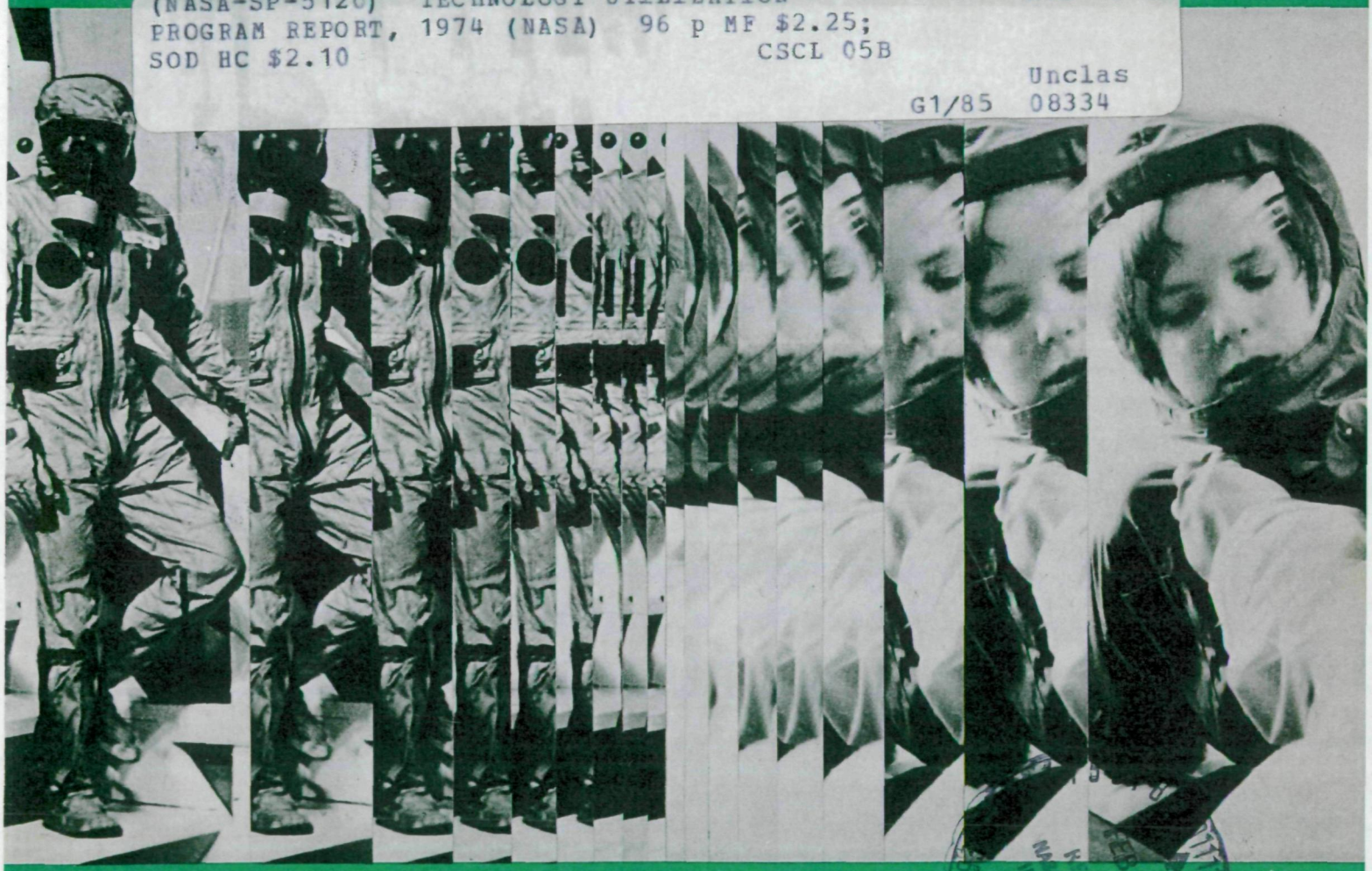
Technology Utilization Program Report 1974



National Aeronautics and Space Administration

NASA SP–5120

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Technology Utilization Program Report 1974

December

Technology Utilization Office
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D.C.
1975

Cover photo:
The Apollo biological isolation garment designed to protect our environment from possible lunar contamination has been adapted to protect young leukemia patients from bacterial contamination. Further information is included in this report in the project description entitled "Biological Isolation Garment."

