread, formation of combustible atmosphere and toxicity, as well as for practical utility. If the aerospace materials appear to offer significant advantages, it is hoped that they will then be made available commercially for such uses.

A final work statement will be reviewed by the Advisory Committee in June and the test is now scheduled to be conducted in the fall of 1972.

## **LAW ENFORCEMENT AND CRIMINALISTICS**

**Measuring Reflection Spectra of Very Small Samples.** A problem identified by the California Criminal Identification and Investigation Bureau is common to all criminalistic laboratories: identification of an automobile from a small paint scraping left in a hit-and-run accident. It has been normal practice to make a visual comparison of the scraping with sets of manufacturers' standard paints by means of a binocular microscope. But comparison is frequently difficult and sometimes impossible. A more objective instrumental method of comparison would be helpful to provide evidence in quantifiable and reproducible form, and facilitate identification of the automobile.



Ultraviolet spectrophotometer, with modified integrating sphere to serve as reflectance attachment, used for criminalistic evaluation of paint chips.

Figure 53. Paint Chip Analysis System

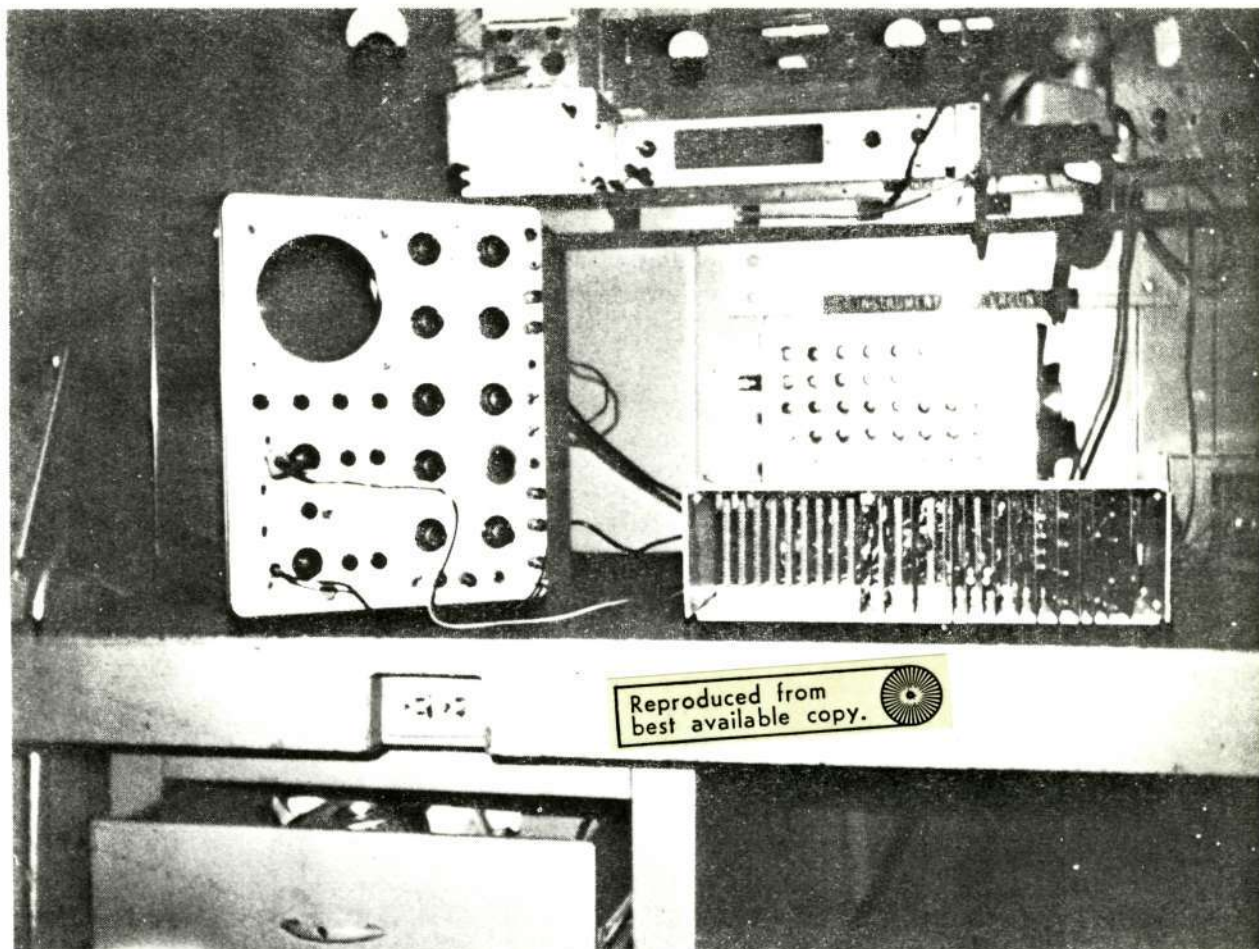
A solution (Figure 53) was suggested and tested by a NASA scientist at Goddard Space Flight Center followed by an evaluation by forensic scientists. The method consists of mounting a paint sample into an integrating sphere which serves as the reflectance attachment of a visible ultraviolet spectrophotometer. Normally, a very small sample will give no measurable absorption in this position. However, the interior surface of the integrating sphere is a diffuse reflector. The number of times the ray hits the sample is increased by mounting a convex lens in the integrating sphere, so that its focus coincides with the sample. The effect is one of enlarging the apparent surface of the sample to approximately that of the lens surface. Any ray that hits the outer surface of the lens is focused onto the sample, from which there are reflections. Thus, the absorption signal is greatly increased and can be recorded in the usual manner. Any of several commercially available spectrophotometers may be used. The proposed system is inexpensive, easy to calibrate, and does not have any adverse effect on the spectrophotometer to which it is attached.

One set of samples from an actual California case was analyzed by NASA's Goddard Space Flight Center. The investigative office thought that two paints were different, but there was no objective way to determine difference in colors. The modified spectrophotometer showed that the two red paint samples were distinctly different, and thereby contributed materially to exonerate an innocent person.

A description of the spectrophotometer system was published in the April 1971 issue of *Journal of Forensic Sciences*. This will help the incorporation of this technology into the daily operating procedures of the nation's crime laboratories.

**Communications Link: Automatic Trouble Shooting.** Many state and local police departments use data communications systems to connect a central computing facility with terminals at remote field stations. However, interruptions in the flow of the data are sometimes caused by telephone network failures and valuable time is lost while the sources of the trouble are traced manually. The main difficulty stems from the fact that there is no quick means of demonstrating to the telephone utility that the fault lies within the telephone network. Because downtime in the data system is costly, both in terms of lost computer time and criminal apprehension, the police are often forced to lease the highest quality, and most expensive telephone lines available.

A "hardline" monitor (Figure 54) developed at NASA's Kennedy Space Center, gives a continuous check on the quality of data-communication cables in the Center's automatic checkout system for testing the components of a launch vehicle. This monitor is capable of continuously sampling 16 telephone lines and warning operators when the quality of transmission has deteriorated beyond recognized tolerance or when the line has catastrophically failed.



Monitor provides continuous check on data communications cables, and may be used by police departments to monitor hardline transmission quality. (Breadboard unit is at the right-hand side of the picture.)

Figure 54. Hardline Monitor

The monitor's circuitry can be adjusted for variable acceptance levels of incoming data to conform to the requirements of the receiving equipment. These critical parameters include amplitude, rise time, frequency response, and background noise. When the quality of the line approaches the present limits, a warning command is given from the monitor. In operation, the monitor continually scans several lines in a selected sequence. It analyzes data being transmitted over the lines and interrogates those lines carrying no data. The interrogation is done by stimulating a small transponder at the other end of the line to send a generated set of pulses for evaluation.

