

(NASA-SP-5119) TECHNOLOGY UTILIZATION N74-21604  
PROGRAM RECEIPT (NASA) ~~78~~ p HC \$4.00  
29 CSCL 05B  
Unclas  
G1/34 31547

# technology utilization program report

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION



NASA SP-5119

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December 1973



*Technology Utilization Office*

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

1974  
*Washington, D.C.*

For sale by the National Technical Information Service  
Springfield, Virginia 22151  
Price -- \$3.50

# Introduction

The year 1973 offered a number of vivid demonstrations of the additional value of the nation's investment in aeronautics and space research and development. Increasing spread and use of material from this rich technical storehouse in vital non-aerospace applications characterized this year's effort.

The past year also brought space technology very close to the heart of more than 100 human beings. These were persons who would normally have required costly operations every two years to replace the worn out batteries in their cardiac pacemakers. They were the first recipients of a revolutionary new externally-rechargeable cardiac pacemaker jointly developed by NASA Goddard Space Flight Center, the Johns Hopkins Medical School, and the Johns Hopkins Applied Physics Laboratory. This aerospace-derived pacemaker, which uses hybrid circuitry and satellite batteries, is now broadly available to heart patients.

During 1973, 550 Tech Briefs were added to the more than 5,000 technical innovations currently available for use by American industry. In addition, more than 68,000 U.S. industrial and commercial firms requested additional

technical data on these innovations. Some 3,000 firms spent \$625,000 for special technical assistance provided by the Technology Utilization Program's Regional Dissemination Centers. Also, 912 firms purchased 335 computer programs and 5900 related documentation packages for \$221,530, which is another measure of the greatly expanded use of space technology throughout the economy.

Another highlight of the past year was the demonstrated utility of NASA-developed ferrofluids--colloidal suspensions of ferrite particles--in the efficient separation of such nonferrous metals as nickel, zinc, copper, and aluminum from shredded automobile scrap. Also, the nation's fire services took a step toward a major improvement in their ability to fight fires and protect the lives of firefighters when a NASA-developed firefighter's breathing system was prepared for delivery to three big-city fire departments for test and evaluation.

We believe that 1973 was truly a year of substantial advances in the delivery of technology transfers to American industry, as well as a period of major progress in the demonstrated applicability of NASA technologies to significant public problems.



Jeffrey T. Hamilton, Director  
Technology Utilization Office  
National Aeronautics and Space  
Administration





# Technology Utilization .....

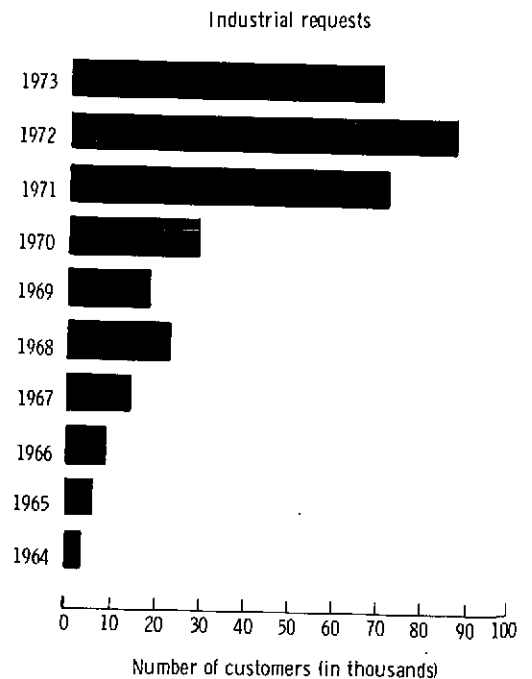
The NASA Technology Utilization Program, originally called the "Industrial Applications Program" was formally established in June 1962. In the very early phase of the program, its charter was derived from Section 203(a)(3) of the Space Act of 1958 which charged NASA with the responsibility to "provide for the widest and most practicable and appropriate dissemination of information concerning its activities and results thereof." By 1967, however, the program evolved a set of specific objectives:

1. To increase the return of the national investment in aerospace research and development by encouraging additional uses of the knowledge gained in those programs.
2. To shorten the time gap between the discovery of new knowledge and its effective use in the marketplace.
3. To aid the movement of new knowledge across industry, disciplinary, and regional boundaries.
4. To contribute to the knowledge of better means of transferring new knowledge from its points of origin to its points of potential use.

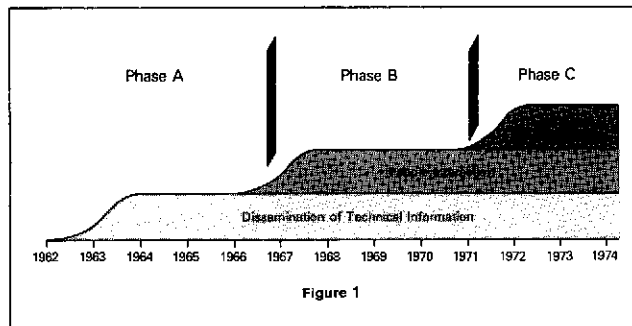
These technology transfer objectives presented a formidable challenge for the Space Agency since no other precedent existed at that time in the Federal government. Thus the NASA Technology Utilization Program in its early days, was highly experimental. Since then, the program has evolved into an operational one in which tried and proven technology transfer mechanisms have become programmatically institutionalized.

The evolving character of the NASA TU Program since its inception is depicted in fig. 1. Initially, technical information dissemination constituted the primary focus of NASA's technology transfer efforts. As the transfer process became better understood, new and more sophisticated mechanisms were added. The three (3) basic program functions which now exist -- dissemination of technical information, people interaction, and hardware adaptation -- grew out of a recognition that new technology and know-how exist in several basic forms, and thus require different methodologies and mechanisms to optimize their transfer and utilization.

Several measures of progress and the breadth of transfer mechanisms, methodologies and activities are highlighted in this brief ten year program summary.



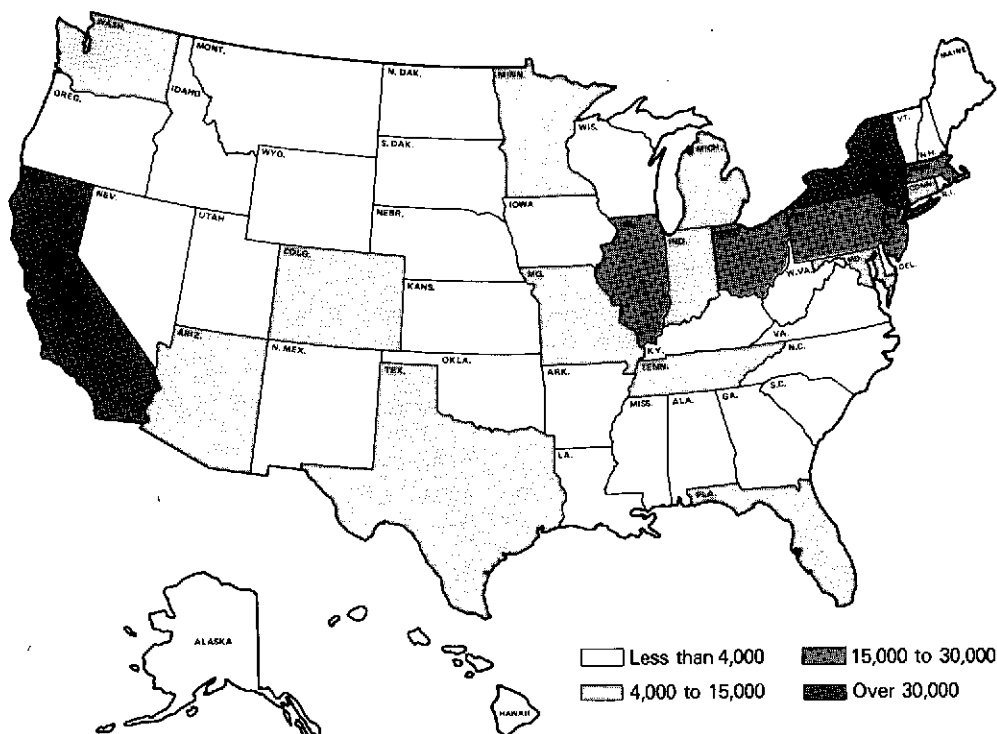
# ..... Ten Years at a Glance .....



## Our Customers

Over the past ten years the number of technology transfer contacts with non-aerospace organizations has been estimated to approach the 1,000,000 mark. Private industrial firms, trade associations, universities, professional societies as well as numerous public

sector institutions at the Federal, state, and local levels have benefited by the nationwide interactive association carried on through the NASA Technology Utilization Program. The aggregate distribution of those customers served via NASA's technology transfer efforts is shown below:



# **NASA's Technology Utilization Program: The Transfer of Aerospace Technology**

As the cases immediately below will illustrate, technology transfer often occurs through a "natural diffusion" process, yet there is a clear need for structured, conscious efforts to organize, stimulate and accelerate the application of new technology to purposes beyond those for which the new technology was originally designed. This is especially true of the nation's aerospace programs. The high costs of developing the technology at public expense underscore the need to extract maximum and repeated benefits from the public investment.

The stimulation and organization of this transfer of technology from aerospace programs to the nonaerospace public and private sectors is the prime mission of the NASA Technology Utilization Program. In this effort NASA is meeting the requirement in the Space Act of 1958 that technology emerging from aerospace programs be disseminated as widely as possible in the public interest.

## **"Natural Diffusion"**

Before tracing the various elements of the Technology Utilization Program, it is useful, by way of illustration, to provide some examples of the "natural diffusion" process -- since the structured approaches of Technology Utilization complement the natural diffusion process in the wide field of technology transfer.

### **Two Examples of "Natural Diffusion"**

Between 1958 and 1961, Pratt and Whitney Aircraft, a division of United Aircraft Corporation in Connecticut, was trying to develop commercial fuel

cells with its own funds. But, by the end of 1960, the company was about to drop the project because developmental problems appeared too complex for economical solutions. Then, the company received a NASA contract to build a 250-watt demonstration fuel cell for aerospace purposes. Later, in 1962, Pratt and Whitney was awarded a contract from the NASA Manned Spacecraft Center to develop and manufacture fuel cells for the Apollo spacecraft program.

This extended the company's fuel cell work for five years and spurred the construction of a production plant with more than 300 workers.

The fuel cells used pure oxygen and hydrogen. Unfortunately, these fuels are not available at economical prices for ground-power uses. So, some \$70 million have been invested since 1962 in work on technology that would make possible the use of standard gas and liquid fuels with oxygen from ambient air. Nearly one-half of this money was provided by a group of 28 gas and gas/electric utility companies through a joint program set up with Pratt and Whitney.

The program is called TARGET (Team to Advance Research for Gas Energy Transformation). As a result, 12.5 kilowatt fuel cell-modules produced in the program have operated nearly 100,000 hours at 20 sites around the country.

Recently, Pratt and Whitney developed a much smaller version of the unit, but with the same electrical rating, which is now on the market. Further refinement is necessary. But it is likely that eventually the fuel cell, spurred by

aerospace requirements and then adapted for ground-power uses, will become economical for the mass market.

The Pratt and Whitney experience might be called mission-oriented natural diffusion. But, there are other ways technology is naturally diffused.

For example, technology can also be transferred through the medium of the professional technical community. This is illustrated by the application of NASA-developed stress-measurement techniques to nonaerospace tasks. Here is how a case in this category proceeded.

NASA's concern with minimizing the weight of flight systems had led to the extensive use of high-strength materials which are often extremely sensitive to flaws.

The NASA Lewis Research Center developed a plane-strain fracture toughness test to define this sensitivity. The test allowed engineers, for the first time, to measure the weakening influence of cracks in selected structural materials.

This test is now embodied in American Society for Testing and Materials (ASTM) test standards, by way of encouraging designers of critical structures to adapt the NASA test procedure as part of their best practice. Westinghouse has already applied the NASA test method to its power-generating equipment. And, producers of primary metals, including Alcoa and U.S. Steel, have noted that a large number of their customers are demanding these tests. This clearly indicates that natural diffusion of an important technical innovation occurred.

There are many other examples and styles of natural diffusion of aerospace technology that could be brought to those who would normally not have access through a structured program.

### **The Need for Structured, Organized Technology Transfer**

NASA recognized early that the

rather informal and sometimes serendipitous process of natural diffusion had to be enhanced and accelerated through the development of an organized technology program; hence, the establishment of the Technology Utilization Program back in 1962.

After ten years of evolution, the Technology Utilization program now uses three basic and complementary technology-transfer mechanisms: Publication, Technical Assistance Dissemination, and Application Demonstrations.

### **Publications**

Each of NASA's field installations has a Technology Utilization Officer. His assignment is to identify, document and evaluate new technology generated by NASA and its contractors. In addition, he is also charged with assuring that such technology is rapidly available to potential users in and out of the aerospace community. These Officers administer a special clause in NASA contracts with private firms. The clause requires contractors to report to NASA any new technology developed in the course of their work. And, such new technology -- when it is deemed to have commercial potential -- is announced to business and industry through various media.

### **The Tech Brief**

The NASA *Tech Brief* is probably the most widely known announcement medium. It is a technical description of an innovation, with straight-forward explanations of basic concepts and principles. The Tech Brief reader can obtain more detailed information from a NASA *Technical Support Package* (TSP). The TSP includes test data, drawings, specifications, and it is available by writing to the Technology Utilization Officer whose address is provided in the original Tech Brief. While obviously innovations often need to be modified for new applications, the record indicates high interest and

considerable technology transfer stimulated by Tech Briefs and TSPs.

For example, NASA Tech Brief 70-10520, which describes a NASA Langley Research Center flowchart, provided an ordered test sequence allowing quick identification of metals and alloys and attracted major industry attention. The accompanying TSP attracted requests by more than 1,000 people. Using the NASA system, even complex alloys can be identified in 30 minutes or less by workers with very little training. The test requires only the application of standard chemical reagents to metal surfaces, spot-plate depressions, or on filter paper. Colors or specific reactions produced by the reagents allow identification, and only a minute amount of the metal is destroyed.

Many of the people who inquired for details have found applications for the system. And, the Institute of Scrap Iron and Steel has distributed copies of the NASA Tech Brief to its member companies.

Here are some examples of applications of the NASA spot-test technique:

- The Houston Branch of the Rockwell Manufacturing Company, a producer of offshore oil rig equipment, uses the spot test as a standard procedure to process customer complaints on malfunctioning equipment. Such malfunctions often result from using incorrect alloys in a given component.
- An industrial hygiene chemist with the New York State Department of Labor is using the spot test to help identify health hazards associated with metal fabrication. He is especially interested in alloys using beryllium and cadmium.

Another example of Tech Brief spurred technology transfer:

- The Boeing Company, under contract to NASA Marshall Space Flight Center, invented a portable, electrically-powered ultrasonic hand tool for rapid scanning of spot-weld discontinuities in small and inaccessible places. The unit includes an ultrasonic search unit attached to a solenoid in a housing assembly that includes the scanning motor. The solenoid is fitted with a recording stylus in contact with pressure-sensitive paper to provide a read-out of results. The front end of the scanner is placed on the area being examined. The spiral scanning motion of the ultrasonic search unit is recorded as a spiral pattern on the pressure-sensitive paper. Weld discontinuities appear as breaks in the spiral pattern.

The Moragne Machine and Manufacturing Corporation in Texas is using several copies of this hand tool, built on its premises, to inspect welds on equipment produced by Moragne for industrial uses. The Company's president has used the original NASA TSP and other TSPs in an extensive investigation of ultrasonics. Those investigations have produced inventions: a patented ultrasonic precipitator to clean the air in the Houston Astrodome, a carbon- and fire-brick plant; and a welding method in which the work piece is vibrated ultrasonically to produce a superior weld. The company president credits NASA technology-transfer for some \$3.5 million worth of new sales.

Another major source of information to industry on NASA innovations that may lend themselves to adaptation is the *Technology Utilization Compilation*. These are collections of a number of related ideas into a single book, covering a general technical subject. These books are generously illustrated, and serve as workbooks on a practical level.

Some recent examples of Technology Utilization Compilation Volumes:

- Biomedicine
- Solid State Technology
- Chemistry Technology
- Electronic Control Circuits
- Computer Programs, Mechanical and Structural Design Criteria

The scope of the Tech Brief and allied dissemination efforts is illustrated by the fact that nearly 6,000 Tech Briefs -- and 84 Compilations, have been published since 1964.

And, during 1973 alone, more than 68,000 requests for detailed Technical Support Packages were received by NASA from American industry. Such a heartening response demonstrates the continued viability of this proven technology transfer mechanism.

#### **Dissemination and Technical Assistance**

Dissemination of technological information is crucial to orderly technology transfer, and the Technology Utilization Offices at the various NASA field centers play a major role in this function. Not only do they respond to inquiries stimulated by the publications programs and to inquiries of a more general nature, but they also conduct periodic conferences on specific technological subjects such as fire safety, ion plating, as well as the convening of technical conferences for specific user groups such as electric power producers.

Also, the Technology Utilization Program operates a network of Regional Dissemination Centers (RDC's) which provide access to aerospace technology for the industrial sector of the economy. Specially structured Biomedical and Technology Application Teams offer technical solutions to problems in the public sector. The overall concept is linkage -- that is, the Technology Utilization Program is geared to the conviction that

only through direct contact with potential users can transfer of aerospace technology be successful beyond the normal groups that have access to it. That means a continuing effort to work with potential users to define problems that might be amenable to aerospace-derived solutions and then to actively assist in problem solving efforts with the customers for such technology.

#### **The RDC's**

NASA's Regional Dissemination Centers are a major element in this effort. They provide available technology in response to specifically stated technical problems and information needs of users ranging from small business to the largest companies. Firms subscribing to RDC services cover a broad spectrum of the U.S. business community. The Centers also serve university faculties and students at the RDC locations, many national, state and local organizations, and government units at all levels.

A telecommunication network connecting the Centers permits RDC customers in any part of the country to reach -- through the Center most convenient to them -- the full technical resources of all the centers, and to avail themselves of the full range of data available in the total network. These include technical contributions, research findings and related material assembled by NASA's Scientific and Technical Information Office, as well as comparable information from other sources on advanced research and development. The RDC's through their working relationships and people-to-people contact with NASA field centers, act as constant catalysts to bring industry closer to problems and needs closer to NASA's technical experiences and capabilities.

The Centers serve as professional technical-assistance consultants to clients in the major industrial regions in which they are located, providing two

basic kinds of service: technical information gathered by retrospective search of the NASA data bank to uncover all information relevant to a given problem and 'current awareness' service that informs clients of innovations. The data includes abstracts, research reports, full-text printouts of technical articles, and other documents. Also, clients can receive technical assistance on specific problems from RDC staffs and from NASA research scientists and engineers.

The response to the RDC service is illustrated by the fact that last year the Centers provided service to *more than 3,100* industrial clients, a 50% increase over 1972. The RDC's also aided a number of state and local governments by providing access to advanced aerospace technology.

#### Regional Dissemination Centers:

- Aerospace Research Applications Center (ARAC), Indiana University, Bloomington, Indiana 47401
- Knowledge Availability Systems Center (KASC) University of Pittsburgh, Pittsburgh, Pennsylvania 15260
- New England Research Application Center (NERAC) The University of Connecticut, Storrs, Connecticut 06268
- North Carolina Science and Technology Research Center (NC-STRC), Research Triangle Park, North Carolina 27709
- Technology Application Center (TAC) The University of New Mexico, Albuquerque, New Mexico 87106
- Western Research Application Center (WESRAC) University of Southern California, Los Angeles, California 90007

The NASA Technology Utilization Program leadership is convinced that many of the discoveries emerging from

the nation's aerospace program have potential nonaerospace applications. And, the RDC's have already developed a strong record of participation in successful technology transfer along these very lines.

One recent example: A Regional Dissemination Center recently assisted a company that was looking for a way to remove bacterial organisms that were contaminating large vats used in the production of antibiotics. An RDC search of NASA data sources revealed chemical methods that had long been used to clean NASA space rocket fuel tanks. The aerospace solution made it possible for the company to solve its problem without diverting expensive technical manpower from their regular work.

Most often, companies call on RDC's for information on a specific problem. For example, Pyronetics, a company in California, was developing a portable, low-cost multi-purpose welding torch. But, the company faced the technical problem of a bulky high-pressure oxygen supply. Pyronetics asked for an RDC search of NASA data for information on chlorate candles. These candles are unique in that they generate oxygen while they burn. The Western Research Application Center at the University of Southern California provided information on chlorate-candle composition, hazards, applications and manufacturing and shipping regulations. The data was crucial to the development of Pyronetic's final market product -- which weighs only seven pounds. By the end of 1972, more than 20,000 units had been sold.

Another very typical example. Owens-Corning Fiberglas in Texas is supplying the insulation for the Alaskan pipeline. Unique thermal stresses and concern with environmental considerations required the company to analyze the mechanical-thermal stresses on the insulation, which was to be made of a jacketed rigid foam. An RDC data bank search identified a NASA report dating

back to 1965 that offered the basis for the required analysis.

Another example of RDC contributions: The ILC Company in California produces pulse lamps and continuous-wave devices and communication equipment. This firm asked the Western Research Applications Center to prepare a state-of-the-art search on arc-lamp cathode technology. Using the data from the search, the firm introduced several innovations into their arc-lamp product line. ILC says that the RDC service saved them \$25,000 and improved their competitive position.

An example, in the field of archaeology: The Department of Anthropology at the University of New Mexico has been working with the Department of the Interior's National Park Service in the search for and identification of an important Indian ruin in the Chaco Canyon (New Mexico). To aid this important scientific effort, the Technology Application Center at the University of New Mexico has been providing remote-sensing mapping assistance. The Chaco area is estimated to be as large as the well-known ruins in the Mesa Verde National Park. Through the use of remote-sensing maps provided by the RDC, the original identification of the site from the ground has been expanded from ten to 200 miles. Ancient roads have been identified in the 200-mile area mapped. Researchers believe that further study of remote sensing data will establish an interconnecting road between the Mesa Verde and Chaco Canyon communities that existed some 3000 years ago.

### **COSMIC**

The U. S. space program has spurred major advances in computer technology and NASA's Technology Utilization Program has provided access to these software benefits to the Nation's computer users. Thus, an important component in the technology transfer effort is NASA's Computer Software and

Management Information Center (COSMIC), located at the University of Georgia. This Center collects, evaluates, and distributes computer tapes, cards, decks, program listings and machine-run instructions. COSMIC and all Regional Dissemination Centers sell "software" to potential users at prices based on cost of reproduction and distribution.

COSMIC serves as a central clearinghouse and dissemination outlet for computer programs and related data developed by NASA and its contractors, as well as those developed by the Department of Defense. The Center is now established as a locus of support for the industrial, educational and business communities. It has already disseminated nearly 20,000 items.

New items are constantly being added to the COSMIC program inventory and nearly 1,000 complete programs are now available.

One example of technology transfer in the computer program field is NASTRAN (NASA Structural Analysis Program). NASTRAN is a general purpose digital-computer program originally developed to analyze static and dynamic behavior of elastic structures. The program was originally and is still used, by NASA and aerospace companies, to analyze aircraft fuselages, wings and tail assemblies, space vehicles (Viking and Skylab) and related launch facilities and turbine engines.

Because of its versatility, this computer program is now widely used by scores of firms including the Ford Motor Company (to assure quality of auto frames). More than 200 companies have purchased the NASTRAN program. Ford, one of the most well-known users, says it is saving \$12 million a year with this computer program.

### **Application Teams**

Nationally significant public problems are the focus of the Technology



Utilization Program's applications teams. These teams, composed of NASA technical specialists and technology transfer agents under contract to NASA, concentrate on public problems, in medicine, environment, transportation, housing and general concerns of the state and local level. Their basic purpose is to work with publicly significant problems and match them with potential aerospace solutions.

Some of the most dramatic achievements of this effort have been in the medical field. A biological isolation garment now being used by the National Cancer Institute (NCI) is a case in point. One of the techniques being used by the NCI to treat leukemia in young children requires that they be protected from infection and they must be kept in a sterile environment. This consideration has prevented the children from leaving the sterile room either for lab tests in other portions of the hospital or for recreation. Working with NCI, the NASA Biomedical Application Team identified the biological isolation garment developed for the Apollo astronauts and arranged for the loan of a garment to NCI. The NCI had a child size version built and has found it to be quite successful, permitting the children to readily leave the isolation of the sterile rooms and providing a considerable psychological boost.

A second example is the development of a lightweight, longer duration breathing apparatus for firefighters. NASA's attention to this problem originated in the strongly expressed need of municipal fire departments for such devices. In cooperation with the National Bureau of Standards Fire Technology Division and Public Technology, Incorporated, NASA initiated an effort in the spring of 1971 to develop improved equipment. An interesting aspect of the program is a User Requirements Committee organized by PTI consisting of fire chiefs, a city manager and union representatives who have met periodically with NASA

engineers to review the program. These meetings have assisted NASA in understanding and meeting fire service needs. Twenty prototype breathing apparatus units will be released for field tests by fire departments in the spring of 1974. This program is described in greater detail in the body of this report.

