MEDICAL BENEFITS FROM SPACE RESEARCH

NATIONAL
AERONAUTICS
AND
SPACE
ADMINISTRATION

MEDICAL BENEFITS FROM SPACE RESEARCH

Computer techniques that clarified photographs televised across 140 million miles of space from Mars are now being used to make medical X-rays more revealing. These ingenious techniques remove irrelevant details and enhance those that doctors want to study.

In a Southern California rehabilitation center, crippled children are able to move about with ease in a little eight-legged electric vehicle adapted from one originally designed to be an unmanned, radio-directed instrument carrier on the Moon.

Analyzing the oxygen consumption of patients in the University of Kansas Medical Center while they exercise is no longer an uncomfortable routine of wearing a nose clip and breathing through a mouth tube. The patients now wear comfortable helmets, resembling those of the astronauts, and breathe freely. For space-minded youngsters the helmets lend an element of fun to an otherwise unpleasant diagnostic procedure.

Victims of neurological diseases such as Parkinsonianism may soon be discovered earlier than before, and get medical help quicker, because a supersensitive device designed to register micrometeorite hits on spacecraft has been adapted to detecting tiny muscle tremors.

These medical advances, described in greater detail and pictured in the following pages, are examples of many ways in which research discoveries and engineering innovations from the nation's space program have been applied to major medical problems. Among others: Space miniaturization techniques have been applied to transmitters for cardiac sensors. Methods of sterilizing spacecraft components to prevent them from contaminating other planets have resulted in new sterilization techniques for operating rooms and surgical instruments.

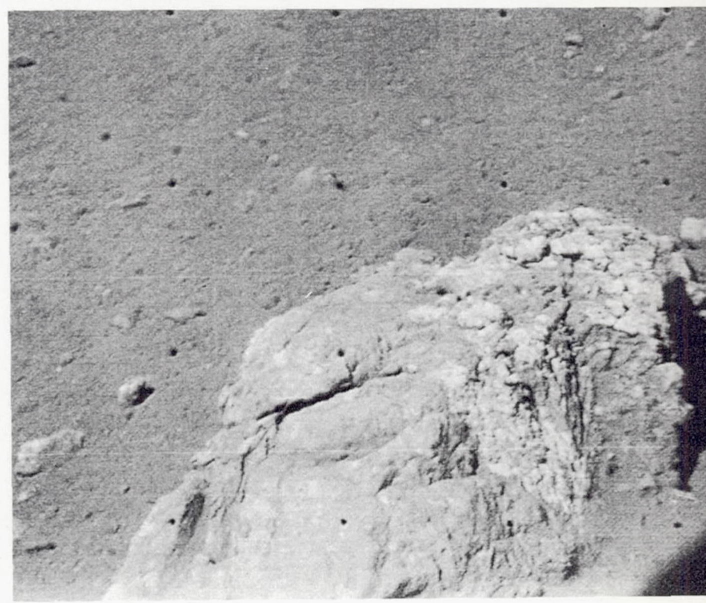
Computer Enhancement of X-Ray Photographs

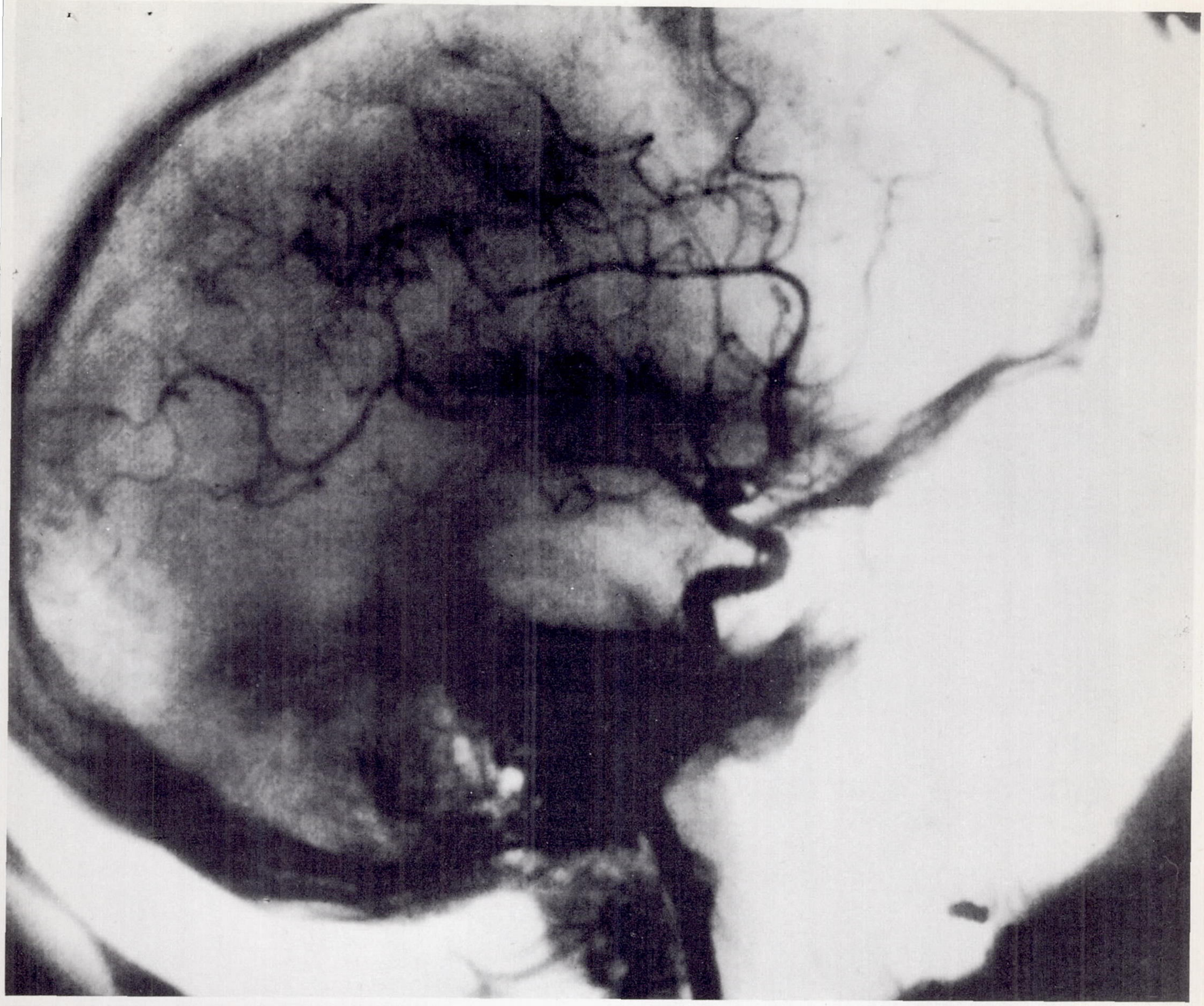
For several years NASA's Jet Propulsion Laboratory has been using digital computers to enhance the clarity of pictures televised from spacecraft. Those photographs include thousands taken near or on the surface of the Moon and a series of 22 made by Mariner IV while passing close to Mars.