The technical details of the monitor were given to the Maryland State Police in October 1970, and the New York State Identification and Intelligence System (NYSIIS) in December 1970. The latter estimated that their use of a similar monitor would produce an annual saving of \$50,000 by eliminating the need for leasing the highest quality telephone lines.

A meeting was held at the Kennedy Space Center to demonstrate the device to representatives from Maryland and New York. Both state agencies agreed that the monitor would meet their needs. A system design study of NYSIIS requirements was then made. The inventor agreed to commit his own funds to develop a prototype line monitor for this application. This prototype was completed in May of 1972.

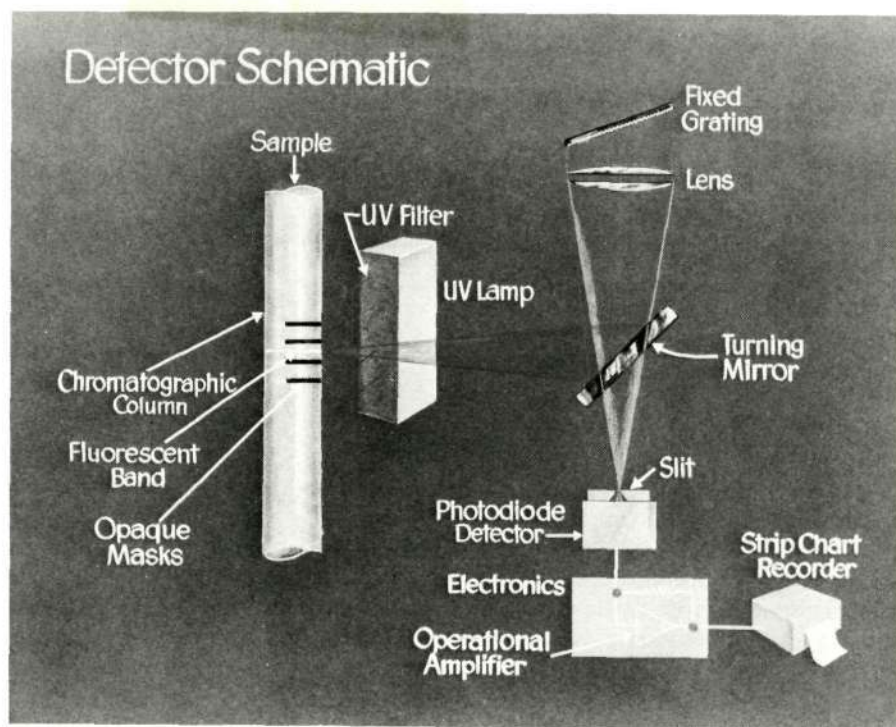
A representative of NYSIIS is now selecting a site for testing and evaluation.



**Simple Analytical Methods for Drugs.** Drug analysis represents a great part of the workload of forensic laboratories. Two types of analysis are involved: identifying the drugs in evidence and determining drug levels in blood, urine, and other physiological specimens. The latter is more difficult since the drugs are present at a very low level. Although analytical instrumentation currently exists, there has been no combination of techniques and instruments which includes all of the necessary features to provide low-cost and portable instrumentation, for rapid, reliable, and routine determination of drugs.

The seriousness of the heroin problem, and the fact that heroin is broken down into morphine derivatives when injected into the body, prompted scientists at NASA's Ames Research Center to give priority to morphine detection. This effort was a natural adjunct to ongoing research into chemical factors impinging on pilot stress. Preliminary chromatographic-column work has shown that it is feasible to detect morphine quickly and unequivocally. The outgrowth of this work, the Ames concept of a compact and inexpensive device, is described below.

The detector (Figure 55) consists of a simple, self-scanning spectrofluorometer designed for use with column chromatography in the detection and identification of morphine in the urine. Chemical treatment of a urine specimen converts morphine, which is weakly fluorescent, to a highly fluorescent fluorophore. The compound is then introduced to the chromatographic column and the morphine moves as a band down the column under standardized column conditions.



Schematic of low-cost, portable instrumentation, for rapid, reliable, and routine determination of drugs in physiological specimens.

Figure 55. Drug Detector

The column is irradiated with monochromatic ultraviolet radiation. If morphine is present, the morphine emits fluorescent radiation. In this optical arrangement, the fluorescent band thus serves as the entrance slit of a spectrofluorometer. The fluorescent radiation from the morphine band is reflected by a diagonal mirror and passes through a collimator lens to a fixed diffraction grating. From the grating the light passes back through the lens, past the mirror, and is focused on the split. Movement of the fluorescent band down the column produces the required spectral scan.

A photodiode detector receives the spectral radiation from the grating. Its output is amplified and is read out on a simple strip-chart recorder. The only moving part in the optical system is the fluorescent band which travels down the column. As the band moves down the column, it passes a number of narrow opaque masks which obscure the band's radiation, thereby interrupting the signal. From the known distance between the masks and the chart speed of the recorder, the rate of movement of the band down the column can be accurately calculated.

This system simultaneously measures the fluorescence spectrum characteristic of morphine, the rate of movement of the band down the column (which is further confirmation of that compound) and the spectral amplitude, which gives a quantitative measure of the amount of morphine present in the urine specimen. In the development of this drug detector to the functional prototype stage, there are three research areas of required work:

1. Chemistry. Optimization of the chromatographic column. This will require variation of all column parameters to arrive at a standardized column giving maximum sensitivity and specificity for morphine detection. Possible use of disposable inexpensive columns will also be considered.
2. Optics. Optical design including spectrophotofluorometric measurements of the morphine band on the column to determine optimum absorption wavelengths, as well as the morphine-emission spectrum and selection of all optical components.
3. Electronics. Design of a stable operational amplifier system matched to detector output and driving an inexpensive chart recorder.

Development of a prototype was funded in December of 1971. Development proposals from industry were received by the end of May 1972.

The program design calls for a production instrument of this type to be produced in quantity to sell for less than \$1000 each. Ames specialists have worked with the Army Surgeon General and the Bureau of Narcotics and Dangerous Drugs on the Federal level and with various municipal jurisdictions in the development of this program.

**Simple Methods of Analysis for Metals and Metal Products.** A problem common to criminalistics laboratories is the inability to quickly identify the metallic composition of objects to determine their source. For example, obliterated serial number plates, tool marks, and bomb fragments must be identified to determine the manufacturer. Spectrographic techniques are useful but are not available in many criminalistic laboratories.

Langley Research Center scientists developed a wet-chemical quality assurance technique to assure quality fabrication of hardware and maximum safety to NASA personnel. The technique is relatively nondestructive. It consumes or affects an amount of material equivalent to that removed by means of a smooth file or cleaning with an abrasive. Standard chemicals are used and the technique takes less than an hour to complete.

The New York City Police Laboratory used this metal analysis technique in four cases involving firearms. Before attempts were made to etch out obliterated serial numbers, the wet-chemical approach was used to determine the metal alloy, in order to choose the most effective etching solution. An Alaska Crime Laboratory also found this technique helpful. They were asked to prepare reagents for a helicopter firm that had been plagued by crashes to differentiate between the various alloys they were using for helicopter blades.

A commercial company, Centre Group, is now planning to manufacture and sell a metal-identification kit based on this technology for use in crime laboratories. Other potential markets will be sought for development of the kits.





Oculometer facilitates research into drivers' reactions to highway signs, as well as to fatigue, drugs and pollutants.