The Application Teams, through working partnerships with the NASA Field Centers and in consultation with potential users of NASA technology, facilitate the process of adaptation of aerospace technology to public-sector uses. The program is planned so that adaptive design and prototype fabrication can be performed when necessary on high priority projects. Field testing by mission-oriented user organizations follows the hardware development program.

This problem-solution matching process and its attendant prototype development and testing phases are especially geared to extracting a second round of benefits for taxpayers who have already invested in aerospace technology.

#### **Technology Sharing**

The Technology Utilization Program has placed special emphasis in dissemination and offering technological assistance to small minority business and sharing the space technology investments with state and local jurisdictions. These initiatives were directed through the NASA Technology Utilization Offices, the Regional Dissemination Centers and the Applications Teams. In fact, 50% of the RDC clients are small businesses and many of the applications team clients are state and local governments. These activities were augmented by some specific experiments:

- An interchange of personnel with the State of Texas assesses the technical needs of a very large state and determines the optimum mechanism to meet them;
- The addition of a representative of

the small minority business community through the President's Executive Interchange Program to refine programs intended to enlarge technology transfer to the special needs of these groups. This new emphasis has developed a market for the NASA complex coordinator for screening of transit operators. The computer coordinator is now being commercialized by J.W. Williams Micro Electronics, a minority business firm in Philadelphia.

A special project was initiated to investigate the feasibility of applying aerospace technology and NASA technical assistance to the solution of important problems facing New York City. A full-time NASA representative, working in and with New York officials, sought out significant problems facing the New York City Administrator and

matched them with existing NASA technology resources. Two of the more significant results in the last year were the installation of an improved security system in two of the city's schools, based on an invention developed at the NASA Jet Propulsion Laboratory, and the evaluation of a NASA Ames-developed drug detector by NYC Police Department.

### **Technology Application**

The last mechanism used to transfer aerospace technology is the adoption and demonstration of specific technical advances to significant public needs. A necessary requirement in most of these application projects is their early commercialization to insure lasting and widespread use.

Detailed description and analysis of the active projects follow in the next section.

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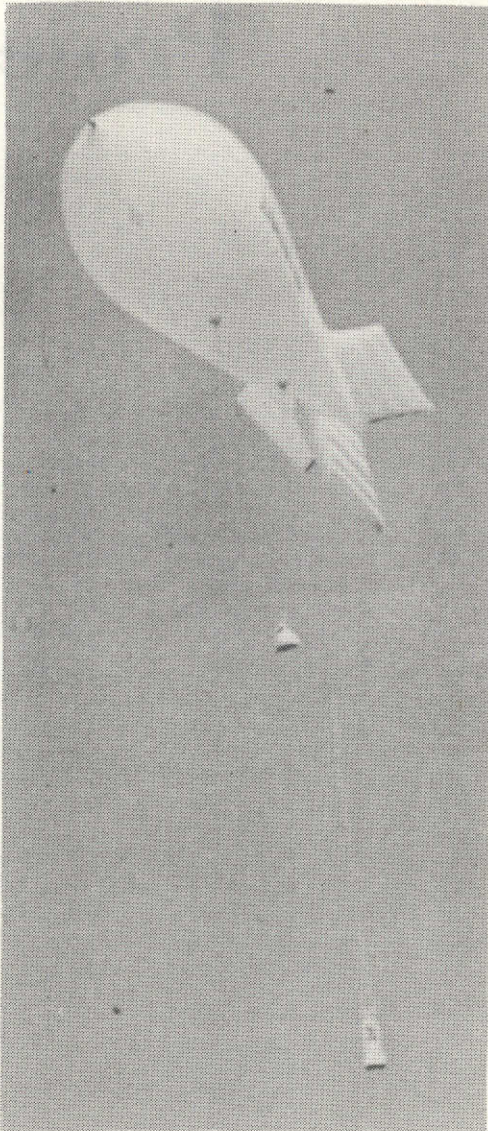
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# Public Sector Projects



# Environment



An instrumented tethered balloon supplied by the NASA Langley Research Center to the University of Wyoming to study aerosols.

**Atmospheric Pollution Programs Using LIDAR and Balloons.** NASA Balloon and LIDAR (laser-radar) technology is being used to aid environmen-

tal analysis of atmospheric aerosols, in order to better understand the effects of man-made chemical pollution.

One project uses LIDAR techniques already applied successfully by NASA to study the clear air turbulence problem that is of major interest to aviation.

The LIDAR environmental study -- sponsored by the California Air Resources Board -- is aimed at obtaining information on the vertical distribution of aerosols near the ground. The overall objective of the project is to show the LIDAR's ability to gather information for air pollution research. Measurements by the LIDAR system will show spatial and temporal distribution of pollutant particles in the earth's mixing air layers, their effects on visibility, and the longitudinal variations of the aerosol formations. This project developed from discussions between NASA Langley Research Center specialists and the Rockwell International Science Center, contractor for the California Air Resources Board. The NASA Langley Research Center is also working with the Virginia State Air Pollution Control Board to study air quality, using the LIDAR at a site in Norfolk, Virginia. A compact LIDAR system is being developed to serve these projects and for use in further studies in Virginia, Texas and New York.

In a related program, with NASA support, the University of Wyoming is studying aerosols by using instrumented tethered balloons of the NASA Langley Research Center. This project also uses Langley Research Center laboratory equipment such as the electron probe and a particle measurement computer. The instrumented balloon packages can measure different

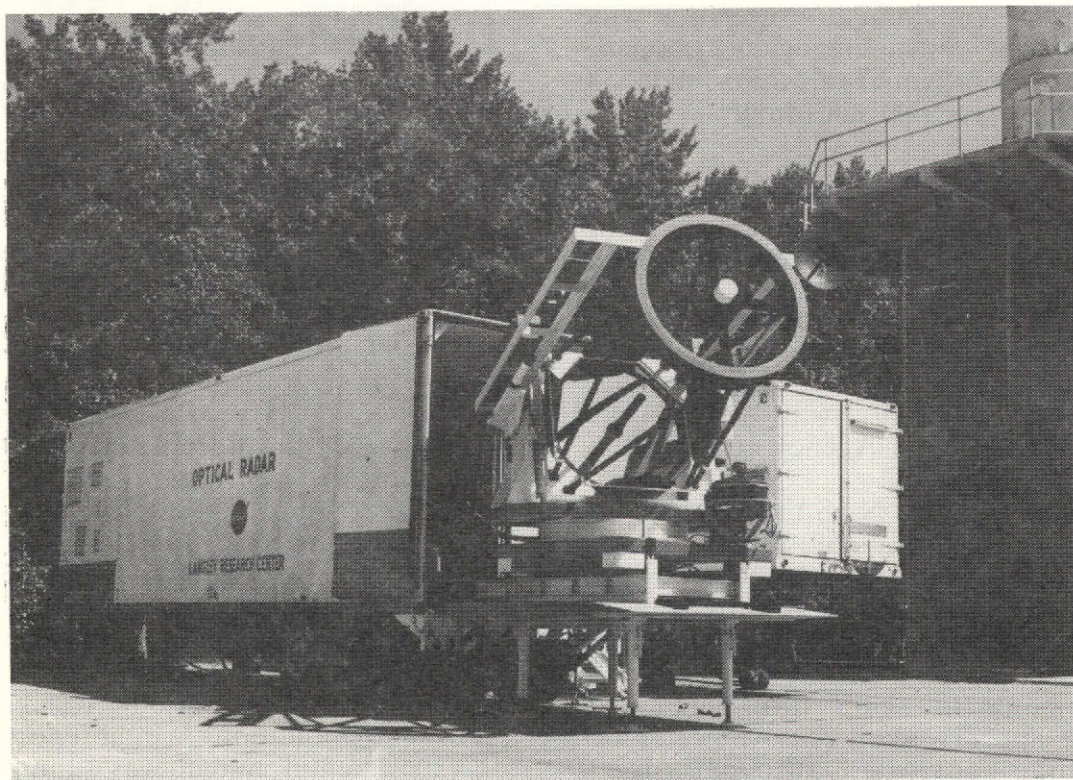


sizes of aerosols, temperature, pressure, ozone concentration, wind speed and direction, then telemeter all the information to a ground station simultaneously.

The overall purpose of this project is to measure the aerosols at various levels of the lower atmosphere and analyze the 'residence' times of the aerosols at particular sites. This will provide information -- crucial to pollution research -- about movement and redistribution of these particles over the long term. Random sampling over urban and remote areas could provide data on how man-made pollution competes with natural aerosols. Local and regional studies will be conducted by the University of Wyoming during 1974 and a data-acquisition system tailored for the air pollution analysis mission will be delivered in 1974.

**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, has served as 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 as an air speed indicator for vertical and short-takeoff-and-landing aircraft. The Bowles Fluidics Corporation of Maryland developed the original hardware for the Electronics Research Center. The operation of the flowmeter is based on the measurement



**LIDAR developed at the NASA Langley Research Center is being evaluated by the California Air Resources Board and the Virginia State Air Pollution Control Board to study vertical distribution of aerosols near the ground.**



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 was delivered to Dallas and promising 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 end of 1973.

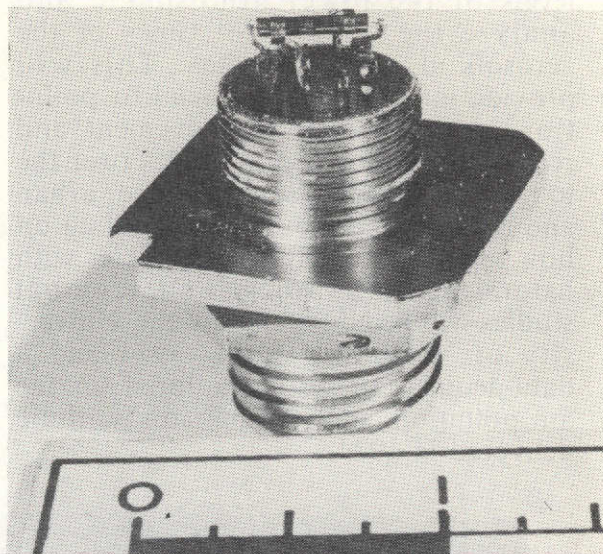
The device under test offers a number of advantages. It has no moving parts. It is self-cleaning and rugged. It provides no obstruction to sewage flow and, in general, can operate unaffected by foreign bodies and corrosive conditions.

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. Market analysis suggests the device has potential for use in a wide variety of waste-management operations, with potential sales of some 4,000 units with a \$1000 sales price.

**Air Pollution Detection.** Technology developed for the detection of gaseous and other contaminants in space cabin atmospheres and NASA's miniaturization requirements are being applied to earthbound air pollution detection programs in cooperation with the Environmental Protection Agency and the Bureau of Mines.

For example, NASA and EPA are testing the utility of aerospace microwave spectrometry techniques to measure formaldehyde in auto exhausts and ambient air. Formaldehyde, a chemical that not only irritates eyes but also contributes to smog formation reactions, appears to increase in catalytic-converter-controlled auto emissions. Thus, while hydrocarbons and nitric oxides are reduced, a new emission problem is apparently created. Present manual or wet-chemical methods of

measuring formaldehyde are cumbersome and time consuming. Working with NASA Langley Research Center and EPA, the Atomic Energy Commission's Lawrence Radiation Laboratory in California has developed a mi-



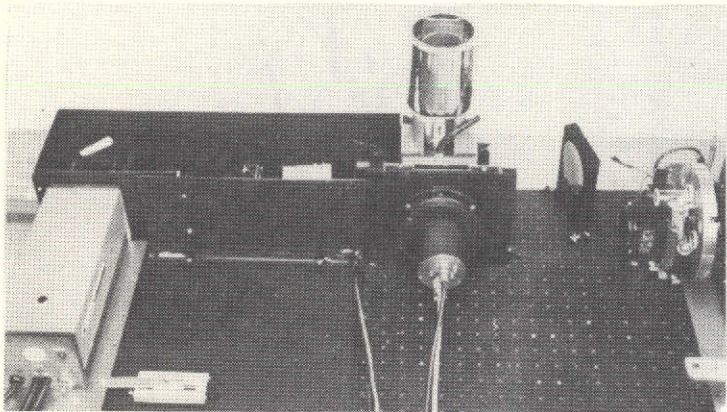
**Methane and other hydrocarbon pollutants can be detected utilizing indium-oxide thin film techniques originally developed to detect hydrogen leaks in spacecraft.**

crowave spectrometer that can detect formaldehyde in quantities as low as one part per million parts of air. Final delivery of the prototype instrument is planned for early 1974.

Also, NASA Ames Research Center, EPA, and Martin-Marietta have developed a prototype infrared detector, based on technology developed for atmospheric analysis, to determine the levels of nitric oxide in industrial and urban areas, as well as other pollutants such as carbon monoxide. The ultimate objective is to develop monitoring arrays for simultaneous or periodic checks of atmospheric pollution. A final report on the experimental system was submitted in October 1973.

Another air pollution project involves the design, fabrication, and evaluation of a field-ionization-mass spec-



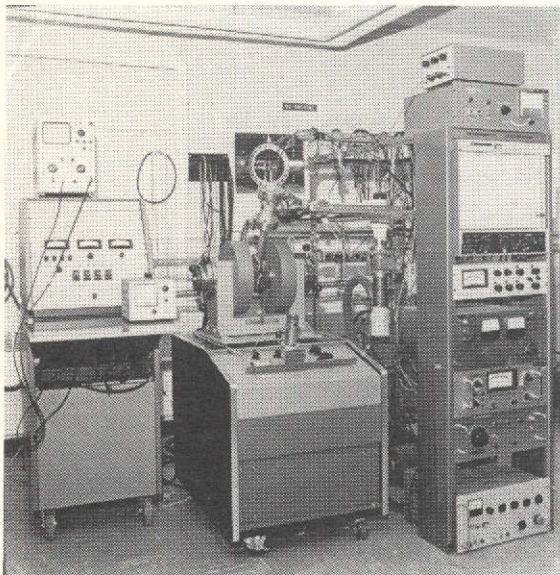


**Prototype infrared detector, based on technology developed for atmospheric analysis, to determine the levels of nitric oxide in industrial and urban areas.**

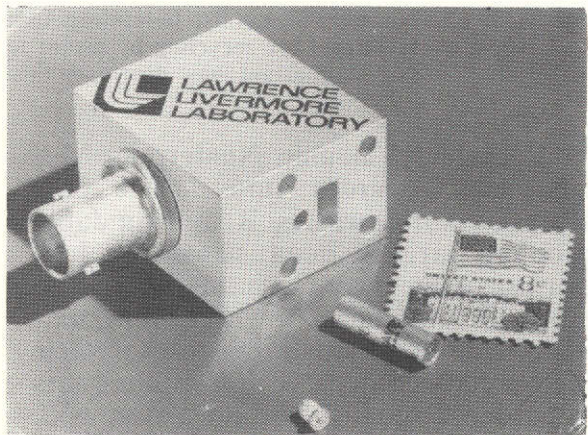
trometer to detect specific pollutants across the broad pollution spectrum. The University of Missouri is developing prototype instrumentation which will be compared against standard contaminant detection equipment. Work on this project is proceeding under the mentorship of the Ames Research Center.

Also, using indium-oxide thin-film techniques originally developed to detect hydrogen leaks in spacecraft, the films show changes in electrical resistance on

exposure to various gases. NASA Marshall Space Flight Center is developing adapted versions of these sensors to determine their sensitivity to methane and other hydrocarbon pollutants. Both EPA and the Bureau of Mines are interested in this effort to adapt General Electric-developed sensors for possible use in mines and in air pollution detection programs. Prototype units have been sent to the Bureau of Mines for testing as methane detectors in mines. Further work will lead to additional field-testing by the Bureau and by EPA.

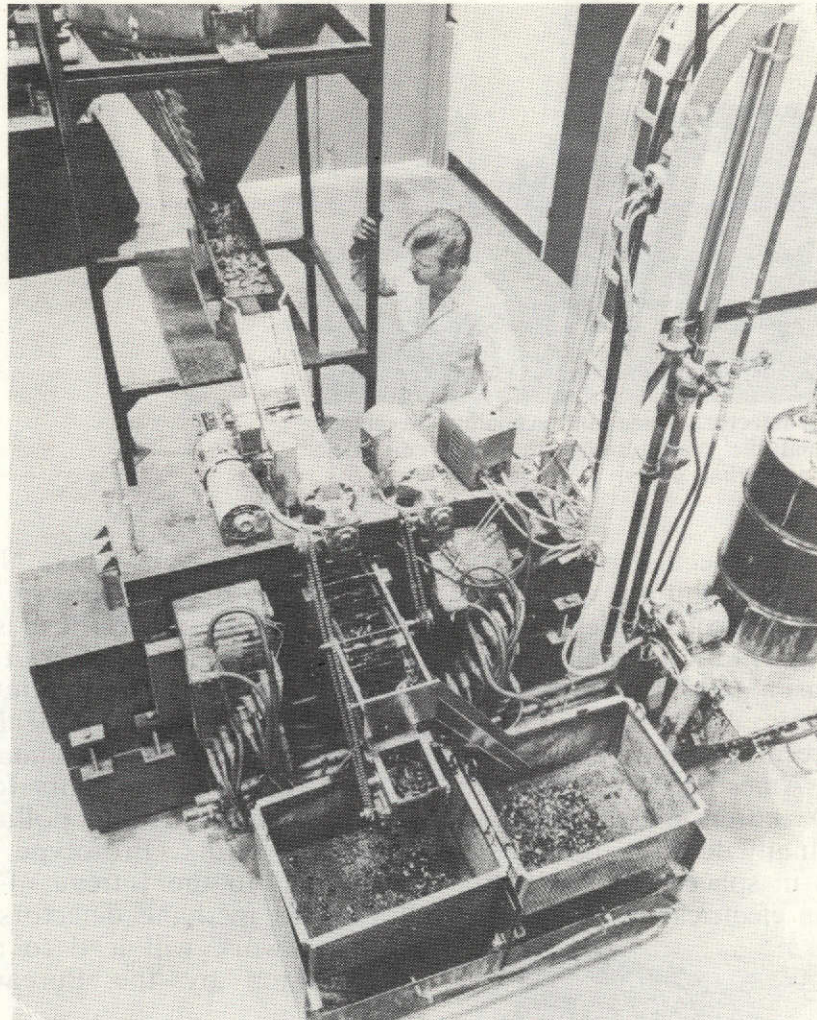


**The University of Missouri is developing a prototype field-ionization-mass spectrometer to detect pollutants across the broad pollution spectrum.**



**Aerospace microwave spectrometry techniques are being developed to measure formaldehyde in auto exhausts and ambient air in a NASA-EPA project. The technique is being developed at the Lawrence Radiation Laboratory.**





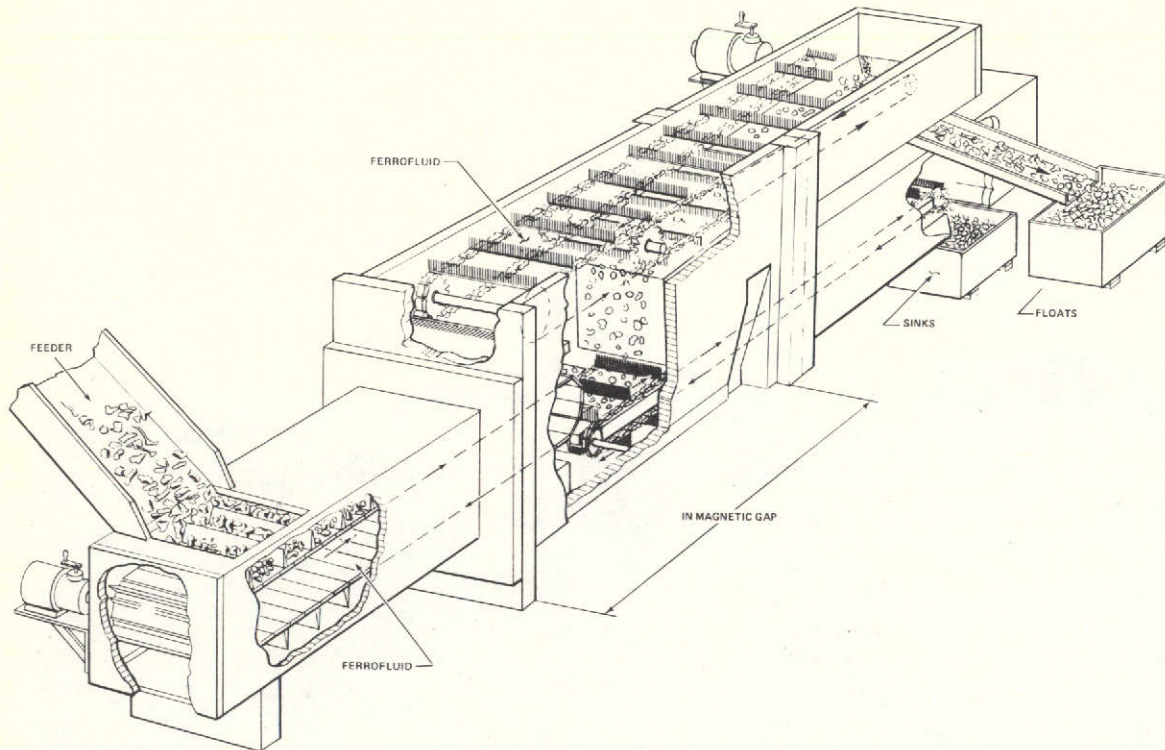
Nonferrous metals, heretofore usually discarded from scrap, can be reclaimed for recycling by use of ferrofluid techniques. AVCO, under NASA contract, has developed this ferrofluid separator unit.

**Recycling Valuable Nonferrous Metals From Discarded Autos.** The recycling of solid wastes is a formidable problem largely because of the low intrinsic value of the discarded material. Junk automobiles, however, represent high-value solid waste because of their high metals content. The 8 million cars discarded annually contain about 650,000 tons of nonferrous metals which are not being fully recovered and recycled for lack of an efficient process. The potential worth of the discarded nonferrous metals ranges from \$6 to \$11 per

car, depending on the current market price of the metals. A cost effective system of reclaiming nonferrous materials would greatly stimulate the removal of junk cars from the national scene. It will also be an aid in the recovery of valuable national resources.

Using newly developed techniques based on the properties of magnetically responsive fluids (known as ferrofluids), NASA supported the development of a prototype device for separating previously wasted nonferrous metals from scrap materials in a commercially feas-





MATERIAL HANDLING SYSTEM

ible reclamation and recycling operation.

The newly-developed method involves a technique called sink-float separation which is based on the phenomenon that nonferrous materials less dense than the ferrofluid will float while materials more dense will sink. Therefore, to separate any two materials of different density, it is only necessary to adjust the ferrofluid to a density between the two metals so that one will float and the other will sink as it passes through the ferrofluid pool on a conveyor belt.

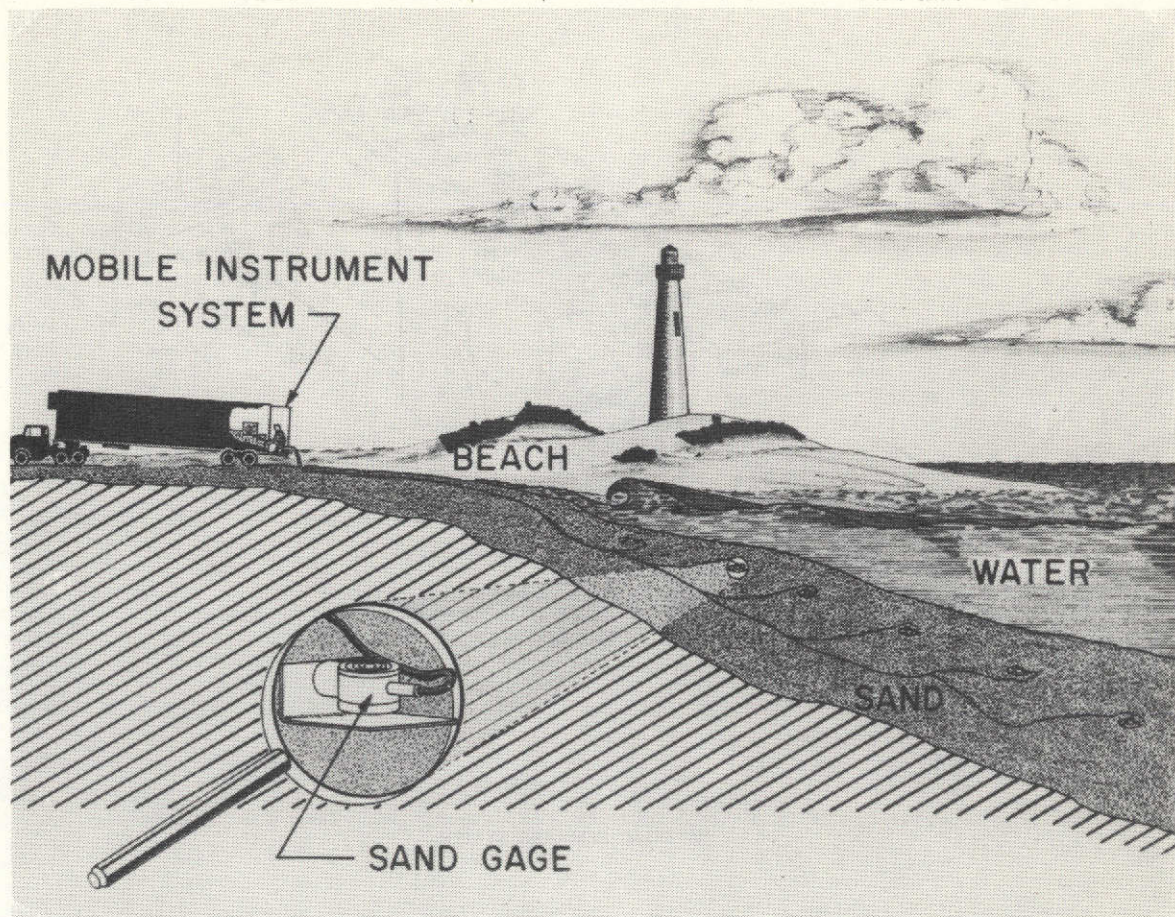
Ferrofluids are very stable suspensions of single-domain magnetic particles. A pool of ferrofluid in the gap of a regulated electromagnet becomes a liquid whose apparent density can be continuously varied over the total range of known densities by controlling the magnetic field. Thus, in a given fer-

rofluid, solid objects of densities that differ by 10% can be made to selectively float or sink by varying a magnetic field.