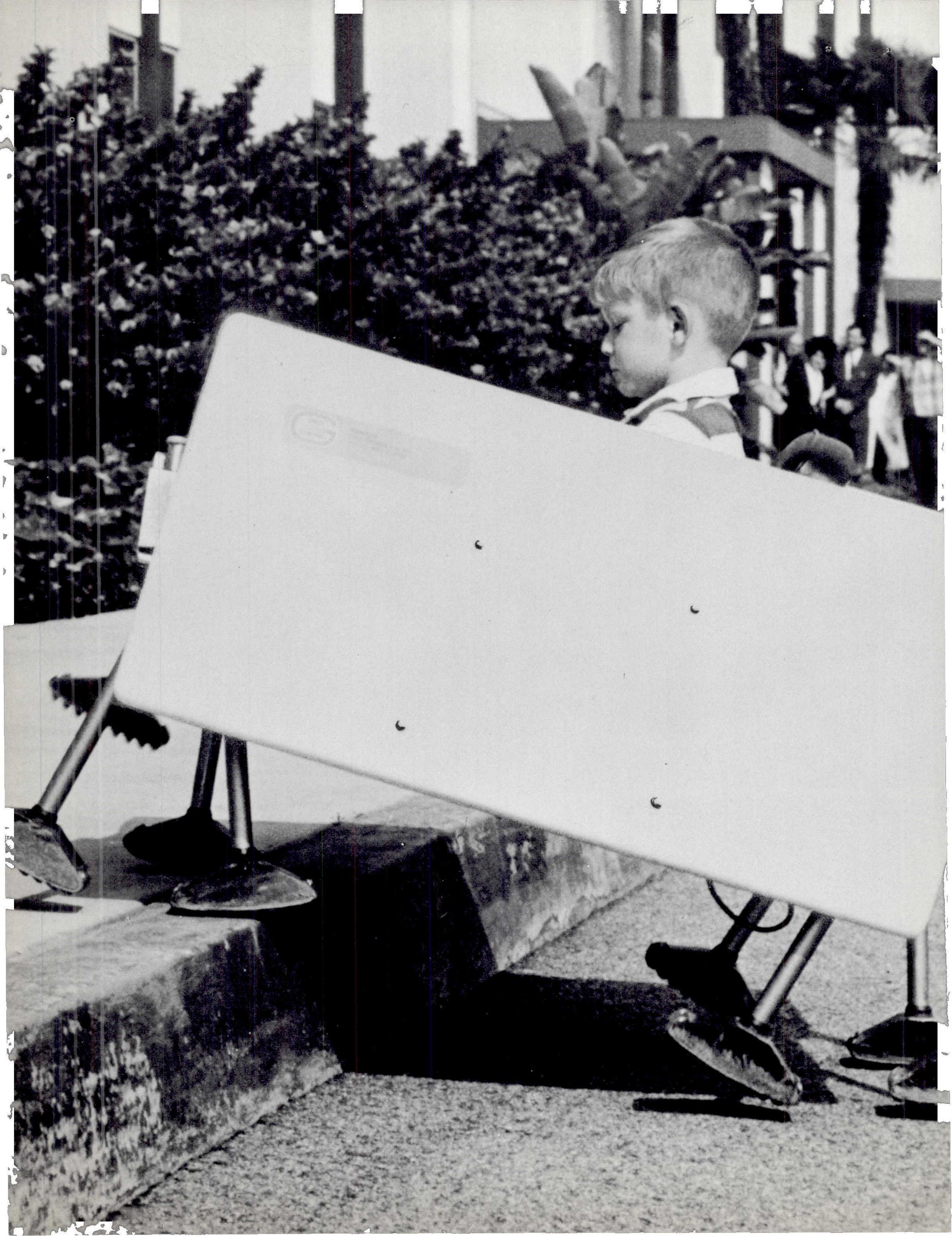
The original pictures were surprisingly sharp, considering the circumstances. But certain technical limitations of a vidicon scanning camera and the distorting effects of electrical noise in radio transmission made some of them less clear than photo interpreters wished. By processing the photos in a digital computer, it was possible to bring out details present but obscured in the original pictures. The computer in this process has been likened to a high-fidelity phonograph, which can be made to emphasize bass or treble sounds to suit the listener's taste.

Note, in the accompanying pair of comparative photos of a 20-inch lunar rock that lay about 15 feet from the TV camera on a Surveyor spacecraft, how the computer-enhanced picture reveals fractures and separate fragments not seen or only barely visible in the unprocessed original.

Early in 1966, JPL in cooperation with the NASA Technology Utilization Division began investigating the possibilities of utilizing this same technique to clarify medical and biological X-rays. The results have been very promising, enabling doctors to get clearer views of details that otherwise would be lost or might be overlooked. You can see, in the contrasting X-ray photos of a human skull reproduced below, how clearly frontal blood vessels, which a doctor needed to study, are revealed in the computer-enhanced picture. Computer enhancement of X-ray photos continues under development.