Figure 56. Portable Device for Recording Eye Motion

**Portable Device for Recording Eye Motion.** When he approaches a highway sign, does the motorist read it from bottom to top or from right to left? Do the colors or the letter sizes, or both, affect the effectiveness of the sign? Are flashing lights near a highway sign significantly distracting? Do the effects of fatigue, drugs, and pollution impair a driver's ability to follow signs and other directions along the highway? These problems are important to researchers in the Department of Transportation (DOT) in both highway sign safety and driver safety.

To study these variables under actual driving conditions, a driver is usually fitted with a head-mounted device to monitor eye motion which can be related to the visual scene. Devices currently used include a motion picture camera with a split view—one of the eye and one of the road ahead—that monitors eye motion. This is sufficient for gross eye movement. But for information of the effects of fatigue, drugs, or pollution, it is necessary to study closely such physiological variables as pupil dilation, blink rate, and pupil position and their relationships to the subject's mental alertness.

A table-mounted oculometer (Figure 56) had been developed for the NASA Electronics Research Center (ERC) by Honeywell. NASA was exploring the possibility of remotely monitoring the physiological responses of an astronaut to relieve him of the inconvenience of electrodes and wire attachment on long space flights. It was

thought that it might be possible to measure not only physiological data through the eyes, but also mental alertness—to be able to observe when he was becoming fatigued or dizzy from the complexity of his tasks. The oculometer has an infrared source and a light detector that reveals the reflection from the cornea and retina of the subject's eye. This instrument permits highly accurate determination and recording of eye movement. It allows more accurate monitoring than the camera approach and permits results to be processed in real time by a computer.

A unit with computer backup was installed in a test car at the Department of Transportation's Transportation Systems Center for analysis of drivers' eye movements in May of 1972.

Commercial development of the device was reviewed by a minority manufacturer. Initial results indicated that the cost per device would be too high to allow establishment of a market large enough to warrant development.

## TRANSPORTATION

**Concrete Repair Material.** The need to keep the dead weight on a suspension bridge to a minimum requires that lanes be paved with a thin layer (less than 1-inch thick) of an epoxy-coal tar mortar mixed with an aggregate. When a hole develops in this thin sheeting, a lane must be closed for repairs. This impedes traffic and creates safety hazards. It is therefore imperative that repair material be quick-drying and durable. The same general problem applies to concrete highway patching.



Thermoplastic material test patches placed on access ramp by California Division of Highways.

Figure 57. Concrete Repair Material

The current method requires spraying the damaged area with epoxy and then spreading it with an aggregate. Although the patch is ready for traffic in about 4 hours, provided weather conditions are favorable, the drying time is considerably greater in bad weather. Other disadvantages of epoxy are its cost, toxicity to workers, and the fact that it is not reusable.

The problem was identified by the Chief Engineer for the California Division of Bay Toll Crossings. A potential solution was found in a study which is reported in NASA Tech Brief 66-10453, "Thermoplastic Rubber-like Material Produced at Low Cost." A thermoplastic material was originally developed during a search for a better fuel-binder for solid propellants. It is prepared by blending a copolymer of ethylenes and vinyl acetate with asphalt and petroleum distillate. The Tech Brief indicates that the cooled blend has good tensile strength and resilience in the temperature range of 50° to 150°F. It is easily handled and applied, and there is no waste since the unused material can be remelted and it is less costly than epoxy.

Because existing street patching material used for cold weather patches of concrete highways tend to deteriorate rapidly and require repeated repairs, the cost to states and cities can be high.

Samples of the NASA-derived thermoplastic material made in the Stanford Research Institute Laboratory (SRI) were tested in the SRI parking lot in late summer of 1971. Three samples were then given to the California Division of Highways for laboratory testing to evaluate adhesion qualities of the thermoplastic to aggregate. As a result of these tests the California Division of Highways recommended that samples be placed in traffic lanes for further observation. This test is now being conducted (Figure 57).

Because of interest in the material by a number of cities, a field test will also be conducted in Washington, D.C. In early June, 1972, a patch was placed on a parking lot in Washington. If this test is successful evaluations will be made in a number of other interested cities.

An important economical aspect of this potential solution is also being investigated: the thermoplastic material might be partly produced from old tires and used crankcase oil. Shredded or ground-up tires might be used as a filler to extend the material's physical properties. Substituting used crankcase oil for fluxing oil appears to make no significant difference in the properties of the thermoplastic material. Thus the solution to this bridge-repair and road-patching problem might also aid in the goal of recycling difficult-to-dispose-of waste materials.

**Improved Friction Materials.** The maintenance expense of Postal Service and other government vehicles could be significantly reduced by developing an economically feasible friction material with improved wear characteristics for brake linings. This problem is also of concern to the Association of American Railroads.

The NASA Ames Research Center research in brake linings for large aircraft is directly related to automotive applications. Bench tests show that a proposed new material may have an operational life of four to five times that of conventional brake linings. These results were received favorably by the Postal Service.

With Postal Service cooperation, NASA has established a program for development of improved brake materials. This program will include: (1) assessment of a wear-enhancing polymer (WEP) as an ingredient of automotive brake linings; (2) development of a brake lining formulation containing standard ingredients and the WEP; (3) investigation of the use of new materials for binders and substitutes for asbestos. A contract will be let in the fall of 1972 to fabricate prototype automotive brakes. After laboratory testing, field testing will be conducted on autos for six months starting around February of 1973.

The railroad problem is different in that linings for railcar wheels must withstand very high temperatures for long periods. Samples of railcar brake shoes have been sent to Ames by the Southern Pacific Transportation Company for comparison with the new NASA-developed material. Southern Pacific will work closely with the Association of American Railroads Research Committee on this problem.

**Complex Coordinator Aids Traffic Safety and Air Pollution Research.** The NASA Langley Research Center Complex Coordinator (Figure 58) was originally developed to test performance degradation in astronauts exposed to stressful environments. It has been used on two underwater experiments. The device was also suggested as a means of demonstrating to automobile drivers the effects of drugs, particularly alcohol, on human motor behavior, and to test the driver response to various air pollutants.





Tests driver perceptual and motor skills by requiring continuous arm and leg responses. It can demonstrate and measure the effect of drugs, particularly alcohol, on human motor behavior and test driver response to various air pollutants.

Figure 58. Complex Coordinator

The Complex Coordinator tests driver perceptual and motor skills by requiring continuous arm-and-leg responses from a test subject. It enables researchers to perform quantitative evaluation of the subject's performance prior to, during and following normal and programmed abnormal conditions. The system consists of an operator-control console, recorder, a subject display panel and limb controls and associated cabling. When a "problem" is presented by the programmer, it appears on the test subject's display panel as a series of lights. The subject must manipulate hand-and-foot controls to set off correct illumination of corresponding lights, thus showing he has correctly handled the problem.

Hand-and-foot movements are timed and counted, displayed on the operator's control console and then permanently recorded. A serial-reaction feature presents a new problem after the completion of each answer and a self-paced feature assures that new problems are presented only upon completion of the previous one. Successful problem completion requires the correct positioning of all four limb controls—the ability to see the combinations of problem lights and to determine the correct action with limb controls. The test is then completed, and a quantitative evaluation of perceptual and motor skills is made.

Initial psychomotor performance data using the Complex Coordinator was gathered by experimenters at Duke University, under contract to the Air Pollution Control Office. The "simulated drivers" tested were first subjected to varying concentrations of carbon monoxide, ranging from 50 to 100 parts per million, for 4-hour periods. The onset of degradation was then detected and recorded as a decrease in skill. Tests were repeated with other pollutants so that those causing performance degradation and the concentration at which degradation occurs could be determined and recorded. The feasibility of the device has thus been demonstrated for pollution studies.