This document was prepared under the direction of Todd Anuskiewicz, with William Thompson and Sandra O'Hara. Editing was by Owen Carlson, Laszlo Dosa and William Leavitt.

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Introduction

Technology utilization, when examined against the background of current national needs, is more than the casual by-product of aeronautics and space research. It is the deliberate, structured and planned system for adaption and application of NASA technology to industrial, medical and social problems. In 1974, NASA's technology was adapted and used by 28 percent more industrial firms than last year. Its successful application to such varied and significant public problems as cataract surgery, burn diagnosis and treatment, fire fighting safety and low-cost household wiring again demonstrated that productivity and quality of life improvements are dividends of national aerospace investment.

To assist in meeting the nation's energy needs, NASA is currently negotiating a cooperative effort to apply its reliability and quality assurance experience to the electric power industry through the Electric Power Research Institute.

In addition through the efforts of NASA's Industrial Applications Centers, aerospace technology made another contribution to the nation's energy shortage and environmental quality. The Skylab heat pipe system, being adapted and applied to a thermal control system on the Alaskan Pipeline, will maintain structural integrity and control the environment by preventing uncontrolled freezing and thawing of the permafrost.

In 1974, 4,200 industrial firms throughout the country spent nearly one million dollars for access to space-generated technology through the regionally located Industrial Applications Centers.

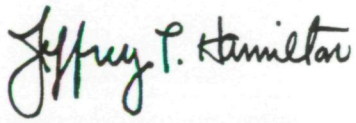
A new line of railroad freight cars needed to carry out the nation's expanding coal and grain shipments has been developed using the NASTRAN computer program, one of 1,500 programs available from COSMIC, the Technology Utilization Office's software center. A total of 778 firms purchased 263 programs and 4,770 items of related documentation for $163,000 contributing greatly to the nation's industrial productivity.

During the past year, more than 2,500 individuals and firms were given access to the NASA research in a practical solar heating and cooling system for housing, in response to one of 525 *Tech Briefs* published in 1973. Over 6,000 technical innovations from the space program are now available for use by American industry.

Health care improvements, ranging from an improved emergency treatment system for heart attack victims, derived from Skylab, to a new surgical instrument for the removal of cataracts, have been demonstrated in the last year. Building on years of research at NASA's Marshall Space Flight Center, the installation of flat electrical wiring in residential and commercial buildings in the last year promises a significant reduction of construction costs.

A significant contribution in the application of astronaut life-support technology to the nation's fire problems was achieved with the field testing of the Johnson Space Center's breathing system by fire fighters in New York, Los Angeles, and Houston. Commercial versions are expected to be available to the nation's fire community in 1975.

These examples reflect the direction of NASA's Technology Utilization program and, more importantly, underscore its efforts to expand the areas of application into new and undeveloped private and public fields. The following pages describe this program in terms of accomplishments and future goals.