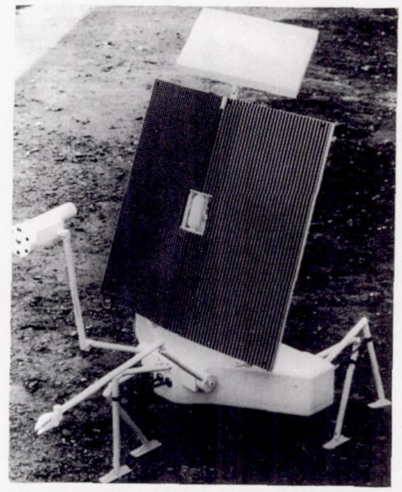




A Wheelless Wheelchair for Crippled Children

A walking vehicle (See photo at right) that a manufacturer designed as part of a proposal to NASA to build an unmanned, radio-directed instrument carrier for exploring the Moon's surface has been adapted to a wholly unexpected, humanitarian purpose. Now, with motors obtained from electric drills and batteries from motorcycles, it functions as the prototype of a wheelless wheelchair for crippled children (See photo at left). It is presently undergoing evaluation at a public rehabilitation center in Southern California.

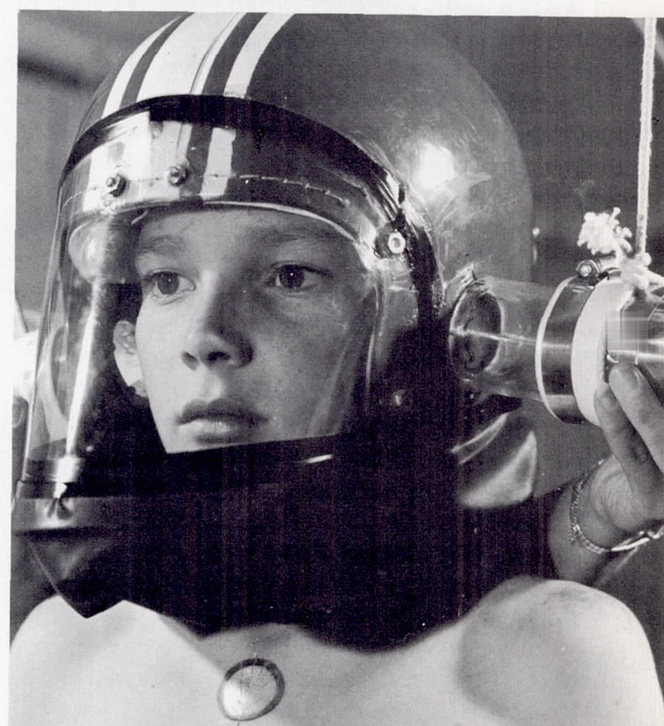
The eight-legged vehicle, which keeps four legs on the ground at all times, moves with stepping motions and is able to move across rough or sandy terrain that would balk an ordinary wheelchair. It can clear curbs and climb stairs. Its sole control is an upright stick, which can be modified with a chin cup to serve children who can't use either arms or legs and must steer the vehicle with their heads. The wheelless wheelchair, which has two speeds forward and in reverse, can be guided by pushing the stick in the desired direction. Evaluators say that children very quickly learn to operate the vehicle and take delight in doing so.



Astronaut Helmet Becomes a Respirometer

Here you see a young man enjoying, rather than enduring, a clinical diagnosis of his oxygen consumption while he exercises. His enjoyment arises from the fact that he is wearing a modified version of an astronaut's helmet, which permits him to breathe freely even when breathing hard. Old-fashioned respirometers required the patient to wear a nose clip and inhale and exhale through a mouthpiece, which too often got puffed out of place during exercise. Thus the respirometer readings were undependable.

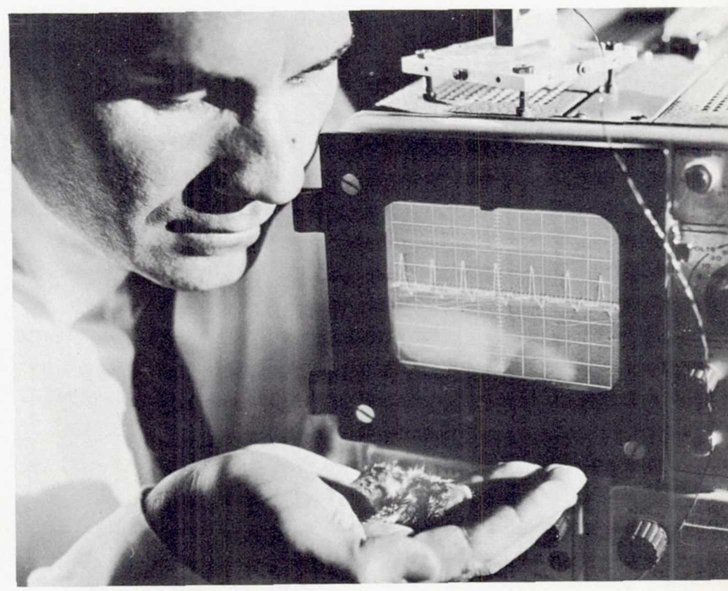
The recently constructed helmet respirometer shown here is equipped with an air inlet and an air outlet and a neck closure. The air outlet is connected to the suction pump of an oxygen analyzer. The helmet is placed over the patient's head and the neck sleeve closed. In operation, the suction pump pulls air through the air inlet, around the patient's head, and into the analyzer. There is no escape of air through the neck closure because of the suction created in the helmet, and no interference with the patient's free breathing. The space-inspired respirometer is now routinely used in clinical tests in the exercise laboratory of the Kansas University Medical Center.