The only moving parts of the system are the conveyors which carry the mixed metals into the pool and the separated metals out of the pool. Mixtures of three or more nonferrous metals can be separated, one at a time, by multiple passes through the ferrofluid pool with the magnet adjusted each time so that only one metal floats (or sinks) per pass.

Under contract to NASA Langley Research Center, AVCO Corporation of Massachusetts has designed, built and tested the prototype sink-float ferrofluid nonferrous metal separator. Based upon the separation test data obtained during the experimental phase of the program, as well as the successful recycling of ferrofluid recovered from scrap, the





A sand height gauge, using technology originally developed for aerodynamic wind tunnels, is being applied to the problem of measuring beach-sand erosion and sedimentation.

recovery of nonferrous metals from automobile scrap promises to be a cost effective way to reclaim such material. It is possible to recover a high yield of aluminum, copper and zinc alloys from mixed, reshredded automobile scrap.

AVCO is currently pursuing opportunities for demonstrating the economic viability of the process, including the use of ferrofluids as a replacement for heavy media now used in many waste recycling systems.

**Sand Height Gauge to Monitor Beach Erosion.** Working with the U.S. Army Corps of Engineers, NASA Langley Research Center has successfully applied

technology, originally used in aerodynamic wind tunnels, to the problem of measuring beach erosion and sedimentation -- data crucial to coastline protection programs. Current measurement methods are essentially manual, that is, the accretions or erosion of sand bottoms are observed by divers reading graduated rods previously placed in positions under the water. This manual method depends heavily on weather conditions and does not provide the kind of timely and reliable information needed to adequately define sea-floor movement.

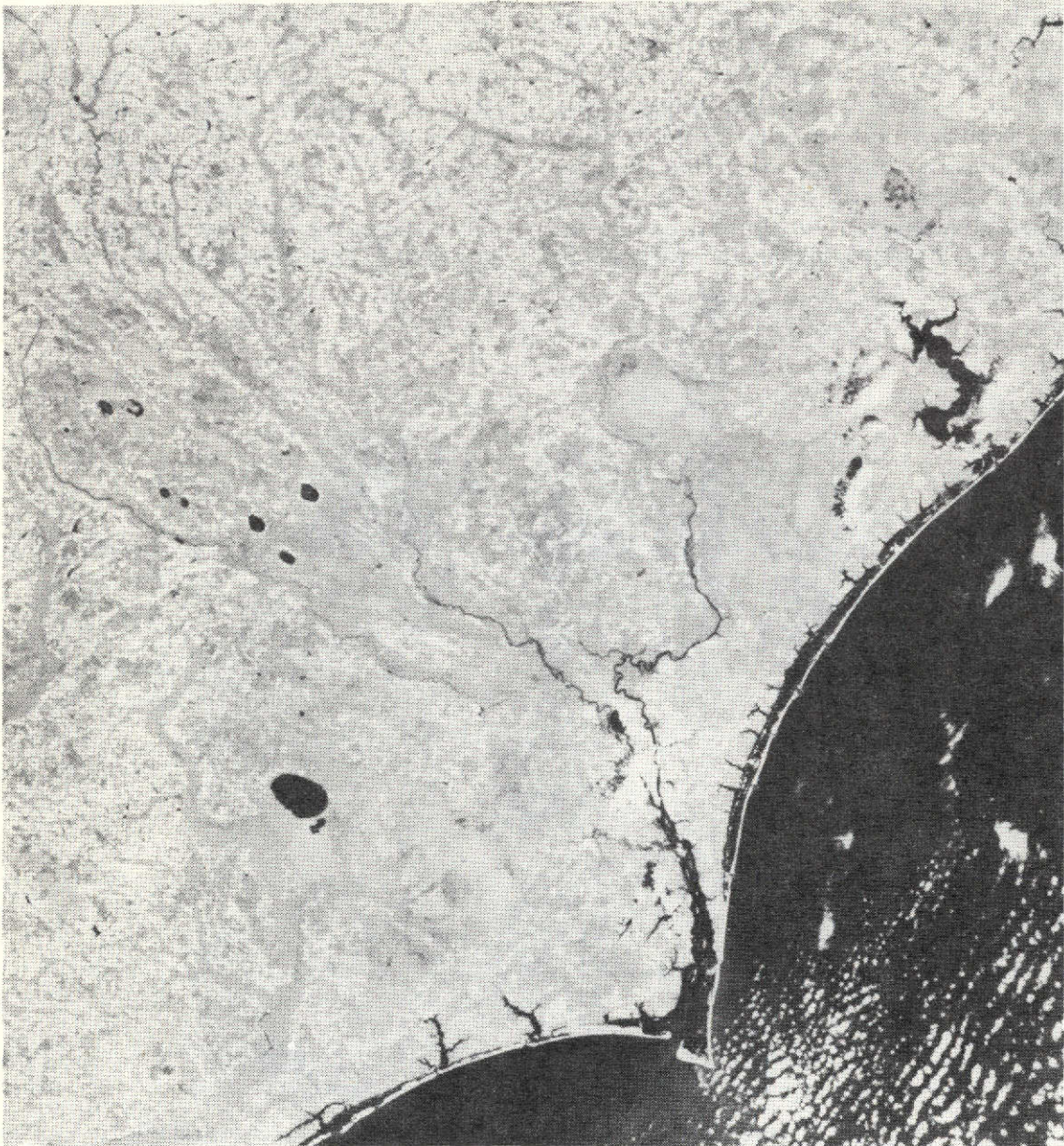
Oceanographers have wanted an economical, reliable, on-site continuous monitoring system that could be



remotely interrogated to provide continuing data on the shifting coastal profile. NASA technology could lead to the eventual development of such a system.

NASA Langley Research Center and Old Dominion University in Virginia together analyzed the feasibility of adapting sensors -- originally developed for wind-tunnel measurements -- to the sand-measurement problem.

The sand height is determined by differential-pressure sensors. Current analysis of the system shows it is capable of measurements of long-term changes in sand movement, although the prototype instrumentation has shortcomings in the measurement of short-term sand-height changes. Recommendations for further experimentation include the development of a radio-link system that would sample gathered data.



Photograph of Eastern North Carolina taken from NASA's ERTS-1 spacecraft shows bays believed to have been caused by marine erosion.

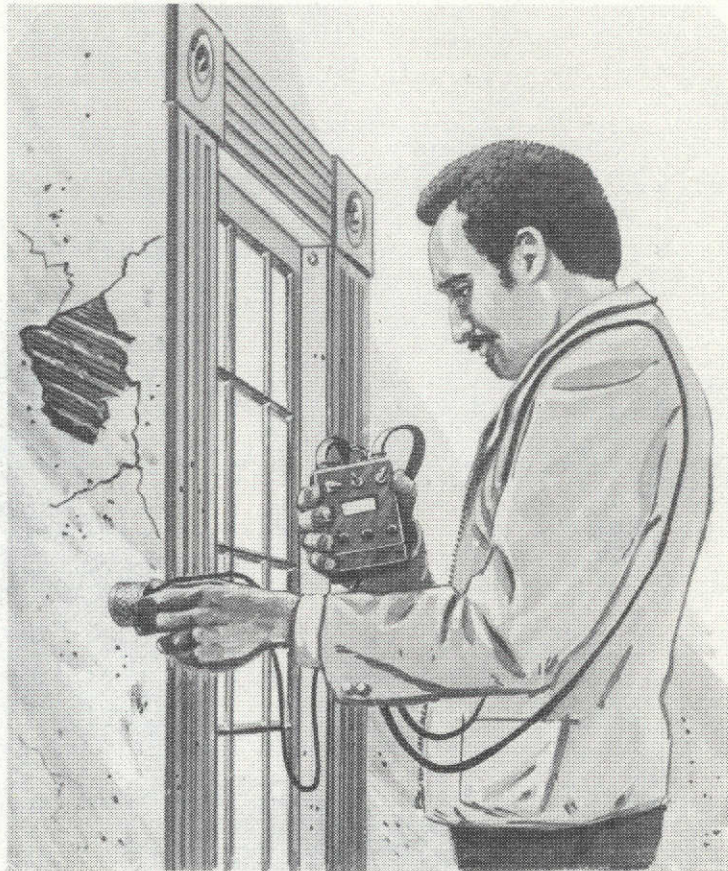


# Housing and Urban Construction

**Lead Paint Detector.** There is rising concern over the health hazards, particularly to children, of residual lead paints that were heavily used for interior decoration of urban housing and other buildings in the decades before World War II. In many older buildings, layers of lead-bearing paints underlie surface coatings applied at a later date. Under such conditions, there is a real danger to children who might eat flakes of paint containing lead, and while

adults are not so directly threatened, the lead can also enter their systems.

Faced with this lead menace, the Department of Housing and Urban Development has identified a critical need for a reliable, low-cost, portable lead detector to measure lead content of painted surfaces. Most currently-used devices -- X-ray based fluorescence analyzers -- are not only relatively expensive, they also are not sensitive enough to detect lead-based paint on surfaces



A device to detect lead paint in older housing is being developed at the University of Chicago with support from HUD. The technology was originally used on the lunar Surveyor mission to analyze the chemical composition of the moon's surface.





**Prototype lead paint detector.**

that have been overlaid with later coatings of non-lead-based paint.

An alpha-particle detection system that was used on the lunar Surveyor mission to analyze the chemical composition of the moon's surface is being adapted to meet the lead-detection problem.

The instrumentation, which was developed for NASA by the University of Chicago, is based on the principle of back-scattering, from the surface, of alpha particles emitted by a radioactive source. The instrument will be portable. It will be designed to detect lead on painted surfaces to a level of 0.5 percent; and it will be low-cost.

This effort to adapt space technology to an important urban-health-and-safety requirement is funded by the Department of Housing and Urban Development. Development prototypes are scheduled to be available for testing by mid-1974.

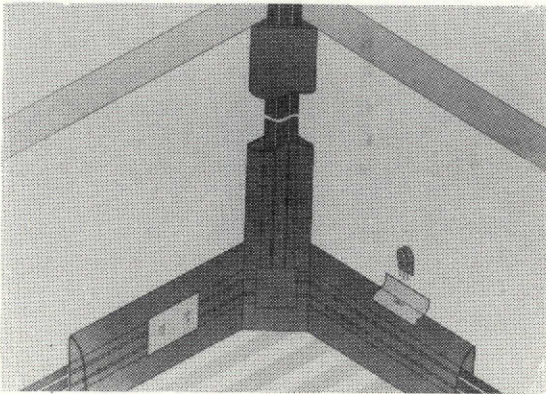
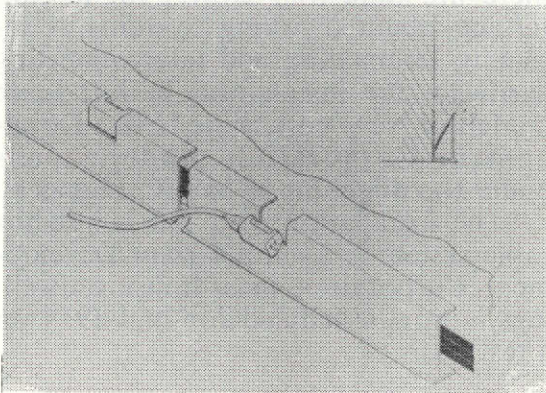
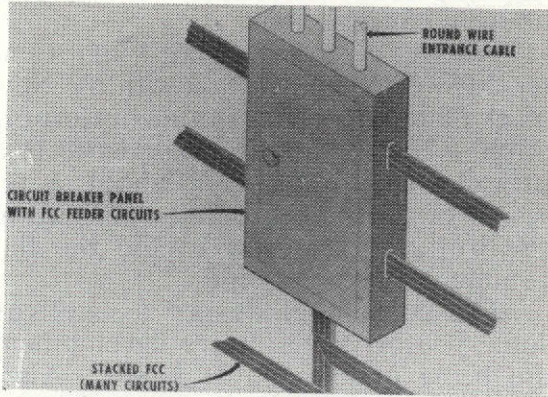
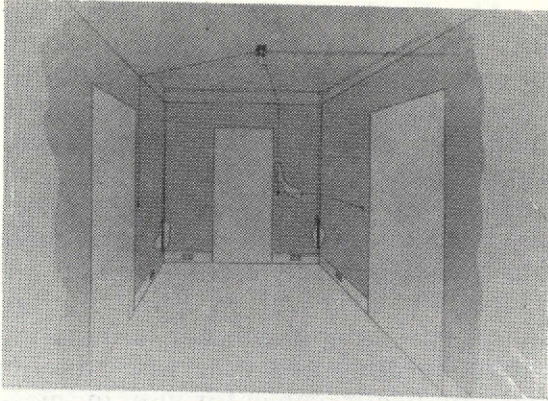
**Flat Conductor Cable for Home Wiring.** The installation of electrical systems in new and renovated buildings is becoming increasingly more expensive. By reducing these costs, flat conductor cable technology adapted from aerospace uses is being considered as a practical solution. Flat conductor cable, has been extensively used in aircraft and spacecraft electrical systems, but requires new components for terminating, interconnecting and otherwise adapting flat conductor cable for use in mass-housing construction.

NASA's Marshall Space Flight Center (MSFC) in cooperation with the New York State Urban Development Corporation -- is applying this experience in a project aimed at bringing about a revision of electrical standards permitting the building industry to use the flat conductor cable concept.

The conceptual design as well as some prototype hardware development are being undertaken at MSFC. Also, there are industrial efforts to develop surface-mounted wiring systems -- including terminating and interconnecting hardware for installation in full-scale models of New York State Urban Development Corporation modular units under the direction of MSFC engineers.

The installation of a flat conductor cable system in several Urban Development Corporation mass-housing dwellings is now scheduled for mid-1974 on a test basis.





**Varying configuration of flat conductor cable to carry power circuits in mass housing.**



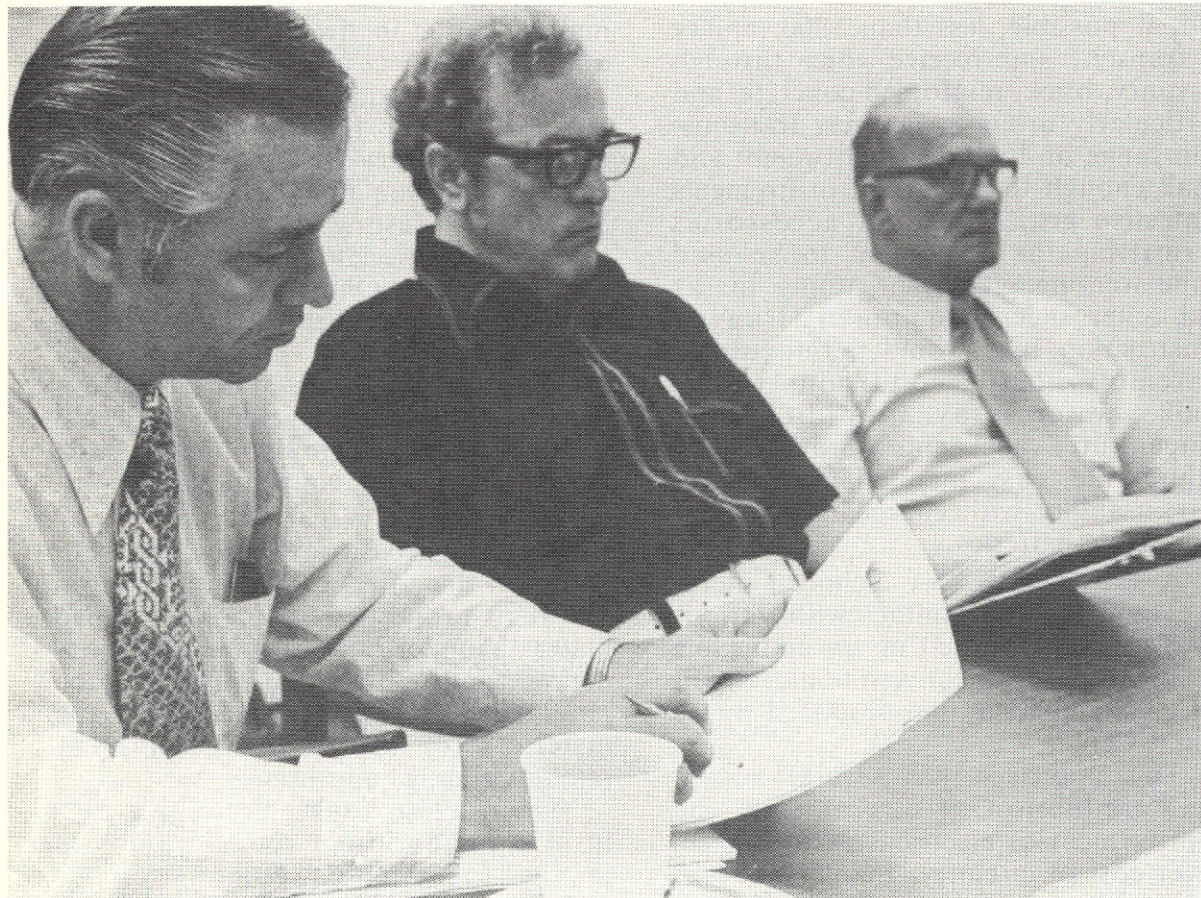
# Safety

## **Improved Short-Range Radio Communication for Firefighters.**

An aerospace integrated-circuit design that replaces inductances in radio frequency circuits with various combinations of transistors, resistors and capacitors is being investigated for its potential utility in the design of low-cost improved short-range communications

equipment for firefighters. The ultimate aim of this project, underway at Public Technology, Inc. is to develop an inexpensive portable radio uniquely suited for firefighters.

The project had its beginnings in the Public Technology, Inc. consultations with firefighters who indicated an urgent need for improved short-range



The planning session of PTI's User Design Committee for improved short-range communications equipment involved 16 people. Shown (L to R) are Robert Chase, Assistant City Administrative Officer, Los Angeles, California; Warren Browning, City Manager, Champaign, Illinois; and Vincent Grote, Communications Superintendent, Cincinnati, Ohio.



communication equipment for use at the scene of fires. Communication is both vital and difficult at a fire scene because of the heat, noise, and poor visibility which together hinder crucial voice communication.

Although there is commercial radio equipment currently available, it is both expensive and unwieldy. While there are some small portable items available, they tend to be unequal to the severe conditions at fire scenes.

Under NASA sponsorship, Public Technology, Inc. and firefighters in 1973 developed a set of specifications for the kind of equipment that would meet the difficult requirements of firefighters.

Under development is a piece of equipment that would have the following characteristics: unit price less than \$300 and, if possible, less than \$200; ability to transmit and receive voice through masonry, brick, reinforced concrete, and particularly urban structures; transmission range of 1500 feet; lightweight and small enough to be carried in firemen's protective gear; optional accessories permitting the equipment to be used while wearing gloves, breathing masks and other special equipment; rugged construction that would permit use in extremely hostile conditions (noise, smoke, water spray, humidity, high temperature, shock and vibration); low failure rate, easy maintenance and repair; usability with chargeable or non-chargeable batteries.

A search of NASA technical literature by PTI, and contact with various NASA centers, turned up an applicable technology -- unconventional circuit design patented at the Goddard Space Flight Center.

This approach has several advantages: reduction of circuit size, the improvement of electrical performance, lower cost of circuitry, smaller package design that increases durability and makes the equipment unit more compatible with firefighter's clothing, and better maintainability.

NASA has already used this technology in special purpose devices such as weather balloon transmitters and ultra-stable radio frequency oscillators and amplifiers.

Currently, under NASA direction, Public Technology, Inc. is soliciting proposals from contractors to design and develop engineering prototypes of the improved firefighters' portable radio unit. The purpose of this effort is to determine if the technology definitely meets the firefighters' specifications.

**Aerospace Fire Retardant Materials Tests.** NASA and the Battelle Columbus Laboratories in Ohio have conducted a series of instrumented fire tests designed to compare aerospace-derived fire retardant materials with conventional materials used in dwellings and institutions. The project involved the cooperation of the National Fire Protection Association, the Department of Housing and Urban Development, the National Bureau of Standards, the American Society for Testing Materials and the Canadian National Research Council. The Columbus, Ohio, Fire Department supplied sites, fire extinguishing services, and other assistance.

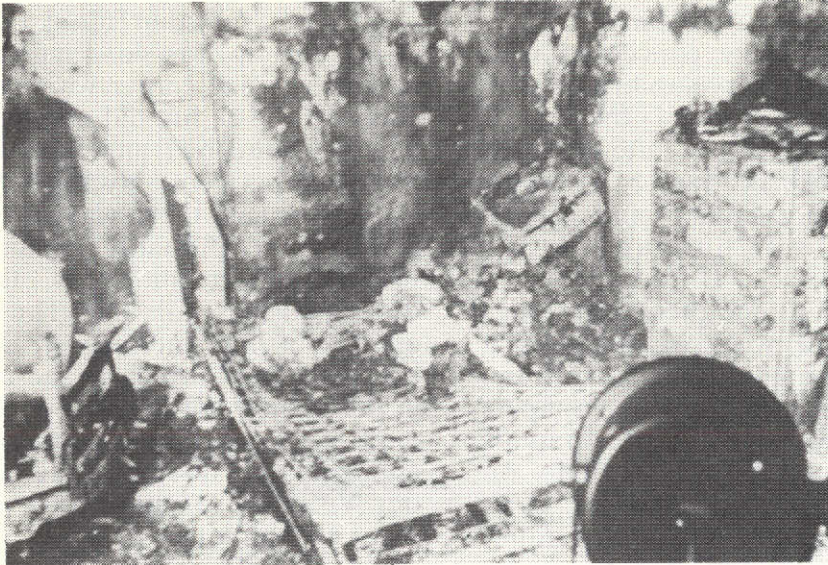
Preliminary results of the test fires indicate that space-developed materials used in furnishings are significantly more fire retardant than conventional materials.

The purpose of the tests was to analyze the fire-resistant and fire-retardant properties of space-developed materials under both burning and smoldering conditions, and to evaluate the potential fire safety advantages of the materials for use in furnishings for public buildings and homes.

The fire tests took place in late 1972 in four prefabricated rooms assembled in the fire training building of the Columbus Fire Department. Materials studied in the program included those used in mattress covers, padding, and cores; box spring covers, padding, and



Newspapers strewn around a bedroom were purposely set on fire for tests in a fire department training building. The photograph below shows how completely the flames destroyed the furnishings.



frames; bedstead frames, bedspreads, sheets, pillows, pillows cases, and blankets; tables, lamps and shades; upholstered chairs; chests of drawers; bookcases; carpeting and floor pads; wall and ceiling coverings; drapes; and doors.

One of the test rooms contained materials and furnishings in common

use. Another contained selected fire-retardant materials and furnishings that are among the best available commercially. A third was furnished with space-developed materials and items constructed from such materials. The fourth room contained a bed constructed of NASA-developed materials, along with commercially available furnishings.



Later, the test was repeated in a room furnished like this one except for a bed made of new aerospace materials. In that test the bed and bookcase near it were only slightly scorched.



Each room was instrumented to monitor smoke density, ventilation rates, heat movement, and important chemical aspects of fire-room atmosphere.

Investigators were concerned with evaluating human survivability, based on three primary factors: (1) the rate of fire development, (2) the rate of accumulation of smoke as a factor in obscuring escape-route visibility, and (3) the extent and rate of buildup of toxic gases.

The four rooms and their furnishings were burned one week apart. In each instance, investigators touched off the blaze by igniting a pound of newspapers in a wastebasket. Another three pounds of newspapers were spread casually on the bed and a chair in one corner. Once the room was engulfed in flames, Columbus firefighters extinguished the blaze.

The preliminary results showed:

Room 1 (typical materials and furnishings in common use) -- The room itself was totally involved in flames in four minutes. The fire was put out in eight minutes. Visibility due to smoke was poor after one minute.

