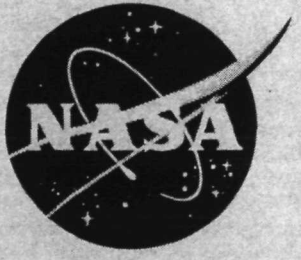
Technology Applications Progress Report

DECEMBER 1972

Technology Applications Group
Biological Sciences Communication Project
The George Washington University
Washington, D.C.



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TECHNOLOGY APPLICATIONS

PROGRESS REPORT

An Annual Review

for

THE TECHNOLOGY UTILIZATION OFFICE
(CODE KT)
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D.C. 20546

For the Period

1 January 1972 — 31 December 1972

This document was prepared for the Technology Utilization Office,
National Aeronautics and Space Administration,
Washington, D.C. 20546

by the

Technology Applications Group

THE GEORGE WASHINGTON UNIVERSITY
Medical Center
Biological Sciences Communication Project
2001 S Street, N.W.
Washington, D.C. 20009

as the

Annual Report for NASA Contract NASw 2055

TO THE READER . . .

This annual report, covering the period 1 January 1972 - 31 December 1972, is aimed at providing the reader with useful information and insights into the accomplishments of the NASA technology-applications effort, the major thrust of which, under the leadership of the NASA Technology Utilization Office, is to effect the transfer of aerospace technology to the nonaerospace sector of society, thereby enhancing the return to the American taxpayer on his investment in the space program. Also offered is general background information on the development of the Technology Utilization Program and a projection of its prospects.

Further detailed information on the Technology Utilization Program is available from:

Director, Technology Utilization Office
Office of Industry Affairs and Technology Utilization
Code KT
National Aeronautics and Space Administration
Washington, D.C. 20546

CONTENTS

NASA TECHNOLOGY UTILIZATION ... The Background

The Technology Utilization Office of the National Aeronautics and Space Administration is about to note its tenth anniversary of service to technology transfer. In the light of ten years' experience, it is useful to review the development of Technology Utilization's operating philosophy and its possible directions for the future, with specific reference to the portion of the program known as Technology Applications.

Launched during 1962-1963, the Technology Utilization program's primary aim was to stimulate the infusion of aeronautical and space-derived research and development into other sectors of the economy. The Space Act of 1958 required that research and development results be made freely available to society and this was initially implemented by dissemination of Tech Briefs and Special Publications. NASA officials also saw that the contents of NASA's comprehensive computerized information system could be of considerable use to technologists outside the NASA community.

The RDC's — An Innovative Step

Another early step toward technology transfer was the establishment of a network of Regional Dissemination Centers (RDC's). The host institutions were predominantly universities. The idea was to build knowledge bridges between the government, the academic sector and industry through the creation of a technical-information search service, using the computerized information system as one resource. These RDC's provided the first interface between NASA and nonaerospace industry.

The Applications-Engineering Approach

A further development was the formulation of the "Application Team" concept and the creation of "Biomedical Application Teams" located at various research institutes staffed by professionals from a variety of disciplines. These teams meet with investigators in the biomedical field to discuss and define problems amenable to solution in part or **in toto** by space-derived technology. In specific instances hardware is constructed either by the teams, the problem originator, or both, to demonstrate the technical feasibility of the proposed solutions.

Successful experience with the Biomedical Application Teams led to diversification into other, nonmedical, public-sector areas. Application Teams have worked or are now working on problems in air and water pollution, fire safety, housing and urban development, transportation, law enforcement, criminalistics, the postal services and mine safety.

An even more recent activity geared to the "Applications" mode of technology transfer has been the funding of applications-engineering work directly within the NASA Field Centers. Again, public-sector problems are the primary target. Such development projects have in part originated from Application Team activities. But, now, quite frequently the Field Centers themselves submit proposals based on their own perceptions of the relevance of their in-house skills and capabilities to public-sector problems.

Some examples of Application Team and Applications Engineering projects are described in the body of this report. A cross reference to many other projects described in earlier reports is contained in the appendix.

Criteria for Selection of Applications Engineering Projects

It is important to list the basic criteria that have been developed over the years for the selection of candidate projects and, more particularly, for the selection of NASA technology which may help solve posed problems.

Clearly, a solution to a public-sector problem can be partially accomplished if a single prototype can be produced and tested. However, the full satisfaction of many public-sector needs requires that manufacture and distribution occur. Thus the involvement of industry is often essential. Experience has taught that proposed solutions should have some or all of the following characteristics:

- Be applicable to the nonaerospace public sector.
- Be novel and inventive.
- Be fully disclosed.
- Be demonstrably feasible in a technical sense.
- Be capable of demonstrating short or medium-term utility and some kind of associated benefit.

• Be arranged so that the inventor can give necessary advice and guidance on the project to the assessors and to any potential developers, users or suppliers.

• Show availability of an adequate, relevant and specific technical-support package, design drawings, circuit diagrams, formulations, specifications for components and critical "know-how."

• Be considered in terms of the patent status.

• Be considered in terms of real information about the market size and characteristics.

• Be capable of having applications engineering completed within a predetermined period and according to an agreed schedule.

Interagency Cooperation

The technology-transfer activities of the Technology Utilization Office have spawned much interagency cooperation. Formal or informal cooperative ventures exist with the Department of Health, Education and Welfare; the Department of Housing and Urban Development; the Bureau of Mines; the Department of Transportation; the Environmental Protection Agency; the Law Enforcement Assistance Administration; the National Bureau of Standards; the Veterans Administration and others. In addition, more than 75 medical schools and health-care institutions are involved as well as such widely disparate groups as The New York State Urban Development Corporation, The National Academy of Engineering, Public Technology, Incorporated and The New York City Government.

Change in Patent Policy

A significant development during the period under review has been a basic change in NASA's patent licensing policy. This change should provide much greater flexibility in NASA's approach to technology transfer.

Under the revision, NASA would be able to accelerate commercial use of space-related inventions or technology by granting exclusive licenses at an earlier date than is now possible. Specifically, rather than wait until two years after a patent has been issued, as presently required, NASA could grant exclusive licenses in appropriate cases as soon as nine months after the patent application has been filed and announced as available for licensing.

If NASA decides to grant an exclusive license, the prime consideration will be whether such a license is necessary to bring an invention to practical application.

Beyond the provision for an earlier issuance of exclusive patent licenses, there are other significant changes in the revised regulations:

• Both non-exclusive and exclusive licenses can now be granted under pending patent applications. Previous regulations called for a longer waiting period, that is, until the patents had been issued for a minimum of two years by the U.S. Patent Office.

• Non-exclusive licenses under the new regulations, other than those granted to original developers of new technology, will be granted only if the applicant qualifies by showing the required enterprise and diligence in using the patent promptly.

• Contractors reporting inventions connected with technology developed under NASA contract will now receive "revocable" rather than irrevocable non-exclusive licenses. This change will permit NASA to grant a more meaningful exclusive license to a qualified applicant where this action is deemed advisable to ensure prompt use of space-agency inventions.

• Although the intent of the regulations is to grant most patent licenses (particularly non-exclusive types) without royalty requirements, NASA regulations, for the first time, will provide for royalty payments if they are considered appropriate. In most instances where royalties or other licensing fees are included they would apply in the granting of exclusive licenses.

• The President's Message to Congress on Science and Technology of March 16, 1972 said: "Federal research-and-development activities generate a great deal of new technology which could be applied in ways which go well beyond the immediate mission of the supportive agency. In such cases, I believe, the government has a responsibility to transfer the results of its research-and-development activities to wide use in the private sector."

• NASA is dedicated to this objective and this report describes representative examples of its efforts to meet this goal.

Technology Applications Program

Simply stated, the NASA Technology Applica-

tions program is a effort operated under the aegis of the NASA Technology Utilization program to search out solutions to technical problems in the nonaerospace public sector through the adaptation and application of new technology and innovative techniques derived from aerospace research and development.

Individuals and organizations interested in working with the NASA Technology Applications program are invited to write directly for more tailed information to the Director, Technology Utilization Office, Code KT, NASA Headquarters, Washington, D.C. 20546.

Putting Aerospace Technology to Work for Earthbound Man

Following is a general review of recent and current efforts to apply aerospace-derived solutions to non-aerospace problems. In the subsequent Highlights Section, a sampling of specific cases is reviewed in detail.

Transportation

Earthbound transportation in a society geared to the never-ending movement of people and goods is benefitting from adaptations of aerospace technology in specialized fields ranging from materials to fire safety.

For example, highway specialists are studying (see Highlights Section) a new thermoplastic compound -- originally developed as a better fuel binder for solid-rocket propellants -- as a quick-drying and durable patch material for suspension-bridge and road-surface-coating repairs. The substance is a blend of a copolymer of ethelyne and vinyl acetate with asphalt and petroleum distillate and is easily handled. It can be remelted for later use. Intriguingly, the substance might be partially produced from shredded discarded tires and used crankcase oil -- a process that would alleviate current disposal problems.

To reduce maintenance costs, postal trucks and railroad trains could benefit from improved friction materials for brake linings. NASA has established a program to search for such new materials in cooperation with the U.S. Postal Service and the Association of American Railroads. Investigators are exploring a wear-enhancing polymer. They will devise several sets of brake shoes using new materials which will be evaluated by the Postal Service on mail trucks and tested by the National Bureau of Standards.

NASA researchers have been studying monitoring technology, originally developed to test astronaut performance, for application to auto-traffic-safety and air-pollution research. Using a NASA-developed device called a Complex Coordinator that tests perceptual and motor skills by eliciting continuous arm-and-leg responses before, during and after programmed abnormal situations, investigators at Duke University have tested the degradation of driver skills during exposures to varying concentrations of carbon monoxide. These tests were performed under contract to the Air Pollution Control Office of the Environmental Protection Agency.

The California Driver Education Association has tested the same device to demonstrate the effects of alcohol on human performance. The California Highway Patrol has considered the device for screening students before they mount motorcycles. Other possible applications include testing motor skills related to driving and weapon-firing proficiency. Some medical-rehabilitation specialists have suggested that the device might be used as a therapeutic exercising tool for mental patients. The Small Business Administration has provided funds for a market study and a minority business now offers the equipment for sale.

A crucial safety problem in railroading is the need to inspect railroad tracks and railcar wheels for thermal and other stresses that cause buckling and create the potential for disasters. NASA, with its sizeable backlog of experience in the nondestructive testing field, is working with the Federal Railroad Administration (see Highlights Section) in a search for techniques that would alleviate this traditional railroading problem. Ultrasonic approaches show promise. A program is under way to determine ultrasonic velocity vs. stress relationships for the types of steel used for wheels and rails, to investigate

the effects of temperature variations on the accuracy of stress measurements, to evaluate measurement problems related to rail geometry, to perform actual stress measurements on wheel and rail segments under controlled laboratory conditions, and to demonstrate the practicability of ultrasonics by making stress measurements on long rail segments under realistic field conditions. Also, a portable test unit is being considered for introduction in the commercial market.

Environmental-Pollution Abatement

Environmental pollution is a new and growing arena for the study of the potential of aerospace derived technology for the solution of air, water and land-quality problems. Beyond the well-known major NASA weather and earth-resource survey satellite programs that hold great promise for synoptic analysis of global and regional environments, NASA is also working with concerned government agencies and other organizations on the development of techniques, adapted from aerospace technology, to solve discrete system and hardware problems in the environmental field. Some examples follow.

In the field of air-pollution monitoring, NASA is assisting the Environmental Protection Agency in its search for an inexpensive, advanced-technology sensor that could measure total hydrocarbons in auto exhaust, ambient air and industrial-stack effluents. Such a device would be a major boon to field monitoring as a replacement for the current costly process of sample collection and later laboratory analysis. Current approaches use flame-ionization detectors and gas chromatographic techniques that are expensive, pose fire-safety hazards, require skilled technicians and necessitate advances in flame-chemistry science.

To solve this problem NASA is studying an indium-oxide thin-film combustible-gas detector that was originally designed to detect hydrogen. The thin film undergoes a change in electrical resistance when it is exposed to different concentrations of combustible gas. The potential of the device for the detection of methane has led to Bureau of Mines interest in the same technology for mine-safety programs.

Microwave spectrometry techniques derived from aerospace technology may contribute to development of practical ways to analyze formaldehyde in ambient air and automobile exhaust. Formaldehyde is an eye irritant that plays a role in the development of smog. Auto exhaust is a major producer of this pollutant. Ironically, current efforts to reduce auto-exhaust hydrocarbon and nitrogen-oxide emissions through catalytic processes may result in increased formaldehyde emissions. The Environmental Protection Agency, charged with specifying a measurement method for formaldehyde, is interested in improvements over current manual and automated wet-chemical techniques that are cumbersome and time-consuming.

NASA microwave spectrometry techniques developed for the measurement of pollutants in space stations are being put to work (see Highlights Section) to solve the problem through the development of pilot miniaturized gas analyzers. An effort is now under way to produce smaller single-frequency versions of the device that would be suitable for general use in air-pollution monitoring.

In the area of water research and management, NASA is working with the Federal Water Quality Office on the development of an improved water-current velocity meter that would be useful for mathematical modeling of lakes, the tracking of pollutants for legal actions, and the prediction of river levels for shippers. A water-current meter originally developed by NASA for wind-tunnel monitoring is being explored as a solution. The NASA device was designed as a comparatively simple and inexpensive method of measuring generally steady flows that characterize certain near-shore waters. Its design is compatible with automatic data-acquisition and reduction equipment. A collection of such meters could be deployed and monitored simultaneously. The meter uses a strain-gauge technique to measure the force exerted on a submerged drag sphere over a flow velocity around the meter.

Urban sewer-management operations are also potentially amenable to infusions of aerospace technology. A key need is the proper and adequate monitoring of sewage flow at suitable points in the collection network so that controls can be exerted to redistribute flow for treatment plants. Currently available conventional flowmeters are not adequate to the task. In cooperation with NASA, using aerospace-derived fluidic-air-sensor technology, the Dallas Water Utilities is now testing a new device that is rugged, self-cleaning, does not obstruct flow and has no moving parts (see Highlights Section).

Power generation in an energy-demanding world also poses environmental dilemmas. Magnetohydrodynamic (MHD) technology has been proposed as an approach to power generation that might serve increasing energy requirements with greater efficiency while at the same time cutting down on pollution. The liquid-metal MHD concept uses a heat source to create a high-velocity electrically conductive fluid stream that interacts with a magnetic field to produce electric power. It could be used either as a prime system or as a topping cycle for central power-station power generation. NASA's extensive experience with MHD as a space-power source has resulted in a wide-ranging study program centered at the NASA Jet Propulsion Laboratory that will assess the potential of liquid-metal MHD (see Highlights Section).

In the field of coastal-erosion study, NASA is currently exploring its extensive transducer technology — originally used for wind-tunnel pressure measurements — as a potential method of measuring sand buildup. These techniques might be substituted for conventional graduated-rod methods.

Also, NASA (see Highlights Section) is working with the Environmental Protection Agency on the development of an airborne laser-based system called LIDAR to monitor sea plankton, the vital tiny sea life that through photosynthesis provides most of the world's oxygen and is a major link in the food chain of the sea.

Another promising study under way involves exploration of a new technique of reclaiming nonferrous metals from scrap heaps. If the innovative technique (see Highlights Section) proves out, it will contribute significantly to abatement of pollution and change a waste product to a valuable recycled material.

Housing and Urban Construction

Aerospace technology offers major potential for housing technology. Specialists in this field recognize the promise of innovative techniques that will reduce costs while at the same time meeting the growing demand for adequate living units.

NASA is working with concerned government agencies and the housing industry on finding new solutions to housing technology problems ranging from water recovery and waste processing to fire prevention and detection.