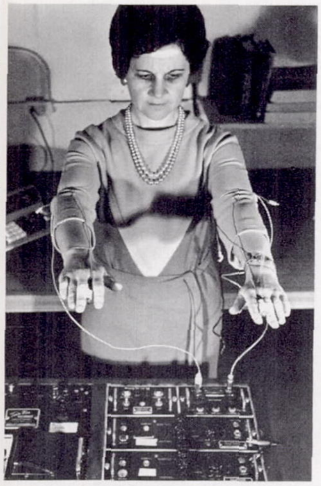


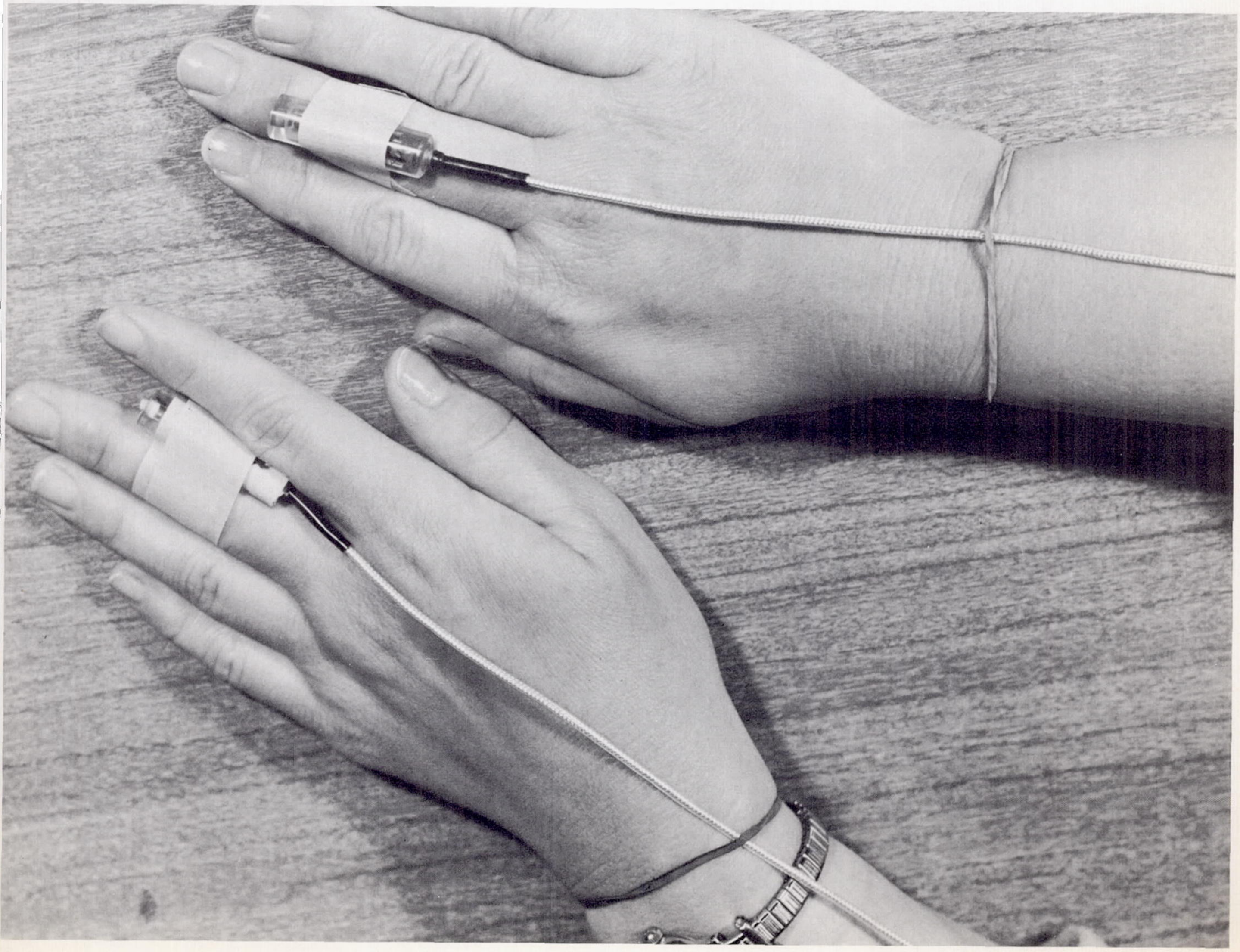
A Potential Boon to Neurology

An unforeseen train of events began when Vernon Rogallo, of NASA's Ames Research Center, converted a highly sensitive instrument he had devised for measuring micrometeorite strikes on spacecraft into a means of measuring the heartbeats of bird embryos for biological researchers. It has now led to entirely unexpected potential medical benefits.

With the active help of a NASA Biomedical Applications Team the Rogallo device is now being modified once more, this time to record the tiny muscle tremors associated with the onset of Parkinsonianism. It is hoped that the delicate new measuring instrument may facilitate early diagnosis and thus more prompt treatment of such neurological diseases. Medical researchers also foresee potential value in the instrument as a sensitive monitor during neurosurgery.







Benefits by Design

The benefits to biomedicine from space research did not come about by chance. These instances are deliberately induced rewards of a program that NASA's Office of Technology Utilization is conducting as part of its effort to pass along the results of space research to others who can use them. This program was established to identify and communicate elements of space technology that seem likely to be helpful in solving medical and biological problems, common or rare. When promising elements are found, they are made known directly to pertinent medical researchers. This provides a two-fold advantage: It accelerates the flow of new concepts through the medical community. And brings from the engineering and physical sciences fresh knowledge that would be unlikely to find its way into medicine by any other channels.

NASA's program for relating aerospace technology to the needs of physicians and biologists in part grew out of a study that George Washington University made, under NASA contract, to discover the means by which existing medical applications of space technology had come about.

Here is one meaningful example of what that study disclosed:

From Micrometeorites to Heartbeats

Vernon Rogallo, an electronics engineer at NASA's Ames Research Center, near San Francisco, was given the task of developing a micrometeorite sensor. He accomplished this by designing an instrument that employed, as a sensing element, a piezoelectric crystal. The slightest impact on a target shield caused the crystal to generate a small current of electricity, which could be amplified and recorded. The instrument was so sensitive that it could measure the equivalent of one one-thousandth of the momentum of a grain of salt dropped from a height of one centimeter.

Shortly after building the sensor, Rogallo happened to overhear a conversation between two biologists in the Ames cafeteria. They were discussing the problem of how to measure the heartbeat of a chick embryo without passing electrodes through the shell into the embryo or breaking a window through the shell so that the beat could be observed. Rogallo, after a few calculations, estimated that with a slight adaptation his device could serve the biologists' purpose very well. He invited them to bring a fertilized egg to his laboratory.