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

Technology Utilization... Perspective

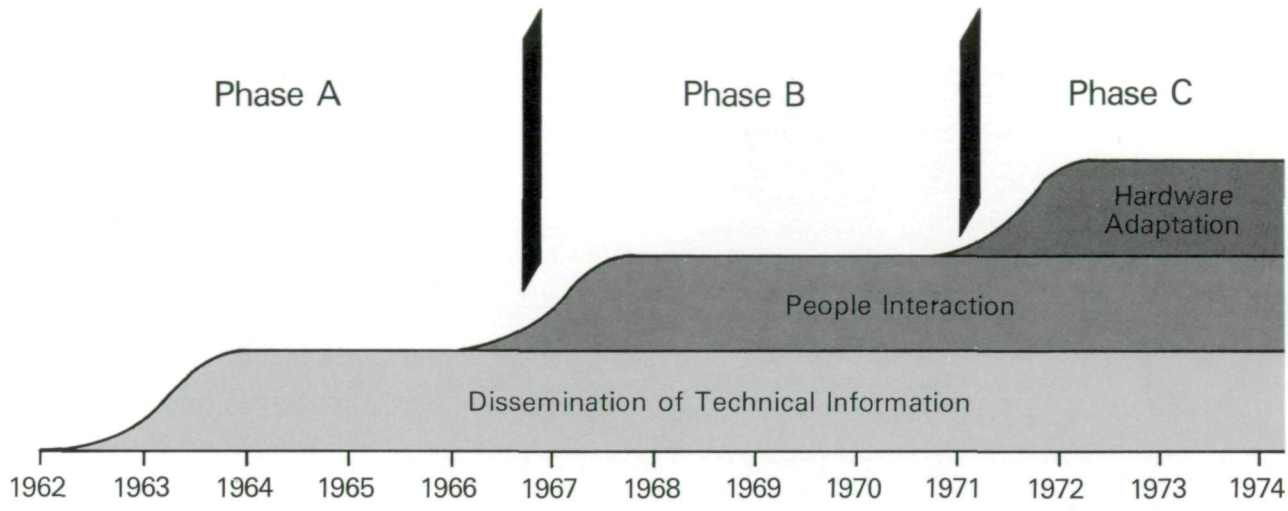


Figure 1

Technology utilization, in the view of a recent National Academy of Engineering panel review, is "the process through which government research and technology is transferred into processes, products, or services that can be applied to actual or potential public or private needs."

Over $175 billion was spent on federal R&D in the past 15 to 20 years. The National Academy of Engineering suggests this vast reservoir of knowledge has not resulted in widespread secondary applications to both the private and public sectors of our economy. Indeed, in 1973 alone, although $17 billion was spent on federal R&D, only $43 million (or 0.25 percent of the total R&D budget) was spent to stimulate the communication and application of this technology.

Most government R&D has centered in the Department of Defense, the Atomic Energy Commission, and NASA, although, in recent years, other agencies have engaged in R&D programs to improve the effectiveness of their mission responsibility in the environment, housing, transportation, and law enforcement. Interestingly enough, most of these civilian mission agencies have recently established technology transfer activities to enhance and stimulate the use of their R&D programs within the industrial community and the public sector.

NASA recognized its obligation to ensure that the investment in R&D was widely available for the benefit of mankind and has attempted to study and measure the natural transfer of technology from its aeronautics and space programs. For example, TRW Systems, after developing the Apollo guidance computer software for NASA, has modified it as a computerized retail sales system for department store chains. TRW has installed systems at Montgomery Ward, the May Company, Neiman Marcus, and J. C. Penney. These installations have brought a 95 percent reduction in bad debt accounts and a 75 percent reduction in fraud purchases while providing more accurate and faster sales transactions and improved inventory control.

Another example of technology transfer having great impact on national productivity and international trade is the adoption of the NASA-developed technique for insuring quality control of microelectronics. Texas Instruments, with annual sales exceeding $1 billion, uses the certified production line and scanning electron microscope method of maintaining quality in all of its products. In both examples, the modification of technology was initiated by the NASA contractor.

NASA also recognized that this natural flow of technology could be enhanced and accelerated through the development of an organized technology transfer program affording small business firms and public institutions access to this technological resource. The NASA Technology Utilization Program, originally called the "Industrial Applications Program," was formally established in June 1962 to "provide for the widest and most practicable and appropriate dissemination of technology." The specific objectives of the program were:

1) To increase the return on 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 industrial, disciplinary, and regional boundaries.
4) To contribute to the knowledge of better means of transferring new knowledge from its points of origin to all points of potential use.

The evolving character of the NASA Technology Utilization Program over the past 12 years is depicted in Figure 1. The chart reflects that the cornerstone of the program is, and remains, the wide communication of technology to potential users through publications. As the transfer process became better understood, an additional dimension was required to accelerate the communication and transfer process. The personal interaction between the technologist and user through the efforts of dedicated NASA Technology Utilization Officers, the establishment of Industrial Applications Centers, and Applications Teams supplied this effective linkage.