For example, NASA is currently developing, in coordination with the Environmental Protection Agency, a hardware module for a system that, using aerospace-derived water-collection and recycling techniques, would reclaim and reuse home waste water in single or multiple family dwellings (see Highlights Section).

In cooperation with the New York State Urban Development Corporation, NASA has helped to develop a low-cost method of installing electrical switches, using a low-voltage switching device and flat conductor cable. Called **Switchpack,** the system, planned for use by the New York State UDC, cuts costs by eliminating the conventional conduit network required for the switch leg of conventional circuits and by surface-mounting the switching units (see Highlights Section).

A NASA-developed fire-retardant material, **Laminite**, originally designed for space-vehicle storage facilities, is finding applications in modular-housing construction. Similar to conventional cardboard, it is rendered fire-resistant by chemical treatment and is competitive with such prefinished materials as plywood and gypsum board. The Department of Housing and Urban Development is studying its use for movable partitions.

NASA has worked with the Department of Housing and Urban Development on the evaluation of a NASA-developed foamed asbestos, trade-named **Litaflex**. Litaflex is an isocyanurate that is made flame-resistant by modifying its molecular bonds. It appears particularly suitable for fire-resistant insulation and soundproofing in housing. Exposed to fire, Litaflex rapidly develops a tough and flame-resistant char.

The building industry needs new classes of fire-retardant intumescent paints for use in single-family dwellings and for components of mass housing. The kinds of intumescents now available tend to break down in high humidity and lack good color stability, among other problems.

NASA, in cooperation with such organizations as the National Association of Home Builders and the International Association of Plumbing and Mechanical Officials, has successfully tested new types of intumescents with superior fire-retardant properties as protective coverings for metal fixtures which are often the sites of fires caused by plumbers' soldering torches. The materials were originally developed for aircraft and spacecraft interiors.

Intumescent mastics, the thick pasty materials, including concrete, that are often used as fire-protective coatings over structural steel, tend to add costly weight to buildings. NASA, working from its experience in heat-ablation techniques, has developed a new and highly stable class of intumescent substances that can be formed into mastics by adding short fibers of glass.

In an allied field, reliable early warning of residential fires, NASA has teamed with the Department of Housing and Urban Development in a search for a modern and effective smoke-detection and alarm system for multilevel dwellings.

Using a new polymeric material, polyphenylacetylene, which has electrical properties that change as it absorbs gases and particulates, as a coating on a device called a field-effect transistor (FET), NASA has developed a system that sets off an alarm. The FET was originally invented by McDonnell Douglas for use on Mars-Voyager space-probe missions. The Massachusetts Institute of Technology, the National Bureau of Standards and McDonnell Douglas have all cooperated on the project. There is a good possibility that a commercial practical device will be produced soon (see Highlights Section).

NASA is also cooperating with fire-safety specialists in the testing of a range of aerospace-derived fire-retardant materials (see Highlights Section).

Firefighter Equipment

Firefighters' equipment is a significant area of NASA interest as a practical testbed for the introduction of aerospace technology. It also presents a particularly useful set of opportunities for NASA specialists and potential urban users of adapted aerospace techniques to develop the "common language" so crucial to the precise definitions of problems to be solved.

In cooperation with the National Bureau of Standards Office of Fire Research and Safety and Public Technology, Inc., NASA has applied its technical knowledge to the precise formulation of the performance requirements of a modernized simple breathing device for firefighters. Members of the "User Design Committee" developing these criteria included fire chiefs, city managers and qualified scientific specialists. The improved equipment is now under development (see Highlights Section).

Mine Safety

Mine safety is of continuing vital concern to the public, the government, industry and, most of all, to the miner himself. NASA is cooperating with the Bureau of Mines in the search for aerospace technology that lends itself to mine-safety applications.

One example of this is a search for technology that will provide accurate measurement of airflow through mine passages. This is a difficult technical problem, in view of the slow air velocity in mines. NASA has suggested using a handheld lightweight fluidic air sensor capable of measuring speeds of less than 10 feet per minute (the technique also being explored for sewage-flow monitoring). Such a device would be especially appropriate for mines since it has no moving mechanical or electrical parts. Essentially, the technology for this subterranean application is the same as the technology used for an wind-tunnel airspeed indicator developed for vertical and short-takeoff-and-landing aircraft. The Bureau of Mines is currently examining a proposal for construction of a prototype fluidic air-sensor device for field evaluation.

Rescue-vehicles for post-disaster use in mines are of special interest to the Bureau of Mines, which has funded a University of Kentucky researcher to develop an unmanned remotely-controlled unit. NASA is currently working with the Bureau to adapt the guidance system from NASA-developed technology used in its Lunar-Rover vehicles to the mine-rescue vehicle (see Highlights Section). A range of other aerospace technology, including miniature video systems and fire-resistant insulation for mine rescue craft, may be applicable to the mine-rescue mission.

Aerospace to Biomedicine

Biomedicine, with its strong emphasis on technology, offers a wide range of opportunities for the successful absorption of aerospace-originated knowledge and innovative techniques.

NASA's considerable experience in this field — the first arena of its efforts at systematic technology transfer — has proved hearteningly successful in many cases.

Aerospace-originated technology has already been infused into or is being studied for use in several disciplines of medicine, ranging from cancer detection, treatment and research to new approaches to prosthetics in rehabilitation medicine (see Highlights Section) and cataract removal (see Highlights Section).

A partial list of such techniques — in the field of cancer treatment — would include: a semiconductor radiation detector small enough to be inserted behind the eye to help detect eye tumors (see Highlights Section), a new method of freezing white cells for leukemia research, new radioactive-isotope methods of scanning for tumors, microplanigraphic x-ray techniques for detecting deeply-sited cancers, ear-oximeter methods of monitoring patient shock, bone-density measurement of decalcification as a diagnostic aid, special-purpose photo-emulsions for the detection of radioactively-labeled cancerous tissue, and improved high-intensity focusing lenses for analysis of cellular actions.

Also being assessed, for medical x-ray work, are radiographic techniques originally developed for testing of aerospacecraft components (see Highlights Section).

Cardiovascular Disease

In the field of cardiovascular disease, improved computer-enhanced cinematic techniques developed originally for aerospace missions are being used to monitor heart action (see Highlights Section). Close-range stereophotogrammetry is exploring aortic valve stress/strain relationships and assisting in the assessment of various proposed artificial aortic valves (see Highlights Section). NASA-developed hardness-testing techniques are being used for post-mortem studies of the softening of heart tissue. Aerospace technology is being applied to the diagnosis of hypertension conditions (see Highlights Section). Space-generated computer-programming techniques are being used in the development of comprehensive automated bedside-biomedical-computer systems for real-time patient monitoring. Experimental studies are under way to find suitable bonding techniques for components of artificial-heart energy sources. Aerospace technology has contributed to development of an economical vital-signs-monitoring-and-alert system for use with critically ill patients in nursing homes and rehabilitation centers. A "long distance" approach to patient monitoring which is under study involves a wristwatch-type EKG telemetry transmitter that could be worn by patients and which would relay data to attending physicians. Clean-room techniques, adapted from space-component manufacturing operations, are enhancing continuing medical efforts to lessen the risk of infection among surgical and other patients. Other projects include a rechargeable pacemaker (see Highlights Section) and a personal coronary-care kit that can be carried by the patient (see Highlights Section).

Medical Instrumentation

The medical instrumentation field is benefiting, too, from adaptations of aerospace-generated technology. New instruments and techniques include refinement of a beta-radiation catheter probe that monitors cerebral blood flow with less hazard and greater comfort for the patient. The use of closed-circuit television to provide medical-diagnostic services to remote areas is currently being assessed (see Highlights Section). Quality-control techniques borrowed from the space program are being modified and tailored for calibration and maintenance of electronic medical instrumentation.

A range of instrumentation, including devices for monitoring newborn-infant respiration, checking the breathing of infants and other patients who have undergone tracheotomies and for assessing the respiratory function of free-moving children are currently in various stages of research and development (see Highlights Section). New devices, using advanced technology, are also being developed for the detection of gastrointestinal disorders and for analysis of visual difficulities. NASA is also helping to develop new techniques for diagnosing brain injuries (see Highlights Section).

Aerospace-developed electroencephalographic telemetry equipment is being explored for use with schizophrenic patients. A NASA-developed electronic sleep-analyzer device, with a comfortable set of electrodes that was originally developed for use in the manned space program, is being used to investigate psychophysiological responses to extreme environmental stress.

Kidney-function Disorders

In the specialized but crucial field of kidney

function disorders, a range of aerospace-originated technology is finding its way into earthbound medicine. These include urine-transport systems (see Highlights Section) for postoperative fluid maintenance, a simple reliable and totally implantable artificial valve (see Highlights Section) allowing voluntary excretion control by incontinent patients, new liquid flowmeter techniques permitting improved measurement of ureter flow, and scanning electron microscope methods for analysis of the surface morphology of kidney stones. New approaches to the rapid detection of bacteria in urine that would permit economical mass screening in hospitals and neighborhood health clinics are also being developed (see Highlights Section). Liquid-crystal sterilization techniques are being studied for potential use in the precise location of surgical sites.

Rehabilitation Medicine

An encouraging record of technology transfer is also being written in the field of rehabilitation medicine. Aerospace technology is being put to work at such diverse tasks as exercise-stress measurement among patients (see Highlights Section), early detection of hearing defects, diagnosis of gait abnormalities, measurement of neuromuscular disorders, voice analysis for assessment of speech defects, airflow monitoring of cleft palate, "paint-on" electrodes to help analyze the rehabilitation-therapy performance of patients, improvement of bedding materials for long-term patients, development of quick-foam casting of orthotic-support devices, research on implants compatible with body tissue (see Highlights Section), development of lightweight prosthetic and orthotic materials and the creation of a comfortable and presentable "everyday" anti-g suit to control bleeding by hemophiliac patients.

The list of aerospace-to-medicine technology transfers is long. It ranges from disease diagnosis to the study of possible hazards of plastics used for blood storage (see Highlights Section). It also includes research on motive sources to power prosthetic devices, development of eye switches and other methods of control, including "tele-operator technology" (see Highlights Section) for control of external objects by paralyzed patients, work on a range of optical and auditory sensor devices for blind and deaf people, and remote-manipulation devices for hookup with prosthetics.

PROJECT HIGHLIGHTS ... Public Sector

To provide the reader an overview of the technology-applications program, the following section describes in some detail a number of projects now under way in the public-problem sector.

Biomedical project highlights are described in the second part of this Highlights Section.

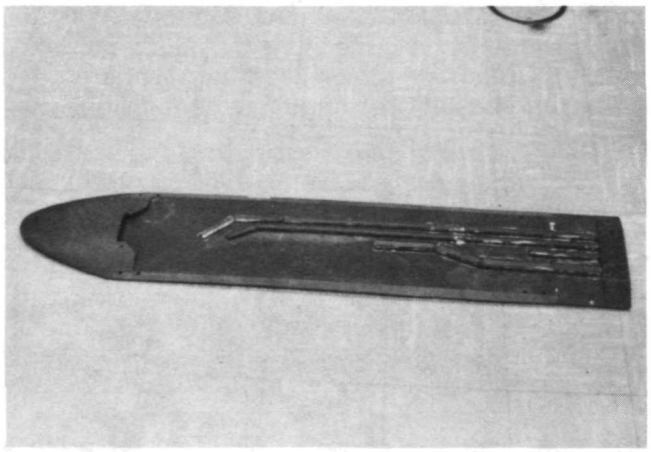
Sewage Flowmeter. Proper distribution of sewage flow is necessary to avoid back-up in the sewer system, with its associated health hazards, and to prevent overload of sewage treatment plants. Accurate information about actual sewage quantities is also mandatory in projecting sewage system needs in terms of urban development and growth.

The city of Dallas, Texas, is to be the site of tests on a newly developed sewage flowmeter based on a modification of a device originally designed at the NASA Electronics Research Center primarily for use in wind-tunnel air speed measurements on vertical and short-takeoff-and-landing aircraft. The Bowles Fluidics Corporation of Maryland developed the original hardware for the Electronics Research Center's wind-tunnel application and, under contract to the Illinois Institute of Technology Research Institute Technology Application Team, has been responsible for its modification for monitoring and measuring sewage flow. The mode of operation of the flowmeter (which is versatile enough to be considered for the problem of air monitoring in coal mines) is based on the measurement of a differential pressure output from two sensors in the pipe. This pressure difference increases and decreases with corresponding changes in sewage flow.

A prototype device has been delivered to the city of Dallas and preliminary tests have been performed. The Dallas authorities are now preparing to build a testbed to permit comparison of the aerospace-derived system with other systems. These tests are expected to be complete by the fall of 1973.

The device under test offers a number of advantages. It has no moving parts. It is self cleaning and rugged. It provides no obstruction to sewage flow and, in general, it can operate unaffected by foreign bodies and corrosive conditions.

In anticipation of a successful outcome of the test program in Dallas, NASA has initiated a limited survey of potential users and manufacturers of the device.



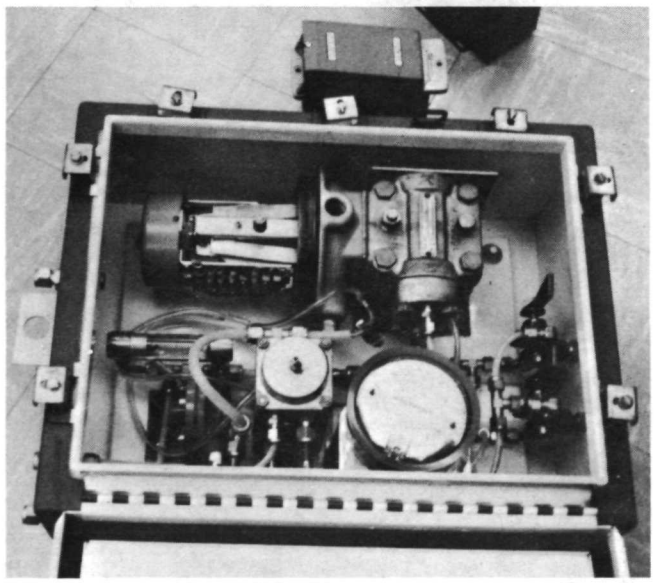


Figure 1. Sewage flowmeter adapted from aerospace fluidic air sensor is being tested by Dallas Water Utilities. Above, simple rugged unit that measures actual flow inside sewer. Below, instrumentation box to which flowmeter is connected.

Improved Air–Pollution Detection. The Environmental Protection Agency is charged with the responsibility of specifying a measurement method for formaldehyde, an eye–irritating product of automobile exhaust. EPA has enlisted the aid of NASA through the Research Triangle Institute Application Team in North Carolina in a search for aerospace technology that might be used to detect concentrations of this chemical, which may also play a role in the formation of smog.

A scientist at NASA's Langley Research Center suggested the use of microwave spectrometry, which is used to measure formaldehyde and other pollutants in space-cabin atmospheres. The aerospace-based technique offers significant advantages over currently available wet-chemical techniques which are cumbersome, time-consuming and subject to various forms of interference.

NASA and EPA are jointly funding a project to develop miniaturized gas analyzers for use in formaldehyde measurement. A contract has been awarded to the Lawrence Radiation Laboratory in California to develop a practical instrument design that would employ modern solid-state technology and which would be produced at a low unit cost. Researchers expect a prototype instrument to be completed and delivered to EPA for evaluation during the summer of 1973.