Room 2 (selected materials and furnishings among the best available commercially) -- The rate of fire development was slower, with total room involvement occurring in 16 minutes. The fire was put out after 29 minutes. There was a considerable amount of smoke and visibility was poor after three minutes.

Room 3 (space-developed materials) -- The starter fire burned itself out without spreading to nearby furnishings. Visibility was good. This room subsequently burned, however, when a much larger starter fire was ignited. Used in the second starter fire were newspapers and 2x4's piled on the floor. This time, the flames were confined for several minutes to the area of the starter fire before gradually spreading to the 'chair corner.' After 27 minutes, a larger fire flared up in the corner and the flames spread throughout the room. The fire was extinguished after 33 minutes.

Room 4 (bed constructed of space-developed materials, along with commercially available furnishings of the same type as used in Room 1) -- The rate of fire buildup was slow and the fire was confined to one corner which was totally consumed. The fire did not spread, however, and the bed and bookcase which were nearby were only slightly damaged by heat. Again, there was no total room involvement, primarily because of the fire-resistant qualities of the space-developed materials bed. The fire developed to a high intensity in 24 minutes and consumed the chair and night-stand in the corner, but the rest of the furnishings were not badly damaged. After approximately one hour, the fire was put out. Visibility was poor after about two-and-a-half minutes.

**Adapted Lunar Rover Guidance for Mine Surveillance Vehicle.** An inertial guidance system based on the one used on the NASA Lunar Rover Vehicle has been adapted by NASA Marshall Space Flight Center engineers for use on an experimental unmanned mine-surveillance vehicle under development at the University of Kentucky for the Bureau of Mines.

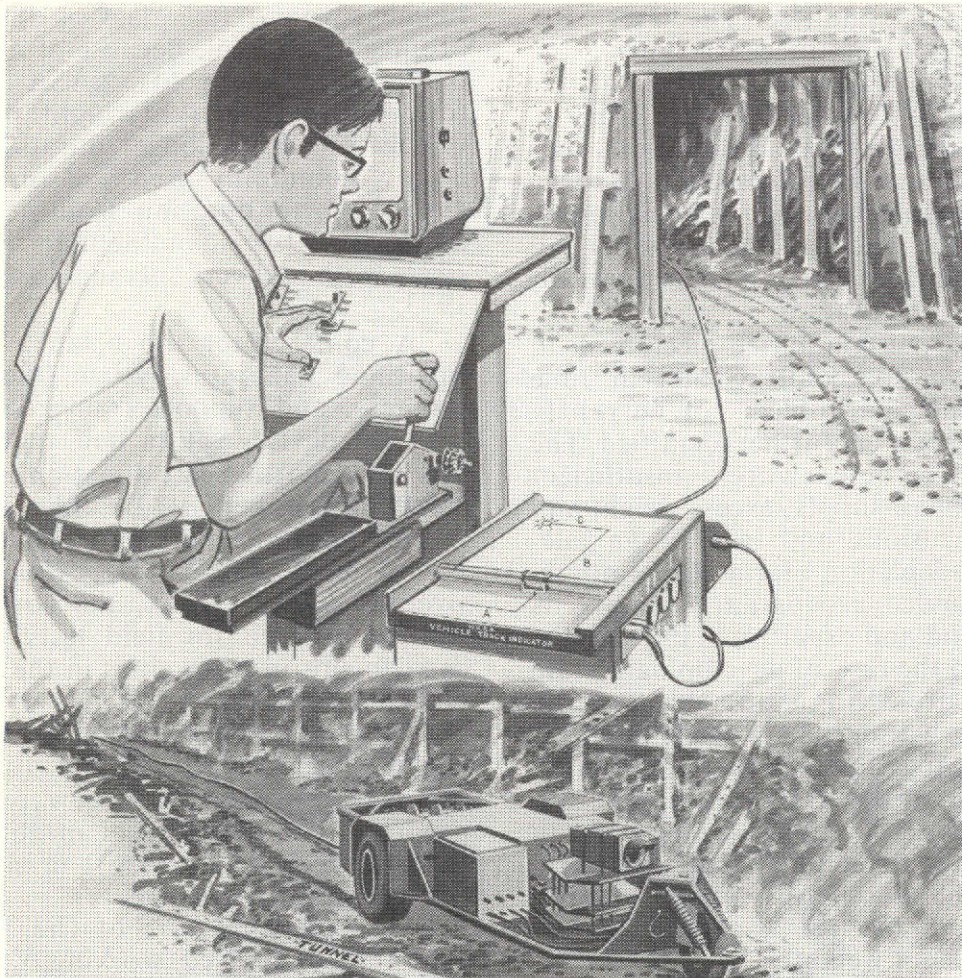
The idea for a remotely-controlled vehicle that would automatically determine and report its position was developed because of the extreme difficulties and hazards that often attend post-disaster scenes. A remotely controlled vehicle, equipped with a TV system, has been constructed by the University of Kentucky under contract to the U.S. Bureau of Mines. Guidance is particularly important because familiar landmarks are often destroyed in such disasters.

The inertial guidance system used on the Lunar Rover Vehicle was designed so that the exact location on the lunar surface could be determined at all times. This was essential since the area being traveled was completely unexplored



from the surface. The only basic design change required of the Lunar Rover guidance system was 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 to determine the vehicle's actual position in a mine tunnel system.

The surveillance vehicle and the guidance system (delivered in 1973 by Marshall to the University of Kentucky) are now being tested for their effectiveness in the primary mission of assessing damage in mine-disaster situations. The project came about through cooperative analyses involving NASA technology application team members, U.S. Bureau of Mines specialists and engineers at the NASA Marshall Space Flight Center.



**NASA Lunar Rover guidance technology is being studied for its potential application to the unmanned mine-surveillance vehicle being developed for the Bureau of Mines at the University of Kentucky.**



**Improved Firefighter's Breathing Apparatus.** NASA's attention to the problem of developing a new type of Firefighter's Breathing Apparatus originated in the strongly expressed need of municipal fire departments for improvements in such devices. Because conventional devices tend to restrict the firefighter's mobility and vision, many firefighters neglect to use a breathing apparatus. This has led to a discouraging rate of smoke inhalation injuries.

In cooperation with the National Bureau of Standards Fire Technology Division and Public Technology, Incorporated, NASA initiated an effort in the spring of 1971 to develop improved equipment. PTI polled cities on their needs, and then organized a User Requirements Committee. The User Requirements Committee includes fire chiefs, city managers and a representative of the NBS Fire Services Program. In addition, fire service organizations such as the National Fire Protection Association, the International Association of Firefighters, and the International Association of Fire Chiefs have periodically reviewed the program.

At the first committee meeting, held at Johnson 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, while remaining within the cost constraints.

Following an extensive engineering analysis to determine an optimum system concept, JSC engineers suggested an open-circuit demand system utilizing a lightweight (4000 psig) pressure vessel would bring about a 30 per cent reduction in system weight.

Other suggestions included making the system more compact and changing

the shoulder mounting of the device to a more comfortable hip position, as well as the design of an air-depletion warning system. Other suggested changes included an improved donning and doffing capability, an improved helmet, and improved system and component performance. The User Requirements Committee agreed that such a development program was desirable. They also agreed that the use of higher pressure air would not be a serious constraint on fire service use.

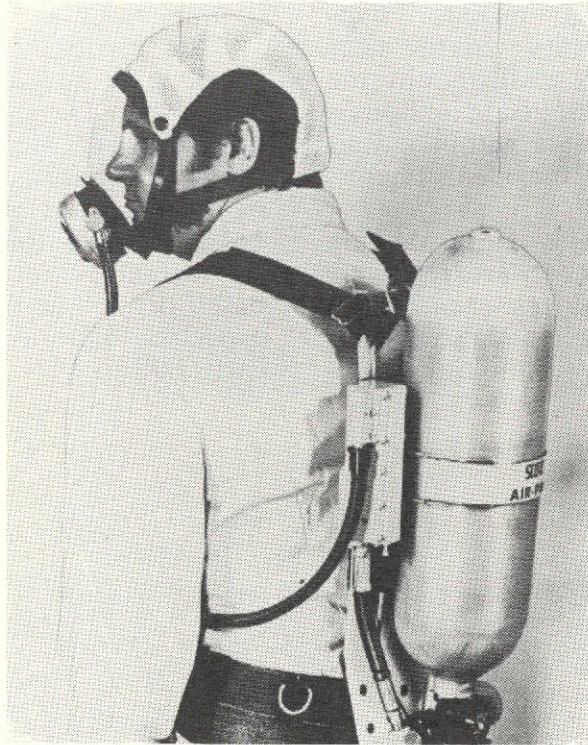
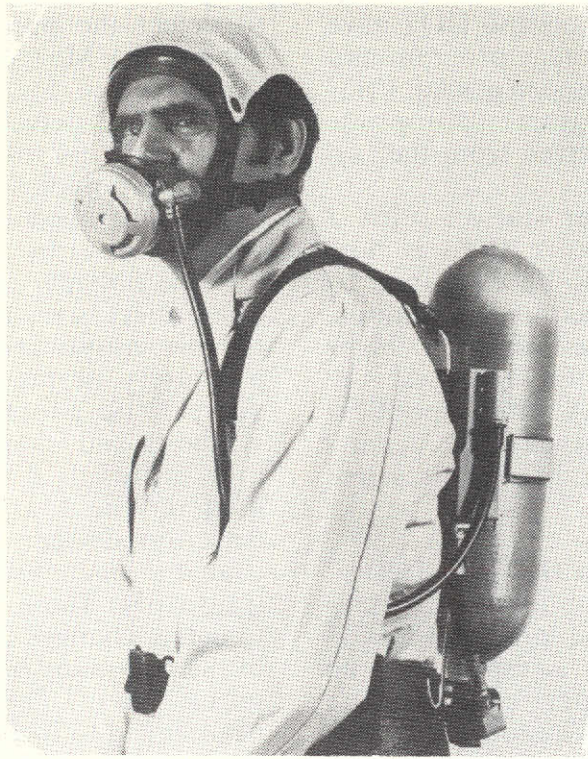
A second User Requirements Committee meeting was held in October 1971 to review NASA developments on the pressure vessel and the balance of the system. After evaluation of alternative materials, NASA specialists selected filament-wound fiberglass as the most promising material. Because of differing municipal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

A contract for the balance of the breathing apparatus system (facemask, harness, and support frame depletion warning device, valves and regulators) was awarded to Scott Aviation of New York in October 1972. The last of twenty prototype units were delivered to NASA in December 1973. After extensive testing by NASA, the equipment will be released for field tests by fire departments in three cities in the Spring of 1974.

The User Requirements Committee has met periodically at the Johnson Spacecraft Center to review program progress. The most recent meeting was in November 1973 to assist in planning the field test program.

An important part of the NASA effort has involved working with the appropriate regulatory agencies during development of the new systems. Both





A lightweight, longer duration breathing apparatus shown above was developed for firefighters' use in a research program sponsored by NASA.



NIOSH (National Institute of Occupational Safety and Health) and DOT have reviewed the development program and required tests are being performed. Prior to the field test program, appropriate approvals will be received from the two agencies.

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 purchased 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.

#### **Early-Warning Fire Detection Device.**

The key to fire safety in terms of lifesaving and prevention of property loss is early detection. This is especially true for residential properties and mass housing. To prevent the enormous losses resulting from residential fires, the Department of Housing and Urban Development plans to propose minimum property standards in the near future. These standards will require the smoke detectors be installed in all houses and apartment buildings within a year after the issuance of the Department's standards.

At present, the only early-warning devices on the market are relatively expensive and in many cases tend to set off an excessive number of false alarms.

A space-derived technology origi-

nally developed by McDonnell Douglas to detect the presence of particulates aboard the Mars-Voyager Spacecraft is being studied for adaptation to earth-bound fire detection. The technology involves the use of a polymeric material known as polyphenylacetylene which has electrical properties that change as the material absorbs gases or particulates.

This polymer technology is the core of a project to develop a small, low-cost, reliable early-warning device for use primarily in residential units. At the outset, the project will involve the synthesis and characterization of polymer materials similar to the material used on the Mars-Voyager particulate detection device. The material will be coated on solid-base field-effect-transistors. These, in turn, will be used to detect changes in electrical properties of the polymeric film as the film absorbs selected gases. The prototype device will be designed to include an alarm that will be actuated when threshold changes in the electrical properties of the polymeric film are reached.

The project is jointly funded by NASA and the Department of Housing and Urban Development; and work is under way at McDonnell Douglas and the Massachusetts Institute of Technology under the technical direction of NASA's Lewis Research Center.

Several prototype smoke detectors based on this aerospace technology are expected to be available for testing by early Fall of 1974.

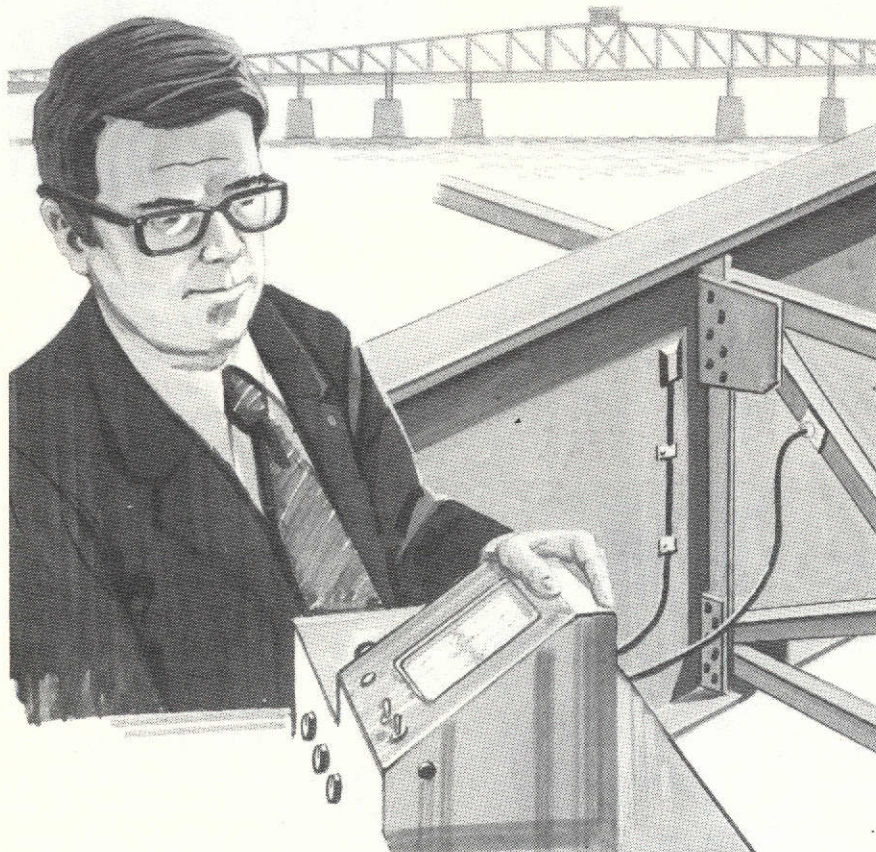


# Transportation

**Computerized Bridge Safety Inspection.** Aerospace-derived techniques of mathematically analyzing structural material fatigue in aircraft is being studied for application to the forecast of bridge collapse. This is a significant safety problem that heretofore has been quite difficult to solve. The degradation of structural materials in bridges can result from several causes: long-term effects such as metal corrosion, metal fatigue, "creep", as well as sudden events such as collisions, fires, wind loads and other single events. Currently, there is no reliable, inexpensive way to detect

damage. The most common technique is careful visual inspection, which has obvious shortcomings. As careful as the search for defects and strains may be, many flaws are hidden by paint and cover plates. What's needed is a method of continuous scientific monitoring so that changes in structural characteristics can be detected long in advance of catastrophe or damage.

NASA Ames Research Center, in the course of its research on aircraft structural dynamics, developed instrumentation that measures the damping characteristics of structures when they are



Aerospace-derived techniques of mathematically analyzing structural fatigue in aircraft are being studied as a means of detecting dangerous defects in highway bridges.



excited by random forces or influences. The computational profile of these characteristics is used as a failure detector in the study of structural fatigue in aircraft and rocket components.

This analytical system -- called Randomdec -- is now being applied experimentally, in a joint NASA-Federal Highway Administration program, to the bridge-failure problem. Randomdec analysis is being applied to Highway Administration records of steel-girder responses to random excitation. The goal of this phase of the program is to establish the minimum size at which a structural flaw can be spotted.

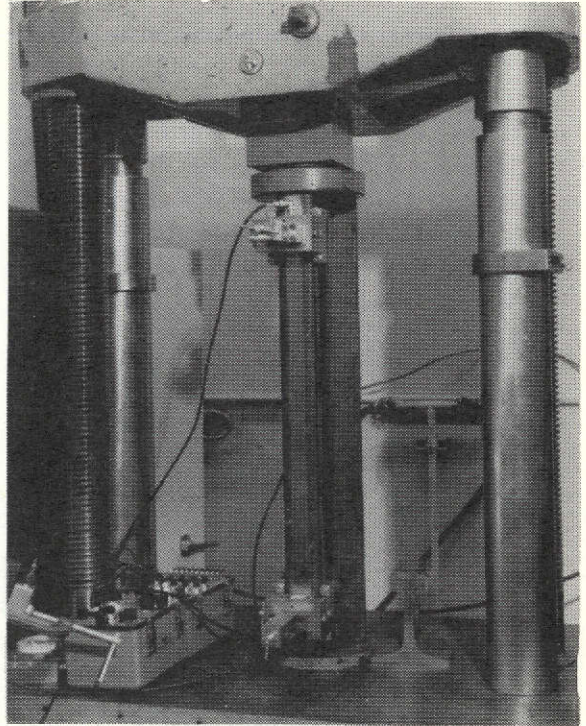
At the same time, a highway bridge near the NASA Ames Research Center has been equipped with a sensor to monitor vibrations from traffic and the effects on the structure by weather. The data will be compared against earlier Randomdec analyses of the bridge to determine what degradation may be occurring.

The two-fold approach -- laboratory Randomdec analysis of steel girders by the Federal Highway Administration at its Washington, D. C. facility and the California field tests on the bridge -- is expected to provide planners with answers to the question of whether the Randomdec technique can finally overcome a safety problem in the public-sector that has previously defied solution.



Test sections of a rail and railcar wheel prior to a test.

The program is being conducted under contract from Ames Research Center with Nielson Engineering and Research, Inc. A final report is expected in the Summer of 1974.

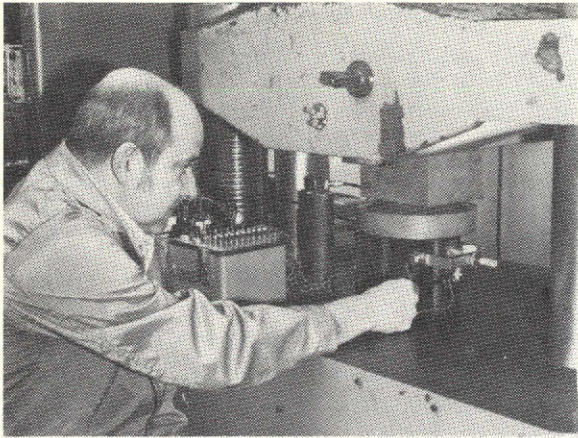


Rail and railcar wheel test equipment.

**Measuring Thermal Stress on Rails and Railcar Wheels.** NASA Marshall Space Flight Center and the Federal Railroad Administration, with the cooperation of the Association of American Railroads, are investigating the feasibility of using ultrasonic techniques -- originally developed for the nondestructive testing of rocket components -- to detect potentially catastrophic thermal stresses on railroad trackage and railcar wheels. Such thermal stresses can cause dangerous derailment accidents.

Using NASA ultrasonic techniques, Marshall researchers have been analyzing thermal stress caused by varying conditions on the types of steel used to build railcar wheels and tracks. Initial analysis has established the basic feasibility of the method, when accurate data were obtained relating shear-wave de-





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.

terminations of stress levels with applied loads at ambient and elevated temperatures. A summary report is being prepared and specifications for an instrument to rapidly determine stress levels on wheels and track are being developed. The eventual aim of the project is to devise a portable, compact ultrasonic instrument that the railroad industry can use to measure the buildup of tensile stress on wheels and tracks.

**Tank-Car Fire Protection.** The Federal Railroad Administration is seeking new ways to protect railroad tank cars carrying liquefied inflammable substances against disastrous fires. These tank cars are subject to ruptures that cause extensive fire damage and risk to life.

Intumescent coating research, already conducted at the NASA Ames Research Center for the fire protection of aircraft, is being put to work on the railroad tank car fire-safety problems.

In a joint program with the Federal Railroad Administration, Ames researchers are analyzing the thermal environment and protection offered by various aerospace-derived materials in simulated rail tank-car fires.

Data from a full-scale tank-car fire test in August 1973 are being examined for precisely defining the tank-car accident environment. This will lead to modification of a fire-test laboratory at Ames Research Center that will simulate tank-car fire conditions and permit careful testing and design of new fire-protection materials.

**Nickel-Zinc Battery.** The rising air-pollution crisis, combined with oil shortages and concern over noise pollution, has spurred research on electrically-powered vehicles. This new emphasis has, in turn, stimulated interest in, and research on, high-energy-density rechargeable batteries for commercial-industrial applications. The nickel-zinc battery is seen as having the potential to meet the need for a practical rechargeable battery because its energy density is nearly three times that of the popular nickel-cadmium battery already in wide use. Also, the nickel-zinc battery would be more economical to produce.

But the basic problems to be overcome before the nickel-zinc battery can come into general use include the deterioration of the zinc electrodes, and inadequate separator performance.

NASA's Lewis Research Center has an extensive background in battery-separator technology, developed in the course of its research on silver-zinc batteries for space-vehicle electric power supplies. Basic separator technology was developed by McDonnell Douglas, and Lewis has adapted the technology to solve zinc-electrode deterioration problems in batteries.

The current effort is geared to develop zinc-electrode separator technology to the point where it can be directly applied to a highly rechargeable, high-energy-density nickel-zinc battery for commercial uses.

The early phases of the program have already produced better-than-expected results. These early phases of the project involved cell design, small-cell fabrica-



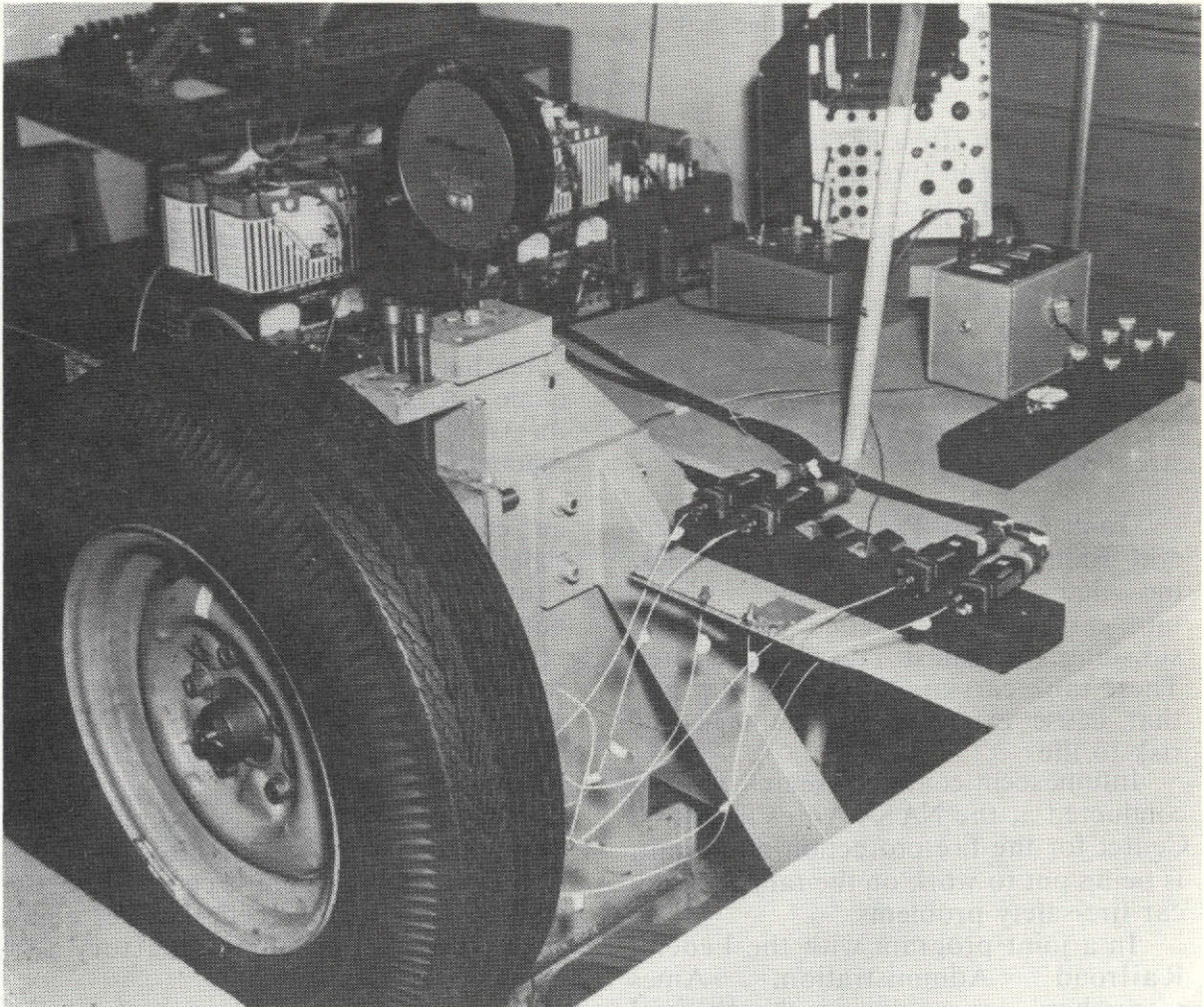
tion, and the testing of full-size 3-ampere-hour cells. Technical corrections suggested by Lewis Research Center have alleviated some difficulties and new 10-ampere-hour test cells have shown properties two-to-four times greater than nickel-cadmium batteries. Forty-five test cells have been produced for future testing.