As the program matured, it became increasingly clear that the usefulness of specific technology to resolve specific problems could only be demonstrated through the application of prototype hardware in a user environment.

This report examines the Technology Utilization Program and explores the many ways -- publications, people interaction, or hardware demonstration -- by which NASA technology has been made available to fulfill public and private economic and social needs.

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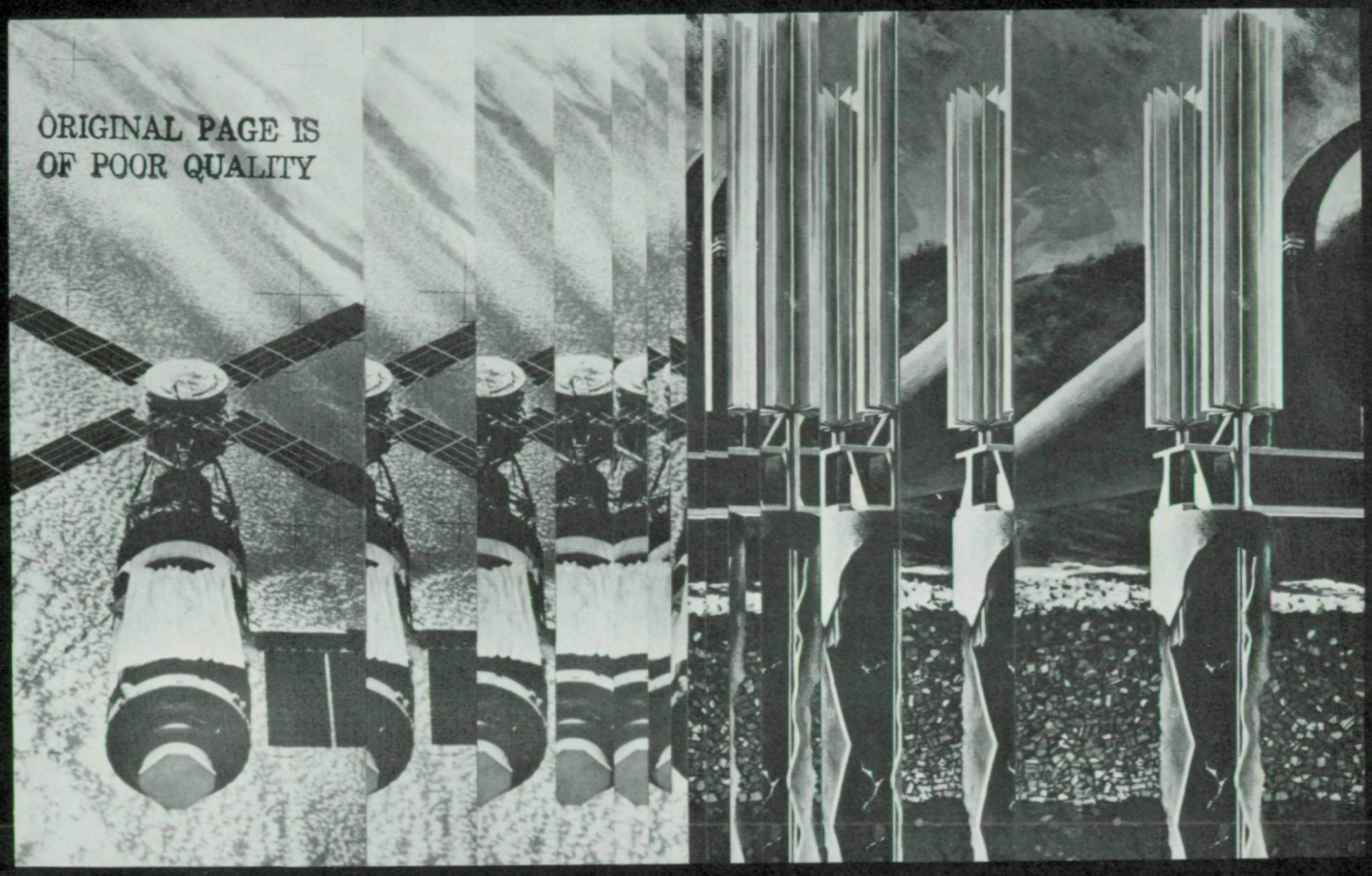
Industrial Applications