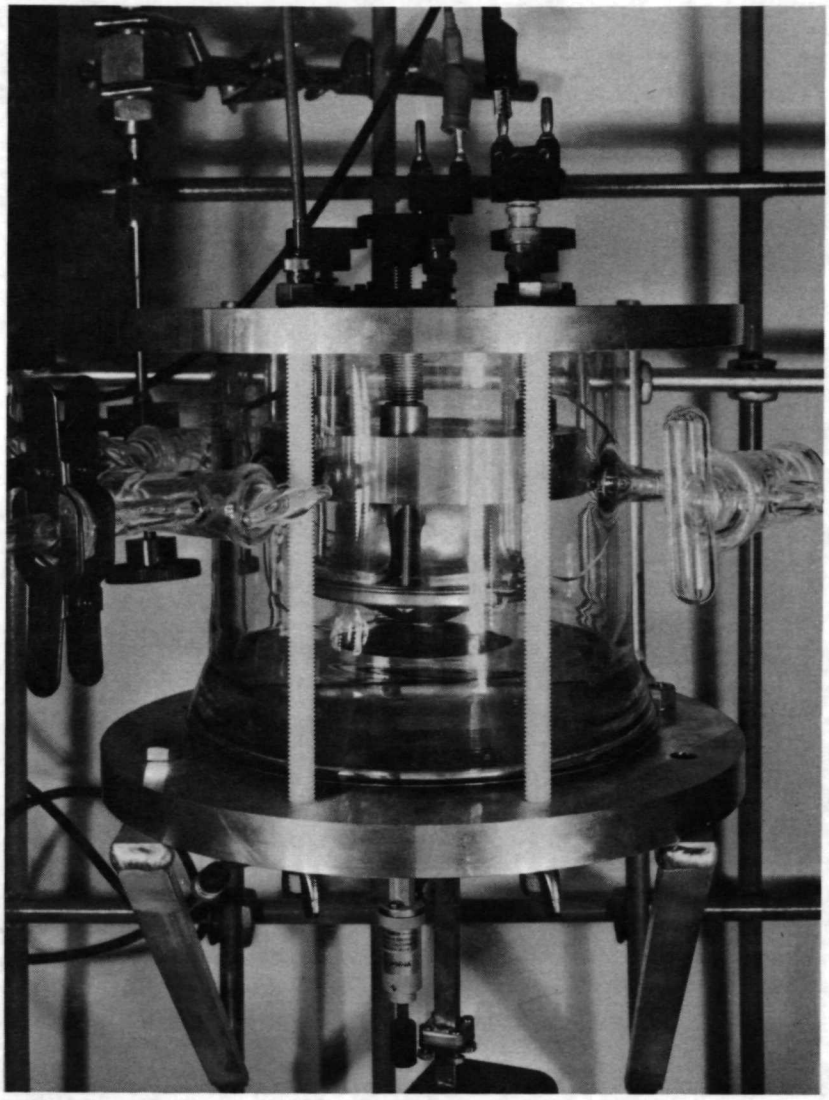


Figure 2.
Resonant-cavity absorption cell for formaldehyde monitoring system under development in NASA-EPA air-pollution project. Cell was developed by Lawrence Radiation Laboratory in California.
[Photo courtesy Lawrence Radiation Laboratory]

Liquid-Metal Magnetohydrodynamics for Power Generation. To help meet the energy crisis, NASA's Jet Propulsion Laboratory in California is currently assessing the potential of liquid-metal magnetohydrodynamics (LMMHD) as a power source. LMMHD is based on the use of a heat source that produces a high-velocity electrically conductive fluid stream that interacts with a magnetic field to produce electric power. The potential advantages of LMMHD over conventional steam plants include savings in fuel, with attendant reductions in waste heat and emissions, both of which create environmental problems. Also, capital costs are potentially lower because with LMMHD there is no need for conventional turbomachinery.

Jet Propulsion Laboratory's current LMMHD feasibility study is examining the various technical, economic and environmental aspects of LMMHD as compared with alternative systems and defining applications for which the new technology seems superior. The ultimate purpose of the study is to create a fund of reliable data that will be readily available to potential users. To maximize the effectiveness of the report to potential users, a User Review Board comprised of representatives of electric utility companies, electrical power associations and component manufacturers is working with JPL to provide data to the study and to analyze JPL's work. The final report was scheduled for release in January 1973.

Airborne Mapping of Phytoplankton. Phytoplankton are a form of marine life which, through photosynthesis, play a major role in the replenishment of the world's oxygen supply and comprise a vital link in the food chain of the sea. Many ecologists have expressed concern about various forms of pollution which could gradually curtail such marine biological activity.

During 1972, in response to needs of the Environmental Protection Agency, NASA-Wallops Station researchers tested a helicopter-borne detection system that uses a laser beam to map the distribution of the vital phytoplankton. Currently, there are few methods for measuring plankton and the laser system has certain advantages over other methods. The airborne system can map phytoplankton distribution rapidly. It carries its own illumination, making day and night monitoring possible. And an improved version of the system can be built to measure plankton distribution not only at the surface but also at varying levels below the surface.

Initial tests were used to measure the presence of drifting phytoplankton in the Chesapeake and Chincoteague Bay offshore areas. As a result, the Environmental Protection Agency invited NASA to participate in the International Field Year of the Great Lakes, where multidisciplinary water–quality surveillance of the Great Lakes is being performed jointly by U.S. and Canadian authorities. Tests performed over sections of Lake Ontario provided considerable useful data that is currently being analyzed. A dip in the chlorophyll density was discovered in the vicinity of a municipal water outfall. Even though comparable sampling data has not been made available yet, supporting evidence of high nitrate readings was found in the area in a 1965 cruise.

The working principle of the system, called LIDAR, is based on the fact that spurts of laser radiation induce fluorescence in the phytoplankton, which are then monitored by the airborne detector. The overflights could mark the first successful field operation of such a system.

An Advanced Pollutant Sensor for Carbon Monoxide. In response to a significant problem raised by the Environmental Protection Agency — the detection of harmful concentrations of carbon monoxide in the air — a sensor originally designed for use in the NASA Skylab program and for cabin-atmosphere monitoring on nuclear submarines was made commercially available in mid-1972. The initial feasibility study for development of infrared fluorescent cells for gas analysis was awarded by NASA to Andros Incorporated of California in late 1969 and the contract for fabrication of the Skylab cabin-atmosphere carbon-monoxide monitors was awarded in 1971. Andros saw further applications for the device and introduced a commercial instrument.

The device emits nondispersive infrared radiation (NDIR) which is absorbed by molecules of the various gases in the air. Since molecules or different gases present different infrared "signatures," the device is able to distinguish carbon monoxide from other gases and measure its level in the air.

This fluorescent-source NDIR detector offers higher sensitivity, improved freedom from interference, better maintainability, a higher degree of portability and better stability as compared to other similiar devices. It is already being used for a number of air-monitoring missions by government agencies, research organizations and industrial firms.

Potential applications beyond ambient air-monitoring include measurement of aircraft and automotive emissions and personnel safety in mines and submarines.

Figure 3. Now commercially available from Andros Incorporated of California, this device detects and measures carbon monoxide in the air. It was adapted from hardware originally designed for use in the NASA Skylab program to monitor space-cabin carbon-monoxide concentrations.

Recycling Valuable Nonferrous Metals from Scrap. Ferrous metals have been reclaimed easily for years but until recently the cost of separating nonferrous metals has discouraged efforts to recover these valuable substances.

Using newly developed techniques based on the properties of magnetically responsive fluids (known as ferrofluids), NASA is supporting the development of a prototype device that would separate previously wasted nonferrous metals from scrap materials and make it commercially feasible to reclaim and recycle them.

The method under study involves a technique called sink-float separation, which is based on the phenomenon that materials less dense than a given liquid float on the liquid while materials that are more dense, sink. Therefore, to separate any two materials of different density it is only necessary to use a liquid medium of a density between the two so that one material will float and the other will sink.

Ferrofluids are very stable suspensions of single-domain magnetic particles. A pool of ferrofluid in the gap of a regulated electromagnet becomes a liquid whose apparent density can be continuously varied at will, over the total range of known densities, by controlling the electric-current supply. Thus, in a given ferrofluid, solid objects of different densities can be made to selectively float or sink by varying the electrical current to the magnet.

Under contract to NASA's Langley Research Center, AVCO Corporation of Massachusetts is designing, building and testing a prototype sink-float ferrofluid separator that will be able to sort out mixed nonferrous scrap-metal mixtures, including shredded automobiles. AVCO will also design and evaluate a full-scale nonferrous-scrap separation process based on results of the initial demonstration of the technical and commercial feasibility of the concept. The full-scale tests are scheduled to take place in the late spring of 1973.

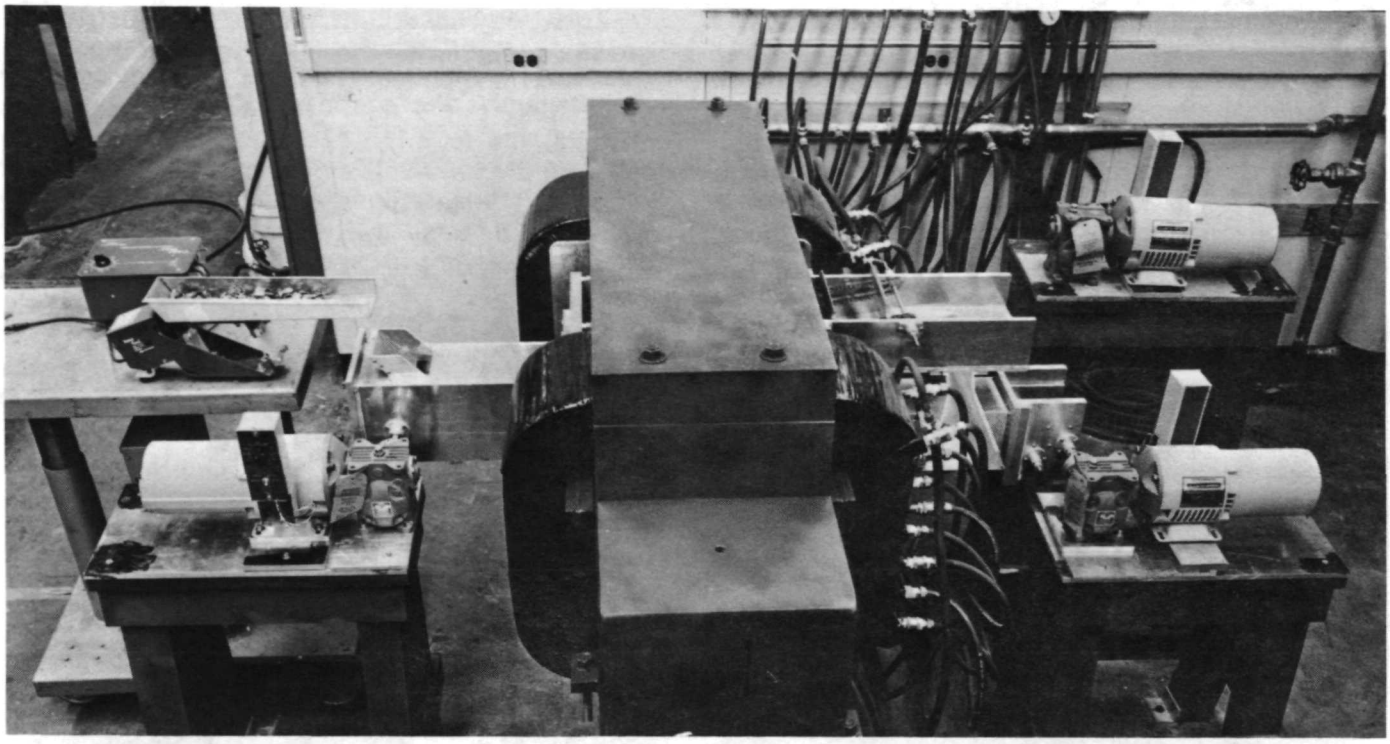


Figure 4. Nonferrous metals, heretofore usually discarded from scrap, can be reclaimed for recycling by use of ferrofluid techniques. AVCO, under NASA contract, is developing this ferrofluid separator unit.

Recycling Water in the Home. Technology resulting from NASA work on space stations is being explored to develop a home water-treatment system which would remove potential pollutants at the source and provide for water recovery and reuse in multiple dwellings. Because of the great potential of such a concept, the NASA Manned Spacecraft Center was funded in December of 1971 to develop a system for residential use. It will utilize aerospace-derived low-water-appliances and waste-collection equipment designs coupled with water–recovery, sterilization and recycling concepts.

The goals of the system are to reduce the quantity of water used for each domestic function and to reclaim and reuse waste water. The program will consist of three phases leading to demonstration of the water/waste management technology in a pilot operation.

The NASA Manned Spacecraft Center awarded contracts to Martin-Marietta, Grumman Aircraft and General Electric in the late winter of 1972 for this project. Grumman is evaluating systems concerned with waste–water recycling. Martin-Marietta is investigating biological and chemical production of potable water. General Electric is reviewing use of available commercial water-saving systems as well as chemical and electrical treatment of wastes and production of potable water. Final reports are due from the contractors by the end of 1973.

Low-Voltage Switching and Flat Conductor Cable. NASA wiring technology is helping to simplify and reduce housing-construction costs.

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, which necessitates bringing the power circuit from the fixture to the switch location.

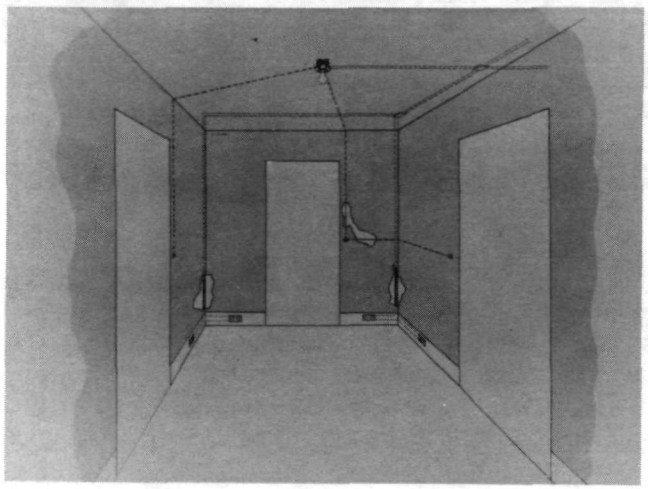
Several problems are associated with switching circuits installed in walls. In some new types of construction walls are very thin, leaving little room for conduit and switch boxes. In panelized and prefabricated construction there is still significant on-site labor associated with fishing wires through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

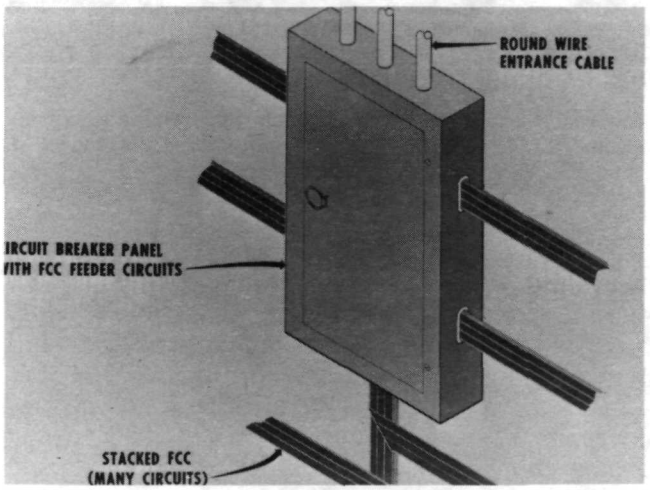
An investigation of alternative and less costly methods for the installation of electrical wiring was requested by the New York State Urban Development Corporation. The low-cost solution suggested by NASA's Application Team for urban construction, Abt Associates of Massachusetts, involves the use of a low-voltage switching device utilizing aerospace technology and flat conductor cable developed at the Marshall Space Flight Center.