Rogallo replaced the shield-like target of his micrometeorite sensor with a small basket and placed the egg in the basket. The impact of the beating embryonic heart within the shell moved the egg enough with each beat so that the embryo's ballistocardiogram was easily read.

A Technology Utilization Officer stationed at Ames Research Center—such men work at all 14 NASA field installations—learned of this development and conveyed the details of it to the Office of Technology Utilization at NASA Headquarters. That office notified the Food and Drug Administration of it, and shortly afterward an FDA investigator evaluated the device at Ames and saw exciting possibilities for its use. A duplicate sensor was constructed and has been lent to FDA for trial in studying the effects of various drugs on developing bird embryos.

Three Lessons in Technology Transfer

From this experience, and others that the university investigators studied, three lessons were learned. The first was that person-to-person communication is important in the transfer of technology from aerospace innovator to potential biomedical user. Furthermore, the professional backgrounds of the communicators are important; for the second lesson of the study was that biomedical applications of aerospace technology can come not only from expected sources, like space medicine, but from less obvious origins: physics, chemistry, engineering. Therefore, a familiarity with both medical language and that of one of these other disciplines makes communication surer. The third lesson of the university study was that aerospace concepts of promise to medicine can best be evaluated by conveying information about them directly to biomedical research teams in medical schools, hospitals, universities, and public-health agencies.

Those "lessons" became some of the basic tenets of the program that NASA's Office of Technology Utilization is undertaking in the biomedical field. The program accomplishes two principal things: It seeks answers from aerospace knowledge for specified medical questions. It also identifies aerospace technology that appears to have potential medical value, and then seeks out biomedical objectives that this technology may help to meet.

To carry out the program, the Office of Technology Utilization, for one thing, has entered into a cooperative effort with the Vocational Rehabilitation Administration (VRA).

NASA's Information System

In compliance with the Space Act of 1958, which established NASA and stipulated that it should "provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof," NASA created its office of Technology Utilization. That office consists of two divisions, with the following informational assets and services:

1. Scientific and Technical Information Division provides a stockpile of readily tapped knowledge from domestic and foreign aerospace sources—presently more than 250,000 scientific and technical documents, announced in abstract journals, indexed on computer tapes, and distributed in printed copies and on 4-by-6-inch rectangles of microfilm, called microfiche. The stockpile is increased by reports and articles—approximately 75,000 a year at the current rate—from NASA's research centers and field offices, from its contractors and grantees, from other branches of the Government that produce technological information, from aerospace activities in more than 40 foreign countries, and from behind the Iron Curtain. Among the more than 6,000 research reports added to this accumulation in an average month are about 500 on biosciences and biotechnology.

2. The Technology Utilization Division selects from the computer-indexed stockpile, and from on-going research and development projects, those discoveries, inventions, ideas, and new techniques that have possible use in the non-aerospace community—including the biomedical field. The division also seeks out useful new ideas resulting from NASA work not otherwise reported in the scientific literature. It distributes space-generated technology to non-aerospace users through eight Regional Dissemination Centers, through a variety of publications, and through a number of unique experimental programs.

Helping Solve VRA Problems

Under the terms of the VRA-NASA interagency agreement, a pilot project is getting underway to make available to the VRA the results of aerospace research that may help solve some of the problems of the four million people of working age in the United States who have physical or mental disabilities. The benefits of the program could range from developing new aids for the blind, lame, and deaf to information that might help free the handicapped who have the additional disadvantage of living in social isolation.

Vocational rehabilitation scientists at four VRA-supported university research centers specify their unsolved problems in restoring the disabled to productive life. NASA's Office of Technology Utilization and Technology Utilization Officers in NASA field installations then seek out information resulting from aerospace research and development that appears to be applicable to the solution of those problems. This information is relayed to the VRA scientists for evaluation, application through adaptive engineering, demonstration of the resulting devices and procedures, and encouragement of commercial introduction of the new products and services.

This VRA-NASA agreement is part of a wider effort by the Office of Technology Utilization to establish similar informational exchanges with other Government agencies.

How Biomedical Application Teams Work

A second major element in the present program in medicine consists of the Biomedical Application Teams, small groups of biological and physical scientists at research centers under contract to NASA. Each team is equipped with firsthand knowledge of NASA's computer-indexed collection of scientific and technical information and how to search it. Each group represents a human connection between NASA and the biomedical research teams at work in medical schools, institutes, and hospitals.

NASA has purposely selected Biomedical Application Teams to obtain different professional backgrounds—in physics, engineering, and medicine. Each team's operational approach to the application of aerospace knowledge to medical research problems is, however, essentially the same.

These teams first define a specific set of medical problems for which solutions are sought. They have found that the best way to do this is through conversations with research physicians specializing in the attack on those particular problems. These discussions are conducted by team consultants who have extensive backgrounds in both physiology and engineering. After each problem is defined, a brief statement of it, called a Medical Problem Digest, is then prepared in terms familiar to engineers and physical scientists.

Biomedical Application Teams

NASA's Office of Technology Utilization has three Biomedical Application Teams in operation at present: at the Midwest Research Institute, Kansas City, Missouri; at the Research Triangle Institute, Durham, North Carolina; and at the Southwest Research Institute, San Antonio, Texas.

The organization of the Biomedical Application Team at the Midwest Research Institute illustrates the deliberate multidisciplinary character of them all. This one is directed by a mechanical engineer. His teammates include professionals in electrical engineering, physics, physiology, and information sciences. The MRI team also includes consultants at the University of Kansas Medical Center, the University of Minnesota Medical School, and the St. Louis University School of Medicine.

This Biomedical Application Team is involved, as are the others, in the following process of transferring NASA-developed technology to the medical community. The process consists of five fundamental steps: (1) definition, in functional terms, of medical problems or barriers that impede the progress of medical research, (2) identification of potential solutions in aerospace technology, (3) evaluation of potential solutions, (4) adaptation, and (5) dissemination of information on solutions.