Both the U.S. Bureau of Mines and the U.S. Postal Service have expressed interest in the research and may join NASA in funding future research.

### **Improved Vehicle Brake Linings.**

There is a strong need for improved brake-lining materials to meet the increased demands of faster and heavier vehicles. Current friction materials for vehicle brakes are complex composites that generally contain chrysotile asbestos fiber plus modifiers to maintain friction levels, and added organic binders.

The NASA Ames Research Center has a significant background in the technology of materials for use in high-temperature aerospace environments.



**Test apparatus at NASA Ames Research Center for the evaluation of friction materials with improved wear characteristics for brake linings.**





These men are making a pothole.



The hole was filled with thermoplastic material that was originally developed for binding solid fuels used in rockets.



Thermoplastic material is being adapted for bridge-surface coating and road repair.

This experience is seen as potentially applicable to the development of new automotive brake-lining materials.

Ames Research Center, working with Bendix, is investigating various materials for use as substitute binders, friction modifiers, and fibrous materials. Bendix will fabricate varying combinations of these materials, and results will be evaluated.

The project evolved from suggestions by Ames researchers that materials already developed at the Center for thermal protection in high-speed aircraft might well have commercial potential.

Both the Department of Transportation and the U.S. Postal Service have expressed interest in this effort. Prototype brakes will be installed on a Postal Service vehicle in 1974.

**All-Weather Permanent Street-Patching Materials.** An adapted version of a thermoplastic material that was originally developed by the NASA/Jet Propulsion Laboratory as a binder for solid-fuel rocket propellants is being tested for utility as a street-patching substance that can be applied in all types of weather and which will stand up to all weather and traffic conditions.

Currently the city of Burbank, California, is testing these thermoplastic-asphalt street patching materials. Other tests are under way in South Lake Tahoe, Nevada and Anchorage, Alaska. The street-patching version of the original fuel-binder was developed by Products Research and Chemicals Corporation in Burbank. Further tests are planned in several other cities with participation by Public Technology, Inc.

Street patching is a costly and repetitive business, because of the destructive effects of extreme temperature and moisture. Thus, there is a strong need for substances that will stand up to weather and heavy traffic longer than the materials now



conventionally used and at competitive prices.

In some cold-weather cities, potholes are refilled as often as 10 to 20 times a year. The labor costs are obvious, when it is recognized that about 90 percent of local-government street-maintenance funding goes for personnel. Beyond that, experts estimate that some \$800-million a year are spent on materials and equipment. The use of aerospace-derived thermoplastic materials was originally tested for potential application to street patching by the Stanford Research Institute in 1971. The tests established the basic feasibility.

Later, potential urban users and Public Technology, Inc. experts devised a set of basic specifications for the adapted space materials. They called for the development of a material that could be applied to streets in ambient temperatures ranging from minus 20 degrees to 150 degrees Fahrenheit and to wet potholes with little or no preparation. The materials would need strong bonding and flexibility properties over a wide temperature range to remain intact even under severe freezing and thawing conditions.

The materials tested in the three test sites were hot-mixes requiring heating equipment to maintain them at 300 degrees Fahrenheit before application. Preliminary tests on cold-mixes which would eliminate the need for heating equipment showed promising results. Both the hot-mix and cold-mix versions of the ethylene vinyl/acetate/asphalt composites will be field-tested during a one-year period under a variety of traffic, climate, and other conditions, in Burbank, Eugene, Anchorage, Duluth,

Wichita, Phoenix, Dallas, Nashville, Kalamazoo, Bangor, New York City, Trenton, Sparta, and Ft. Lauderdale.

Further analysis and evaluation of the extensive field test are planned in the Spring of 1974.

**Improved Pavement Striping for Road Safety.** Rain-flooded or rain-soaked conventional lane markings on highways are virtually invisible to drivers, particularly at night. This poses a major road-safety problem. The Federal Highway Administration has been looking for new materials that would ensure visibility of road markings.

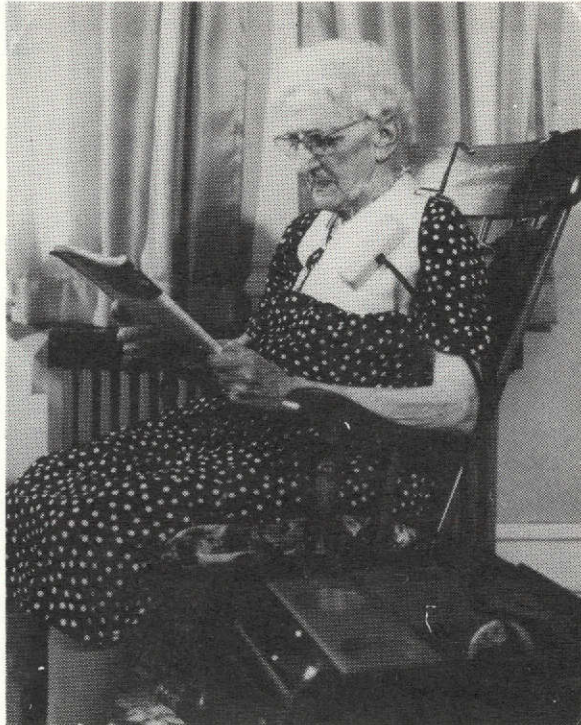
Space-related research emerging from planetary life detection system projects are being investigated. NASA Goddard Space Flight Center technologists have wide experience in the field of bioluminescence, and they are now engaged in an effort to determine the feasibility of using bioluminescent or chemiluminescent materials for effective self-illuminating highway markers that could be seen by motorists on wet roads at night. The materials would also have to be relatively resistant to deterioration in normal service and be able to survive snow removal operations in winter.

Because of their interest, the Federal Highway Administration is sponsoring a feasibility study under the direction of technologists at Goddard. The primary effort involved a survey of materials performed by Fairchild Space and Electronics Company and ATP Systems. Of five possible candidate materials, one was recommended to the Federal Highway Administration for future development. This recommendation is now being reviewed.

# **Biomedical Sector Projects**



# Cardiology



The charging procedure for the cardiac pacemaker is accomplished by use of a portable console operated by the patient in her own home.

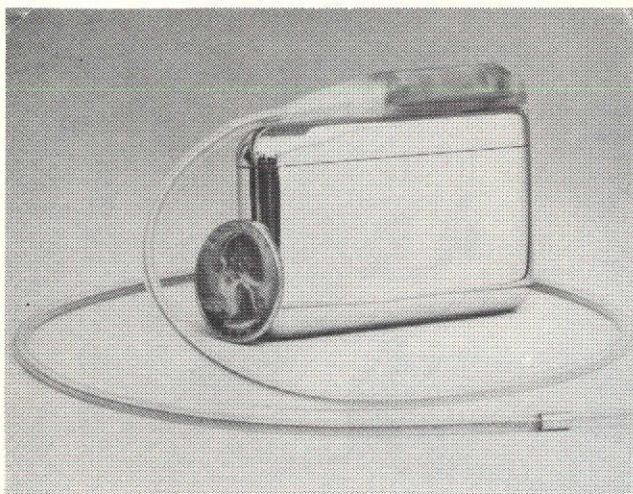
**Rechargeable Cardiac Pacemaker.** A rechargeable cardiac pacemaker smaller than a cigarette pack and powered by nickel-cadmium batteries originally developed for NASA spacecraft power systems is now being worn by heart patients in the United States. The unit, developed by the Johns Hopkins Applied Physics Laboratory in Maryland with NASA support is now commercially available. Hybrid circuitry combined with the rechargeable nickel-cadmium batteries and special packaging techniques are the keys to the unit's small size and longevity.

The highly miniaturized pacemaker's rechargeability -- using a portable recharging unit the size of a briefcase --

eliminates the previous requirement for periodic removal of implanted pacemakers because of battery depletion. Such surgical removals and re-implantations of the old-style and bulkier units posed unavoidable risks and discomfort and costs to patients who depend on electronic pacemakers to control erratic or weak heart rates. Whereas conventional mercury cell powered pacemakers must be replaced at least once every two years, the rechargeable unit should last a minimum of 10 and possibly 20 years. This reduction in costs to the patient and surgical risk is particularly important.

The new pacemaker allows the heart patient -- young, middle-aged, or elderly





**This implantable rechargeable cardiac pacemaker is one-half the size of early pacemakers, is insensitive to electrical interference and should last for up to 20 years.**

-- to recharge his pacemaker conveniently and comfortably once a week at home. Should the patient forget or neglect his weekly recharge, he will, in fact, face no danger as the system contains enough energy for at least 8 weeks' operation. For infants requiring pacemakers, the parent can operate the recharging unit. The new pacemakers being less than half the volume of conventional pacers facilitates its use in children. All the patient needs to do is don a special vest to which the pacemaker is then magnetically coupled for recharging. The recharging takes about 90 minutes.

The rechargeable pacemaker also can be kept at a low safe-charge level while in storage at the hospital prior to implantation. This is in positive contrast to conventional pacemakers that begin losing energy as soon as they leave the production line.

The pacemaker is surgically implanted under the skin in the conventional manner, usually in the upper left or upper right section of the chest, although sometimes in the abdomen. The pacemaker itself is one part of the total system, which also includes the lead

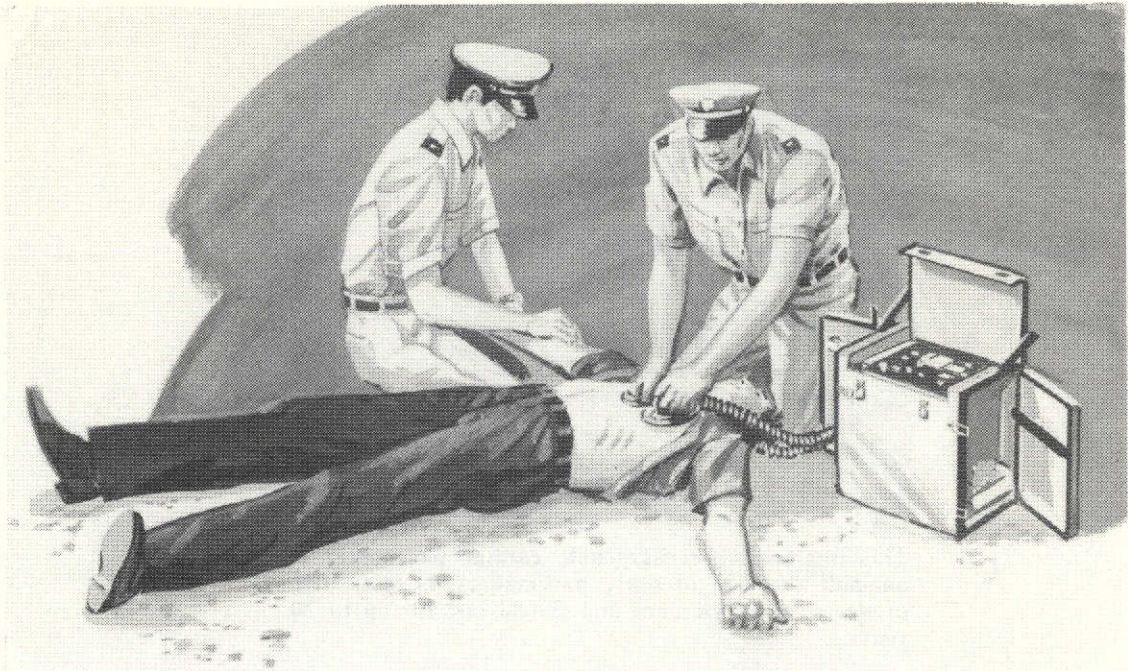
wire and charger console. The unit is enclosed in a hermetically sealed metal case designed to prevent body fluids from compromising performance.

Also, the unit has been carefully designed for immunity to electrical interference from such sources as car ignitions, radar and microwave ovens. It is so immune to interference that its performance will not be affected even inside an operating microwave oven.

Successful development of the unit climaxed six years of test and research including experimentation on animals. Involved in the support of the development were Baltimore City Hospital, Johns Hopkins University School of Medicine, Heart Association of Maryland, G.D. Searle and Company, and NASA. Pacesetter Systems, Inc. of California, has been licensed to manufacture and market the unit.

**Emergency Ambulance Cardiac Care System.** In cooperation with NASA, SCI Systems, Inc. of Houston, has adapted SKYLAB technology in the development of an ambulance-carried compact medical unit that contains

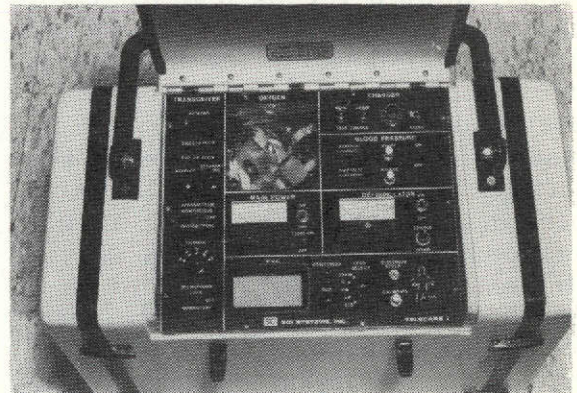




**Emergency medical technicians can immediately examine the heart attack victim's EKG, transmit it to a control hospital for further medical advice, and administer the appropriate treatment.**

essential equipment designed to meet heart patients' diagnostic and therapeutic needs at the scene of an emergency. The unit based in part on technology derived from the NASA manned spaceflight program includes two-way voice and EKG telemetry systems, weighs only 40 pounds, and is now commercially available.

The unit, called Telecare, brings together all the basic components required to meet medical emergencies. They are combined for the first time in a single portable package about the size of a suitcase. These components, to be used by ambulance personnel and physicians, include: a respiratory resuscitation system; a 15-minute chlorate candle oxygen supply contained in a lightweight canister whose design is derived from space technology; an electrocardiogram display and telemetry system that can relay cardiac data to the receiving hospital and the physicians who will provide later treatment to the patient; a defibrillator for external heart stimulation; a semiautomatic indirect blood pressure



**The portable Telecare unit combines all of the devices essential to the emergency treatment of heart attacks into one convenient unit.**

measurement system using a special microphone positioned under a hand-inflated cuff similar to the blood pressure device developed for the NASA Skylab program; and a basic pharmaceutical pack. Optional equipment available includes an electroencephalograph that can provide remote observation of brain-wave action. Its technology is derived from the Skylab sleep analyzer



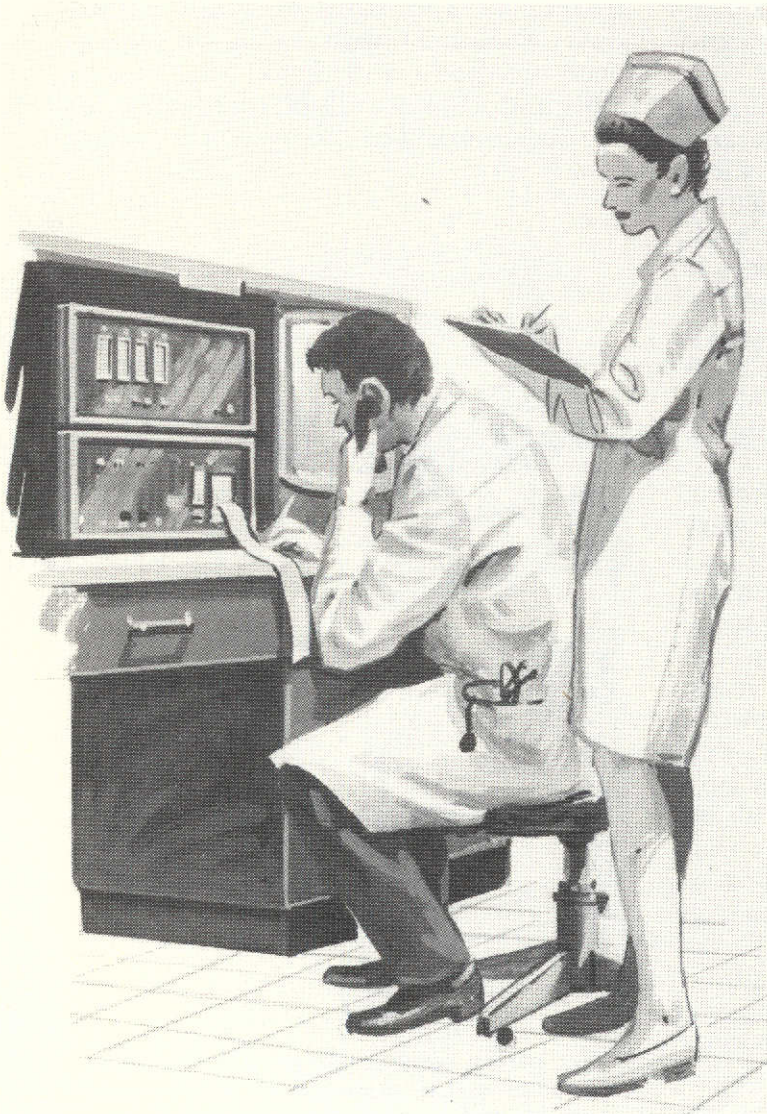
-- plus a strip-chart data recorder and tape recorder.

The Telecare system has already been tested successfully by the city of Houston. Houston is now equipping 28 of its municipal medical rescue vehicles with Telecare units and is training technicians to use the units. A number of other cities are currently evaluating the new unit.

#### **Cardiac Diagnostic Assist Computer.**

Apollo technology in the fields of small computers, man-machine interactions, and real-time signal processing methods, is being used at The Draper Laboratory

in Massachusetts to develop a bedside biomedical computer to aid the diagnosis and treatment of cardiovascular disease. The purpose of the project is to create a free-standing system combining computer analysis and biomedical instrumentation that can be deployed at the bedside of the patient or in the outpatient area of the hospital. Such a system would use non-invasive measurements of the patient's physiology and could provide the doctor or his assistants with rapid analysis of a patient's condition, give assistance in differential diagnosis and help predict the response to therapy.



**A physician at a central hospital receives the patient's EKG by a radio-transmission and can immediately advise the emergency medical technician of the proper course of action.**



Physicians and cardiologists at the MIT Clinical Research Center and the Massachusetts General Hospital are collaborating with The Draper Laboratory on this project. The prototype system is expected to be ready for clinical field trials and evaluation by late 1974.

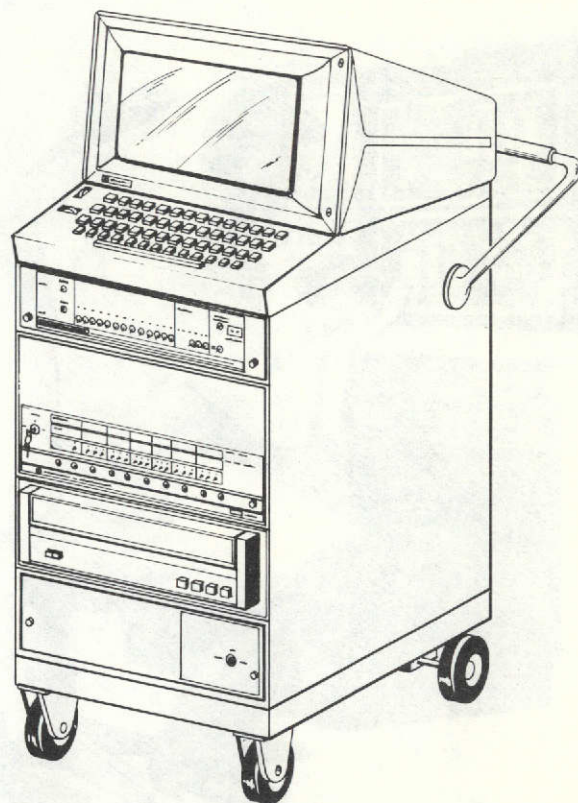
The long-term goal of the project is to develop a 'dedicated' minicomputer system that could aid the attending general physician's diagnosis of cardiovascular disease. The final system will be small enough and portable enough to be wheeled from bedside to bedside and would be low enough in price to be deployed in large numbers in small community hospitals and in rural and urban clinics.

The system will aid the physician in a number of ways. It will acquire and process the electrical and acoustical output of the patient's cardiovascular system and compare these data with information in the patient's history. It will allow rapid assessment of diagnostic information. It will provide a unified record of data from the patient. And, it will give the attending physician statistical data relating the pattern of findings with possible diagnoses.

A considerable portion of this project has been related to computer software development. Programming techniques originally used in the Apollo project are used to allow very large programs to be run on machines of modest cost and memory size. Modifications were made to enable the small computer to control complex graphic display systems as well as making it compatible with data prepared for larger machines, such as an IBM 360/75. Computer programs that help interpret electrocardiograms were adapted to run on the minicomputer in less than 4 1/2 minutes, compared with a 7- to 9-minute execution time required on much larger and more expensive computers. A program for the analysis of Systolic Time Interval was speeded up by a factor of 6. Frequency analysis programs are used to analyze acoustic

data for signs of arterial lesions related to narrowing or hardening of the arteries, to check valves with impaired flow or regurgitation, and to analyze lung sounds related to obstructive lung disease.

Further work is now under way to prepare the system for clinical field trials in 1974. The major task remaining prior to clinical trials is to develop the man-machine interface through the interactive graphics terminal. The goal of this interface is to permit available medical personnel, unskilled in computer science, to successfully utilize the applications programs and store or recall patient data. Personnel with extensive experience in Apollo and Space Shuttle controls and displays will be responsible for the development of this system interface.



The entire cardiac diagnostic assistance computer will be packaged on a roll-around cart for use in small hospitals and medical clinics.



The mini-computer and tape drives employed in the development of the initial Biomedical Bedside Computer.



It will contain a maximum of self-teaching features and will be configured to accept and tolerate error corrections in program sequencing or data input.

**Artificial Heart Valve Mapping.** NASA is collaborating in work at the University of Illinois in Urbana, and at Washington University in St. Louis aimed at gathering data needed for the development of artificial aortic valves for the heart. Stereophotogrammetry -- a precision stereophotographic 'mapping' technique similar to that used to map the surface of the moon -- is being used to measure, through precise geometric analysis, the distribution of flexion (bending) and stress in heart

valves under varying conditions of pressure and flow.

The stress distribution analysis performed on aortic valve molds is fundamental to the design of an artificial heart valve. The principal stumbling block in that development has been the geometric definition of the complex asymmetric shape of the valve. The NASA mapping techniques have been a significant contribution to the solution of this problem in work now in progress at the University of Illinois (Urbana). The work is being coordinated with a large effort to develop a trileaflet aortic valve prosthesis under way at Washington University in St. Louis.

Point plotting, grid orientation, and other technical problems have already



been solved, and refinement of the measurements is in progress. Polymer and composite-materials advances, combined with progress in blood surface interface research sponsored by the National Institutes of Health Artificial Heart program, have laid the basic ground work for the development of a trileaflet artificial heart valve.

A major portion of the overall task is designing the leaves of an artificial aortic valve. The natural aortic valve comprises three leaflets that combine to close a circular opening. These leaflets are flexible and flap open and closed with each heartbeat millions of times a year. Any artificial trileaflet valve must be able to withstand many years of flexing. Hence there is the need to measure precisely the dynamic stresses and strains.

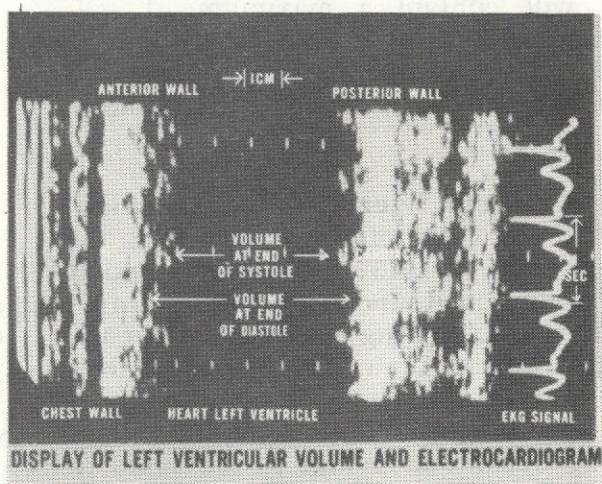
The NASA stereophotogrammetric techniques are used to photograph the leaflet motion at various flow pressures and speeds. The record is computerized for further evaluation, in order to provide designers with data required for changes to strengthen those portions of the artificial leaflet subject to the greatest stresses, and to minimize the turbulence of blood flow through the valve.