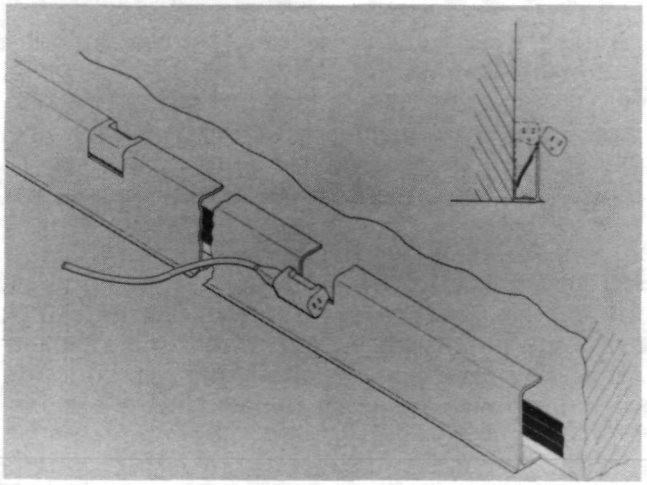
Several meetings were held with manufacturers to discuss adaptation of low-voltage switching devices to the flat conductor cable. Non-Linear Systems of California, a small company that produces electronic parts and equipment for the aerospace industry, expressed strong interest in this technology and developed with its own funds the necessary low-voltage solid-state switching device.

The system, called **Switchpack**, uses extremely flat cable (4 mils thick) to connect a thin-profile, surface-mounted switch to a wall outlet or ceiling fixture in which a tiny transformer is implanted. The transformer converts 120-volt current into a safe 2-volt signal capable of activating any electrical appliance. The flat cable, like the switch, is adhesive-backed and can be taped to a wall, ceiling or floor. It is invisible when covered by paint or wallpaper.

Switchpack is expected to realize substantial savings by eliminating the switching-circuit conduit, switchboxes, 120-volt switches and heavy-duty wire in new construction. It is estimated that the cost of installing electrical switches could be reduced by $15 to $35 per switch fixture with even greater potential savings in rehabilitation and renovation projects. Underwriters Laboratory approved the system in







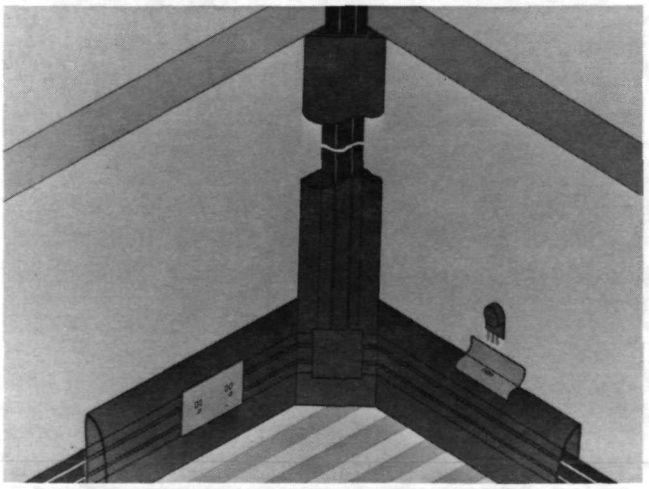


Figure 5. Varying configurations of flat conductor cable to carry power circuits in mass housing.

May, 1972 and it is now actively marketed by Switchpack Systems, Inc., a subsidiary of Non-Linear Systems.

Because of its innovative nature, Switchpack was chosen by **Industrial Research** magazine as one of the 100 most significant new products of 1971. It has recently been added to The New York State Urban Development Corporation's list of the 11 most economical innovations in their building program. Switchpack has also received national news coverage and has been featured on national television.

In a related application of aerospace technology to public-sector problems, the Marshall Space Flight Center was funded to develop a system utilizing flat conductor cable to carry power circuits for residences. The aims of the program, which began in December 1971, are to bring about revision of electrical standards and to provide the building industry, and New York State Urban Development Corporation 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, attachment and safety techniques.

The New York State Urban Development Corporation has expressed its commitment to the flat-conductor-cable development project and its intention to install, on an experimental basis, 220/120-volt surface-mounted wiring systems in 10 apartment units. Two contracts were subsequently awarded in the late fall of 1972 to develop and test hardware for UDC use. The contracts were for prototype base-board system hardware and breaker-panel adaptation. Tentative plans call for installation and evaluation of the hardware by mid-1974.

A Low-Cost Reliable Fire-Warning System for Mass Housing. NASA is working with the Department of Housing and Urban Development on early smoke detection — one of the top priority technological requirements of HUD's mass-housing Operation Breakthrough Program. This requirement is underscored in HUD's Guide Criteria for Operation Breakthrough, which re-require that smoke detection and alarm systems be installed in all multilevel dwellings under the program's sponsorship. The National Commission on Fire Prevention and Control is also deeply concerned with the problem.

There are several different kinds of home fire alarms — available on the commercial market — which are activated in the final, active-flaming phase of a fire. In residential structures, however, by the time the fire has reached the active-flaming phase, it is often too late for occupants to escape. Thus, fire alarms that are activated in the earliest, or incipient, phase of a fire are highly desirable. The incipient phase of a fire involves the production of combustion gases and very small particles (aerosols). The particles can be detected by commercially available ionization detectors, but these detectors are relatively expensive ($100 or more) and have a high rate of false alarms. There are many kinds of gas detectors now available, but most of these are extremely expensive laboratory scale instruments costing several thousand dollars. No cheap reliable detector of combustion gases suitable for use as a home-fire alarm is now on the market. In this context, the goal of the program described here is to investigate a promising new method of gas detection and to develop a cheap reliable gas detector which can be used as an early-warning home-fire alarm.

Figure 6. Adapted from a device developed originally to detect gaseous contaminants aboard spacecraft, this smokedetection unit shows promise for fire safety programs in federal and state mass-housing units.

Alternate technological approaches for a solution were reviewed by Abt Associates, the NASA Application Team concerned with housing. These included infrared, ultrasonic and ultraviolet detection methods. The most promising potential solution is a polymeric material, polyphenylacetylene, which has electrical properties

that change as it absorbs gases or particulates. The polymer acts as an effective contaminant-detection device for gaseous products of combustion when it is 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 had earlier synthesized polyphenylacetylene and developed a contaminant-detection device for use on the NASA Mars-Voyager mission. The Department of Housing and Urban Development, McDonnell-Douglas, the Massachusetts Institute of Technology and the National Bureau of Standards worked together with NASA to develop design criteria for the early-warning system for contaminants using adapted aerospace technology.

Currently, McDonnell-Douglas and MIT are planning development of the detection device for application to residential structures with joint NASA and HUD funding. Plans call for work to begin in early 1973. During the first year of effort feasibility will be further established. It is estimated that three years of development will be required before a device will be ready for commercial sale.

Tests of Fire-Retardant Materials. To evaluate the relative merits of aerospace fireproof and fire-retardant materials in a nonaerospace environment NASA recently completed several tests utilizing a specially constructed full-scale test room. Working with an advisory committee of fire-safety experts, NASA and the Battelle Columbus Laboratories in Ohio conducted the tests in the fall of 1972 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.

The purpose of the tests was to evaluate aerospace materials for such parameters as flame spread, formation of flammable and toxic vapors and practical utility.

The test room was representative of most domiciliary settings of public or institutional concern. The fully instrumented room was built, in cooperation with the Columbus Fire Department, inside the Columbus, Ohio fire tower, to assure repeatability of the tests. Four tests were conducted in which the contents of the room were ignited. The first test room contained an amount of flammable material normally found in such a room. In the second test the room contained the best commercially available fireproof and fire-retardant materials. The contents of the room in the third test were made of aerospace-developed fireproof and fire-retardant materials. The fourth test was conducted using conventional materials except for aerospace materials used in the bed.

Test data are now being analyzed. Preliminary results indicate that the fires were considerably more severe in the rooms with conventional and improved materials than in the rooms with aerospace materials. The toxicity has not yet been completely analyzed. In the room with the conventional materials and the bed with aerospace materials much better results were also observed. A final report is scheduled for early 1973, at which time a conference will be held in Washington to disseminate the test results to interested parties and to plan future activity.

Improved Fireman's Breathing Apparatus. NASA's attention to the problem of developing a new type of Fireman's Breathing Apparatus originated in the need of municipal fire departments for improvements in such devices. While conventional apparatus have been available for some years, many fire fighters neglect to use them because they tend to restrict mobility and vision. This has led to a discouraging rate of smoke-inhalation injuries.

In cooperation with the National Bureau of Standards Office of Fire Research and Safety and Public Technology, Incorporated of Washington, D.C., (a NASA contractor), NASA initiated an effort in the spring of 1971 to develop improved equipment. PTI polled cities on their needs, and then organized a User Design Committee. The User Design Committee includes fire chiefs, city managers and a representative of the NBS Office of Fire Research and Safety.

At the first committee meeting, held at NASA's Manned Spacecraft Center in June 1971, principal problems of currently used systems were further identified. The main deficiencies were: insufficient duration of air supply, 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 a more efficient breathing apparatus.

NASA and the User Design Committee determined that currently available compressed-air breathing apparatus could be improved significantly by developing a lightweight pressure vessel. This would bring about a potential 30 percent reduction in system weight. Other improve-

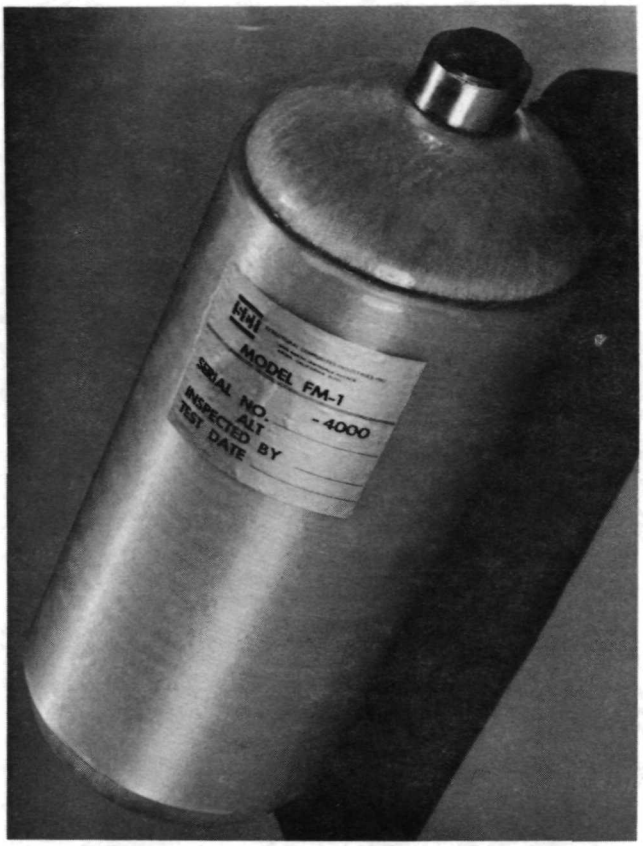


Figure 7. Lightweight fiber-glass air bottle for improved breathing apparatus for firefighters developed in NASA-sponsored programs.

ments included making the system more compact and changing the shoulder mounting of the device to a more comfortable hip position. The User Design Committee agreed that such a development program was desirable.

A second User Design Committee meeting was held in October 1971 to review NASA developments on the pressure vessel and the balance of the system. After evaluation of alternative materials NASA specialists selected filament-wound fiber-glass as the most promising material. NASA decided to procure two lightweight pressure vessels — one for a longer duration system than is now commonly used and one for slightly less duration. Contracts were awarded to two manufacturers in early 1972, with delivery planned for early in 1973.

A contract for the balance of the breathing-apparatus system was awarded to Scott Aviation of New York in October, 1972. This contract will be completed in October, 1973. After extensive testing by NASA the equipment will be released for field tests by Fire Departments in several cities.

An air-compressor station with a higher supply pressure than is now commonly used will be required to charge the new breathing apparatus. NASA has written a specification and is purchasing such a high-pressure system for use in testing the breathing apparatus. A similar specification could be used by city fire departments in purchasing higher-pressure compressor stations.

New Concrete-Repair Material. NASA-developed materials are helping solve bridge and road-surface maintenance problems. For example, 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. Thus, repair material must be quick-drying and durable. The same general problem applies to concrete-highway patching.

The current method of bridge repair requires spraying the damaged area with epoxy and then spreading it with an aggregate. In favorable weather conditions the patch is ready for traffic in about 4 hours. But the drying time is considerably greater in bad weather. Other disadvantages of epoxy are its cost and its toxicity. Also, because of its low durability, a high frequency of renewal creates high labor costs.

The problem was relayed to NASA by the Chief Engineer for the California Division of Bay Toll Crossings in discussions with the Stanford Research Institute Application Team in California. A potential new material was suggested by a NASA Tech Brief found during a search of the NASA data bank. This was a thermoplastic material originally developed as a better fuel-binder for solid propellants.

Samples of the NASA-derived thermoplastic material made in the Stanford Research Institute Laboratory were tested in the SRI parking lot in mid-1971. Samples were then given to the California Division of Highways for laboratory testing to evaluate the adhesion qualities of the thermoplastic aggregate. Later, the new material was applied as a surface treatment to a major California highway. After several months it appears to be doing well. As a result, an extensive series of tests related to the coating of highways will be conducted in cooperation with state highway officials and the Federal Highway Administration.

The material is also being studied for pothole patching. Under the lead of Public Technology, Incorporated, testing is being planned in a number of cities.

An important economic and environmental plus of this potential solution is the possibility that the thermoplastic material might be partly produced from old tires and used crankcase oil. Another possibility is using the thermoplastic material as a binder for waste glass crushed into aggregate. Hence the solution to this bridge-repair and road-patching problem might also help serve the purpose of recycling hard-to-dispose-of waste materials.

Figure 8. Thermoplastic material originally developed for binding solid fuels for rockets is being adapted for bridge-surface coating and road repair. A potential bonus is that shredded tires and used crankcase oil might be used as an ingredient.

Fire Protection of Rail Tank Cars. NASA is working with the Association of American Railroads and the Federal Railroad Administration on the continuing problem of rail tank-car safety. One aspect of the study requires materials to protect tank cars in post-derailment fuel fires. A protective coating is needed to prevent the steel tank car shell from reaching a temperature of 800 degrees Fahrenheit within a period of a half-hour to four hours. This need is underscored by the fact that the damage radius of the fire that usually follows derailment can spread appreciably to nearby tank cars, rupturing them as a consequence of severe heat loads.

Application of NASA Technology in this area was initiated by the Stanford Research Institute Application Team, which contacted the Chemical Research Projects Office at the NASA Ames Research Center. This office has done extensive work in the development of materials for fire protection, primarily for aircraft and spacecraft.

After discussions with the Association of American Railroads and the Federal Railroad Administration, it was determined that a fruitful approach would be for the Chemical Research Projects Office to direct a program to define the heating-environment and thermal-shield material response in railroad tank-car fires. The Federal Railroad Administration will fund the effort. Initial fire tests will be conducted at White Sands, New Mexico in the winter of 1973, with Ames staff members participating.