Broad Hunt for Suitable Technology

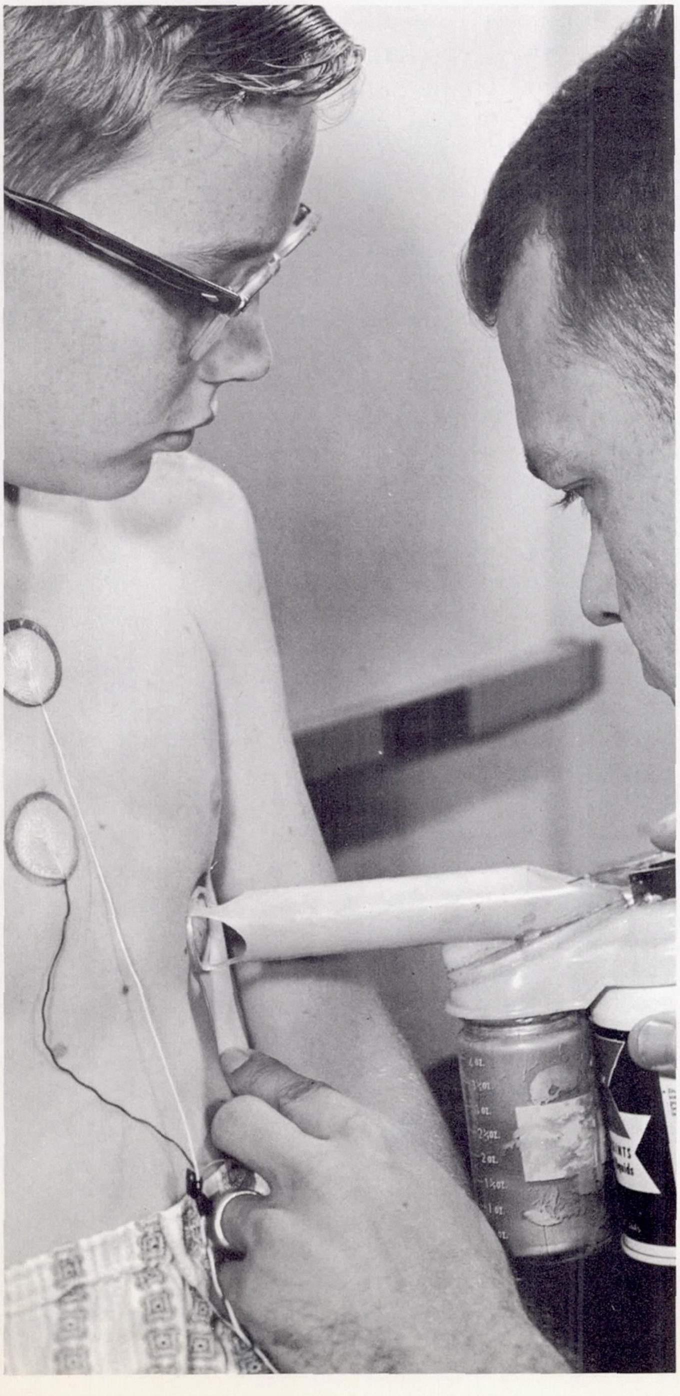
With a definition of the problem at hand, the Biomedical Application Team prepares to survey the broad sweep of aerospace technology and identify those specific portions of it that have potential application to the problem. The process of identification takes several directions. First, the Medical Problem Digests are routed through NASA Headquarters to the various NASA Centers to solicit suggestions from the Technology Utilization Officers there and from other Center personnel. The aerospace literature also is searched, making full use of the various NASA services for that purpose. In addition, members of the Biomedical Application Team visit pertinent NASA Centers for firsthand discussions of the problem with the technical staffs.

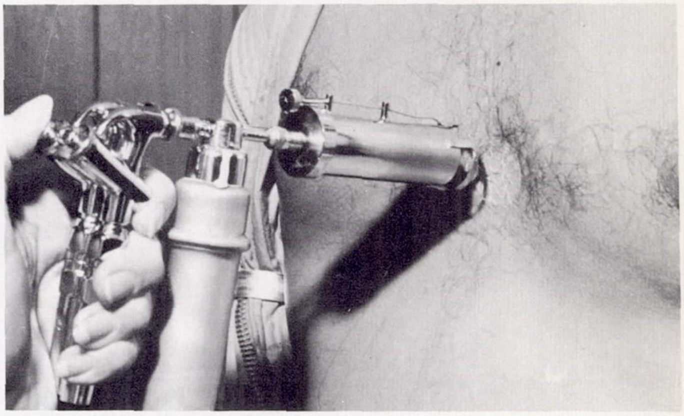
After an item, or group of items, of NASA technology has been identified as potentially useful in the quest, the team collects the maximum available information about it. When a device seems likely to solve the problem, a model of it may be constructed.

The project team makes a preliminary evaluation to determine whether or not the item, either in present or modified form, is applicable to the problem. Items that survive this preliminary evaluation are given to the research physician who posed the original problem, for more thorough trial in laboratory and clinic.

Often the evaluation of an item will indicate that some modification or adaptation is needed to make it suitable for medical use. The adaptation required may range from minor change to a substantial development effort. The evaluation and adaptation stages of the transfer process are closely inter-related, and frequently a number of evaluation-adaptation-evaluation cycles are needed to establish the medical value of an item of aerospace technology.

When a transfer has been accomplished, it is fully documented and the information distributed. The participating physician prepares papers for presentation at medical meetings and for publication in medical journals. The engineers or physical scientists involved also prepare papers to present to their own professional groups. Information is furnished to equipment manufacturers through seminars, written reports, and personal contacts.