**Portable, Battery Operated Ultrasonic Echocardioscope.** A portable, battery operated ultrasonic device originally designed by the NASA Ames Research Center to be carried aboard spacecraft to assess the performance of the heart in the weightlessness of space is being evaluated at the Stanford University School of Medicine for use in the care of heart disease patients. Ultrasound already has been quite useful clinically in the diagnosis of aortic, mitral and tricuspid valve disease, foreign bodies in the heart, the presence of pericardial effusion and specific congenital heart defects.

The active program of ultrasonic diagnosis at Stanford University Hospital has shown that most commercially

available equipment is both bulky and potentially hazardous from an electrical standpoint. This is particularly true when the commercial equipment is used in a medical environment involving electrically-sensitive patients such as those found in the cardiac catheterization laboratory or in the newborn nursery. To overcome such problems it is conceivable and anticipated that ultrasonic imaging may eventually replace the use of X-rays for studying and evaluating the condition of a patient's heart.

A four-part program is underway at Stanford using the NASA-developed instrument to validate the simplicity, portability, and diagnostic accuracy in the performance of non-invasive diagnostic studies. Three of the four projects in progress involve a series of pediatric patients with a variety of cardiac abnormalities. As they are in the newborn nursery and in the pediatric ward, electrical safety is of utmost importance. These patients are in a controlled environment, many within isolettes having electrically controlled temperature and humidity. Furthermore, they are commonly monitored with a variety of electrically powered equipment. It is not desirable to expose these infants to

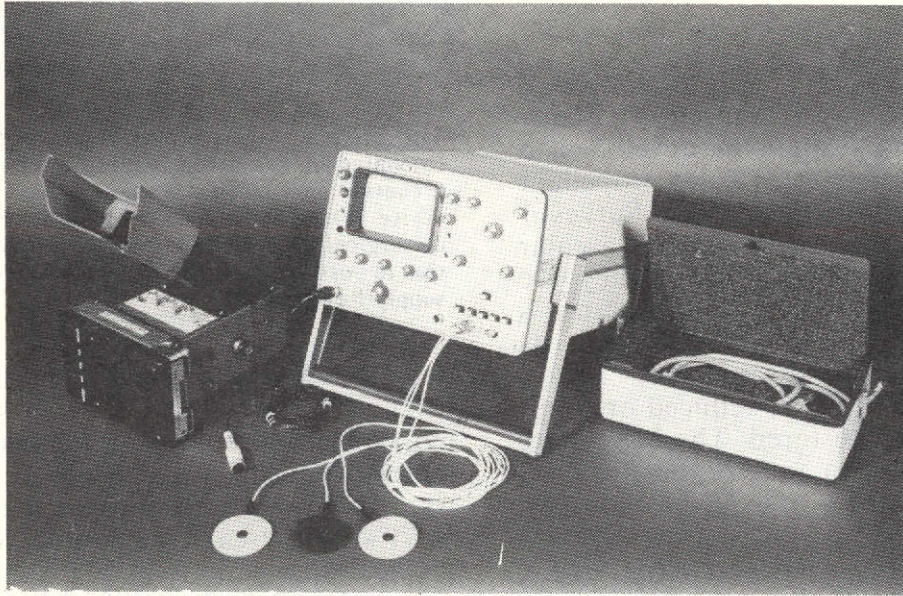


The cardiac ultrasonoscope immediately displays the contractile action of the heart as well as the patient's EKG. The display is photographed to make a permanent record.



repeated doses of X-rays, nor is it possible to disconnect all monitoring instrumentation during the time necessary to complete an ultrasonic measurement. Since hazardous levels of current leakage could be transmitted through the heart and total body when multiple line operated devices are used simultaneously

patients selected for previously defined anatomical congenital heart defects are being studied. In this test, the accuracy of the ultrasonoscope is being assessed in relation to the known congenital defect and studies of the same patients with commercially available equipment. This test will compare the accuracy of



**The portable cardiac ultrasonoscope uses high frequency sound to rapidly determine the heart's performance in the hospital or in a physician's office.**

on a patient, this battery operated ultrasonic device is ideal. Now the physician can obtain ultrasonic information on the patients with very small hearts while life support systems continue their function. The first project is a comparison of alternate methods for presenting of the ultrasonic information. The second project is assessing the use of the ultrasonoscope in the emergency situation of evaluating possible congenital heart defects shortly after birth. The amount of information gained with the ultrasonoscope is being assessed against the more traumatic procedures necessary to currently diagnose these conditions.

Thirdly, the ultrasonoscope is used routinely on children between the ages of 2 months and 14 years when they are examined in pediatric wards and in pediatric outpatient departments. Thirty

both ultrasonic devices with respect to the patterns thought to accompany the anatomic defects.

The fourth project is to assess the validity and accuracy of this instrument in studies of ventricular volume and ventricular function. Fifteen patients are being studied by ultrasonic methods as well as by measurement of cardiac structures obtained through conventional angiographic techniques in the Stanford Catheterization Laboratory. Comparison of the motion of cardiac structures recorded ultrasonically versus motion by standard angiographic techniques is being accomplished. Clinical evaluation studies will be carried out until a full spectrum of heart disease parameters has been seen and the instrument has proven its diagnostic quality as compared with presently available

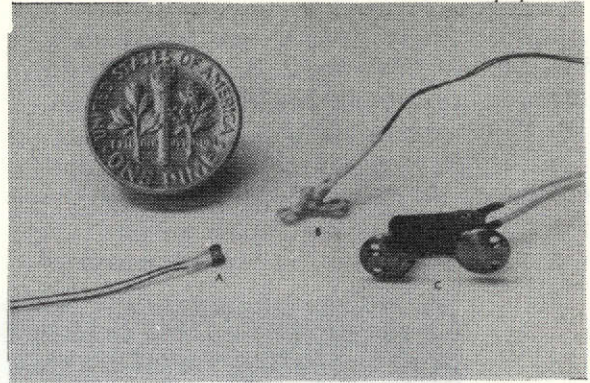


larger units, that are less mobile and more costly than this equipment. It is planned to modify the instrument to allow simple operation of the unit so that individual patients or experimental subjects may perform self-operation. Efforts are continuing to make this device commercially available at the successful completion of the clinical test program.

**Pericardial Stress Transducer.** Measurement devices originally developed to monitor the stresses in solid-propellant rocket motors on the NASA Surveyor Project are being used in cardiovascular research. Known as MST's, they are used to measure the myocardium's (heart muscle's) ability to regain its pumping effectiveness after its blood supply has been either reduced or eliminated and later restored. The MST's are also being used to analyze the effects of various drugs on the heart muscles.

Researchers at the Cedar-Sinai Medical Center in Los Angeles and the NASA Jet Propulsion Laboratory have been using the modified stress transducer to examine the 'regional' effects of local coronary artery blockages in dogs. This is part of a major research effort into the progressive changes in cardiac functions and myocardial (heart muscle) alterations associated with coronary occlusions and subsequent reperfusion. The objectives of the measurements are to develop data on the myocardium's (heart muscle's) viability and the effects of restoring blood flow to areas of muscles to which the blood flow has been restricted. These data will provide a baseline for evaluation of the effectiveness of pharmacological, surgical and circulatory-assist interventions.

In 1971 researchers attempted to measure the forces in the muscle wall of an intact, viable canine heart, using conventional medical gauges. The bulk and mass of these devices hampered the efficient measurement of physical pa-



The original rocket engine strain gauge (A) compared in size to the suturable version (B) and a conventional medical strain gauge (C). This (B) device is now being used to study the effectiveness of surgical procedures intended to restore circulation to portions of heart tissue whose normal blood supply has been disrupted.

rameters in a live animal. Since the MST provided a much smaller size and mass than presently available commercial medical gauges, exploratory tests were conducted to determine if the MST's were useable or adaptable to the medical applications. It was found that the MST had to be modified to facilitate suturing to the heart wall. These modifications tripled the overall length (from 0.212 cm to 0.700 cm) and increased the weight (from 0.0123 grams to 0.0810 grams) but presented a package that was suturable by the surgeon with less than half the size and weight of the smallest available medical gauge.

Although sutures are commonly used in medical research as a method of attaching measurement devices to the surface of viable heart muscle, the adaptability of adhesive and embedment procedures is being studied. The techniques should avoid the problems of pre-tension encountered with suturing. In a test of the embedment procedure, an MST 0.106 cm long was embedded within the myocardium through a small puncture made with one-millimeter diameter needle. Results of this test indicate that an embeddable device is feasible, and, while much work remains,



an embeddable MST could answer many questions dealing with the force distribution throughout the layers of myocardial tissue.

Measurements being taken by this device cannot presently be performed on humans. Hence, controlled animal experimentation is resorted to, with great emphasis on appropriate physiological simulations. Recent developments in cardiology and cardiovascular surgery such as coronary artery bypass and

circulatory-assist treatment of the failing heart have focused attention on the mechanical performance of the heart's chambers--particularly on the localized and regional response of the left ventricle wall to various insults and interventions. Thus, a new era has opened up, requiring the development and experimental evaluation of advanced approaches to sophisticated mapping of the forces, stresses, and strains characteristic of normal and deficient functioning of the heart.



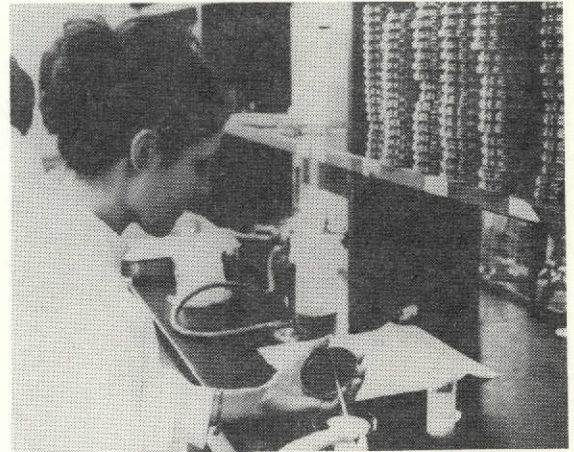
# Bacteriology

**Automated Bacteria Detection System.** Hospitals, physicians, clinics, the food processing industry, the brewing industry, and others requiring sterile manufacturing conditions may soon benefit from an automated rapid bacteria detection system based on instrumentation originally designed for life-detection missions on NASA's Mars-Voyager spacecraft.

The system offers a quick indication of the presence and quantity of bacteria by registering the amount of light emitted by the reaction between the ATP and luciferase, an enzyme derived from fireflies.

Johns Hopkins University, Tufts University-Medical Center, and Delaware State University are working with NASA to develop this technology. It is being investigated for the analysis of the effectiveness of antibiotic drugs against infectious agents and for its potential in monitoring kidney transplants, and for the detection of viruses. The major advantage of the new system is its ability to determine the amount of bacteria in a fluid in about 15 minutes, as compared with the 48 to 72 hours it normally takes to achieve similar results with conventional culturing medical laboratory techniques. By enabling physicians to determine rapidly the most appropriate antibiotics for treating infections, it is possible that the time required to effect a treatment may be greatly decreased -- reducing the costs of hospitalization for the patient and freeing hospital facilities for other patients. Similarly, the determination of the most effective drug for fighting an infection can be accomplished now in less than 5 hours compared to the conventional 48 to 72 hours.

When fully developed, the system would permit the automation of hospital bacteriology labs--one of the few laboratory operations which is presently entirely manual. A smaller, simpler version of the device might also be used in a doctor's office, in out-patient departments or community health centers. By rapidly indicating the absence or presence of an infection, it will permit the rapid prescription of an appropriate antibiotic drug and reduce the problem of patient follow-up which occurs when



**The conventional hospital laboratory technique for determining the presence of an infection requires a delay of 48 to 72 hours and must be manually performed by the technician.**

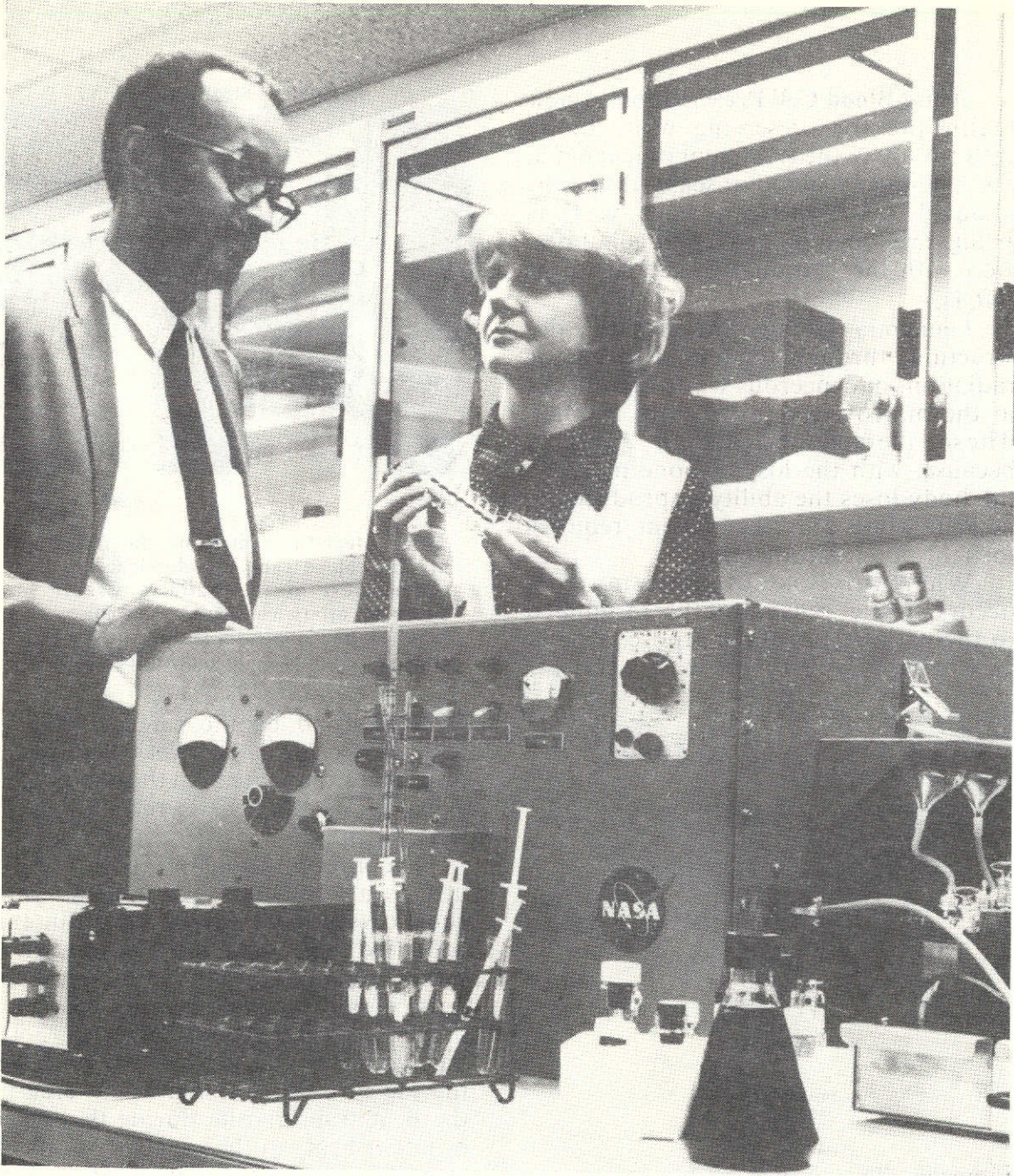
these results are not available until 2-3 days after the patient has left the office.

The system is based on the chemical reaction between luciferase and a substance called adenosine triphosphate, or ATP, a high-energy compound that is found in all living organisms. The use of the enzymatic reaction system was chosen over other approaches to the detection of ATP because it does not require the presence of ATP in a pure



form. This characteristic gives the enzyme system advantages in speed and simplicity, particularly over conven-

tional manual culturing techniques now used for examining urine and other biological fluids.



Scientists at the NASA Goddard Space Flight Center have developed a rapid technique for determining the presence of bacteria in biological fluid samples. The early prototype of the instrument shown provides an answer in 15 minutes as compared to 48 to 72 hours required by the conventional laboratory method.

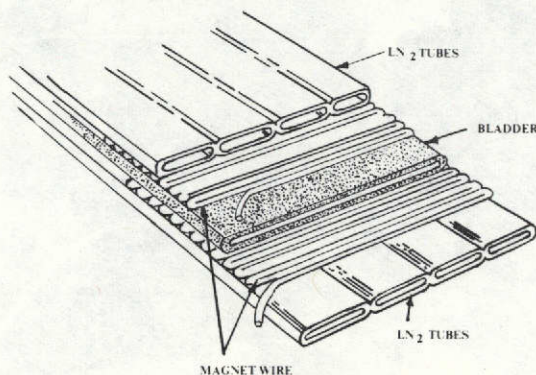


# Leukemia

**White Blood Cell Preservation.** A new technique for preserving white blood cells for use in the treatment of leukemia, the malignant blood disease that kills about 15,000 Americans each year, is being developed by NASA in collaboration with the National Cancer Institute (NCI).

Leukemia therapy involves the destruction, through the use of drugs or radiation, of cancerous white blood cells in the marrow where they are formed. These therapies create a problem because, with the loss of bone marrow, the body loses the ability to produce the normal white cells the patient requires to fight potential infections.

When this loss of bone marrow occurs, white cells must be resupplied to the patient. For this purpose, a bank or storage facility of white cells is



CONTROLLED FREEZING UNIT

required. This is impossible at present because adequate storage procedures are unavailable. Although red cells can be preserved by freezing, white cells are destroyed by the existing freezing and thawing techniques. One important parameter in freezing white blood cells



This system for controlling the rate of freezing of white blood cells was developed by NASA at the request of the National Cancer Institute. Freezing offers considerable promise as a technique for the long term storage of the white cells, needed by the body to fight infection.

is believed to be the rate of freezing. Rate of freezing cannot yet be controlled because of the plateau in the cooling rate when the latent heat is released at the freezing point.

The present method for freezing utilizes a liquid nitrogen system, which cools a secondary liquid, which in turn cools the cells contained in a flat Teflon<sup>®</sup> bag. To prevent contamination of the cells, it is desirable that any new technique utilize a Teflon<sup>®</sup> container. The basic requirement is a method of detecting the onset of freezing and increasing the heat transfer rate during the release of latent heat, so that a nearly constant rate of cooling can be maintained from room temperature to -50° C.

This problem was forwarded to the NASA Jet Propulsion Laboratory (JPL) where a new configuration was suggested. The cells are held in a Teflon<sup>®</sup> bladder surrounded by an electrical



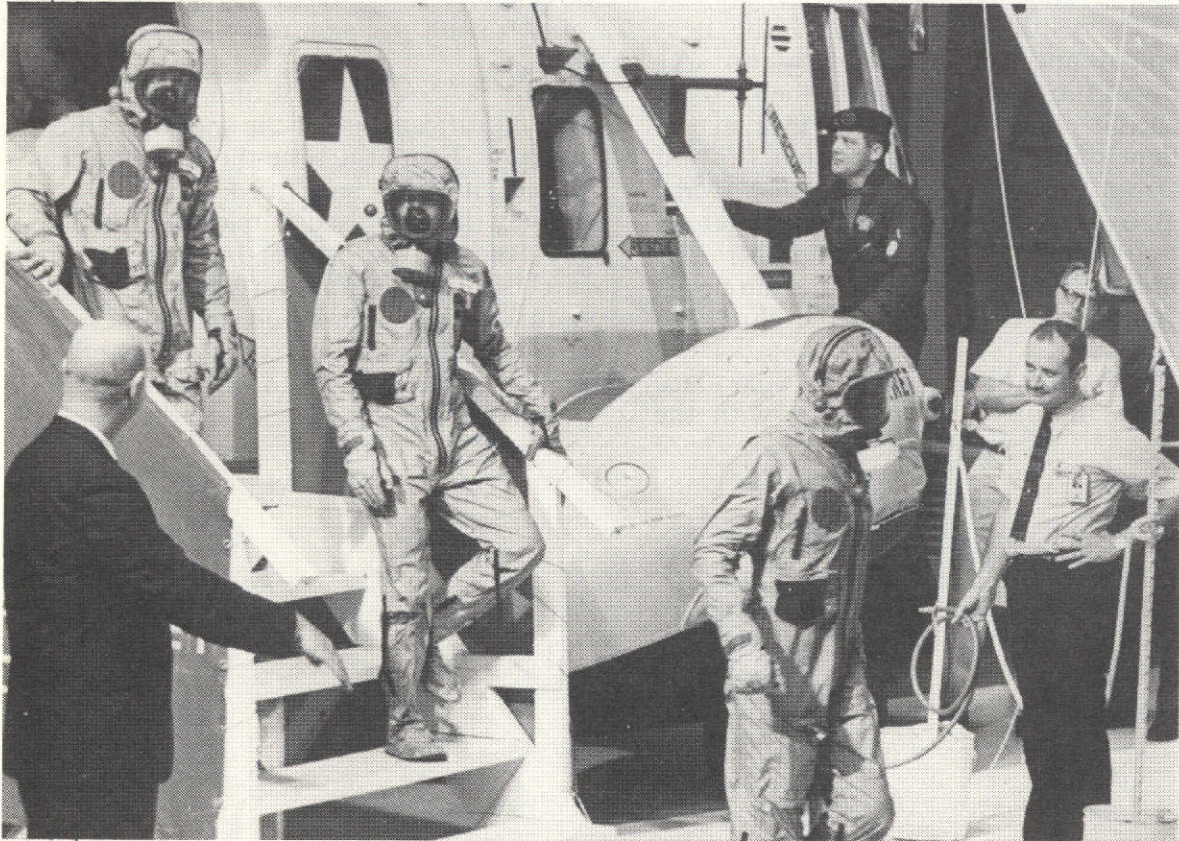
heating element and liquid nitrogen tubes. During the cooling cycle from room temperature to the freezing point, the heating coils control the cooling rate. At the freezing point, the electrically produced heat is reduced and the latent heat of the cells is rapidly removed. Then the heat is turned on again to control the rate until  $-50^{\circ}\text{C}$  is reached.

Although the proposed solution originated at JPL, implementation of this idea is being pursued by the NASA Goddard Space Flight Center (GSFC) because of the geographic proximity of NCI. GSFC personnel used computer-aided design to optimize the basic configuration before hardware construction. A computer simulation model was developed that allowed design modifications to be quickly evaluated. The computer analysis utilized the same techniques that NASA uses in space applications such as achieving thermal balance in space-

craft. Coordination between NCI and GSFC research staff members was closely maintained to ensure that the final device met all medical and engineering requirements. A prototype model of the design has been built and successfully tested. A laboratory model has been delivered to NCI for further research and evaluation.

**Biological Isolation Garment.** A special garment originally designed to provide a portable sterile environment for returning Apollo astronauts has been adapted by the National Cancer Institute to protect leukemia patients from infection while undergoing chemotherapy.

NCI has pioneered the use of laminar air flow rooms to provide a sterile environment for this therapy. But they have also wanted a portable sterile environment to permit patients to move



Apollo 11 astronauts wearing biological isolation garments on the return to the recovery ship.



from the sterile chambers to other places of treatment. The need was especially important for children who psychologically are less able to tolerate confinement in one room. The isolation garment permits them to leave the sterile laminar flow room for treatment and for recreation or visits with parents.

Queried by NCI, a NASA Biomedical Application Team suggested modifying the Apollo garment as a possible solution. The NASA Biological Isolation Garment has been designed for the Apollo astronauts to wear from the time of exit from the splashed-down capsule to the time of arrival in the portable quarantine facility aboard the recovery ship.

The original garment, and particularly its associated headgear, posed certain heat, weight, and claustrophobia problems for medical patients, especially children. The NCI specialists decided to add a positive-pressure portable air supply system to overcome the heat problem and provide ventilation. As many of the contaminants in the medical situation come from the surface of the patient's own body, a directed flow of air from the top of the head downward is provided to reduce the danger of self-contamination. An NCI contractor modified the face mask to suit the needs of patients and fabricated the child-size suit.

This technology transfer took place rapidly, thanks to experience with the



**The NASA-derived biological isolation garment is now being used by the National Cancer Institute to protect young leukemia patients while outside of their sterile treatment rooms.**

earlier NASA garment and rapid, effective modifications for the special medical purpose. From the time the problem was posed, it took less than a month to deliver the modified version adapted to the needs of the Cancer Institute.

Used in conjunction with the sterile laminar flow rooms and chemotherapy, the new garment provides mobility, comfort and access to recreation for patients with very special needs.



# Instrumentation

**Computer Analysis of Infrared Photos of Skin Burns.** The study and treatment of serious burn injuries is being assisted by computer-image enhancement techniques previously used to produce dramatic photos of distant planetary surfaces from data relayed by the NASA space probes.