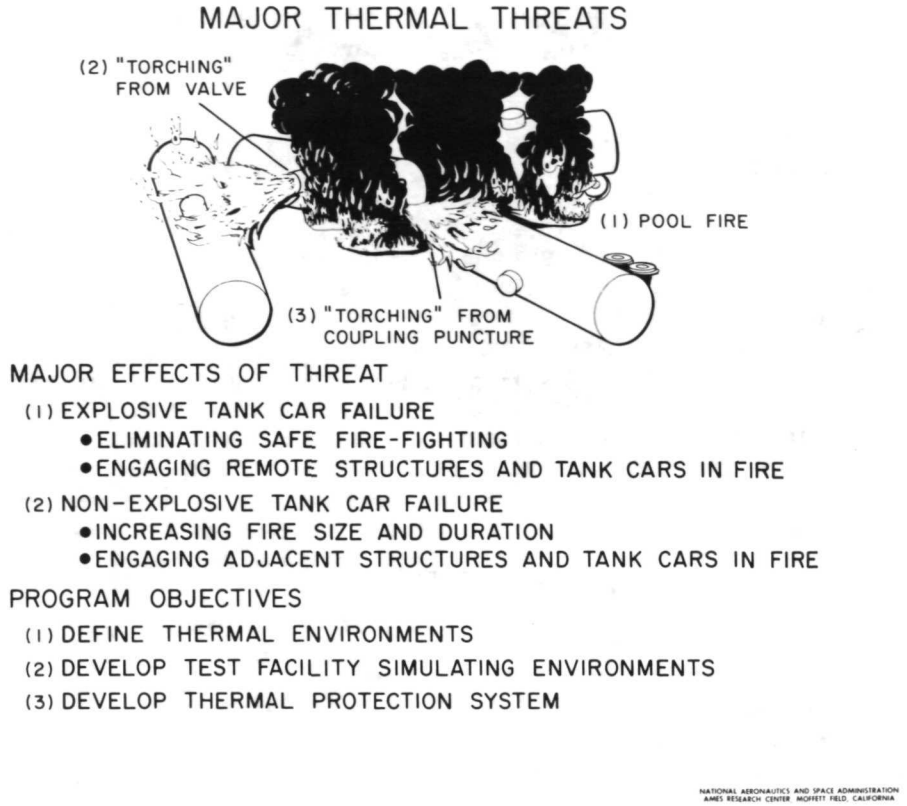


Figure 9. Major thermal threats to rail tank cars.

Measuring Railcar–Wheel and Rail Stresses. Thermal stresses that build up in long and continuous modern railroad tracks can cause buckling and breaks in the metal. This happens when the uniform distribution of these heat-induced stresses is disturbed by improper alignment of ties, ballast or rail anchors. An effective and rapidly applied method of nondestructively detecting high pre-yield stresses is needed for use by rail-inspection crews in the maintenance of rail sections.

Derailment caused by catastrophic failure of railcar wheels is another railroad problem. 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. Application of NASA technology in this area was initiated by the Stanford Research Institute Application Team.

Ultrasonic techniques of measuring stress are currently being developed at the NASA Marshall

Figure 10. NASA Marshall Space Flight Center researcher measures applied stress on a railcar wheel in NASA-Federal Railroad Administration study of application of aerospace ultrasonic testing methods to railroad safety.

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.

A program was funded in late 1971 to determine the ultrasonic velocity vs. stress relationships for the particular types of steel used in making wheels and rails, investigate the effects of temperature variations on the accuracy of stress measurements, evaluate measurement problems related to rail geometry, make actual stress measurements on wheel and rail segments under controlled laboratory conditions, and 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 determined by the resulting stress as measured by ultrasonic shear-wave methods.

Tests comparing the residual stresses in brand new railroad wheels vs. older wheels are being completed. They reveal that the compressive stresses in the new wheels are high. But as the wheel ages in service this stress drops off to zero and then becomes a tensile stress which weakens the wheel.

The Association of American Railroads has provided samples of rail and wheels and has closely followed the tests. The Federal Railroad Administration has provided most of the funds for this project. If the laboratory work proceeds as scheduled field tests will be conducted in the summer of 1973.

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.

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 while at the same time reducing brake fade. 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 assessment of a wear-enhancing polymer (WEP) as an ingredient of automotive brake linings, development of a brake lining formulation containing standard ingredients and the WEP, and investigation of the use of new materials for binders and substitutes for asbestos. A contract to fabricate prototype automobile brakes is now being negotiated and should be awarded by January of 1973. After laboratory testing, field testing will be conducted on automobiles for 6 months starting in mid-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.

Rescue Vehicle For Use In Coal Mines. In its search for technology applicable to disaster rescue, the Bureau of Mines has funded work by a researcher at the University of Kentucky to develop an unmanned remotely-controlled unit. To assist the project, the Illinois Institute of Technology Research Institute's Application Team explored available NASA technology and found that guidance-system technology developed by the Marshall Space Flight Center for the Lunar Rover vehicle appeared to be particularly relevant. The Bureau of Mines has agreed to jointly fund with NASA the adaptation of the guidance system for use in an unmanned mine-rescue vehicle.

The only basic design change required of the Lunar Rover guidance system is simplification of the system's readout. The system consists basically of an odometer to measure distance traversed, a directional gyro to give bearing relative to a fixed reference (such as North) and a processor to take the odometer and gyro data and convert it to X and Y coordinates.

Tentative plans project delivery of the adapted Lunar Rover guidance system to the University of Kentucky for installation in the vehicle in the late winter of 1973.

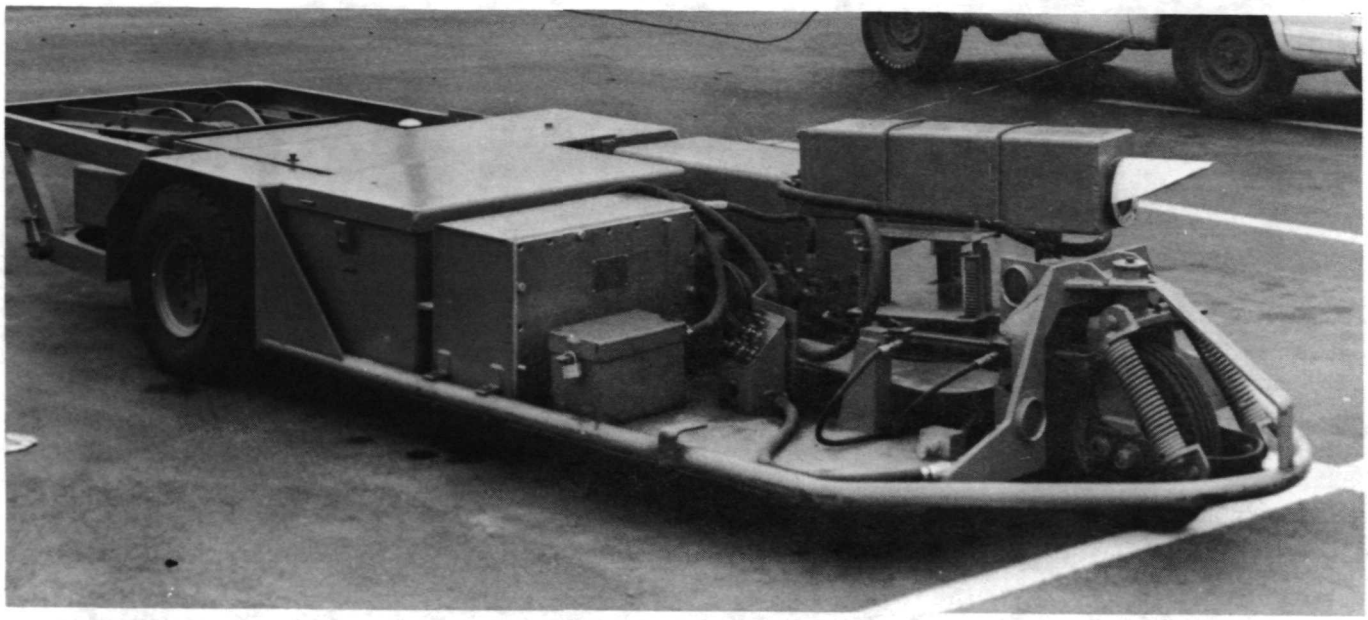


Figure 11. NASA Lunar Rover guidance technology is being studied for its potential application to unmanned mine-rescue craft being developed for the Bureau of Mines at the University of Kentucky.

A New Device for Speed Policing on Highways. Highway safety is an ever-pressing problem. More than 50,000 lives are lost in this country annually on the highways and many more people are maimed. Since speed is a significant contributing factor in many of these accidents, a simple device which is less costly than conventional radar and other complex techniques and could determine the speed of an observed automobile would be invaluable as an aid in discouraging speeding.

A Marshall Space Flight Center engineer who is also an auxiliary state trooper has designed and built a simple inexpensive electronic device that can be used in place of more complex systems.

The system consists of a low-cost electronic computer and two roadside markers on the route being observed. Its operator is positioned so that he can see a vehicle when it encounters each of the markers. A timing switch is turned on when a vehicle passes the first marker and turned off when it reaches the second. Elapsed time is measured accurately by an internal clock and a minicomputer that divides distance by time, thus finding the speed. The entire system — expected to cost no more than $200 — compares in size with a thick textbook and weighs only 3 pounds.

Used in a vehicle, the unit is powered by the car's battery through the cigarette lighter outlet. When used independently of a vehicle, a battery pack mounted on the operator's belt is used.

The low estimated cost of the computerized system could make it very desirable for small-town and county law enforcement agencies which cannot afford radar units that cost $2000 or more.

Two prototypes have been designed, assembled, and tested at Marshall Space Flight Center. The units have been shown to the Military Police, Alabama State Troopers and the Huntsville, Alabama Police Department. All three agencies expressed interest. In a field test the Huntsville Police Department compared the results obtained from the NASA unit to conventional radar readout. They were favorably impressed by the operation and accuracy of the speed computer.

Two units have been lent to the Huntsville Police Department for field use. The field operation of the computer was shown to the local Recorder Court Judge, who gave his approval for its use in apprehending speeders. During the first two weeks of the program more than 200 speeding citations were issued.

Four more units will be fabricated and lent to law enforcement agencies for further tests and evaluation in early 1973. A large commercial company has expressed interest in manufacturing and selling the device.

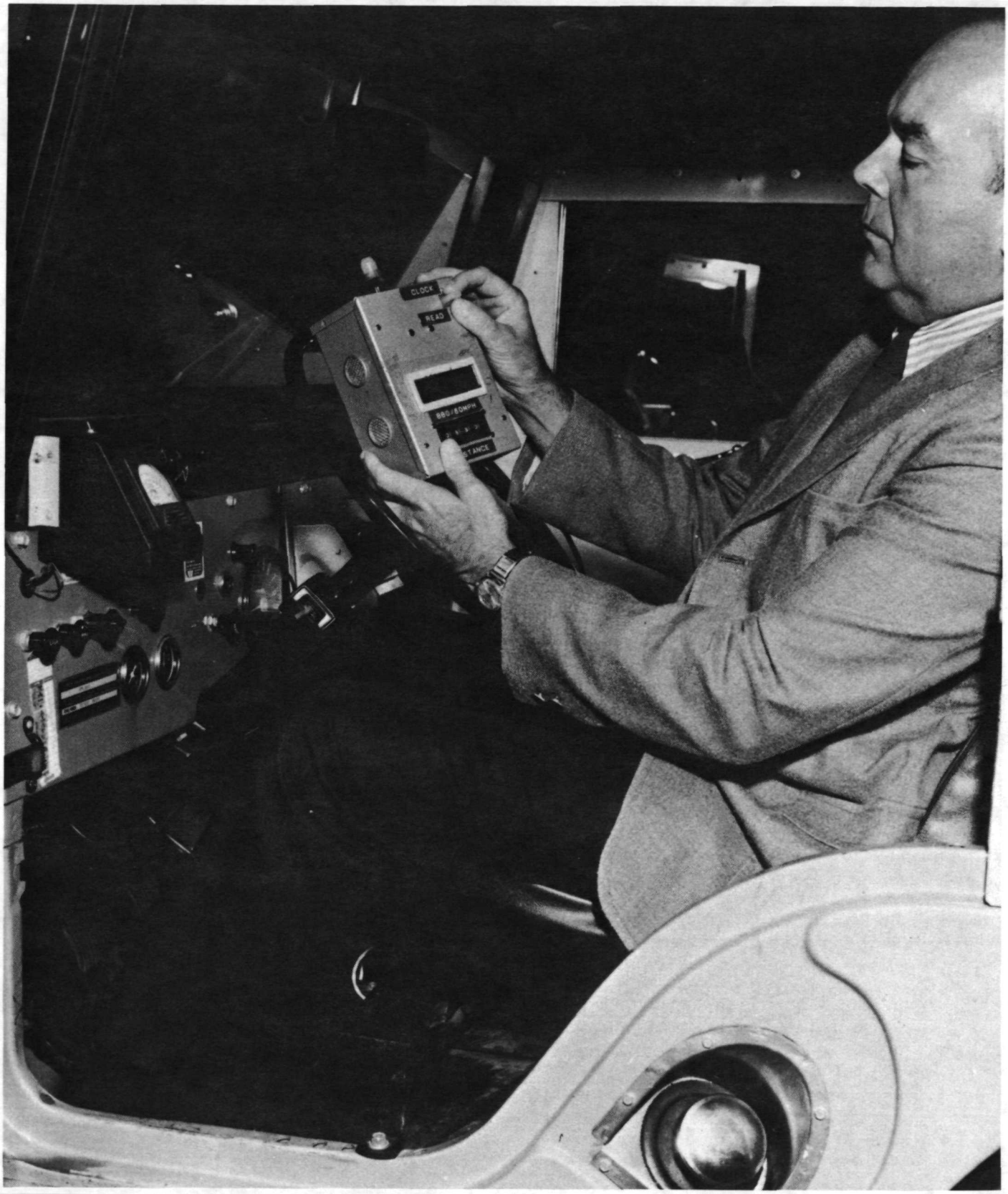


Figure 12. Low-cost, simple, minicomputerized road-speed monitoring system based on aerospace technology is being used in Huntsville, Alabama, home of the inventor, an engineer at Marshall Space Flight Center. System can be installed in police cars or at roadside.

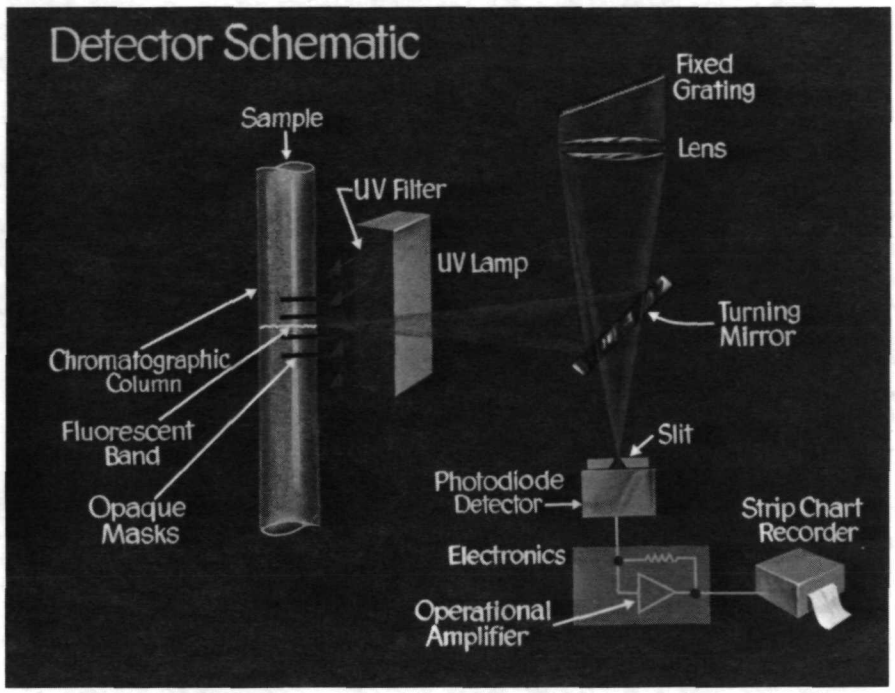


Figure 13.
Schematic of drug-detector system based on technology originally developed to measure chemical factors involved in stress among astronauts.