The Complex Coordinator was provided to the California Driver Education Association for a demonstration of the effects of alcohol on human performance. The instructors tested the device before and after consuming cocktails and considered it a good method for demonstrating the adverse effects of alcohol.

The Complex Coordinator was also demonstrated at the Annual Meeting of the Texas Rehabilitation Association. Interest was expressed in using the device as an exercising tool as therapy for mental patients with psychomotor disturbances and as a screening device.

Another possible application may develop in the California Highway Patrol Training Activity to screen students prior to the time they learn to operate a motorcycle.

Through the Small Business Administration program of disseminating NASA Tech Briefs, a minority business firm heard of the Complex Coordinator and expressed a strong interest in manufacturing the device. The Small Business Administration provided funds for a market study. In February 1972, NASA provided funds to this company for redesign of the device for nonaerospace use and for the fabrication of three prototypes. These units should be ready for marketing acceptance tests in September 1972.

The Complex Coordinator has been renamed by this company the Electronic Programmable Interactive Coorditester/Trainer (EPIC). The company making the prototype has contacted a number of law enforcement, highway, and health oriented organizations to help promote sales of EPIC.

**Foam Building Materials for Use in Railroad Ties.** Wood is by far the most widely used material for railroad ties, but it is in short supply and relatively expensive. Also, wood ties have a shorter life than most roadbeds. Sixteen million ties must be replaced each year and there is no adequate way to dispose of wornout ties. According to the Association of American Railroads (AAR), a tie made of a material with greater availability and durability is needed or perhaps a system that can extend the life of existing ties.

High-density plastic foams (Figure 59) developed at the NASA Ames Research Center for use in aircraft and spacecraft are seen as a possible source of substances to serve these requirements. Responding to the AAR's interest in this technology, NASA funded further development of materials for railroad ties in December of 1971. Preliminary formulation of cost data on basic polymers using inexpensive extenders, fillers and reinforcing agents is underway. The base polymers currently under investigation are epoxies, polyesters and phenolics. Preliminary comparative testing (modular and compressive strength) of various plastic composites and currently used crosstie materials (oak, pine, douglas fir) has been completed.

The work at Ames will lead to an outside contract to fabricate and test specific formulations. The contract will be issued in the summer of all of 1972 and full size ties for AAR testing should be available six months afterwards. This development work is being aided by technical contact between an AAR staff member and specialists at Ames.

**Fire Protection of Rail Tank Cars.** The Association of American Railroads (AAR) is carrying out an extensive tank-car safety study. One aspect of the study requires materials to protect tank cars in postderailment fuel fires. A protective coating is needed to prevent the steel tank car shell from reaching a temperature of 800°F within a period of a half an hour to 4 hours. This need is underscored by the fact that damage radius of the fire that usually follows derailment can spread appreciably by further rupturing tank cars, as a consequence of severe heat loads.

The Chemical Research Projects Office at the NASA Ames Research Center has done extensive work in the development of materials for fire protection, essentially for use with aircraft and spacecraft. A fiber-loaded intumescent coating (Figure 60) has been developed that has fire protection, strength and weathering characteristics. It is superior in some respects to commercially available coatings and meets the requirements for tankcar protection.

Samples of this intumescent coating have been evaluated by the AAR/Railroad Progress Institute (RPI) Tank Car Safety Group, along with more than 40 other substances. The Ames material was one of seven meeting the time-temperature specification and was the only coating meeting the specifications for ease of application, weatherability and structural integrity. Its only major shortcoming is its high cost.

Ames has also developed a new and less costly inorganic coating, for which Laboratory tests are now in progress. These tests will serve to screen the coatings before submitting them to a contractor to develop them into workable compounds. The work statement calls for processing and testing of the inorganic coatings and comparing them with suggested commercial coating systems. This contract should be awarded in late 1972. There will be a review meeting with Ames specialists and representatives of the AAR in July of 1972.



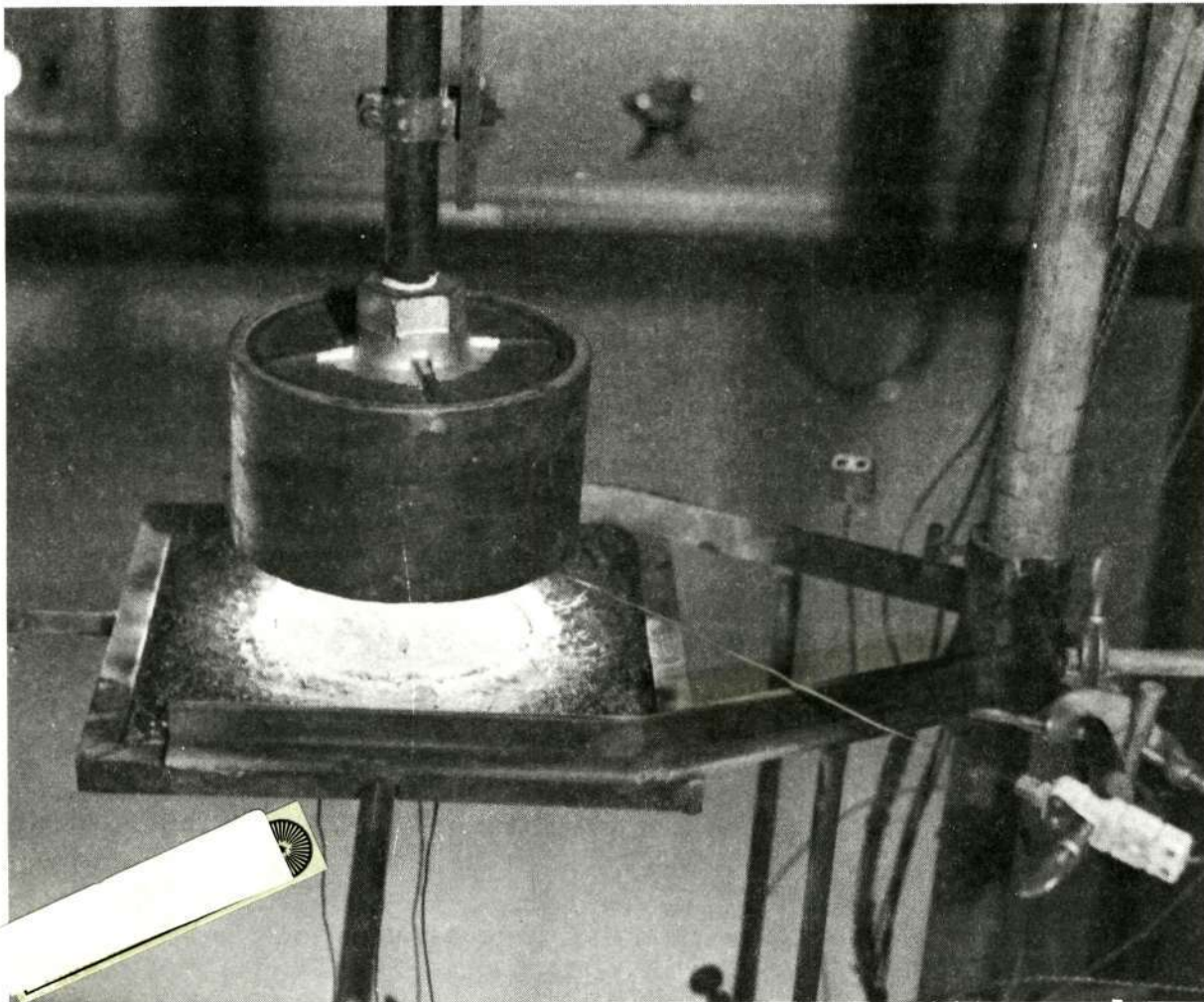


Fasteners imbedded in foam indicate some of its characteristics.