To meet mission objectives of Skylab, Viking, and aircraft programs, materials, equipment, and men were challenged to new and often unknown environments at unprecedented performance-levels with added requirements for absolute life safety, lowest weight, highest reliability and affordable cost. These requirements have created a great stream of advances across a wide spectrum of technologies and techniques, all having broad utility outside the aerospace community.

In our relatively free consumer-driven economy, existing research knowledge is translated into useful products or processes if it assures lower costs or improved profitability. This test must always be made and is a perspective that government technology transfer efforts should maintain to be effective. Most of the 300,000 manufacturers with no R&D capability, as well as 11,000 companies with some formal R&D, engage in technology transfer to remain innovative and competitive.

Within this framework, NASA's Technology Utilization Program has been structured to provide a transfer mechanism by introducing new publications of recent technological concepts and by developing a system of regionally located applications centers to serve as a bridge between the industrial user's problems and technology solutions.

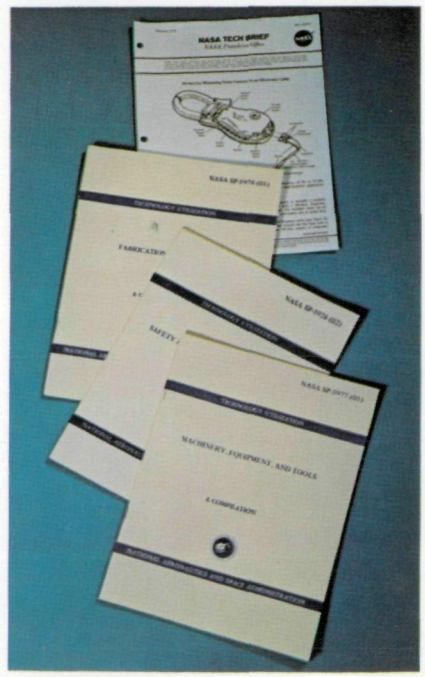
Publications

One important transfer mechanism is simply announcing new knowledge and telling as many potential users as possible about the availability of new technology from NASA research centers. Here, the main announcement tool is the by-now familiar NASA *Tech Brief*.

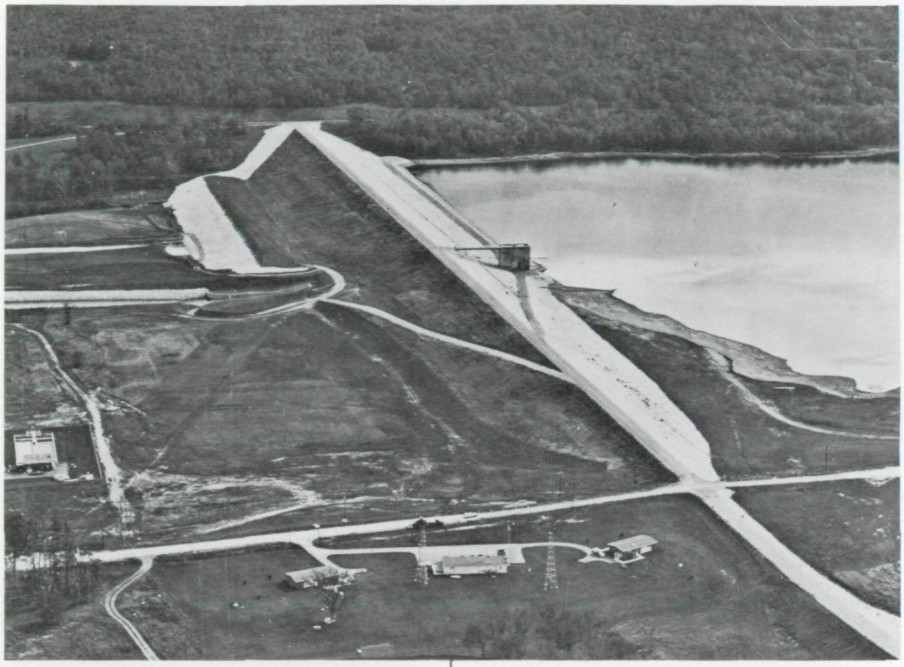
Technology Utilization Officers in each of the space agency's eight field installations constantly work at identifying significant innovations believed to have application beyond the aerospace community. These data are digested and edited into *Tech Briefs*, straightforward technical descriptions of innovations with explanations of basic concepts, conveniently printed on a single page.