The NASA Jet Propulsion Laboratory and the University of Southern California Medical Center are performing a detailed study of the use of computer-enhanced infrared photography for the early diagnosis of cutaneous thermal burn wounds. The immediate consequence of this study is to provide a simple clinical tool to accelerate the accurate diagnosis of the burn wound.

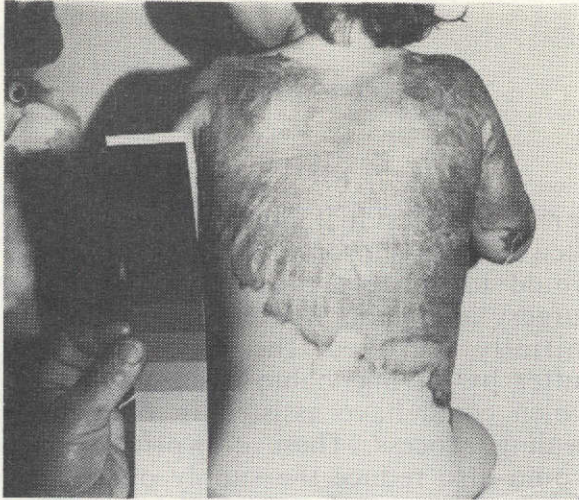
Developments in the treatment of burns over the past few years have indicated that early removal of the irreversibly destroyed tissue has many advantages. It reduces the risk of infection, the onset of thick scar tissue, and the loss of function to the damaged limb. It also appears to provide the best surgical results in the shortest time. However, in many cases it is impossible to differentiate between irreversibly damaged areas and those which would spontaneously heal with time. Treatment of the questionable areas thus depends quite heavily on the intuition and experience of the physician. Even though the physician is aided by many tools covering sensory, mechanical, and thermal phenomena, the only positive method available to him is to wait from three to four weeks until the natural healing pattern is established and the areas of the irreversibly damaged and putrefied tissue are indicated. If the physician decides to excise tissue before a precise diagnosis is available, the patient may suffer by not having sufficient tissue

removed. Residual dead tissue would then remain as a source of infection and would ultimately require additional surgery and pain. If excessive tissue is initially removed, the patient would suffer by having viable tissue removed which could have assisted in the vital healing process. These complications would also reduce the supply of viable tissue which may be required for grafting. In any case, the delay or inaccuracy in the diagnosis of the irreversibly damaged tissue increases the danger of infection. Infection is the most common cause of death of the burned patient.

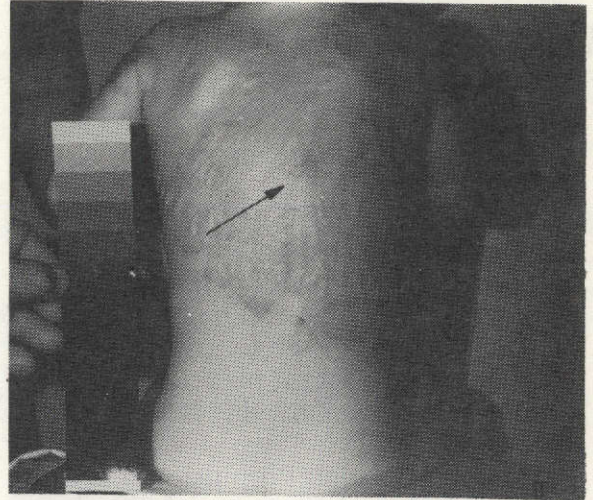
This technique is particularly attractive because, although a computer capability is required for the analysis of the image, the image of the burns can be photographed by an ordinary 35-mm camera using readily available commercial film and infrared filters. Since a wait of several days is normally required for surgeons to begin removing dead tissue, it would be quite feasible to send the infrared photo images to a centralized computer facility for rapid analysis.

In a series of early studies, it was possible to predict those areas which two days to two weeks later developed into areas which would require grafting. Based on an admittedly small data sample, it seems that computer-enhanced infrared photographs can reveal clotting deep within the skin or deep layers of dead tissue--an indication of a full thickness burn. Thus, it appears that infrared photography, enhanced in some cases by image processing, could be a powerful tool in a burn clinic. It should be possible to predict the viability or nonviability of burnt tissue and thereby accelerate the diagnosis process

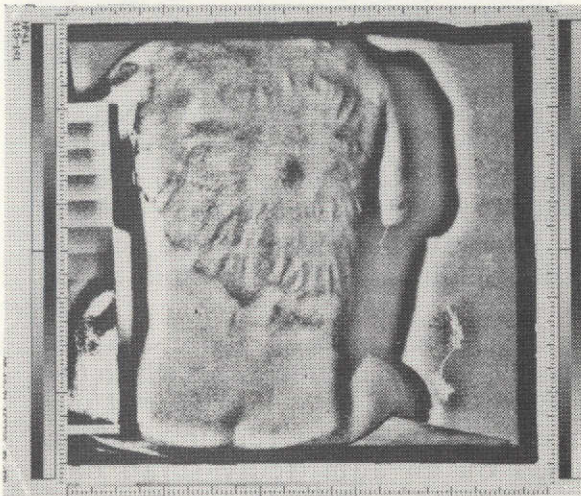




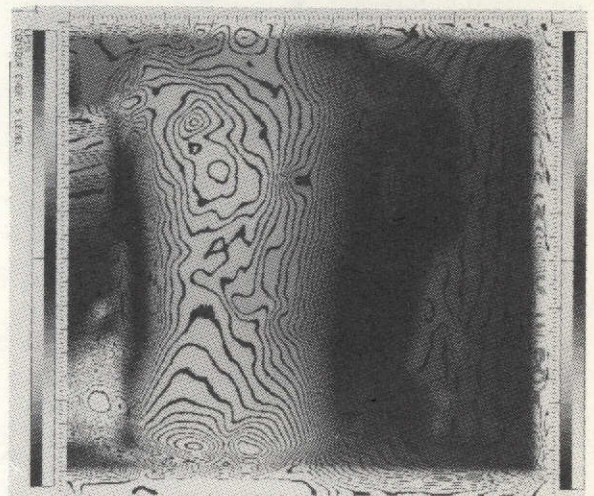
A conventional 35 mm camera loaded with infrared film is used to photograph the patient's burn. This unfiltered photograph was taken three days after the burn occurred due to a spilled pot of hot coffee.



This filtered infrared photograph shows a very different situation than the unfiltered one. A full thickness burn has occurred only in the darkened area indicated by the arrow. The ridges are thought to be due to shrinkage.



After computer processing using high pass filtering and image enhancement, dark areas indicate possible deep tissue damage. The dark spot corresponds to the point indicated by the arrow in photo B. The dark areas along the ridges may be eliminated as potential problem areas as they also appear in the unfiltered photo A.



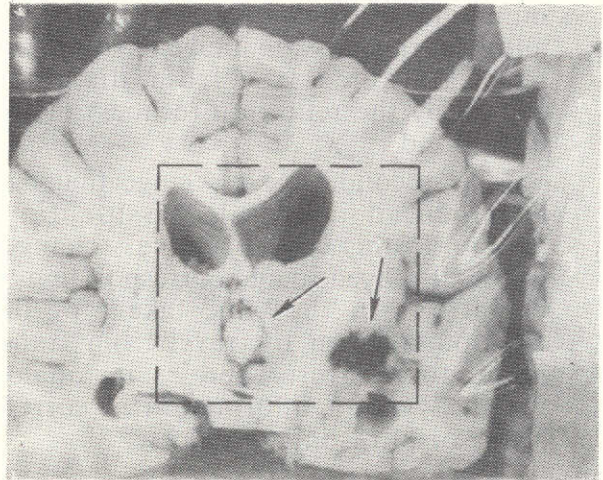
This is photo B after processing with low pass filtering and contour lines. A deviation from the normally smooth contour lines provide a basis for quantitative data.



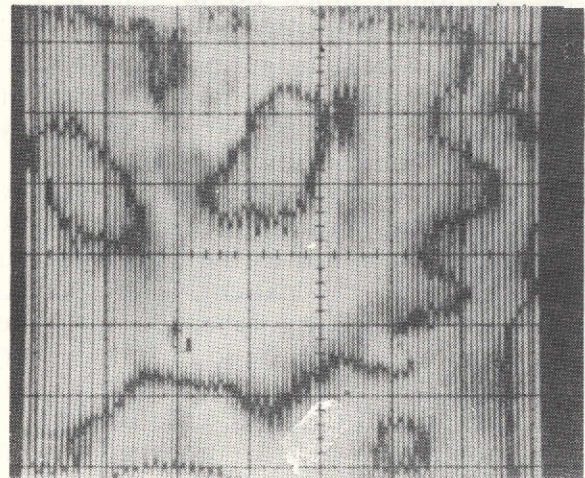
by weeks. This would allow the early surgical removal of nonviable tissue; and, would result in a major reduction of trauma and expense for the patient.

Selected volunteer patients from the Los Angeles County-University of Southern California Medical Center Burn Ward are being studied throughout the course of their care, beginning with admission and continuing to the time of accurate diagnosis. Data from processed photographs will be correlated with tissue biopsies and visible landmarks over this period. Image-processing techniques will be studied to determine optimum processing algorithms; and protocols will be established to yield maximal benefits of early clinical diagnosis for minimal cost.

**A section of brain tissue used to study the imaging capability of ultrasound transmission.**



**An ultrasonic image of the contours of the cavities and abnormal areas referred to by arrows in the accompanying photograph. The display is the result of small variations in the velocity of ultrasound as it travels through the brain tissue and the surrounding fluid.**



**A New Imaging System Using Ultrasonic Transmission.** A new method of forming a visual image of a biological specimen based on the ultrasonic high frequency sound energy transmitted through a biological specimen has been demonstrated by researchers at the NASA Jet Propulsion Laboratory. A shadowgraphic transmission image similar to an X-ray radiograph is produced by a technique known as time delay spectrometry.

Conventional clinical X-ray images are formed by recording on film the varying intensity of X-radiation which results from the differential absorption of X-radiation by tissue and bone structures of varying density. Thus the conventional X-ray image is dark where the



X-ray particles have easily passed through soft tissue such as muscle and flesh, and light where the X-ray particles have been stopped and absorbed by denser substances such as bone or calcium deposits.

The JPL ultrasonic transmission imaging system is capable of producing two distinct types of images. In the first type, brightness (shades of gray) at any point in the picture is a function of the energy received by a transducer as it is scanned over a predetermined area. In a medical diagnostic system, this scanned area will be located to obtain a shadowgraphic image of the region of interest. An image will be formed that is a representation of the absorption of the ultrasound beam transmitted through soft tissue or bone with the minimum of transmission time. This allows a transmission image of soft tissue to be obtained free from distortion caused by the reflection (echoes) of the ultrasound.

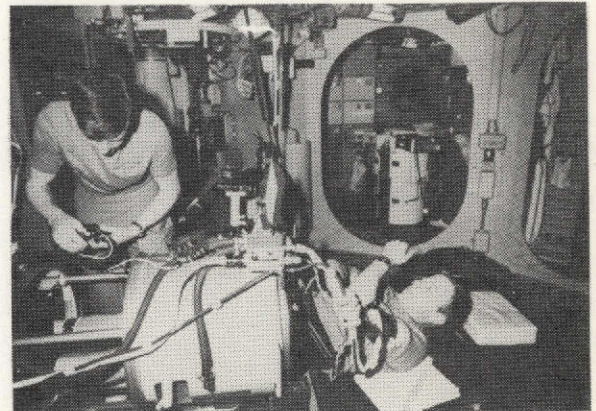
The second type of image that can be produced is a transmission time picture. In this case, brightness changes in the displayed image corresponding to variations in the time taken for the ultrasound beam to travel from transmitter to receiver. There is no analog for this type of information in current X-ray or ultrasonic practices.

Although much useful clinical and diagnostic information can be obtained from an X-ray image, physicians must always be mindful of minimizing their patients' exposure to X-rays. Were they able to monitor a patient more frequently or for a longer interval at any one time, the physicians might gain new information useful to the diagnosis and treatment of the patient. The second factor motivating research into the capabilities of ultrasonic imaging is the hope that this new imaging technique will be able to detect disease conditions in soft tissue which are not readily seen by X-rays.

Several hundred transmission images have been made to date. The specimens used have ranged from simple geometrical shapes formed by metals and plastics, to excised animal organs, and to the human forearm.

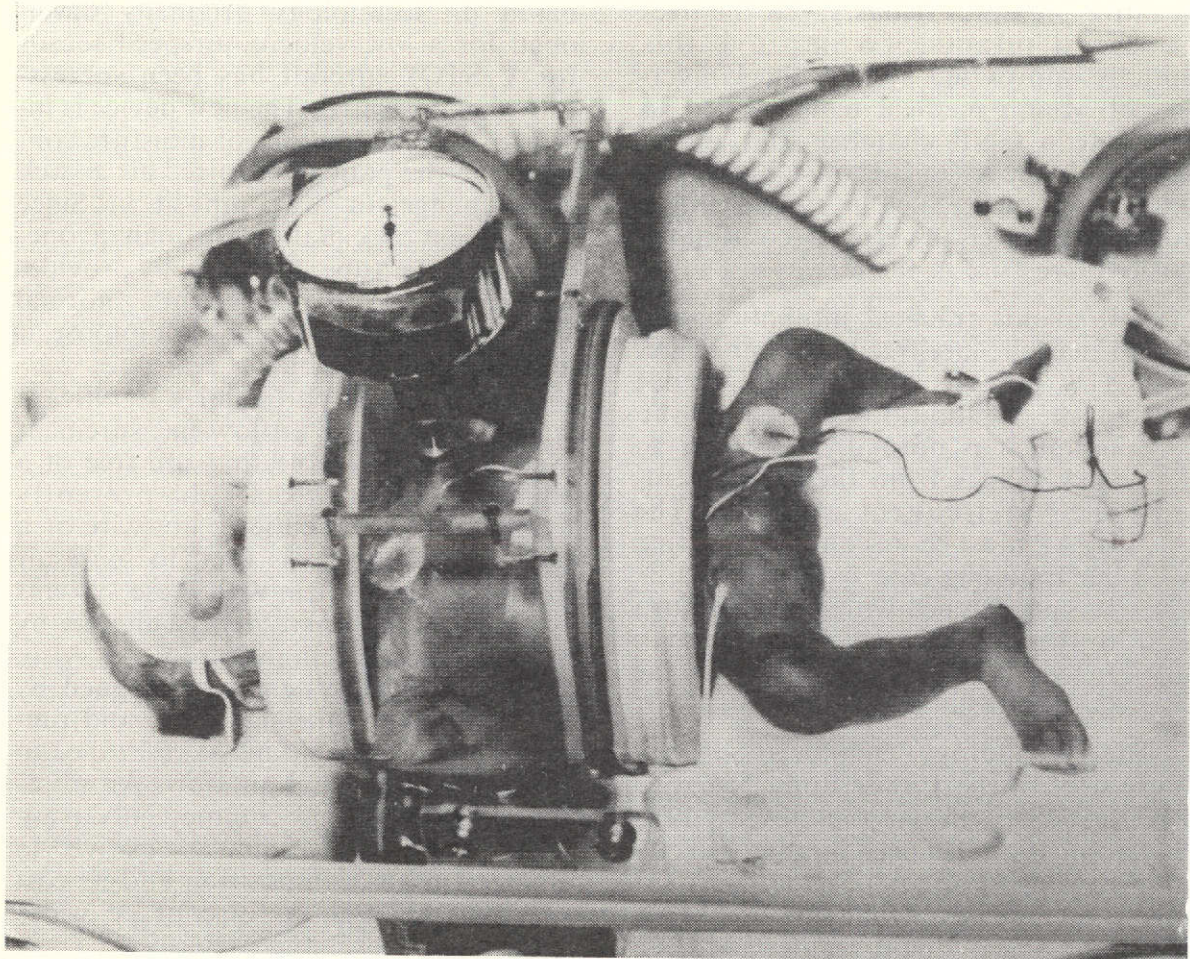
In "in vitro" studies performed in cooperation with Childrens Hospital of Los Angeles, measurements of the absorption of ultrasonic energy in brain tissue have shown extremely high attenuation in tumorous regions. Also, an edge effect occurs which helps to outline boundaries. Image features formed by ultrasonic transmission have been correlated with known tissue structures. Additional work is continuing to improve the ultrasonic scanning system and to explore the range of tissue pathology which can be detected by this new technique.

**Infant Respiratory Assist Device.** The treatment of hyaline membrane disease (respiratory distress syndrome) by medical researchers at the University of Miami is being aided by technology used onboard the NASA SKYLAB. The respiratory assist device is patterned after the lower-body negative-pressure system developed for the SKYLAB program to control the body's blood distribution in zero gravity.



The lower body negative pressure (LBNP) device onboard SKYLAB used to study the heart's response to increased work loads.





**An early prototype of the continuous negative pressure device used to treat respiratory distress syndrome in newborn infants used technology developed for the SKYLAB LBNP device.**

Respiratory distress syndrome is the major cause of death in the newborn. It is estimated that more than 20,000 babies succumb to this disease in the United States each year. Respiratory distress syndrome is a condition of the newborn in which the lungs are collapsed. It is believed to be caused by the absence, because of immaturity, of an alveolar substance that decreases the surface tension and permits the lungs to reexpand after each expiration.

Recently, researchers at several medical centers in the United States and Canada have reported encouraging results with the use of continuous positive airway pressure (CPAP) and continuous negative pressure (CNP) therapeutic techniques. The CPAP method uses an

endotracheal tube which continuously forces oxygen-rich air into the lungs, while the CNP method keeps the infant's lungs expanded by subjecting the chest to continuous negative pressure. The negative pressure around the chest helps the infant to expand his lungs and to maintain the proper residual volume of air. If life can be sustained for 4 days by either method of treatment, the missing alveolar substance will be present in a sufficient quantity for normal unassisted breathing to occur.

The CNP method has been employed by specialists at the University of Miami School of Medicine, who were among the first to utilize the technique. First, a commercially available respirator was modified to produce a constant



negative pressure. It has saved the lives of several infants. To improve this initially improvised system, the University of Miami medical team wished to fabricate a CNP chamber that would cover only the infant's thorax, arms, and upper abdomen. Such a system offers advantages over the use of continuous positive pressure in the airways:

- (1) It avoids tracheal intubation and leaves the face free for nursing care. This point is of great importance since, in addition to feeding the infant, it is normally necessary to suck mucus from the infant's trachea at frequent intervals. The CPAP must be discontinued during such nursing care.
- (2) Its interference with venous return to the right heart will be minimal.
- (3) It avoids the increase of air in the gastrointestinal tract.

The technology employed in the body seals of the Lower Body Negative Pressure System on the NASA 1973 Skylab mission has been applied directly in providing therapeutic treatment for respiratory distress syndrome. A NASA Marshall Space Flight Center (MSFC) engineer visited the University of Miami medical team to assist in the design of the air seal required at the waist in the CNP system. The waist seal designed for NASA's Lower Body Negative Pressure System appears to provide an excellent solution to the problem of sealing the CNP unit at the infant's waist. Additionally, the NASA seal is adjustable, which will allow the CNP chamber to accommodate infants of various sizes.

A preliminary design for the CNP system has been finished. The Department of Biomedical Engineering at the University of Miami plans to complete the fabrication of the CNP unit by the Spring of 1974.

**Fluidic Respiratory Flowmeter.** A fluidic medical respiratory flowmeter

based on technology originally developed for a low velocity airspeed sensor for V/STOL aircraft has been successfully demonstrated. The new device is insensitive to the amount of moisture contained in the patient's expired air as well as to changes in gas composition. Since the patient is exhaling through a one-inch diameter tube, it essentially provides no resistance to a patient's normal breathing pattern and does not impose an additional load on him.

The device is particularly significant since no low-cost airflow-measurement systems are available that are free of a collection of drawbacks. In presently available systems, either a hot wire or a mechanical turbine is used to sense air motion. The problem with these systems is that their sensitivity is altered by moisture carried in respired air. Also, the mechanical systems are plagued by problems of inertia and drag, and present an unusual amount of resistance to the patient's normal air flow. An ultrasonic flowmeter now commercially available tends to be quite sensitive to changes in gas composition and its cost is sufficiently high to discourage widespread use.

A respiratory flow measurement device such as this is used for the diagnosis of lung disease and for the prescription of medical care. It is used to evaluate a patient's respiratory parameters for comparison with values, to measure changes occurring over a period of time, in pre- and post-surgical care in anesthesia, to determine when to remove a patient from a mechanical ventilator (i.e. a breathing assist device) and, in suspected allergy situations, to determine the difference between asthma and emphysema. It is also used in industrial health programs to determine gross lung impairment resulting from exposure to hazardous materials.

The heart of the system is a fluidic flowmeter, portable and easily operated, intended for pulmonary function testing. Based on air flow measurement, the



device calculates and displays the forced vital capacity, the timed forced vital capacity (for 1, 2, or 3 seconds), the percentage expired per unit time, and the maximum expiratory flow rate.

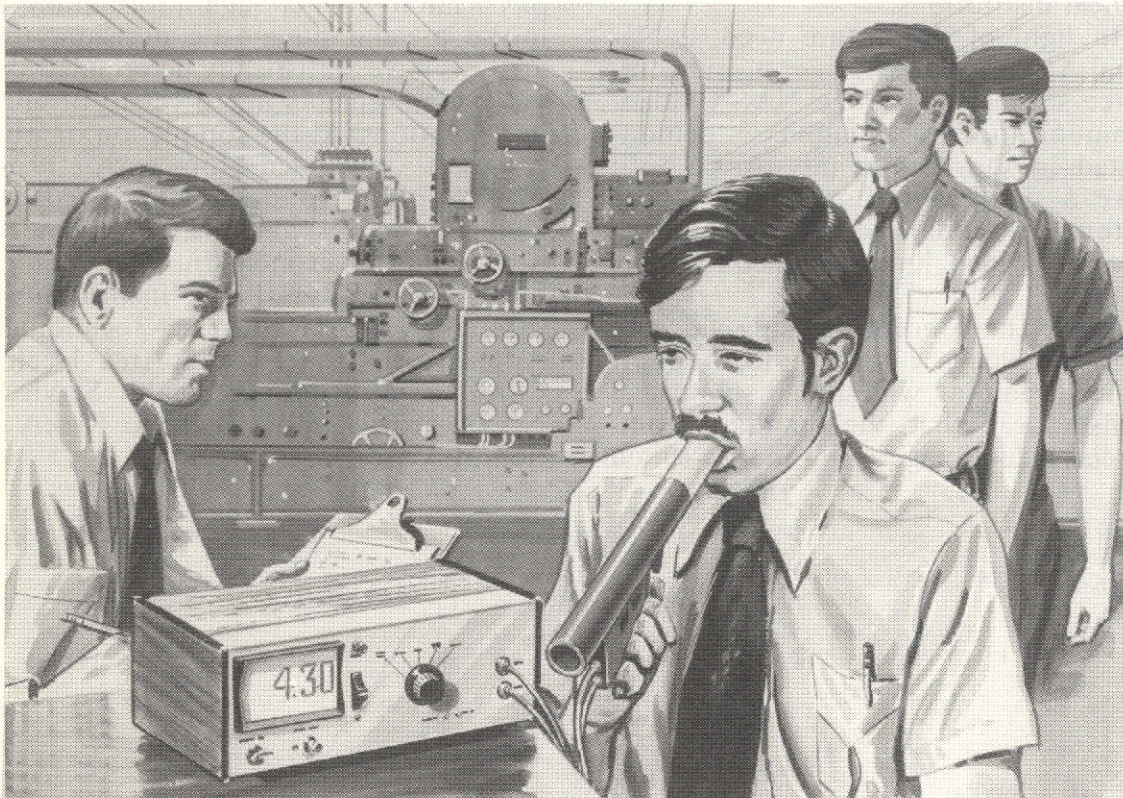
In addition to the device configured for pulmonary function testing, a second design suited for patient monitoring in respiratory intensive care units is being built. Clinical evaluation of both devices will take place in 1974.

**Trace Element Analysis.** Methods used by NASA to analyze lunar soil and rock samples brought back to earth by Apollo crews are being applied to the complex problem of analyzing minute traces of various metals in human tissue. The ultimate purpose of this effort, conducted at the College of William and Mary in Virginia, is to explore the effects of the various trace elements on human

tissue. The project is viewed with particular interest by the Environmental Protection Agency.

The system being used is a nondestructive method of assaying the samples that employs a charged-particle-induced fluorescence technique that reveals trace elements in extremely small amounts (parts per billion).

The William and Mary research group is developing an automated approach that could analyze several hundred samples a day. Both the Environmental Protection Agency and the Food and Drug Administration have expressed strong interest in a technique and a facility that could nondestructively analyze large numbers of samples for as many as twenty elements. Such a capability could serve the needs of a wide range of local, state, and federal agencies concerned with biological, environmental, health, and geological studies.



The NASA fluidic respiratory flowmeter offers a rapid, effective technique for assessing the condition of the lungs.