Figure 59. Foam Building Material for Use in Railroad Ties

**Measurement of Stress in Long Welded Rails and in Railcar Wheels.** Thermal stresses that build up in long and continuous modern railroad tracks can cause buckling and breaking of the rail. This happens when the uniform distribution of these heat-induced stresses is disturbed by improper alignment of ties, ballast or rail anchors. An effective, rapidly applied method of nondestructively detecting high pre-yield stresses is needed for use by rail-inspection crews in the maintenance of rail section. Another railroading problem is that of derailments caused by the catastrophic failure of railcar wheels. Such failures are caused by stresses resulting from known vertical and lateral loads superimposed on unknown residual stresses in the wheel. A method is needed for inspecting railcar wheels in the field, to determine whether residual stresses are above a critical level.

Ultrasonic techniques of measuring stress are currently being developed at the NASA Marshall Space Flight Center for the nondestructive testing of spacecraft structures. These appear to have great potential application to rail problems. These ultrasonic velocity techniques are effective for measuring stress in specimens made of well-characterized materials having uniform, reasonably flat smooth surfaces.



Tests being conducted on fiber-loaded intumescent coating that has fire protection, strength, and weathering characteristics.

Figure 60. Tank Car Fire Protection

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A program was funded in late 1971 to:

1. Determine the ultrasonic velocity vs. stress relationships for the particular types of steel used in making wheels and rails.
2. Investigate the effects of temperature variations on the accuracy of stress measurements.
3. Evaluate measurement problems related to rail geometry.
4. Make actual stress measurements on wheel and rail segments under controlled laboratory conditions.
5. Demonstrate the practicability of the technology by making stress measurements on long rail segments under realistic field conditions.

Initial testing has included obtaining data relating shear-wave determination of stress levels with applied loads. The data confirmed that applied loads can be accurately measured by the resulting stress as measured by ultrasonic shear-wave methods.

The American Association of Railroads provided the samples of rail and wheels and has closely followed the tests. The Federal Railroad Administration has expressed interest in the project and is now planning to fund NASA for a follow-up field test of the system.

**Nondestructive Testing of Large Metal Structures.** There are more than half a million highway bridges in the United States. In consideration of public safety, a federal law was recently enacted that requires biennial inspection of these bridges. The National Bridge Inspection Standards set forth the procedures and requirements for field inspection of in-service highway bridges. With existing field inspection procedures, however, it is not possible to determine whether small cracks in the critical load-bearing members have jeopardized the structural integrity of the bridge. This kind of hidden defect was responsible for the 1968 Point Pleasant Bridge disaster in which 23 people were killed and many others injured.

The Federal Highway Administration (FHWA) is anxious to develop technology that would nondestructively determine the presence of these hidden structural flaws. The need for this kind of technology becomes more critical as vehicle loads and traffic densities increase and as bridge structures become more susceptible to structural damage due to fatigue.

Several solutions were submitted by NASA personnel when the two bridge inspection problem statements were circulated. The suggestion showing the most promise in solving the bridge inspection problem is a NASA patent, Randomdec, described in NASA Tech Brief 71-10281.

The Randomdec method and apparatus were developed at NASA Ames Research Center and first applied to the failure analysis of wind tunnel models. It is a method for obtaining characteristic signatures of a structure operating in its natural environment. Randomdec monitors can monitor a structure's response to random vibrations, derive the system-free vibration curve, and signal any deviation in this output that would indicate impending structural damage.

It is estimated that Randomdec can eventually be produced to occupy less space than a breadbox at a cost of approximately \$2000. Experimental work will have to be undertaken to determine the feasibility of the technology in this application and the area of its greatest usefulness. It may work on entire bridges or be limited to critical structural beams or cables. It may be used periodically to compare a system's signature against a previous signature or standard, or it may be used in real time to signal any signature change that would indicate impending structural failure.

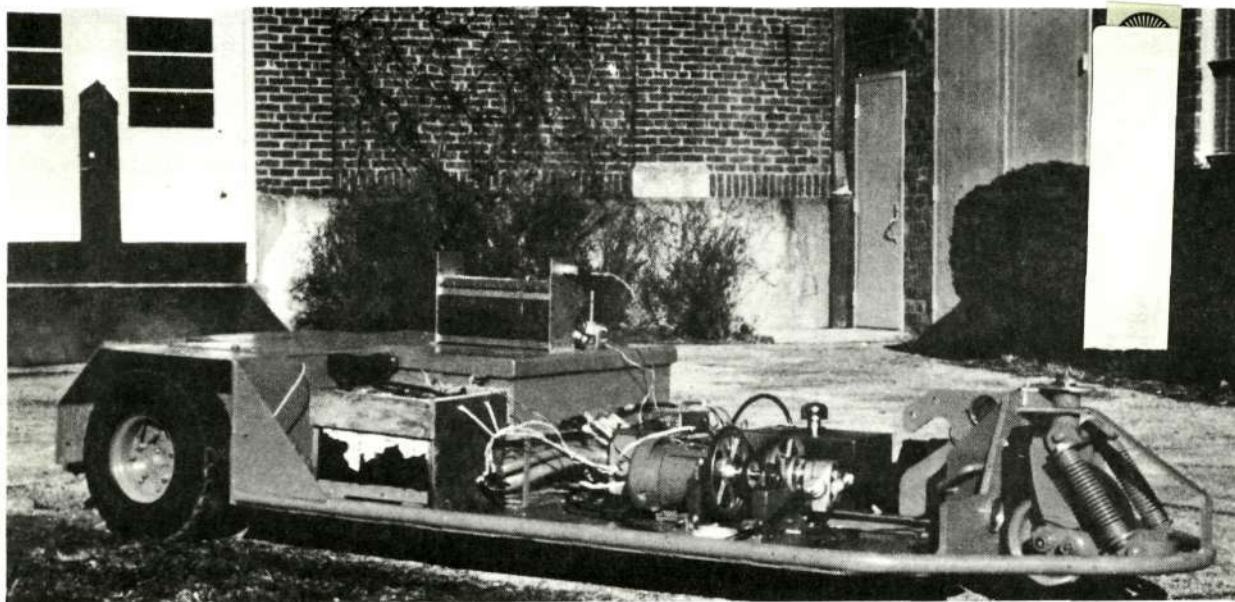
A meeting was held in February 1972 to acquaint the chief of the Bridge Structures Group of the FHWA with the Randomdec technology and its potential application to bridge inspection. He sees potential in the use of this device in structural inspection programs of the various state highway departments and other agencies responsible for bridge maintenance. The Director, Office of Research of the FHWA, has extensively reviewed and critiqued the Randomdec technique.

An applications project is now being planned to demonstrate the feasibility of this device for bridge inspection.



## MINE SAFETY

**Rescue Vehicle For Use in Coal Mines.** The Bureau of Mines is interested in developing special vehicles for use in mines after a disaster. A professor at the University of Kentucky has been funded by the Bureau of Mines to develop an unmanned remotely-controlled unit (Figure 61). There are several areas where NASA technology appears useful. The guidance system technology utilized in the NASA "lunar rover" vehicle appears particularly applicable. Other NASA technology which might be put to work includes a miniature, mine-safe television camera and fire-resistant thermal insulations to protect the various systems of mine-rescue vehicles. Also, the NASA Marshall Space Flight Center has assisted the Bureau of Mines by reviewing their Request For Proposal for manned mine-rescue vehicles. NASA has committed to provide and to apply its experience in developing and testing lunar-rovers to mine-rescue vehicle development if a contribution can be made.