Improved Instrumentation For Drug Detection. There is an established need for low-cost and portable instrumentation for rapid, reliable and routine determination of the presence of drugs in the body. Applications for such improved analytical instrumentation would include use by methadone-maintenance clinics to monitor patients and use by hospitals and rescue squads to rapidly determine whether or not a comatose patient has overdosed. Such instrumentation might also be used as a means of routine screening for early drug use so that rehabilitation may be begun as soon as possible.

The instrumentation described below is the natural outgrowth of research conducted by NASA's Ames Research Center on chemical factors impinging on pilot stress, which included simulating neurochemical receptor sites in the brain. 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 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

Figure 14. Compact drug-detection unit based on aerospace techniques now under development for commercial sale by Whittaker Corporation of California.

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. The column is irradiated with monochromatic ultraviolet radiation.

The detector 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.

A contract has been awarded to Whittaker Corporation Space Sciences Division of Massachusetts for the fabrication and delivery of four instruments. The instruments were to be delivered to NASA in February of 1973. Two instruments will be sent to the U. S. Army Walter Reed Army Institute of Research and one will go to the New York City Health Department for field evaluation. The fourth instrument will be modified to detect barbiturates, amphetamines and methadone. To date the system has been tested and found suitable for detecting heroin (morphine) and quinine in urine. The detection of other drugs will be achieved once the appropriate chemical preparation procedures are fully developed and simplified.

A further cooperative program with the Army is under way to effect greater improvements in the chromatographic column of the drug detector and to improve the sensitivity and specificity of the instrument.

A production instrument of the type described produced in quantity would be expected to sell for less than $1,000.

PROJECT HIGHLIGHTS ... Biomedical Sector

By way of affording the reader an insight into the Technology Applications program, as it is related to putting aerospace technology to work in the field of biomedicine, the following projects currently in progress, are described in some detail.

Rechargeable Cardiac Pacemaker. Aerospace technology originally developed for rechargeable nickel-cadmium cells for spacecraft power systems is being directly applied to a NASA-supported effort by the Johns Hopkins Applied Physics Laboratory to produce a rechargeable cardiac pacemaker unit that would eliminate the present requirement for surgical replacement of such devices when their batteries are depleted. Currently, nearly 90 percent of the pacemakers using conventional mercury batteries must be replaced every 24 months due to battery failure. The wearer of a rechargeable unit would simply recharge his unit by donning a special vest for several hours. This is an especially useful feature for infants and aged patients.

The rechargeable unit, which has been tested successfully on dogs, offers other significant advantages. Since it does not require a large battery, it can be drastically reduced in size, down from the present 8 cubic inches to a unit ¼ that size.

Use of a hybrid circuit also helps reduce size and weight. Also, unlike pacemaker units currently manufactured in the United States, which begin to lose their energy as soon as they come off the production line, the rechargeable pacemaker can be kept at a safe charge level until it is implanted in the patient. The new device also has a telemetry system that measures battery voltage and charging current.

The aerospace-derived hermetically sealed nickel-cadmium power cell is the key to the unit's operation. The power cell is essentially a miniature version of cells used in virtually all U. S. spacecraft. The hybrid circuitry, a technology to which Johns Hopkins Applied Physics Laboratory had made major contributions, offers a great advantage in circuit reliability as well as weight and size reduction.

Further evaluation of tests on animals will precede implantation of the new device in humans.

Hypertension Screening Device. In a cooperative program with the Veterans Administration, a transducer developed at NASA's Goddard Space Flight Center to externally record arterial-pulse pressure waves has completed six months of successful clinical evaluation at the Washington, D. C. Veterans Administration Hospital. The special value of the NASA device is that it allows physicians to evaluate the functional status of the carotid arteries in atherosclerosis patients without having to insert monitoring catheter devices into their bodies.

The transducer is being used in a Hypertension Study at the Washington VA Hospital. The data acquired is used to determine the relative elasticity of each patient's carotid artery and the responsiveness of his circulatory system to various drug treatments. Field tests of the device are now being conducted at six other VA hospitals around the country.

The NASA device, which uses a Pitran displacement pressure transducer, has good high-sensitivity and low-frequency response. Although displacement-pressure measurements of the carotid artery do not replicate the pulse shape as can be done by an inserted catheter, the external measurements do convey clinically useful information. Permanent records can be made quickly and without penetration of the skin or discomfort to the patient.

Previous attempts to implement an external displacement type pressure transducer had been unsuccessful due to mechanical design problems or extreme mechanical complexity resulting in high production cost. The simpler design of the NASA-developed transducer is expected to be much more reliable and much less costly to manufacture.

Flexible Electrodes for Low-Cost Personal Coronary-Care Kits. Flexible electrodes based on equipment developed at the NASA Ames Research Center are being field-tested as significant components of emergency coronary-care units which could be used by cardiac patients or emergency attendants to send electrocardiographic data gathered by the kit to physicians by telephone. After examining the relayed EKG data, the doctor could direct the patient or attendant to administer appropriate medication

carried in the kit. The kit's development is being sponsored by the National Heart and Lung Institute.

The adapted NASA electrodes are made of a conducting elastomer and shaped like golf balls. They can quickly be placed under the armpits of a heart-attack patient to rapidly provide an artifact-free EKG signal that can be relayed by phone.

Designed for emergency use by patients themselves, ambulance personnel and police, the coronary kit contains two drugs and a hand-held monitor. The electrodes of the hand-held monitor are placed under the armpits of the patient suffering classic coronary symptoms. Depending on the presence of either a low heart rate or a fast erratic heart beat, one of the two drugs contained in the kit is administered. The application of the drugs is quite simple because they are contained in an automatic syringe similar to the system used in the Apollo medical package. Also, 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 trouble properly attaching the conventional electrodes originally used with the kit. NASA cooperation was sought to provide electrodes that would be reliable and require little training for proper use.

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

Evaluation of the NASA-derived electrodes has been quite promising to date.

Artificial Aortic Valves. NASA close-range stereophotogrammetry — precision stereophotographic mapping techniques — is aiding in the development of artificial aortic valves.

Fiber and composite-materials technology, combined with advancements that have been made in blood-surface interface research under the auspices of the National Institutes of Health Artificial Heart Program, have laid the fundamental groundwork for the development of a tri-leaflet artificial heart valve.

A significant part of the development task is the fabrication of the leaves of an artificial aortic valve. The natural aortic valve is composed of three leaflets which come together to close a circular opening. The leaflets are flexible and flap open and closed with each heartbeat nearly 40 million times a year. It is most important that any artificial tri-leaflet valve be able to withstand many years of complex flexing. To ensure that capability, the dynamic stresses and strains on the valve leaflets must be known.

NASA stereophotogrammetry is used to photograph the leaflet motion at various flow pressures and velocities. The record of the valve motion is then put into computer format for further evaluation. The data will help engineers specify design changes to strengthen those parts of the leaflet subject to the greatest stresses and to minimize the turbulence of the flow through the valve.

Stereophotogrammetric map data currently being developed by a group at the University of Illinois will be applied to the aortic-valve fabrication and evaluation program at Washington University in St. Louis which is now being supported by the National Heart and Lung Institute.

Biocarbon Implants. NASA Technology Utilization funds have been made available through the NASA Marshall Space Flight Center for a special project at Rancho Los Amigos Hospital in California to develop and test high-purity, high-strength forms of carbon — originally designed for space capsule heat shields — for use in implantable prosthetic devices. 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. But until recently the available carbon was not strong enough for prosthetics use. Materials of lesser biocompatibility had to be used.

Vitreous carbon developed for aerospace use is now strong enough to be used for prosthetic devices and pure enough to be biocompatible. Vitreous carbon combines strength with chemical inertness. Compared with other materials used for implantation, it is light in weight and hard enough to permit low-mass implants. It also has a low coefficient of thermal expansion. Being a pure carbon, it is highly resistant to body fluids because it does not corrode at body temperature. The nonmetallic composition suggests that vitreous carbon should be free of adverse tissue responses including 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 because it contains no impurities or additives.

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

The first stage of the program will evaluate 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 more than 20 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 — one protruding end is made of the biocarbon while the other end of the pin is made of 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.

Another aspect of the project involves one of the most serious clinical problems facing the orthopedic surgeon — the attachment of prosthetic devices to the skeletal structures. There is little understanding of the optimum configuration and materials for attachment. Currently, a plastic filler — methyl methacrylate — is the most successful cement for fixing prosthetic material to bone. Exactly what happens to this material under dynamic mechanical and biological stresses is unkown. The same applies to the use of titanium and vitallium at the interface between bone and prosthesis. Considerable basic information could be provided by study of the interface after functional stresses have been applied.

While the first two phases of this study require human subjects for evaluation, the third phase will use animals. 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 stress. 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. By comparing one material with another under similar mechanical stresses in the same limb of an animal, a highly-controlled basic study can be accomplished. The results would have considerable impact on the scientific community and give credence to the claim of unusual biocompatible properties for medical-grade carbons.

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 reason to believe that the information developed out of the three preliminary phases will define the ultimate design of a NASA Skeletal Attachment System.

Evaluation of Hazards of Plasticizers from PVC Plastic. NASA's Goddard Space Flight Center is working with the Johns Hopkins School of Hygiene and Public Health in a detailed toxicological evaluation of the hazards 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 potential damage of the plasticizer (DEHP) to the cellular elements of the stored blood. 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 product. The amount of plasticizer added varies from product to product. But

it is not trivial and can hardly be considered a trace additive since it ranges in many applications up to 35 percent 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 is a distinct possibility. NASA recognized the problem of plastizer 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 volatized plasticizer with the performance of various optical devices in spacecraft.

Although NASA had experienced various problems with plasticized PVC, until recently the biomedical community had scarcely noted the volatization and migration of the plasticizer from PVC surfaces. But in 1970, scientific papers 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.

There is recent evidence suggesting that the phthlate 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 surgical procedures involving direct contact of the blood with a plasticized device. 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, through the skin, and by inhalation — will be investigated. Phthlate ester plasticizers have also now been identified in fish taken from the waters of several states. The presence of phthlate 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 experts.

Lightweight Prosthesis and Orthosis Materials. A NASA-developed variety of hybrid composite materials consisting of fibers of boron-graphite-glass embedded in a matrix of epoxy resins offers major potential for use in the development of lighter-weight orthotic and prosthetic devices for rehabilitation patients. These cured composites are equal or superior to steel in stiffness and strength and weigh about half as much as aluminum. They also offer advantages in contouring and shaping because they are cloth-like in the precured state. Also, by adjusting their epoxy-resin components, they can be cured in a wide range of temperatures, even room temperatures.

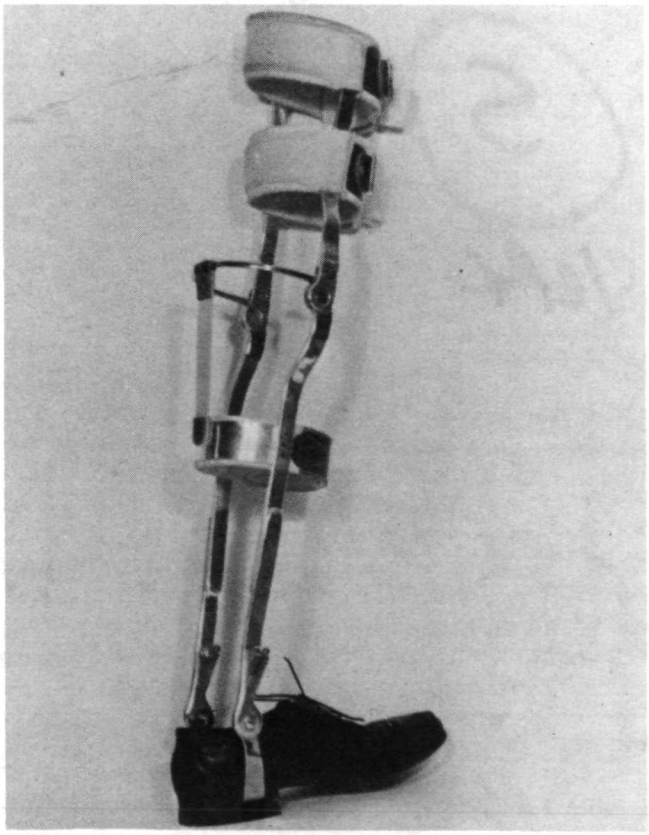


Figure 15. Heavier conventional stainless-steel leg brace.

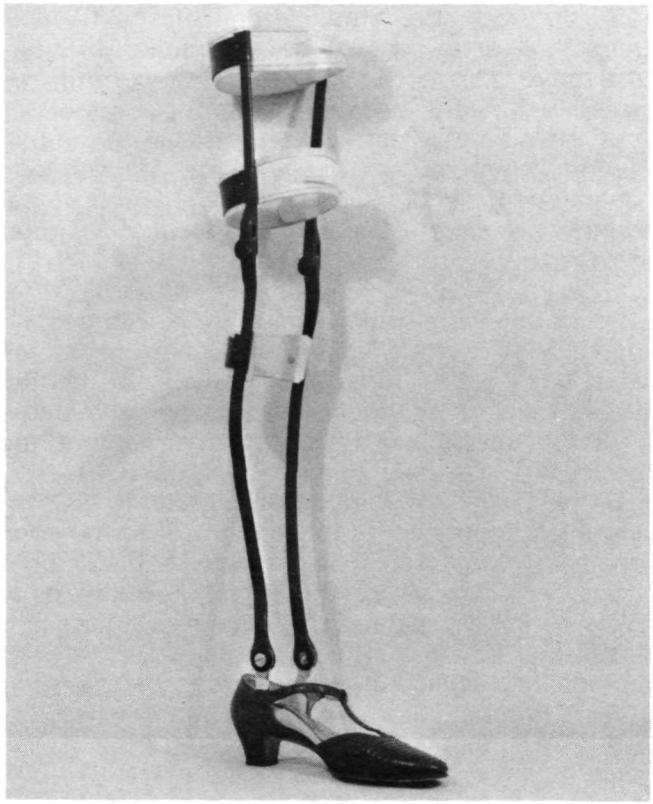


Figure 15a. A much lighter brace, built of boron-graphite composite materials.

These aerospace materials, originally developed for use in aircraft and spacecraft, offer significant advantages over stainless steel, which is conventionally used as a supportive material for prosthetics and orthotics because of its durability, reliability and resistance to stress.

Unfortunately, stainless steel adds discomforting bulk and weight to such devices and has esthetic disadvantages as well. The NASA materials hold great promise for solving the weight and bulk problems without sacrificing durability, dependability or resistance to stress. Fabrication and feasibility testing of the composite materials is now in progress.

Aerospace Valve for Urinary Control. NASA technology is aiding in the development of an implantable urethral valve for use by incontinent patients.

The program came about in response to an inquiry from a medical researcher treating paraplegic patients. He 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 the one used in manometer tubes might solve the problem. The valve is now included in the design of an implantable control system.

The patient will be able to mechanically control his urination by applying pressure to a small air-filled bulb implanted under his skin. The design of the bulb involved a search of NASA technology for a biocompatible material that would also withstand constant exposure to the chemical actions of urine. The NASA Applications Engineering Project located a material that met these requirements. Initial problems encountered in fabricating the material into bulbs and tubing were mastered.

Five prototype systems have been fabricated and delivered for laboratory testing in dogs at the University of Virginia to determine if there are any unfavorable long-term effects. The tests, if completed satisfactorily, could lead to mass production of the unit. This could benefit as many as 15,000 patients a year.