Electrodes that Can Stand Exercise

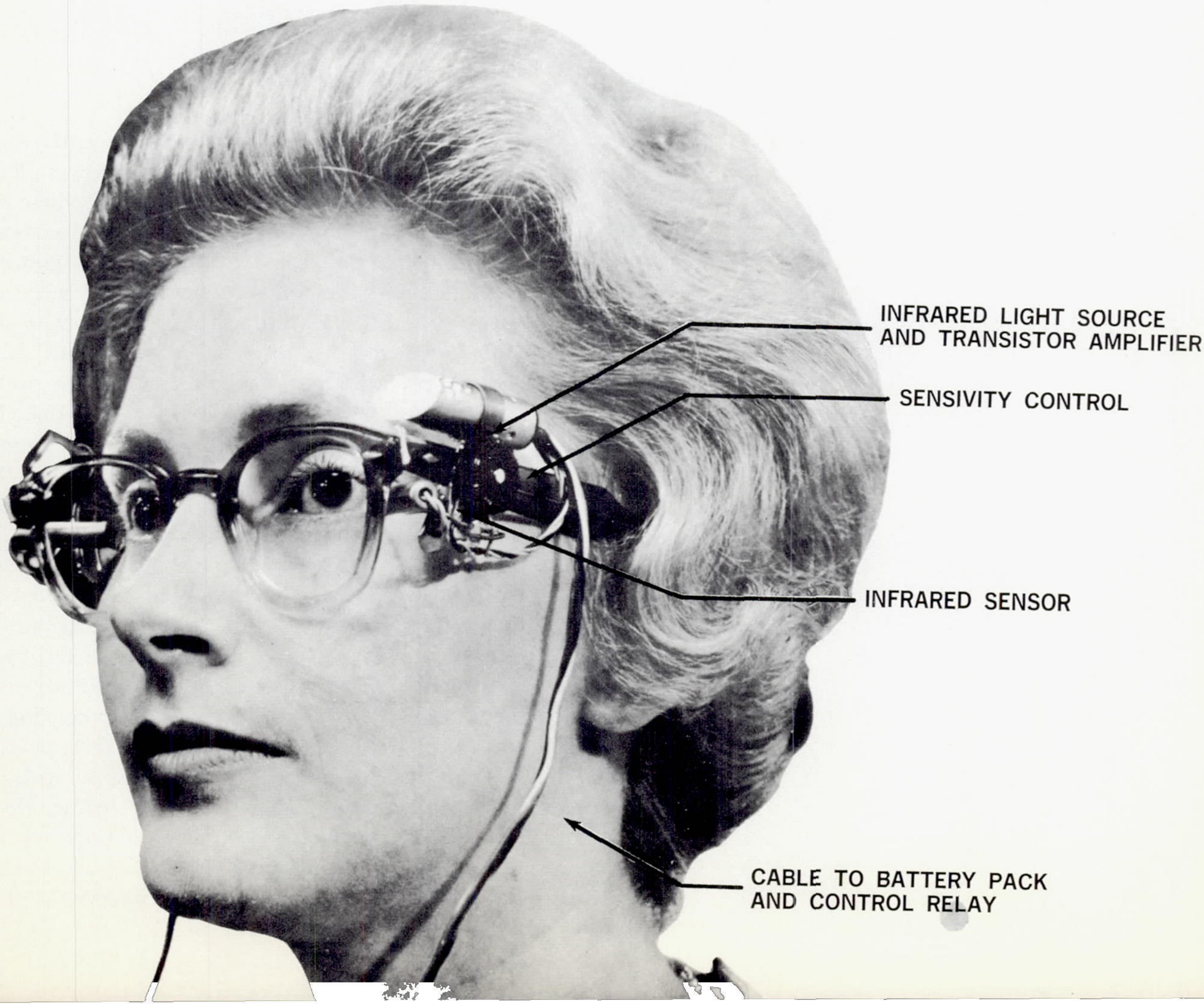
Here is an example of a transfer recently made by the Biomedical Application Team at Midwest Research Institute, in Kansas City. The medical problem was how to provide a better method for applying electrocardiograph electrodes to patients for use during vigorous exercise. Conventional metal-disk electrodes often came loose or made intermittent contact with the skin, causing large variations in the records. A search of NASA technology revealed that a new technique for applying electrodes had been developed at the NASA Flight Research Center in California, for use in instrumenting pilots under strenuous flight conditions (See photo above). The technique consists of spraying a conductive mixture over the wire leads and the skin. A solvent in the mixture dries quickly, leaving a thin, flexible layer of conductive material that holds the lead wires firmly in contact with the skin. Arrangements were made to have the spray-on electrode technique evaluated at the University of Kansas Medical Center. The technique has been applied successfully there for recording the heart action of children during exercise (See photo at left). Using this technique, a patient can ride a bicycle ergometer or run on a treadmill while electrocardiograms and cardiotachometer records are taken, without difficulty due to motion or to the electrodes coming loose. When the tests have been completed, the electrodes can be easily removed.