NASA-developed technology for the lunar rover vehicle might be used for its guidance system.

Figure 61. Rescue Vehicle for Use in Coal Mines

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## SUPPORTING ACTIVITIES

**National Academy of Engineering.** In support of NASA's Application project activities, the National Academy of Engineering's Committee on the Interplay of Engineering with Biology and Medicine (CIEBM) has undertaken a study of aerospace-technology utilization in the civilian biomedical field. The study is being done under the aegis of the Academy's Subcommittee on Technology Transfer, which is chaired by Dr. David Rutstein of the Harvard Medical School. Now in its second year, this NASA-sponsored effort is designed to:

- Identify aerospace engineering technology that appears relevant to specific technological requirements in the biomedical field.
- Relate biomedical requirements to identified engineering technology in a manner which will facilitate follow-up activities by NASA at its option.
- Provide expert professional advice with respect to the initiation of specific projects that emerge from the preceding activities.
- Identify and recommend to NASA those interfaces with the mission-oriented organizations that would contribute to furthering the goal of transferring engineering technology to biomedicine.

The Subcommittee has created three *ad hoc* groups to focus study efforts on the areas of *cardiovascular care*, *pulmonary care*, and *remote diagnosis and treatment*. Each of these groups has prepared initial statements identifying significant medical problems amenable to technological solutions within their specialties. They have reviewed and evaluated a variety of current NASA projects and technologies related to biomedical technology. Conferences, working visits, meetings and trips to NASA field centers have facilitated the identification of problems and the review of technology. Based on their correlations of needs and available technology, the panels have submitted a set of recommendations for further concentrated development of NASA biomedical technology of significant potential to the biomedical community. The panels have also suggested various means for improving the application process.

The first Subcommittee recommendation being pursued is the further development of mass spectrometers and respiratory flow sensors. The Subcommittee *ad hoc* group on pulmonary care recommended that mass spectrometry technology could contribute substantially to clinical care. Instruments that are unstable and unreliable, with short-component lifetime, inflexibility, and high costs have handicapped accurate and continuous monitoring and analysis of blood and respiratory gases. Through the efforts of the Subcommittee, HEW's National Heart and Lung Institute (NHLI) and National Center for Health Services Research and Development (NCHSRD) have expressed interest in pursuing a joint program for further development of such instrumentation.

Another recommendation was to evaluate the applicability to civilian health care of reliability and quality-assurance methodologies which were originally codified by NASA. Further use of the bioassay device for automated fast urine-bacteria detection was recommended by the Subcommittee at large. NASA is now supporting demonstration and evaluation projects in both of these areas.

The *ad hoc* committee on cardiovascular care concluded that further research and development are needed in noninvasive cardiovascular measurements before they can be used clinically.

The Remote-Diagnosis and Treatment (RDT) *ad hoc* group was concerned with a new method of health-service delivery, as opposed to the other two *ad hoc* groups that focused on instrumentation problems in current delivery modes. The RDT group uncovered some crucial unanswered questions with respect to the physicians' needs in connection with concepts for new kinds of communication links. The Subcommittee identified specific NASA facilities and personnel who will assist in the research efforts (e.g. evaluation of slow-scan TV systems) to provide answers to some of these questions.

All these activities bear directly on health-care delivery. The CIEBM and the Subcommittee believe that mission-oriented Federal agencies dealing with health care should join in the technology-transfer process and have contacted representatives from the White House Office of Science and Technology, the Veterans Administration and several agencies within the Department of Health, Education and Welfare. Subcommittee findings have been



discussed with them and opportunities for joint participatory programs with these agencies and NASA are being explored. It is hoped that the major suggestions for technology transfer (specific development and evaluation protocols) will be implemented under jointly funded and supported interagency projects.

For the next 6 months, the CIEBM will continue to augment its services to NASA. Maintaining the Subcommittee on Systems and Technology Transfer as the basis, the CIEBM has proposed two primary efforts.

First, the Committee will continue work on the already-initiated transfer process for specific devices—mass spectrometer, flowmeter, and urine-bacteria detector. Efforts are under way to involve the National Heart and Lung Institute of NIH and/or the Veterans Administration in collaborative projects toward effective civilian applications of these devices. The Committee will act as an overview and liaison body as the development and evaluation of projects (the next phases of the transfer process) are undertaken, and will keep the mission-oriented agencies informed on work progress. Second, the Committee proposes to carry on its initial study of remote diagnosis and treatment more extensively during the next 6 months. The report of the *ad hoc* Group on Remote Diagnosis and Treatment documented the need for a thorough examination of the potential for remote health care, alternative strategies that can be used, and the roles that technology (primarily measurement, communication, and transportation) can play in developing such systems for health-services delivery. Specifically, the Committee has outlined controlled parametric studies which should be undertaken as a part of an overall assessment of 'telemedicine' (remote diagnosis and treatment) particularly for emergency medical service. The Committee noted further that within NASA there is the requisite expertise in communication, transportation, system analysis and operation research. These are the necessary tools for the interdisciplinary team which would undertake the assessment.

**"Engineering in Medicine-Biotelemetry" Conference.** A conference to explore technical problems and the coordination of biomedical communications within regions was cosponsored by NASA's Technology Utilization Office and the National Academy of Engineering. Conference arrangements were made by the Engineering Foundation for an August 1971 conference in Henniker, New Hampshire. The Foundation develops research conferences that focus on vital areas in engineering research as they relate to urban problems and the public sector.

The topics discussed by the conference were:

- Biotelemetry from remote emergency vehicles
- Biotelemetry in remote health care
- Biotelemetry in intensive and coronary care units

Specialists from industry, government and the biomedical community were brought together at the conference. It was structured to provide background information in various problem areas and to identify national funding resources to support problem solutions. The conference also served as a forum for defining future developmental work.

It became clear at the meeting that the major obstacles in the path of implementing improved systems were economic and institutional in character. The conferees agreed that the technological problems themselves could be dealt with by a modest research and development effort.

Representatives from the federal health-related agencies indicated clearly that funds were in very short supply. But they did indicate a willingness to engage in cooperative ventures that did not require dollar funding. Exhortations to consider the interplay between devices and people echoed throughout the meetings. Participants were cautioned that in attempting to improve medical telemetry systems they must carefully determine their final goals. This is essential to avoid the situation of having "a gadget looking for a job." In the final analysis, the value of any technology must be determined by its ability to diminish disease, disability and untimely death.

**Technology and the Neurologically Handicapped.** Ways by which technology might help neurologically handicapped people were the subject of a 3-day conference jointly sponsored by NASA and the United Cerebral Palsy Research Foundation. The meeting was held at NASA's Ames Research Center, Moffett Field, California. Conferees heard a presentation on the etiology and physiology of neurological handicaps. Techniques for meeting the basic needs of the neurologically handicapped were discussed. The conference focused primarily on current

therapeutic techniques and on adapting technologies already developed for other purposes to the needs of the handicapped. Topics discussed were: long-range prospects for neural control, objective measurement of recovery from neurological disease, exoskeletal technology, artificial sensory systems, models of the sensory system and postural control, manual-control theory and applications, neurological applications of man-machine systems analysis and the role of intelligent mechanical aids.

Discussion at the close of the meeting centered on future means of improving communications, and technology transfer from physiology and engineering to neurology and rehabilitation.