The bulb may also be useful as a drainage-bag valve for leg-bag urinals. This could be a boon to spinal–injury patients many of whom wear such devices and who lack the muscular coordination to drain them. This leads to an embarrassing and inconvenient dependence on others.

Since the ability to make a fist and push on an object are among the few controlled muscular actions such patients can perform, the bulb-controlled valve appears to answer their needs. Also, since no implantation would be required for such patients, the device could be manufactured at low cost using readily available materials.

"Teleoperator" Technology for the Handicapped. Following up on its extensive experience in "teleoperator" technology — the remote control of devices — many aspects of which have already been put to work in equipment used by the handicapped, NASA is currently engaged in an in-depth analysis of existing equipment. The prime purpose of the study is to determine additional applications of state-of-the-art technology for the handicapped.

Existing literature is being searched and discussions are under way with manufacturers and research-and-development specialists at private and governmental institutions. This effort will be followed by an analysis of current problems in

prosthetics, orthotics and sensory aids for which needed teleoperator technology is either currently not available, ineffective or is being unsatisfactorily applied.

Specialists will interview users of the available technology — the handicapped patients themselves — and will confer with personnel working in this field at Veterans Administration hospitals, the National Institutes of Health and in industry.

This review and classification of teleoperator developments current and potential, plus the description of the state of the art in prosthetics, orthotics and sensory-aid technology, is expected to produce a number of new "matchings" of technology and needs. The study's findings will be recorded in a NASA report for public dissemination.

Assist Devices for Totally Paralyzed Patients. Patients paralyzed in all four limbs, multiple-amputee patients and patients with severe neurological disorders are almost totally dependent upon outside support. Their morale is markedly improved and the demands on patient-care personnel are greatly relieved by any device of procedure which enhances their self-sufficiency. NASA technology is aiding in the effort to produce such advances.

For example, paralyzed patients and amputees are now using a NASA-developed sight switch to control electrically-operated assist devices. Originally developed at Marshall Space Flight Center to allow astronauts to perform various control functions while they were 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 has been used to enable patients to control various orthotic devices as well as wheelchairs. The switch allows a person to start, stop, reverse and turn the wheelchair by eye motion alone. By enabling patients to control orthotic and pick-up devices, the switch permits many daily functions for which they would otherwise be dependent on others.

Traditionally, such patients 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. But some patients, particularly those afflicted with the complications of spasticity or muscle tremor, have considerable difficulty operating conventional mechanical-control devices. The sight switch relieves these problems by providing a basic on-off, all-or-nothing switch which is not likely to be inadvertently operated. It should 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 the rehabilitation-medicine community aware of what can be done, several special publications and demonstration projects are being prepared.

To explore a range of eye-switch and other aerospace-derived patient-assist devices, NASA Marshall Space Flight Center has built a fully instrumented room which will allow paraplegics, paralysis patients and amputees to control all of the equipment and devices in their hospital environment. Installed for evaluation in the rehabilitation center at the Huntsville Hospital, the system will enable patients to control room lights, a page turner, a radio or TV, message panels and a variety of servos capable of controlling appliances, bed positioning and even a telephone.

A variety of patient-controlled switches will be available to permit matching of control switches with individual patients' 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. All these control systems will be available.

Extensive testing has proven the feasibility and operational capacity for each of the alternative switches within the capabilities of the patients who would use them.

Installation of the system is now complete and evaluation is in progress.

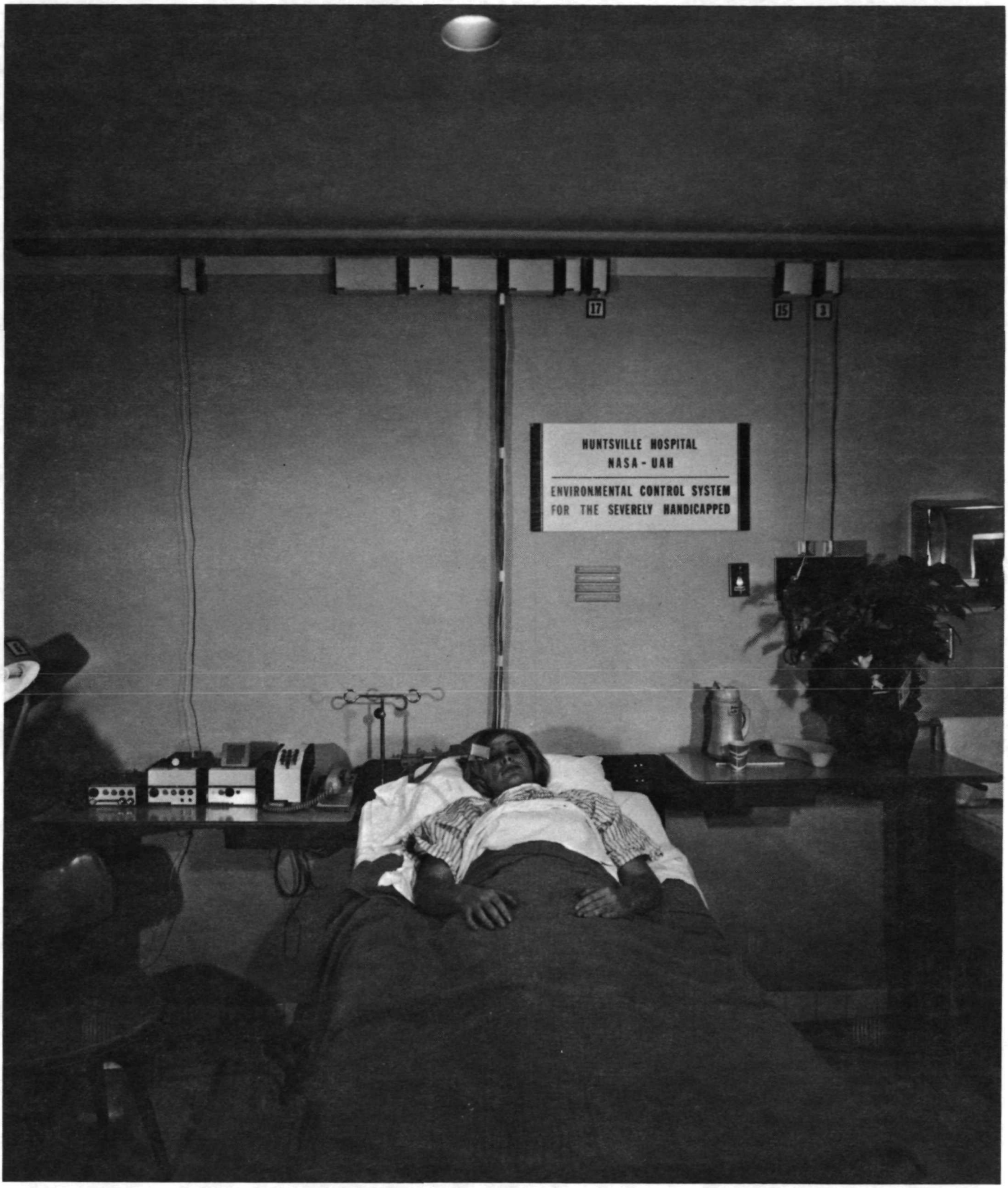


Figure 16. This fully-instrumented room, equipped with a variety of patient-assist devices for paraplegic, paralysis and amputee patients, is being evaluated at the Huntsville, Alabama, Hospital Rehabilitation Center. Using a variety of patient-controlled switches, severely handicapped patients can perform a range of control functions.

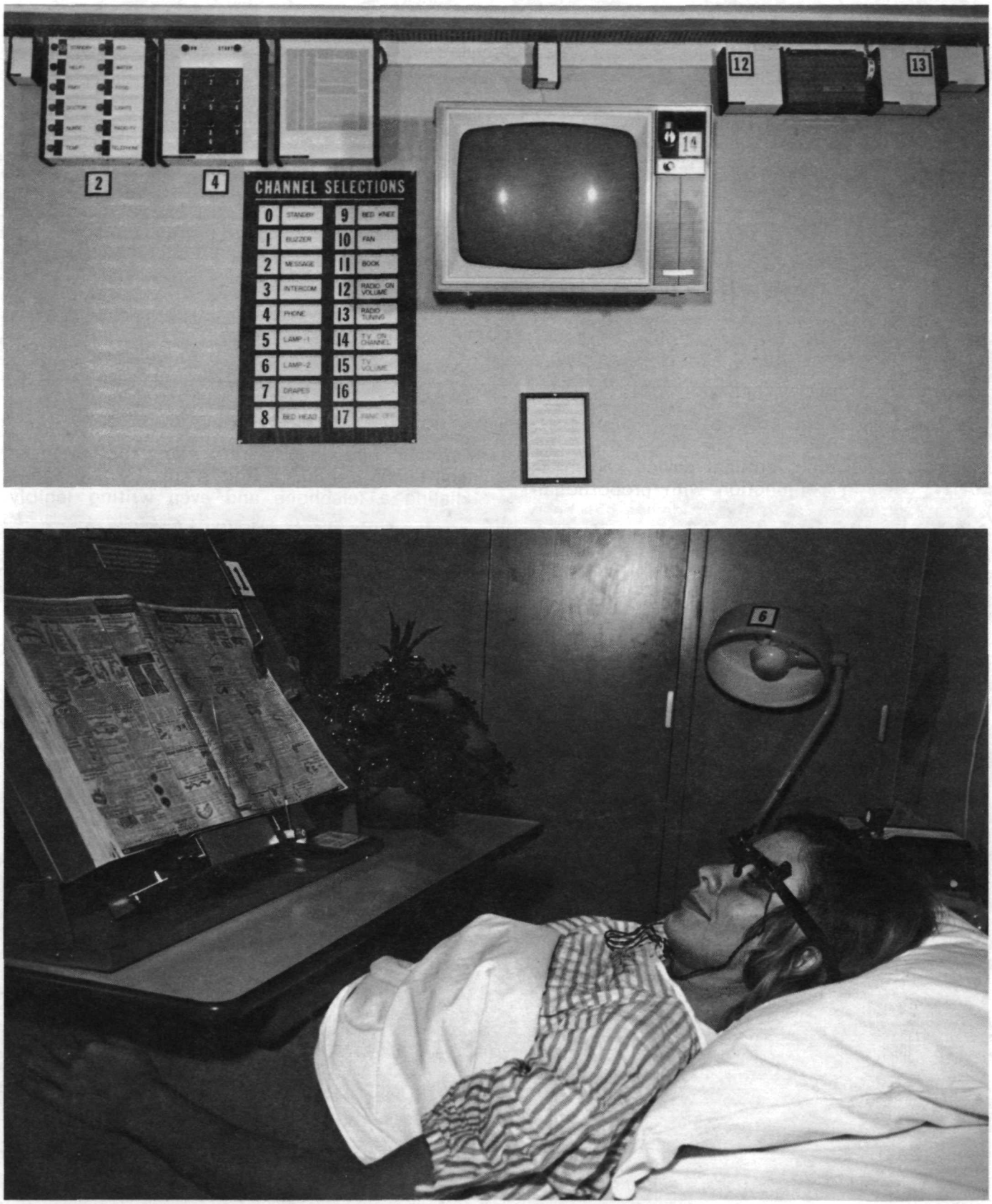


Figure 16a. Top, the channel selector for control systems. Bottom, patient wearing sight-switch glasses in able to turn pages of reading material. Range of controls available to such patients widens their horizons and increases their sense of independence. NASA Marshall Space Flight Center built the facility.

Prosthetic-Control Systems for Paralyzed Patients. NASA systems originally devised for the control of remotely-operated mechanical hands and manipulator devices in hazardous environments are being successfully adapted to assist paralyzed and amputee patients. The technology of NASA's space-oriented program has been combined to produce an upgraded proportional-control system which vastly increases the dexterity and the ease with which a totally paralyzed or amputee patient can use a prosthetic arm or hand.

Since most patients equipped with currently available artificial-hand devices have trouble handling power tools, rehabilitation researchers have been seeking improvements in manipulating capabilities in order to expand self-reliance among the handicapped.

Adapting a powered terminal device known as MATH, used in conjunction with proportional-control techniques, a prosthetic device has been developed which allows an amputee to use his prosthetic to operate power tools such as electric drills, soldering guns, etc. Control of the device is positive and delicate enough to permit handling and drinking a hot cup of coffee.

The proportional-control system is also being used to control complex manipulative devices that may restore a large degree of independence to patients by allowing them to voluntarily control their paralyzed arms.

Until recently, externally-powered orthotic arm braces with as many as seven joints — and thus seven reversible motors — were controlled by simple on-off switches. Prior to the introduction of the NASA proportional-control devices, it was difficult to achieve smooth, accurate motion control with so many working joints.

Incorporated into the seven-degree-of-freedom externally-powered orthotic arm brace, the proportional-control system provides both velocity and force proportional control of the seven small direct-current motors. Now in daily use at Rancho Los Amigos Hospital in California, the proportional-control system enables a totally paralyzed patient to perform tasks requiring considerable accuracy and dexterity. The control is "fine" enough to permit many routine tasks, self-feeding, drinking from a cup, turning pages, dialing a telephone and even writing legibly. Using a typewriter with a specially modified keyboard, one paralyzed patient is now able to type 22 words per minute.

Beyond enhancing the patients' ability to physically interact with their environments, the system also improves the psychological outlook for patients through the creation of greater self-sufficiency and the reduction of dependence on others.

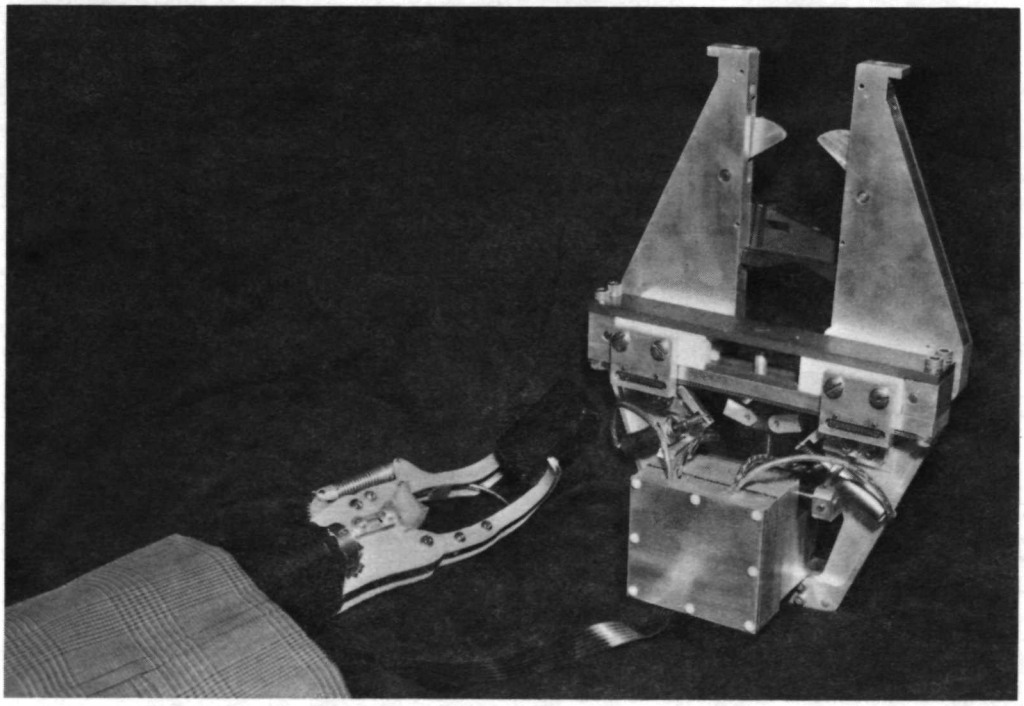


Figure 17.
Prosthetic hand, adapted from manipulator device at right developed for space use, makes it easier for amputees to perform delicate tasks such as operating power tools and handling and drinking a hot cup of coffee.