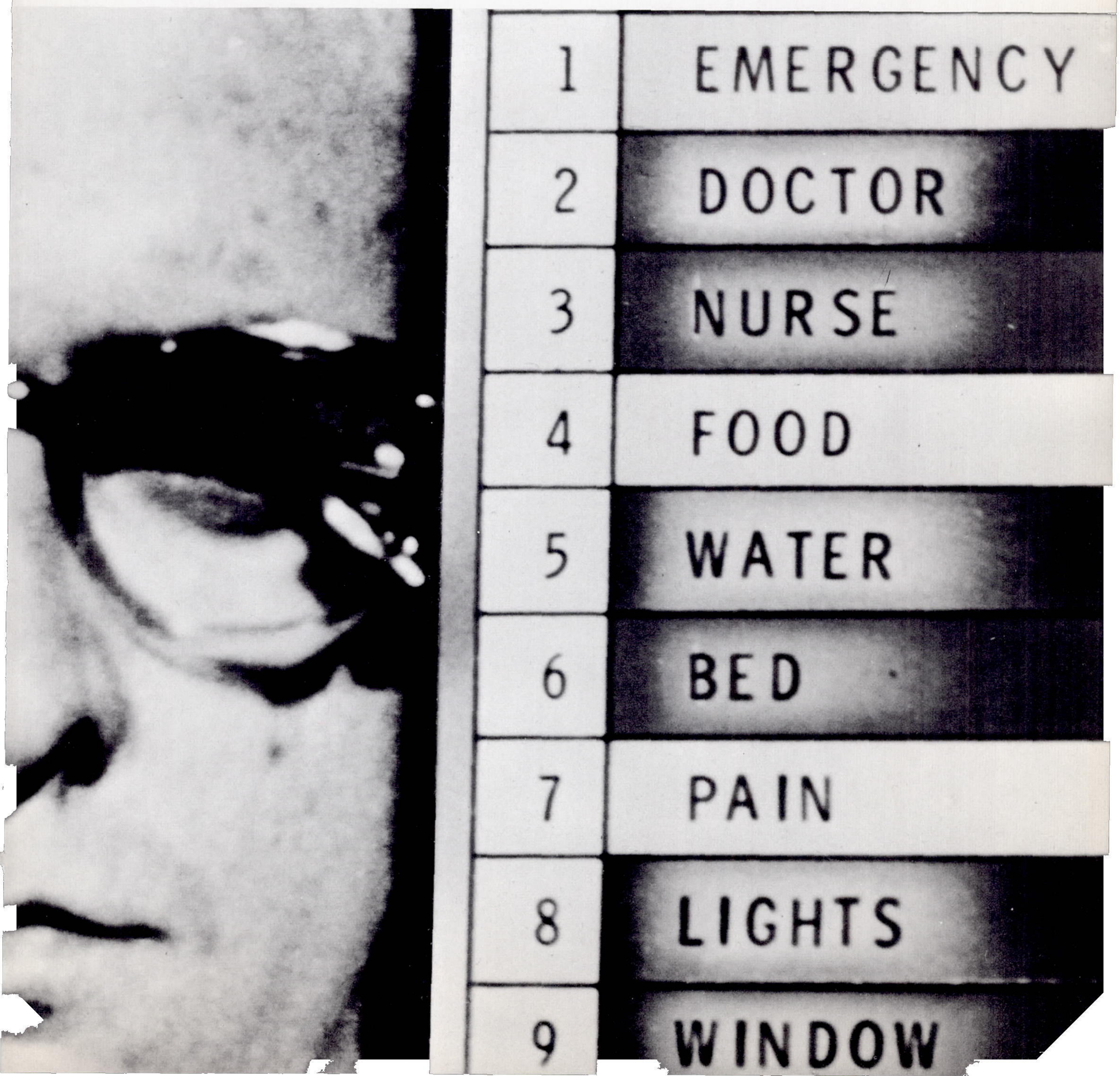
Interesting Biomedical Applications

Actual or potential biomedical applications of space technology that have already been found represent both impressive variety and appealing ingenuity. Here are a few additional examples:

1. *New Alloy for Artificial Joints.* At the NASA Lewis Research Center, near Cleveland, Ohio, two researchers in the materials laboratory were seeking more durable alloys for use in mechanical bearings that must function in the high vacuum and low temperatures of space—an environment where evaporation of conventional lubricants results in metal-to-metal contact, high friction, and bearing failure. In tests of various titanium alloys, the researchers found that those having a hexagonal crystal structure outperformed conventional alloys, with a cubic crystal structure, in reducing friction and resisting wear. The new alloys, besides being useful for bearings and seals in spacecraft and airplanes, appear to be valuable, because of their low friction and noncorrosive character, for making artificial hip and elbow joints.

2. *Sight Switch.* A switch actuated only by voluntary movement of the eyes was developed for NASA by an Alabama company as a potential aid to astronauts in




1 EMERGENCY
2 DOCTOR
3 NURSE
4 FOOD
5 WATER
6 BED
7 PAIN
8 LIGHTS
9 WINDOW

situations where high G-forces might make them unable to move their arms or legs. It is a clever device, in which light sources, mounted at each side of a pair of eyeglasses (See photo below), bounce a light into the wearer's eyes and detect the difference between the reflection from the whites and the darker pupils. Whenever the pupil of an eye moves across the path of the light beam, the reduced reflection activates an electric switch. The sight switch, properly relayed, can be put to a variety of uses to assist a patient who cannot move his hands or legs. Among them: remote operation of a machine to turn the pages of a book, to switch on and off a hospital call board (See photo at right), room lights, a thermostat, a television set, a radio, and so forth. With modifications, it could be employed to operate industrial machines, control panels, electric-typewriter keyboards, and other devices. The sight switch has already been adapted to a motorized wheelchair that enables a paraplegic to control the chair solely with his eyes.

3. *Biotelemetry.* A NASA contractor produced for biomedical experiments at the Ames Research Center a telemetry unit designed to continuously monitor the electrocardiograms of astronauts while they performed various duties. The unit consisted of a small, battery-operated transmitter with electrodes (to be pasted to the chest of a subject) and a portable FM receiver. Heart signals transmitted to the receiver were amplified for visual readout on a polygraph or oscilloscope. Now a slightly modified wireless telemetering system is being used in a New York hospital in the intensive-care cardiac monitoring unit. The system is excellent for monitoring a heart patient, and the wireless feature permits the patient to move freely within 100 feet of the receiver while his EKG is being constantly monitored.

Getting More for the Space Dollar

The NASA program to facilitate application of aerospace technology to biomedical problems is one of several efforts by the Office of Technology Utilization to carry out the following objectives:

- To increase the return on the national investment in aeronautical and space programs by helping to bring about additional uses of the knowledge gained in these programs.
- To shorten the time gap between the development of new knowledge and its broad and effective utilization.
- To aid the movement of new knowledge across industrial, disciplinary, and regional boundaries.
- To help develop better methods for communicating and applying Government-generated knowledge in the private economy.

NASA's growing file of biomedical benefits from space research is evidence that in still another area of life the gap is steadily closing between space technology and the pressing needs of man back on Earth.

U. S. GOVERNMENT PRINTING OFFICE : 1967 O - 273-541

Information concerning other educational publications of the National Aeronautics and Space Administration may be obtained from the Educational Programs Division, Code FE, NASA, Washington, D.C., 20546.

Further information on the NASA Technology Utilization Program, including biomedical activities, may be obtained by writing to Code UT, NASA, Washington, D.C., 20546

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 · Price 20 cents