A number of projects have resulted from discussions at this conference. Studies have begun on NASA-developed exoskeletal devices to improve a spastic's control of limb motion and to develop improved methods of measuring limb motion for evaluation of therapeutic effectiveness.

**NASA-American College of Radiology Joint Conference on Technology Transfer.** NASA and the American College of Radiology held a joint conference in Albuquerque, New Mexico, February 19-21, 1972. Nearly seventy participants, half from the NASA family and half from the radiological community engaged in intensive discussions on ways that NASA-supported research and technology could be applied to the problems of radiology. The conference focused on four "core" workshop subjects: imaging systems, computers, instrumentation and therapy.

Each workshop was composed of equal numbers of radiologists and NASA specialists.

The therapy workshop centered all of its discussions on high-energy particle beams (neutrons, protons, alpha particles, pi mesons, and heavier ions), most forms of which are not yet available for cancer management. Within a few years, however, they will be available from such machines as the Los Alamos Meson Physics Facility near Albuquerque, New Mexico. In the meantime, the therapists agreed that they have a full schedule of research to do in beam localization and radiobiology before clinical trials can begin. And when therapeutic work does get under way, they said, it must be done in a limited number of programs "to get away from anecdotal experience." Top investigators, in nearly constant communication about their results, will first "have to establish the realities of the initial advance" before a proliferation of particle-beam facilities is justified, the summary report cautioned.

New techniques with ultrasound were interesting to both the instrument and imaging participants, who at the same time made the observation that very little is known about the biophysics of ultrasound. However, it appears to be relatively nondestructive and could "free us from radiation" as a physiologic probe, a summary report said. Biggest interest centered on work at the Jet Propulsion Laboratory, which is using a low-power continuous tone to make a shadowgraph of energy that passes through an object at any precise moment.

The image workshopers, who found a feasibility in satellite transmission, also thought it would be worthwhile to develop holography for three-dimensional x-ray displays. And they urged radiologists to help evaluate developments in solid-state electroluminescent storage panels that could replace film in some applications. Also asked were developments in microfocus x-ray tubes and monochromatic x-ray sources, both of which are being worked on by NASA.

The computer group discovered that a considerable amount of technology exists in NASA that radiologists could take advantage of if they only knew about it. To correct that omission the group recommended the establishment of a "visiting radiologist" program like the one that now gives other scientists three months or more at NASA installations to watch and help the space agency at work. Also recommended were cooperative projects between NASA and the American College of Radiology to do a feasibility study on image storage and retrieval and to design a "total radiologic information system" such as a large hospital might want to handle its data and planning in both diagnosis and therapy. NASA is now in the throes of a big improvement effort demanded by the glut of multispectral photographs expected from the first Earth Resources Technology Satellite (ERTS), which is supposed to help survey matters ranging from corn blight to water pollution. This image-storage and retrieval program will be equally applicable to the problems faced by the radiologist.

Some of the observations that emerged in the give-and-take of workshops were surprising to clinicians and technologists whose research has necessarily been limited to small areas of big problems. For example, when it comes to remote transmission of radiographs, such as would be desirable in the expansion of medical services to

rural areas, it may be more accurate and cheaper to send the data by way of satellite than to try to use telephone lines. The reasons are that satellites offer wider bands for electromagnetic communication and, as one speaker pointed out, are "getting to be more dependable than the phone service in the boon-docks."

In instrumentation, the conferees found no particular role for NASA now in either patient-handling equipment or devices to inject contrast media. But they did see considerable potential in the various NASA research projects that have to do with catheters—heparin coatings for anti-thrombogenesis, miniaturized transducers that could be incorporated in a tip to measure blood flow, pressure, and acoustic signals all at once, and an endoscopic device for visualization of vessel walls.

Dr. Louis Arnoldi, director of NASA's Occupational Medicine and Environmental Health Divisions and Dr. Robert D. Moseley of the University of New Mexico School of Medicine served as conference cochairmen. Summary reports and recommendations by the workshops suggested strongly that technologic spin-off from the space scientist to radiology is "a matter of long range relationship rather than immediate transfer." Representatives of NASA and the American College of Radiology are continuing to work together to develop follow-up plans for the cooperative efforts the conferees hope to establish in the wake of this important meeting.

**PTI/NASA Technology Application Program.** A joint program between Public Technology, Inc. (PTI) and the NASA Technology Utilization Office began in the fall of 1970. The program was initiated with the concept that PTI (formerly the International City Management Association's Technology Application Program) would establish liaison with municipalities to identify and select significant but relatively short-term technological needs common to a number of cities. The two organizations would work together to determine feasible technological approaches and to design projects that would specifically adapt existing technologies to municipal applications. PTI would insure municipal interaction during prototype design, development, testing, demonstration, and problem identification. It will also develop mechanisms to disseminate information to the cities about the projects.

A selected number of one-hundred municipalities were invited to participate in the program. Seventy-nine cities and one metropolitan county with a total population of over 25 million people have joined the program. On 1 January 1972, PTI was formally chartered under the sponsorship of the six major public-interest groups representing state and local governments. These are: the International City Management Association, National League of Cities, U.S. Conference of Mayors, National Association of Counties, National Governor's Conference, and the Council of State Governments.

NASA and PTI held a working conference in October 1970 at the Kennedy Space Center. For two days, representatives from participating cities explored intensively the range of NASA technology and potentials for application to urban problems. City representatives also attended concentrated work sessions in problem definition. The aim was to simplify the assigning of priorities to urban problems that might be solved through new or improved technology. After the conference, when the representatives had returned to their cities, they drew up an initial set of problems which was submitted to PTI for review by a coordinating group of city representatives.

Nearly 500 problem statements, submitted by January 1971, were independently reviewed by NASA and PTI prior to the coordinating group review. The coordinating group compounded this set of problems into 45 generic, high-impact urban technology requirements. Major problem areas included communications, law enforcement, fire safety, transportation-system control, public works and utilities, health, sewage disposal, solid waste management, and water-pollution control. The problem statements for fifteen top priority problems were rewritten and these were reviewed and modified by three regional groups of city representatives to create regional problem priorities. The coordinating group reconvened in April 1971 to agree on a set of six target problems on which to begin work immediately. The fifteen problems in order of priority are:

1. Firemen's Breathing Apparatus
2. Short-Range Communications Equipment for Firemen and Police
3. Pavement Striping
4. Firemen's Protective Clothing
5. Underground Pipe & Conduit Locator
6. Automatic Fire Hose Flow Regulator
7. Command/Control System
8. Protective Body Armor
9. Disposal of Toxic and Flammable Waste

10. Electrical Fault Detection
11. Electronic Traffic Counter
12. New Fire Hose and Hose Couplings
13. Patient Monitoring Equipment, Emergency
14. High Voltage Power Transmission
15. Patient Monitoring Equipment, Non-Emergency

User-Design Committees, consisting of both technical and administrative personnel from the cities, have been established for several problems. Their meetings with NASA provide an opportunity for the municipal representatives and NASA technical personnel to develop a better understanding of problems, performance needs of end products, and to evaluate proposed solutions. This close coupling between the user and the design team represents an important link in the technology-application process. It is a necessary step in developing specifications that will meet the needs of the municipalities and, hopefully, to aggregate municipal markets for new products.

The current status of the top six problems is:

1. *Firemen's Breathing Apparatus.* Specifications for a lightweight compressed-air bottle and regulator, harness, and mask have been prepared at NASA's Manned Spacecraft Center. Contracts for the bottle development were let in early 1972 with requests for proposals for the balance of the system received in April 1972. A User-Design Committee has reviewed, evaluated, and approved all systems-design specifications. Prototypes for demonstration in selected cities are expected in late 1973. Activities are described in greater detail in the projects section of this report.