Measuring Disabled Patients' Exercise Workloads. 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 NASA 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 programs. 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 are 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 laboratory treadmills.

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 electrocardiographic 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 aid the design of assist devices and therapeutic techniques that will minimize the stress on patients.

The instrumentation will be installed at the Spahn Rehabilitation Center in Alabama. 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.

Rapid Detection Of Bacteria in Biological Fluids. Researchers at Johns Hopkins Medical Center and at the Washington, D. C. Veterans Hospital are currently testing two devices based on aerospace technology which show considerable promise for speeding and automating the detection of bacteria in biological fluids. In less than 15 minutes these new techniques can indicate the quantity of bacteria present in a body-fluid sample. Such analysis by conventional techniques usually takes 24 to 72 hours. The devices are each based on different approaches to this significant medical task.

One device is designed to detect ATP, a biochemical compound present in all living cells. In that system, the quantitative determination of bacteria is made by measuring light emitted in the reaction of the ATP in the bacteria with luciferase, which is an enzyme derived from fireflies. The reaction produces an observable flash of light.

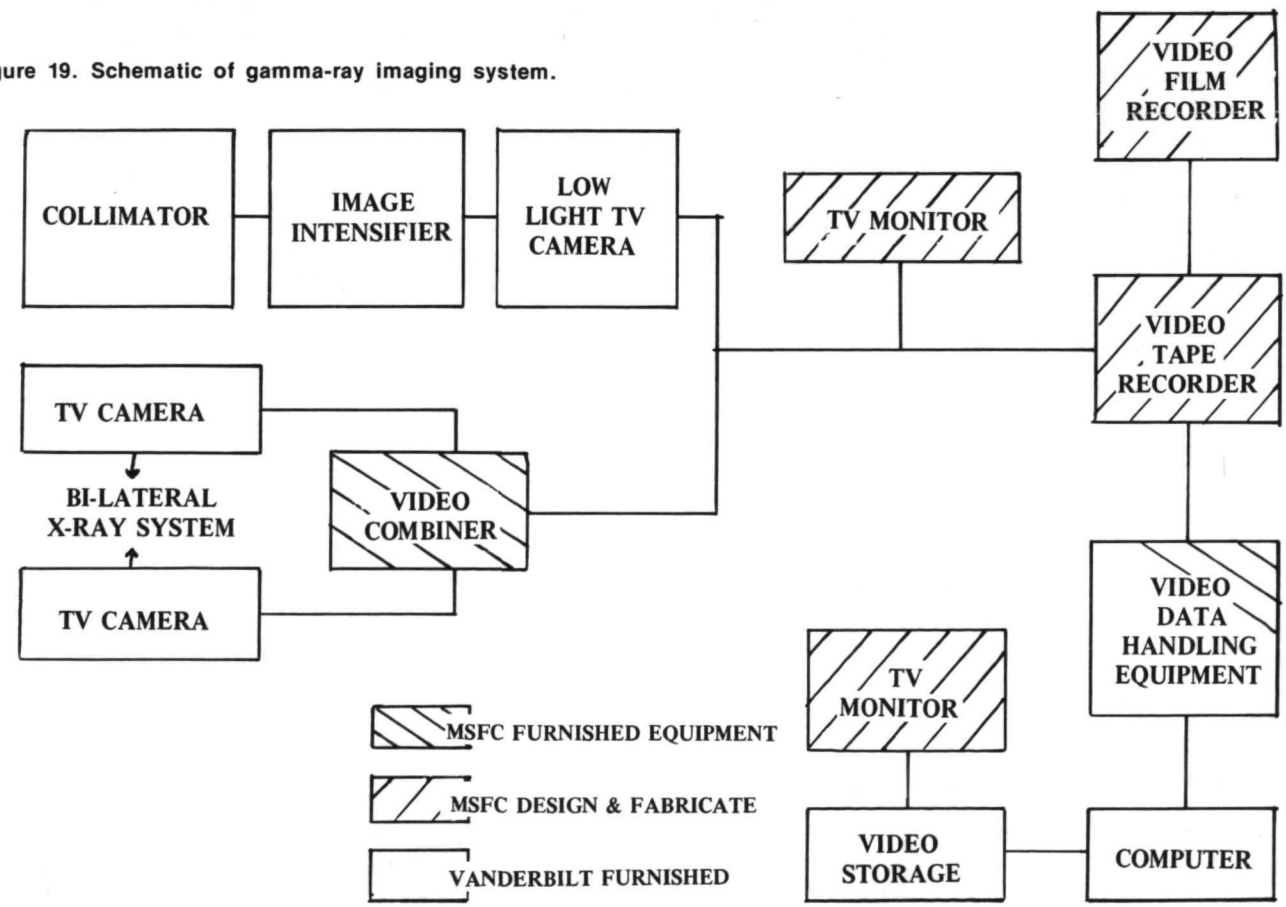
The other device uses a technique based on changes that occur in the electrical potential of growth medium as the oxygen is consumed by growing bacteria. It also provides an immediate reading to the observer.

The two techniques and systems under study — both of which are automated to alert the laboratory workers to the presence of bacteria — offer important potential advantages to physicians. The devices could help determine not only the presence of infection in body fluids but also provide information on the patient's response to various kinds of medication.

Recently, a program has been started at Tufts University to use the ATP detection system to evaluate the effectiveness of various antibiotics against certain bacteria. It is expected that this system will allow a lab technician to rapidly determine not only the presence of bacteria in a biological fluid sample but also aid in determining the antibiotic which most effectively destroys that bacteria.

Figure 18.
Automated urine-bacteria-detection system gives quantitative determination of bacteria by measuring light emitted when bacteria encounter luciferase.

Figure 19. Schematic of gamma-ray imaging system.



Direct Viewing Radiography. Solid-state image-amplifier panels originally developed for non-destructive testing of materials at NASA Marshall Space Flight Center appear to have properties that make them appealing for clinical and diagnostic x-ray procedures in medicine.

A particular advantage of the panels is that their high sensitivity of x-rays permits the use of smaller doses of radiation. In fact, conventional fluorescent image-amplifiers now being used require 50 times more radiation than the aerospace-derived solid-state panels. Also, the contrast range on the new screens is claimed to be four times as great as the range on currently-used devices. This could make certain kinds of interpretation and diagnosis much easier. Also, the new panels, which were originally developed for in-space inspection and checkout in an environment where room for film storage and development was likely to be unavailable, could be easily used by doctors in remote locations. This would make possible radiographic examination for fractures, internal-organ damage and disease in settings where conventional equipment was not available.

NASA and the Tulane University School of Medicine are working together to evaluate the diagnostic utility of these aerospace solid-state image amplifiers.

Fluidic Respiratory Flowmeter. Until recently, there has been no low-cost airflow-measurement system available to physicians who would like to be able to obtain a reliable continuous accurate measurement of respiratory airflow among their patients. The problem with present systems is that their sensitivity is altered by the moisture carried in respired air or that they impose too great a load on the patient's respiratory system. While an ultrasonic flowmeter is now commercially available, it tends to be too sensitive to changes in gas composition and its cost is too high for widespread use.

NASA is currently supporting the development of a fluidic respiratory flowmeter based on aerospace technology originally developed for a fluidic low-speed airspeed sensor. The new device is expected to be insensitive to the amount of moisture contained in the patient's expired air as well as to changes in gas composition. Also, it is designed to impose a relatively small load on the patient breathing through it. The NASA fluidic respirometer will be compatible with a miniaturized mass-spectrometer based on NASA technology — described elsewhere in this report — that will help physicians to study both respiratory patterns and the gas-exchange characteristics of the lungs.

Bowles Fluidics of Maryland will build a number of working prototypes of the new fluidic respiratory flowmeter during 1973 which will then be released for clinical trials in respiratory intensive-care units and pulmonary-function testing labs.

Head-Injury Diagnosis. In response to a request from the University of Texas at Galveston School of Medicine, NASA circuitry is being applied to the development of an improved technique for monitoring of fluid pressure within the skull. Telemetry permits continuous measurement 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 that reduces the blood supply to delicate tissues. This condition can lead to inadequate oxygenation and cell death. Medication is available to reduce the intracranial pressure by drawing fluid from the brain. But accurate measurement of the pressure is needed to guide the dosage of drugs and to assess their effects.

Conventionally, a pressure transducer, mounted to a burr hole that must be drilled through the skull, is used to monitor pressure in the cerebrospinal fluid. The conventional transducer is connected to the electronics and recording system via wires. But such connections can serve as paths for infection. Also, encumbering wires have to be relatively short and the associated equipment has to be close to the patient.

The applicability of NASA circuitry to this problem showed up in a search of the NASA data bank. A prototype of the new "wireless" device has been built at the Southwest Research Institute in Texas.

While the present prototype is about one cubic inch in size, further miniaturization is easily achievable. Laboratory tests of the prototype have been successful and it has been delivered to the problem originator at the University of Texas at Galveston where clinical evaluation is now in progress.

Improved Photographic System for X-Ray Diagnosis of Tumors and Cardiovascular Problems.

NASA's Marshall Space Flight Center and Vanderbilt University have adapted a real-time neutron-radiography welding inspection system for use in rapid x-ray diagnosis of tumors and examination of cardiovascular flow. Image-intensification, video-data processing and display and kinescope photographic recording system have been added to extend the usefulness of the system.

The combined system will be used in Vanderbilt studies of children suffering from congenital heart disorders. The system will be put to work visualizing the site of the heart defect and measuring the amount of blood flow through anomalous channels. The information gained is expected to help doctors determine which patients should have operations and at what age.

The sensing system is based on proton-electron interchanges that are amplified in an image-intensifier tube. The tube's output can be fed directly to a high-resolution video display. The data can be recorded on magnetic tapes or digital-disc recorders.

A particular advantage of the system is that since pictures can be made directly from the video system, a tenfold reduction in radiation dosage can be achieved. This is especially valuable in the diagnosis and treatment of children.

The techniques utilized in this system for high-quality translation of video tape to motion picture film were developed by NASA in early Apollo-Saturn flight tests.

Urine-Measurement System for Postoperative Fluid Maintenance. An aerospace-derived system to improve the postoperative measurement and 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 can then be used to control the rate at which additional fluids are administered to the patient.

One of the essential indicators of a post-operative 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 of patient difficulty. The present practice is for a nurse to record manually the amount of urine in a calibrated container at specified intervals. This procedure is not completely satisfactory. Patients often slip into electrolyte imbalance with scant note made of increased urine output.

The urine-transport system originally developed for the monkeys in the Biosatellite program provided a solid basis for further development leading to a more precise and reliable clinical urine-measurement 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 inform nursing personnel of unusual conditions. Through computer hook-up, it can also be used to control the rate at which additional fluids are administered to the patient, permitting precise maintenance of body-fluid content.

A less sophisticated version of this device has been in clinical use for more than a year. Used to maintain the fluid levels of cardiac patients during the first 24 hours after surgery, it has proved useful 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. Following successful demonstrations of these units, additional prototypes will be released for further clinical evaluation. The unit is being studied for commercial development and marketing.

Ultrasonics-Assisted Removal of Cataracts. Eye researchers at the Baylor College of Medicine in Houston are evaluating a new surgical technique for removing eye cataracts which uses the Archimedes-pump principle and ultrasonics to

emulsify the hardened lens material and keep it in suspension as it is removed from the eye. The new approach allows the surgery to be performed rapidly through a very small incision and with minimal trauma to the patient. The technique and associated equipment were originally developed in a joint effort involving the NASA Lewis Research Center and Dr. William McGannon, a Cleveland opthalmologist. An immediate advantage to the patient is rapid recuperation, a matter of three or four days as contrasted with the six-week recovery period that follows conventional cataract surgery.

The surgical tool used combines ultrasonic energy with a miniature screw pump that rapidly dissolves and removes the cataract. The tool may also be useful for the removal of vitreous material from the eye.

Testing of the new technique and instrument will be on laboratory animals. The ultrasonic approach will be compared with other available and proposed cataract-removal techniques and data will be disseminated to the medical community, particularly the National Eye Institute.

Detection of Eye Tumors Using Radiation Probes. A semiconductor radiation detector developed for NASA has been adapted to a probe for greater diagnostic precision in the diagnosis of eye tumors.

The device — now commercially available — is being used by physicians to detect the beta-radiation emitted by radioisotopes which are administered intraveneously to patients with suspected tumors that are either hidden from direct observation or are in such an early stage of development that they cannot be detected by conventional means. Since tumor cells absorb radiation differently than normal tissue, detection of increased radioactive emissions can help determine if a tumor is present.

Currently, physicians using the radiation-detection technique for diagnosis, have to insert a dime-sized Geiger counter probe between the patient's eyeball and eye socket. The probe is both excessively large and lacks sufficient directionality to provide precise information on whether increased levels of radiation indicate a tumor or simply an increased blood flow in one of the eye muscles.

In contrast, the adapted NASA radiation detector is small enough to put in a 2-millimeter diameter probe. Mounted at the tip of a catheter, it can be inserted behind the eye with minimum trauma. The probe, which incorporates a thick-film preamplifier next to the detector, has a signal-to-noise ratio that is compatible with recording equipment. It is highly sensitive and produces a realistic measurement of the spatial and energy distributions of beta-radiation.

Using the device, doctors can determine more accurately the distribution of the isotope, making their diagnoses more specific. This could reduce the present high number of false-positive tumor diagnoses and unnecessary surgical removals of the eye.

Video Requirements for Remote Medical Diagnosis. With the increasing commitment to provide quality medical care to all citizens — be they in remote rural or inner-city areas — it has become clear that widespread use of television will become an important tool for the support of facilities remote from major medical institutions.

In light of this future need, a National Academy of Engineering subcommittee has suggested that the NASA video-communications capability demonstrated in the Apollo missions could make a significant contribution to the system design and evaluation of the necessary video links for medical purposes.

While the concept of using video to assist the delivery of remote medical service is gaining widespread support, it is also clear that the standard commercial video image is not ideally suited to many medical applications. Also, given the scarcity of available spectrum space, bandwidth, and the economics of transmission systems, it is important to determine what is truly required of the video system. For instance, the viewing of an x-ray negative or a microscope slide obviously does not require the high frame rates normally necessary for motion conditions although improved resolution would be desirable. High frame rates may only be necessary for certain specialized applications such as neurologic examination and physical or speech therapy.

In July 1972, NASA's Telemetry and Communications Division at the Houston Manned Spacecraft Center signed a contract to perform a study of Video Requirements for Remote Medical Diagnosis. The NASA technical monitors for the contract include medical, bioengineering and communications specialists. By determining minimum qualities of the video

image necessary for a physician to gain enough information to make a valid diagnostic discussion, the analysts hope to determine the video requirements in a diversity of clinical situations. At the completion of the contract, NASA plans to define the video capability which can be acquired for varying investments. They will also report on the costs of added capability.

This study is being coordinated with the Health Services and Mental Health Administration of the Department of Health, Education, and Welfare in keeping with HEW's role as the health-care agency with final responsibility for the development and implementation of technology for the improvement of health care.

SUBJECT INDEX

ORGANIZATION INDEX

TECHNOLOGY APPLICATIONS PROJECTS COVERED IN DETAIL IN EARLIER REPORTS

1. Technology Applications Progress Report. May, 1972.

BIOMEDICAL PROJECTS **Page**

PUBLIC SECTOR PROJECTS

2. Applications of Aerospace Technology in the Public Sector. November, 1971.

BIOMEDICAL PROJECTS **Page**

PUBLIC SECTOR PROJECTS