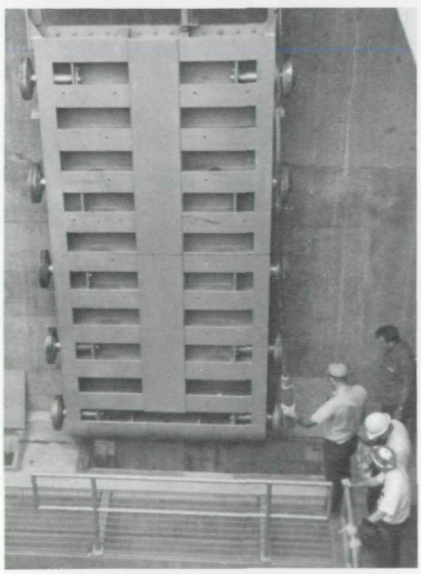
The interested reader can get more detailed information from a NASA *Technical Support Package*, a follow up publication that includes more comprehensive information, test data, drawings and specifications.

For example, *Tech Brief* No. B73-10156, issued in May 1973, describes a NASA project which concluded that a solar-powered residential heating and cooling system is now technically and economically feasible. The proposed system provides space heating, air conditioning and hot water.



Top: Trade Press Coverage
Above: NASA Publications





Through utilization of a Tech Brief, *considerable time and money were saved in establishing the criteria for welds in stainless steel gates in the Foster Joseph Sayers Dam near Lock Haven, Pennsylvania. The storage capacity of the dam is 92,700 acre-feet and the gate is 15 feet high by 7 feet wide and 1 foot thick.*

Over 2400 requests were made for the *Technical Support Package* by companies interested in producing the entire system or parts of it; by companies to heat and cool their buildings or provide hot water; by municipalities for space and/or water heating; and by individuals for heating their own homes.

Two examples of the application of the technology announced by this *Tech Brief* are:

- The Walker Plumbing and Heatting Company in Columbia, South Carolina, used information from it to design and build a prototype solar heat-transfer unit. This unit will be completely installed in a prototype solar water-heater for residential use during 1975. Designs are also being developed for solar water heaters for use in swimming pools and commercial car washes.
- The County of San Diego developed an energy-saving program in response to the decreasing availability of fossil fuels, increased cost of these fuels, and air pollution. As part of this effort, an engineer in the Architectural Division of San Diego County's Public Works Agency requested the *Tech Brief* and *TSP* after reading about the NASA technology in a professional journal. Small solar water-heating units for county recreation facilities will probably be built within the next 12 months as part of the county's energy saving program.