2. *Short-Range Communications Equipment for Firemen and Police.* New products under development or commercially available are being reviewed. Following a review of NASA's advanced communications-technology program, specific plans for test and evaluation of the manufacturer's equipment will be made and tests conducted in selected cities.

3. *Pavement Striping Materials.* A search of the NASA and Department of Defense literature, as well as the literature of other government agencies, indicates that this problem may soon be solved by private sector. However, the cities' need for a marking material that can be easily removed is not likely to be met by industry in the near future. The decision on whether or not to initiate a development project will depend on the importance and feasibility of easily removing the marking materials.

4. *Firemen's Protective Clothing.* Contracts have been let from the Manned Spacecraft Center to produce twenty-one sets of garments for delivery in 1972 for evaluation by selected cities. The garments being developed include both structural and proximity suits, caps, gloves and boots.

5. *Underground Pipe and Conduit Locator.* Discussions between a User-Design Committee and Marshall Space Flight Center (MSFC) engineers led to a better understanding of the cities requirements and an evaluation of alternative technological approaches. The group concluded that a downward-looking radar system seemed to be the most promising approach given the state of existing technology. As a result of this, MSFC engineers met with army personnel at Fort Belvoir, Virginia to discuss their radar systems for underground-target detection. A New England firm, which has developed a similar but not identical system, now provides underground-detection services both for geographical and utility-line applications. At a second User-Design Committee meeting approaches for developing this technique into an instrument for application in cities were reviewed.

6. *Automatic Fire Hose Flow Regulator.* At a meeting at Lewis Research Center in July 1972, the project's User-Design Committee agreed that the problem was more properly defined as flow regulation rather than pressure regulation. As a result of the NASA/PTI efforts, several aerospace companies have expressed interest in developing a flow-regulation system for fire-department pumps.

The first year of activities in this program has concentrated on defining urban needs and matching them with technical resources. The second year is concentrating on developing mechanisms for implementing solutions. During this period the program will focus on the development of new product development, testing and delivery.



**Minority Enterprise Program.** The NASA Technology Utilization Office initiated a contract in February 1971, with the National Progress Association for Economic Development (NPAED), which was formed by the Reverend Leon Sullivan to aid minority groups in business ownership and management. After a review of the application effort NPAED selected 24 NASA technologies which they believe have potential for either creating a new enterprise or for strengthening an existing one. A report which outlines the marketability, development costs, and a proposed business plan for each technology will be widely distributed to encourage other minority groups to consider these technologies.

Also, the Office is cooperating with a minority business firm in a pilot project to make commercially available a NASA-developed behavioral/motor skills testing device with broad potential application in medicine, law enforcement, transportation and other fields. A field-tested product should be widely available by the latter part of 1972.

**The George Washington University.** The Technology Application Group (TAG) of the Biological Sciences Communication Project, The George Washington University Medical Center, under contract with NASA's Technology Utilization Office since 1965, provides technical and analytical assistance to the Program. The TAG provides NASA with continuing support in analysis of the Technology Application Program. It supplies detailed reviews of various aspects of the technology transfer process, and helps to improve transfer systems. The TAG determines significant problem areas for the entire Technology Application Program, and calls them to the attention of NASA.

Reports on the technological state-of-the-art in the public sector were submitted to NASA in the past year. The TAG works with agencies or organizations to identify new problems, or to further the NASA technology transfer, as required. It coordinated the American College of Radiology Conference held in February of 1972. The TAG has worked closely during the past year with the National Academy of Engineering Committee on the Interplay of Engineering with Biology and Medicine Project. It evaluated the activities of Public Technology Incorporated/NASA Technology Applications Project and lent assistance to the effort with the National Progress Association for Economic Development.

**Efforts to Commercialize Biomedical Technology.** In early 1970, an Aerospace Subcommittee was established (under the Association for the Advancement of Medical Instrumentation (AAMI) Standards Committee), to find means of stimulating the interest of the biomedical industry in NASA biomedical technology. The Subcommittee was formed through cooperation of AAMI, NASA's Technology Utilization Office, and the RTI Biomedical Application Team. It is composed of representatives from NASA bioinstrumentation groups, physicians, and the biomedical instrumentation industry. At the Subcommittee's first meeting, during the Annual AAMI Meeting in March 1971, a detailed briefing on the NASA Application Team Program was presented. At a later conference (Fall 1971), the Subcommittee received extensive material on NASA biomedical technology.

The subcommittee's concern and discussions center on ways to inform industry that fully developed NASA devices are available, and to encourage their manufacture and marketing. The recently revised NASA patent licensing regulations enable NASA to grant exclusive licenses at an earlier date than was previously possible. It is anticipated that this will accelerate the commercial use of space-related patented inventions or technology. Specifically, rather than wait until two years after a patent has been issued, as previously required, NASA could grant exclusive licenses in appropriate cases as soon as nine months after the invention had been announced as available for licensing. The prime consideration in granting an exclusive license will be whether such a license is necessary to bring an invention to practical application.

The annual AAMI conference in the spring of 1972 included a special session on NASA developments in biomedical instrumentation. Discussions were conducted with industry representatives to determine how to make the transfer mechanism more effective.

**Goddard Space Flight Center's Third Annual Summer Institute for Biomedical Research.** The Summer Institute for Biomedical Research in Technology Utilization is a unique program to further accelerate the flow of NASA aerospace technology toward application to problems in biomedicine. It was undertaken this summer for the third successive year.

The Institute was a joint project of The George Washington University and NASA's Goddard Space Flight Center. It was undertaken to enable ten senior undergraduate students selected from a number of colleges and universities throughout the eastern United States to spend ten weeks in an active technology-application program.

The students were able to apply their background and aerospace technology toward the solution of defined biomedical problems under the direction of University faculty and Goddard scientists and engineers.

During the first half of the ten-week period, the students spent two mornings each week in a classroom lecture series designed to provide them with a broad, comprehensive view of the biomedical engineering profession and, in particular, the system-engineering approach to health care. The lectures, seminars, and demonstrations were conducted by The George Washington University Department of Clinical Engineering in Washington, D.C.

Five well-defined research projects were developed by the Department of Clinical Engineering. These projects were focused on ideas, concepts, or existing instrumentation which needed further design and engineering improvement, so that significant progress in terms of working prototypes could be accomplished by the students during the ten-week program.

More detailed information concerning the 1971 Summer Institute is included in a report issued by the Technology Utilization Office of the Goddard Space Flight Center.

**PROJECTS NO LONGER COVERED IN THIS REPORT BECAUSE OF TERMINATION OR  
LACK OF SIGNIFICANT ACTIVITY IN THIS REPORTING PERIOD**

**BIOMEDICAL PROJECTS**

Scanning Tumors in Small Animals with Gallium-67  
Improved Lens for Cancer Research  
EKG Isolator  
Recording and Playback of EKG Signals  
Surgical Suites Contamination Control  
Newborn Infant Respiration Monitor  
Breathing (Apnea) Monitor  
Kidney Dialysis Matrix  
Cleft Palate Airflow Monitor  
Battery State-of-Charge Indicator for Powered Prosthesis Device  
Hydro-John

**PUBLIC SECTOR PROJECTS**

Ultrasonic Torque Wrench  
Indented Writing Detection  
Dust Monitoring in Coal Mines  
Fluidic Flow Sensor for Use in Coal Mines