The program is also drawing on NASA experience with ultraclean rooms to meet the project's need to prevent contamination of samples. Also used in the project is a NASA Langley Research Center Accelerator originally used as a micrometeoroid simulator.

Other potential applications of the technology include its use as a research tool for answering questions about the toxic and beneficial roles of trace elements in human nutrition and the kinetics of elements in various life processes.

**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 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 frequency spectrum space, band-width, 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 Lyndon B. Johnson Space Center, began a study of video requirements for remote medical diagnosis. The NASA program includes medical, bio-engineering and communications specialists. By determining minimum qualities of the video image necessary for a physician to gain enough information to make a valid diagnostic decision, the analysts have statistically determined the video requirements in a diversity of clinical situations. At the completion of the program, scheduled for early 1974, NASA plans to define the extent of medical services which can be provided for varying investments in video equipment. The study will be incorporated into STARPAHC (Space Technology Applied to Rural Papago Area Health Care), a joint Indian Health Service/NASA project on the Papago Reservation in Arizona.



# Rehabilitation

**Remote Manipulator Technology.** As a prelude to further interactions with the Veterans Administration and the Social and Rehabilitation Services of the Department of Health, Education and Welfare in the area of aids for the handicapped, a study to define the systems requirements for the application of space teleoperator technology to the problems of the handicapped has been completed by NASA. An HEW study indicates that 2.75 percent of the general population is limited in the capability to perform normal activities due to paralysis, loss of limbs and non-paralytic orthopedic impairments.

The first portion of the NASA systems study was to develop a set of integrated system user requirements upon which to base the design concepts. Relying on requirements reduces not only the time required for conceptual design but also the number of, and cost of, concepts which, when fabricated, are found to be ineffective. The careful identification of system requirements also facilitates the identification of problems for the handicapped.

The primary need of the handicapped person is independence in daily living. To the degree that a person is hindered in performing a task, he is dependent on someone else for assistance. It can be argued that causing a handicapped person to rely or depend on a mechanical device to perform his required functions is really not making him independent. But even normal man depends more and more on mechanical aids in his everyday life. He depends on transportation systems to take him where his legs cannot. He depends on the telephone to carry his voice to great distances. He depends on typewriters, ovens, elevators, oil well machinery, etc., without thinking twice

about being dependent on these machines. Rather, dependency is an interpersonal relationship which connotes reliance on other people. Case histories of disabled individuals are replete with the psychological problems that accompany dependency on another person for even the most basic of human functions.

The needs of the handicapped form the basis for the systems requirements. The major needs can be described as:

- Ensure a high degree of independence for the handicapped person.
- Permit the performance of required and desired activities in a manner which is effective, safe, and comfortable.
- Emphasize the performance of activities in a manner which approximates the "normal".
- Enhance the accessibility and handling of objects used in everyday activities.

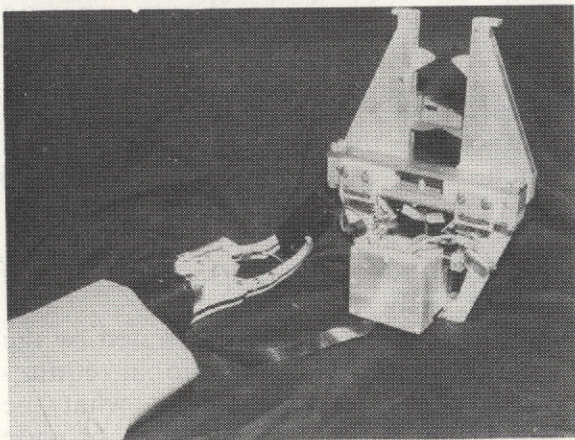
Precisely what activities should the system facilitate? Obviously, the ultimate goal is to enable the handicapped person to perform any activity he would be capable of performing if he was not handicapped. With the present state of technology, this goal remains beyond reach. Therefore, a more practical approach is to ensure that the handicapped can at least perform those activities identified as important in normal daily activities.

The activities to be facilitated by the system constitute the functional requirements of the system, that is what the system must do. As such, they provide the framework for establishing the capabilities which the system must possess. The level of capability to be incorporated into the system is derived from



performance requirements. These define the accuracy, time, and energy requirements associated with each system function.

In the future, NASA will be working with the VA and HEW to apply its teleoperator research and development experience to the above functional requirements. NASA's experience in teleoperator development has covered sensors, manipulators, actuators, control systems, and mobility -- each concerned with the man/machine interface. Sensors under development include video systems, touch sensors, force sensors and environment sensors. Manipulators include mechanical arm-like devices, grapplers, surface samplers and end effectors or tools for performing required mission operations. Actuators include hand and finger-like devices to perform tasks. Control system technology includes use of computer-aided devices for manual control of manipulators, free fliers, sensors and support systems. Control technology for planetary teleoperators also includes artificial intelligence, which involves development of techniques of machine learning and adaptive control for providing some level of semi-autonomous behavior for systems too distant to be controlled

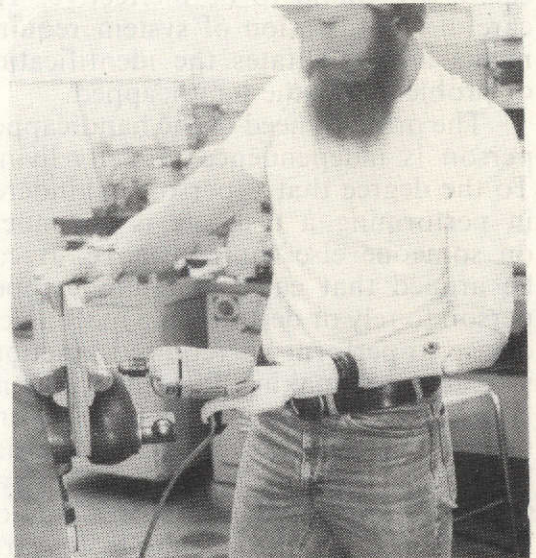


The concepts developed for the large remote manipulator on the right are now employed in an artificial hand with a trigger finger.

directly. These approaches provide the teleoperator with a limited amount of on-board intelligent behavior. Mobility system technology comprises integration of subsystems and development of navigation, guidance, and propulsion or locomotion systems. The man/machine interface area includes all aspects of the effort to integrate the human operator with the system hardware and software. On the machine site this involves work-site technology, manipulator/effector technology, and controllers and displays. On the human end, the technology area includes sensory feedback, determination and maintenance of skills and skill levels, and measurement of operator workloads.

The NASA study matching functional requirements with teleoperator technology has been completed in the areas of manipulator devices, mobility units, remote-control systems and sensor systems.

Among the applications are: aids for auto driving, advanced control systems (including voice controlled systems), manipulators to increase patient reach, remote-controlled devices to serve as 'mechanical servants', tactile and prox-



The artificial hand with trigger finger allows unilateral amputees to use power tools while freeing their good hand.



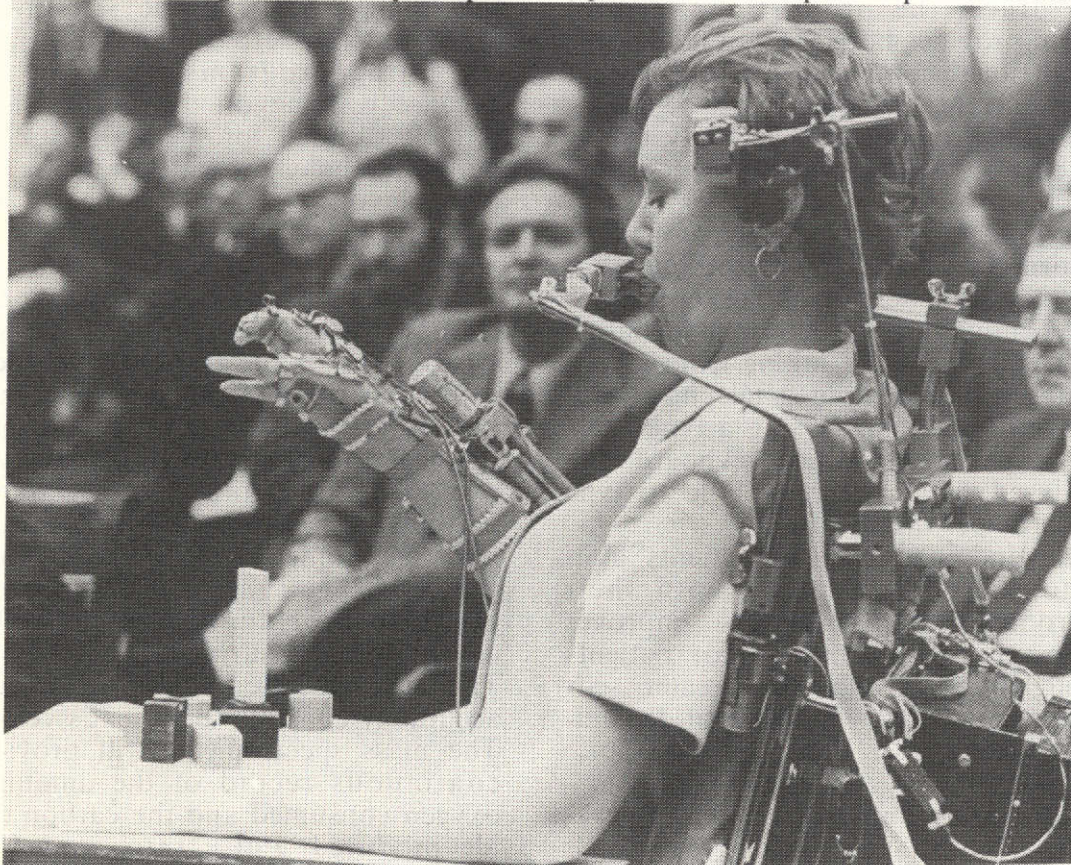
imity sensors, manipulator attachments for prosthetics, and the development of standard criteria and evaluation tests. These have been ranked in terms of potential numbers of handicapped people to be served, the value of the potential benefits, and technical feasibility. NASA and the Veterans Administration Prosthetic Center are now working together in planning and coordinating the development, evaluation and implementation of devices in several of the above named categories.

**Prosthetic-Control Systems for Paralyzed Patients.** NASA developed 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



The externally powered arm brace allows a woman paralyzed with polio new independence and ability to feed and care for herself. Advanced electronic control systems allow her to write legibly, turn pages to read, type, and perform other tasks requiring considerable accuracy and dexterity.



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 commercially available and 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.

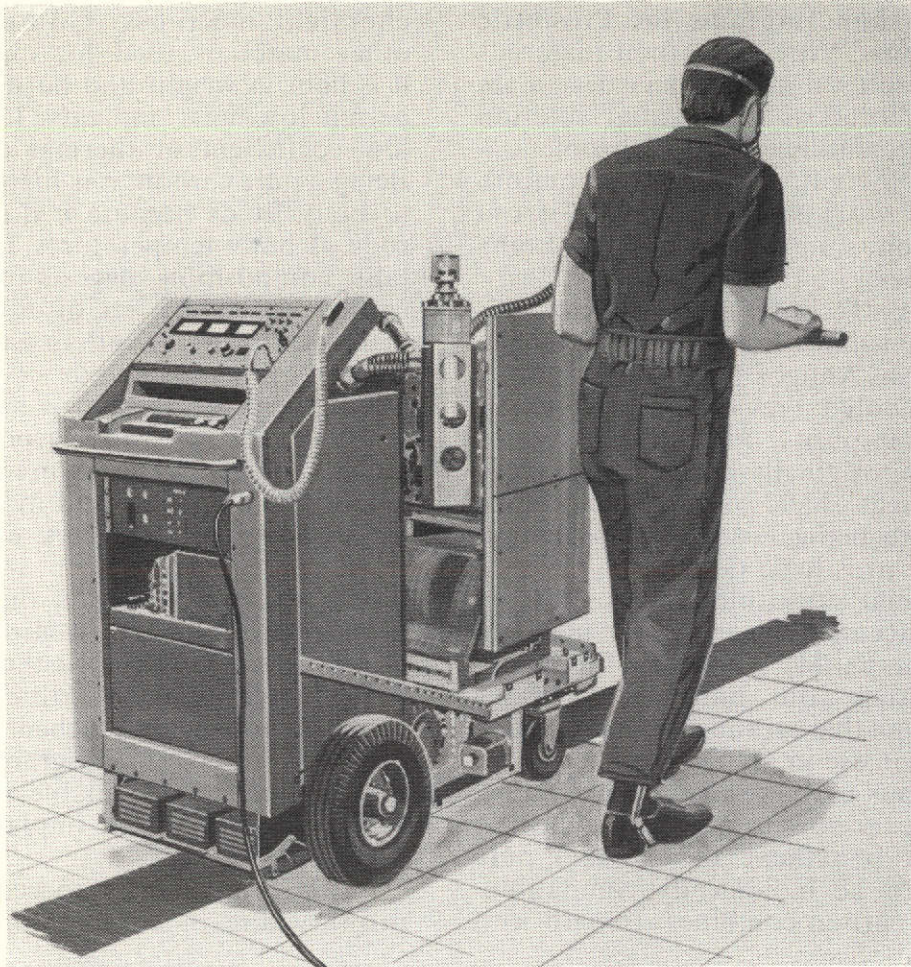
**Measuring Patient's Exercise Workloads.** Information on the workloads encountered by severely disabled patients in rehabilitation programs will be provided by instrumentation and tech-

niques 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 MSFC instrumentation will provide accurate measurement of metabolic activity of both normal and severely disabled subjects during actual "walking" conditions. It can also be used to follow the progress of severely disabled persons through the many phases of their rehabilitation training programs. In the past, 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 because walking on a treadmill is extremely difficult for such patients. Ambulation studies on patients whose disability involves a leg are nearly nonexistent.

In a cooperative effort between a DHEW social and rehabilitation services training center and NASA a special motorized cart and an instrumentation system provided by MSFC will 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 and the carbon dioxide produced. Pulse rates and EKG tracings, as well as inspiratory and expiratory volumes, will also be recorded.





**The metabolic analyzer mounted on a self powered cart developed by NASA/MSFC to assist in the design and evaluation of artificial limbs and walking assist devices.**

Accurate velocity measurements are essential to meaningful workload data. Coupled with accurate physiological data, velocity data will allow medical personnel to measure the actual work performed by a patient. This will aid in the design of assist devices and therapeutic techniques to minimize the stress on patients.

The instrumentation will be installed at the Spain 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.

The functional system was fully tested during the summer of 1973 and delivered to the Spain Rehabilitation Center for use in their studies in January 1974.



**Biocarbon Implants for Prosthetic Connections.** Vitreous carbon materials which were used in aerospace design are being explored as a potential solution to a long-standing medical problem -- the need for more convenient, comfortable and workable connectors from amputation stumps to artificial limbs (prosthetics).

NASA's Technology Utilization program is supporting research at the Rancho Los Amigos Hospital in California, a noted rehabilitation center. There, high-purity, high-strength forms of carbon, originally designed for space capsule heat shields and rocket engine linings are being tested for use in implantable prosthetic devices.

Artificial substitutes for bone, teeth and replacement heart valves must be highly compatible with body fluids and body tissues. But until relatively recently, available carbons were not strong enough for use in artificial limbs.

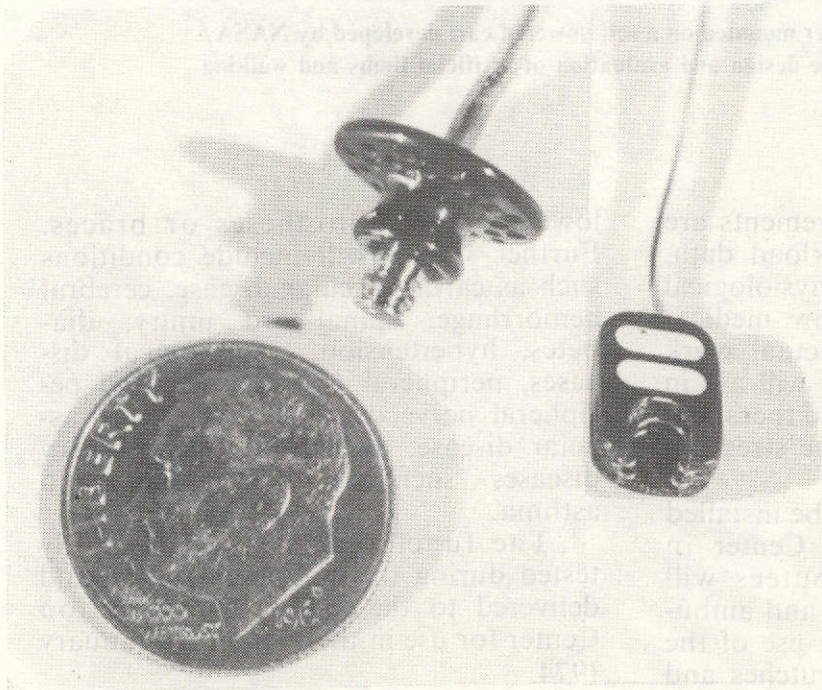
Vitreous carbon developed for aerospace use is now strong enough to be used for prosthetic devices and pure enough to be biologically compatible. Vitreous carbon combines strength with

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 materials and living skin is the most demanding challenge in direct 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 is evaluating the currently available, high-purity biocarbons for use in implants passing through the skin.

This project has proceeded to the point where biocarbon implants have

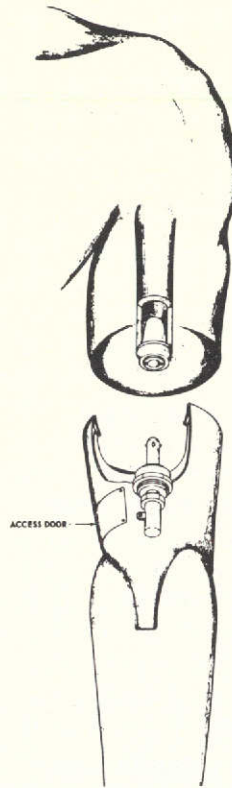
**Miniature implantable high purity carbon electrodes are used for long term implantation for the treatment of chronic pain and the functional stimulation of neurologically impaired muscles.**



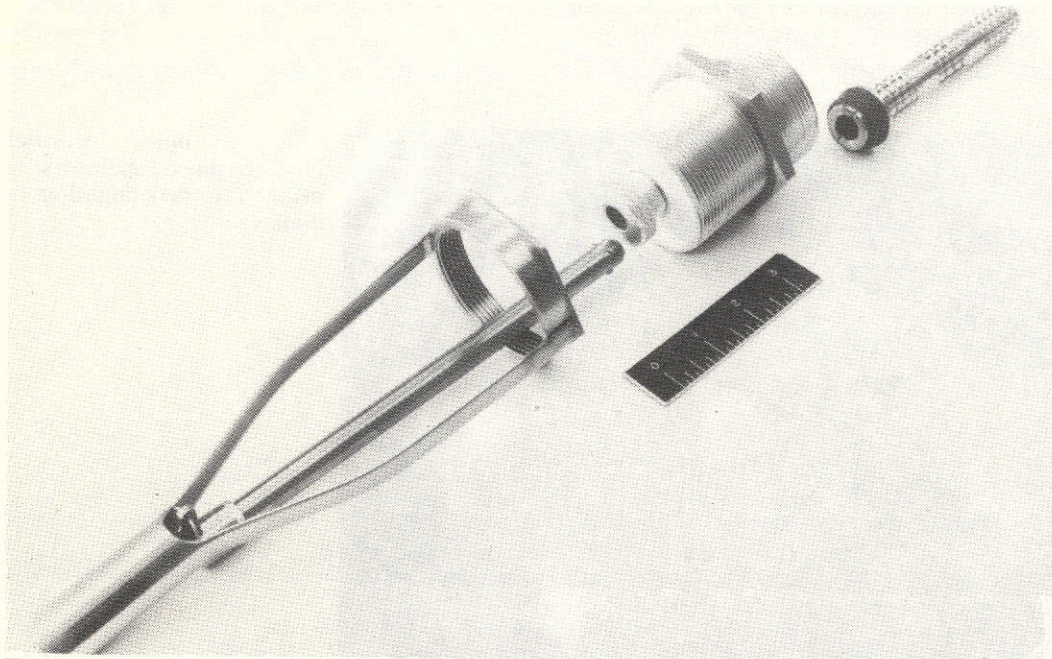


been used now for traction pin collars (Steinman pins), neuroelectric nerve stimulation, to exercise the muscles of stroke patients, pain control with electric stimulation, and for direct skeletal attachments where the biocarbons are being used at the interface with the skin at the end of the amputee's stump. More than twenty patients at the hospital have had implants for electrical stimulation. The results have been quite promising. Of recent significance in this work is the acceptance by the Archives of Surgery of a paper by Rancho researchers entitled "The Use of Pure Carbon for Permanent Percutaneous Electrical Connector Systems", which is the first accepted medical publication on the subject.

These biocarbon devices and accompanying electrode systems already have been used successfully to relieve pain via direct electrical stimulation and to exercise muscles which have begun to involuntarily contract. Although additional development is still required to refine the mechanical design, it has



The high purity carbon material fulfills an age old dream of directly attaching artificial limbs to bone.



The mechanical components of the system for directly attaching an artificial limb to the skeletal structure. The unit on the right is permanently implanted in the bone with the black carbon collar passing through the skin. The other components allow the artificial limb to be easily attached or detached by the patient, also protect the bone from mechanical shock. This device was developed at the NASA Kennedy Space Center.



been demonstrated to be a reliable device.

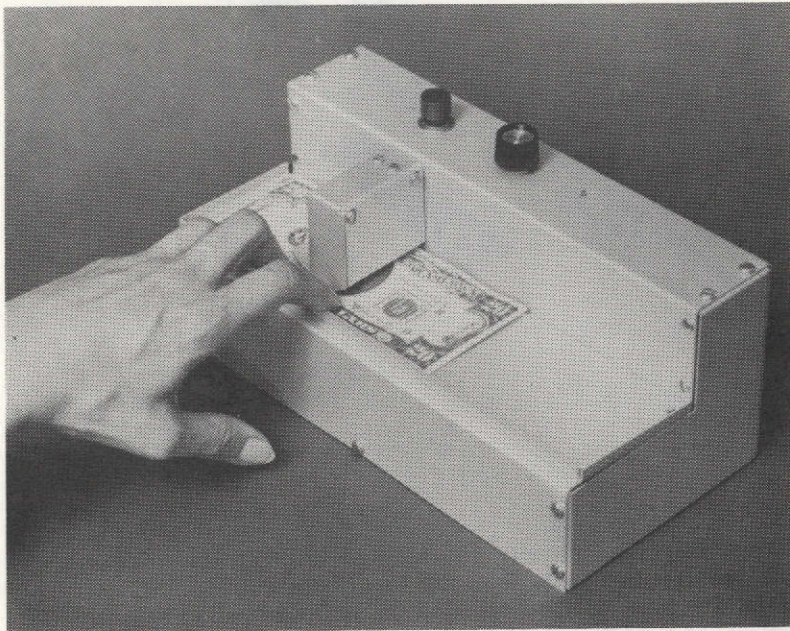
Two very different designs for direct skeletal attachment systems for prosthetic devices have also been implemented. The first system employs a tube implanted transversely in the stump with carbon collars used where the tube passes through the skin. Two patients have had their prosthetic devices suspended by way of this system. From the skin interface aspect, the system has functioned well. The second approach uses a tube implanted axially in the central channel of the bone (the medullary canal) and allows the amputee to rapidly and conveniently connect or disconnect his prosthesis. Again, further device-design work will be required before it will be available for general clinical application. Nonetheless, it is quite reasonable to expect that prosthetic fittings of the future will utilize the system once standardization of specifications and attachment fittings become available.

This pilot project has demonstrated that medical applications of high-purity carbons are feasible for infection-free

passage through the skin. This unique characteristic of being able to traverse the skin without threat of infection offers a wide range of practical clinical applications. Chronic muscle stimulation may be possible. A set of electrodes used to stimulate the appropriate muscles might be used to effect straightening of curvature of the spine. Implanted carbon electrodes might be used to stimulate new bone growth at the site of a fracture which had been healing poorly, and the electrodes then could be left in place indefinitely.

**An Automated Paper Money Identifier for Blind People.** The NASA Biomedical Application Team at the Southwest Research Institute, in Texas has developed an automated money identifier for use by blind people. The system is based on technology originally developed by NASA to inspect microfilm records.

Using the device, a blind person can identify various paper money denominations by their sound "signatures". The system works this way: The bill to be inspected is passed under a light source.



The paper money identifier allows blind business operators to determine the denomination of paper money.



A phototransistor measures changes in the bill's light patterns. These changes are converted into sound signals by an oscillator. The sounds are like the beeping tones heard on long distance telephone calls. The key to the varying signals identifying different denominations is the variation in design of the different denominations. Thus, each denomination gives off its own easily identified sound.

The money identifier has been successfully tested at the Arkansas Enterprises for the Blind in Little Rock. About three hours of practice are required for a blind person to learn to use the new system. The paper money identifier is being manufactured by the Marchak Engineering Company and being marketed by the Applied Rehabilitation Systems. Both organizations are in Austin, Texas.



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