Other examples of secondary uses of NASA innovations published as *Tech Briefs* are:

- Kodak engineers used data contained in *Tech Brief* No. B69-10055, *Thermal Expansion Properties of Aerospace Materials*, to develop a handbook for designing and constructing a new facility at their large plant in Tennessee which employs 16,000 workers. An estimated 25 percent of the design cost was saved as was a considerable portion of the construction cost. According to the engineer at Kodak, the handbook is continually being used.
- In another example an engineer for a civil engineering firm was able to save considerable time and money in establishing the criteria for welds in stainless steel gates for a large dam project in Pennsylvania by utilizing data contained in *Tech Brief* No. B67-10200, *Workmanship Standards for Fusion Welding*. The engineer reported a cost

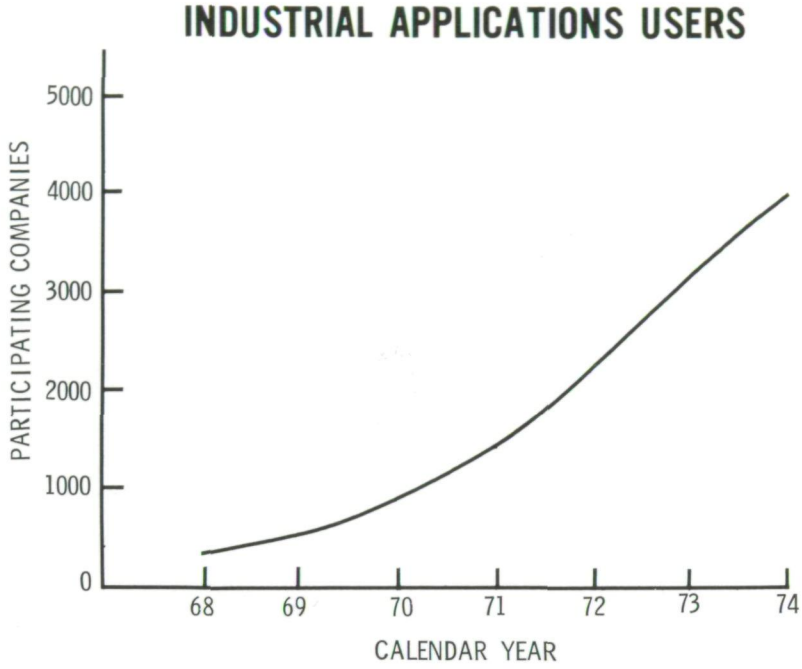
savings of over $200,000. The same firm is designing another large dam and plans the use of the same evaluation technique for the design of other facilities and equipment and for selection of compatible material.

While *Tech Briefs* and other publications, including *Special Compilations* and *Special Surveys*, are dissemination fundamentals in the NASA Technology Utilization Program, the real effort merely begins there. Not enough industrial researchers, business leaders, city officials, and other potential users of adaptable space technology can take time from their tasks to read, digest and apply this wealth of input to problems in their own fields. As a result, more direct communication between NASA and potential technology customers is required.

NASA Industrial Applications Centers

In recognition of this need, NASA, since 1963, has maintained a network of Industrial Applications Centers at universities throughout the country. Six NASA/university centers now provide the direct interface between private industry and space technology.

Today the centers maintain computerized access to about a million technical reports in every field of the space-related activity that lifted man to the Moon and scientific instruments to the planets. The NASA information storehouse, which has become the largest bank of scientific and engineering data in the world, reaches into almost every existing technical and medical field.



Yet this represents but a small part of the total information base these unique centers have accumulated. Even the totality of research performed or sponsored by NASA represents but a small part of available technology. Companies sold on "searching before researching" need the assurance that their literature searches are complete.

As a result, NASA's six Industrial Applications Centers now have access to more than seven million documents. Further, the data base shared by these centers is growing at the rate of 50,000 documents each month!

The continuing goal of the NASA/university centers is to transfer technology from government to industry and from industry to industry, a logical extension of the space technology-transfer process.

Thus, in addition to the NASA files, the centers have access to Air Pollution Abstracts, Applied Science & Technology Index, Government Reports Announcements (unclassified DOD information), Nuclear Science Abstracts (AEC information), Pollution Abstracts, and dozens of other specialized files dealing with water resources, metals, food, textiles, and education research. The contents of more than 15,000 scientific and technical journals throughout the world are part of their truly mammoth resource.

Last year more than 4,300 large and small companies used the services of these centers--a 28 percent increase over 1973.

Although the gigantic data base is their primary resource tool, the NASA Industrial Applications Centers are organized, as their names imply, for applications. Their role is solving specific problems brought to them by industry.

INDUSTRIAL ASSISTANCE NETWORK

A highly skilled staff of specialists in such fields as chemistry, physics, electronics, or pharmaceuticals is available at each center. When an industrial problem cannot be handled by a staff specialist, he has access to the consulting services of most of the university faculty as well as the scientists and engineers at the eight NASA Field Centers.

These resources are important to an industrial user because he can communicate frequently with his information specialist who is preparing his study. And he often can discuss technical problems directly with the scientist whose innovation is being adapted. Direct contact between the creators and users of technology obviously speeds the transfer and application of technology.

The type of problems clients bring to the centers are as diverse as a company's product lines or R&D activities. An industrial client, for instance, may request a complete retrospective search of all available information to establish the background necessary to begin a new R&D program, or he may require only a specific answer to a vibration, materials, or processing problem.

Contributions of NASA Industrial Applications Centers in 1974 include progress in Alaskan pipeline safety and nematic liquid crystals for digital watches. These will be described, along with other examples, representing the hundreds of similar technology transfers made during the year.

NASA INDUSTRIAL APPLICATIONS CENTERS

Aerospace Research Applications Center (ARAC)
Indiana University
400 E 7th Street
Bloomington, Indiana 47401

Dr. Robert D. Shriner, Director
Phone: (812) 337-7833

Knowledge Availability Systems Center (KASC)
University of Pittsburgh
Pittsburgh, Pennsylvania 15260

Edmond Howie, Associate Director
Phone: (412) 624-5212

New England Research Application Center (NERAC)
Mansfield Professional Park, Box U-41N
The University of Connecticut
Storrs, Connecticut 06268

Dr. Daniel U. Wilde, Director
Phone: (203) 486-4533

North Carolina Science and Technology
Research Center (NC/STRC)
P. O. Box 12235
Research Triangle Park, North Carolina 27709

Peter J. Chenery, Director
Phone: (919) 549-8291

Technology Application Center (TAC)
The University of New Mexico
Albuquerque, New Mexico 87131

Western Research Application Center (WESRAC)
University of Southern California
809 West 34th Street
Los Angeles, California 90007

Radford King, Director
Phone: (213) 746-6132

COMPUTER SOFTWARE CENTER

Computer Software Management & Information
Center (COSMIC)
Suite 112, Barrow Hall
The University of Georgia
Athens, Georgia 30601

Thomas W. Quigley, Jr., Director
Phone: (404) 542-3265

NASA FIELD CENTERS

Ames Research Center (ARC)
National Aeronautics and Space Administration
Moffett Field, California 94035

Technology Utilization Officer: Charles C. Kubokawa
Phone: (415) 965-5554

Flight Research Center (FRC)
National Aeronautics and Space Administration
P. O. Box 273
Edwards, California 93523

Technology Utilization Officer: Clinton T. Johnson
Phone: (805) 258-3311, Ext. 500

Goddard Space Flight Center (GSFC)
National Aeronautics and Space Administration
Greenbelt, Maryland 20771

Technology Utilization Officer: Donald S. Friedman
Phone: (301) 982-6242

Lyndon B. Johnson Space Center (JSC)
National Aeronautics and Space Administration
Houston, Texas 77058

Technology Utilization Officer: John T. Wheeler
Phone: (713) 483-3809

John F. Kennedy Space Center (KSC)
National Aeronautics and Space Administration
Kennedy Space Center, Florida 32899

Technology Utilization Officer: James O. Harrell
Phone: (305) 867-2544

Langley Research Center (LaRC)
National Aeronautics and Space Administration
Langley Station
Hampton, Virginia 23665

Technology Utilization and Applications Program
Officer: John Samos Phone: (804) 827-3281

Lewis Research Center (LeRC)
National Aeronautics and Space Administration
21000 Brookpark Road
Cleveland, Ohio 44135

Technology Utilization Officer: Paul Foster
Phone: (216) 433-6833

George C. Marshall Space Flight Center (MSFC)
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama 35812

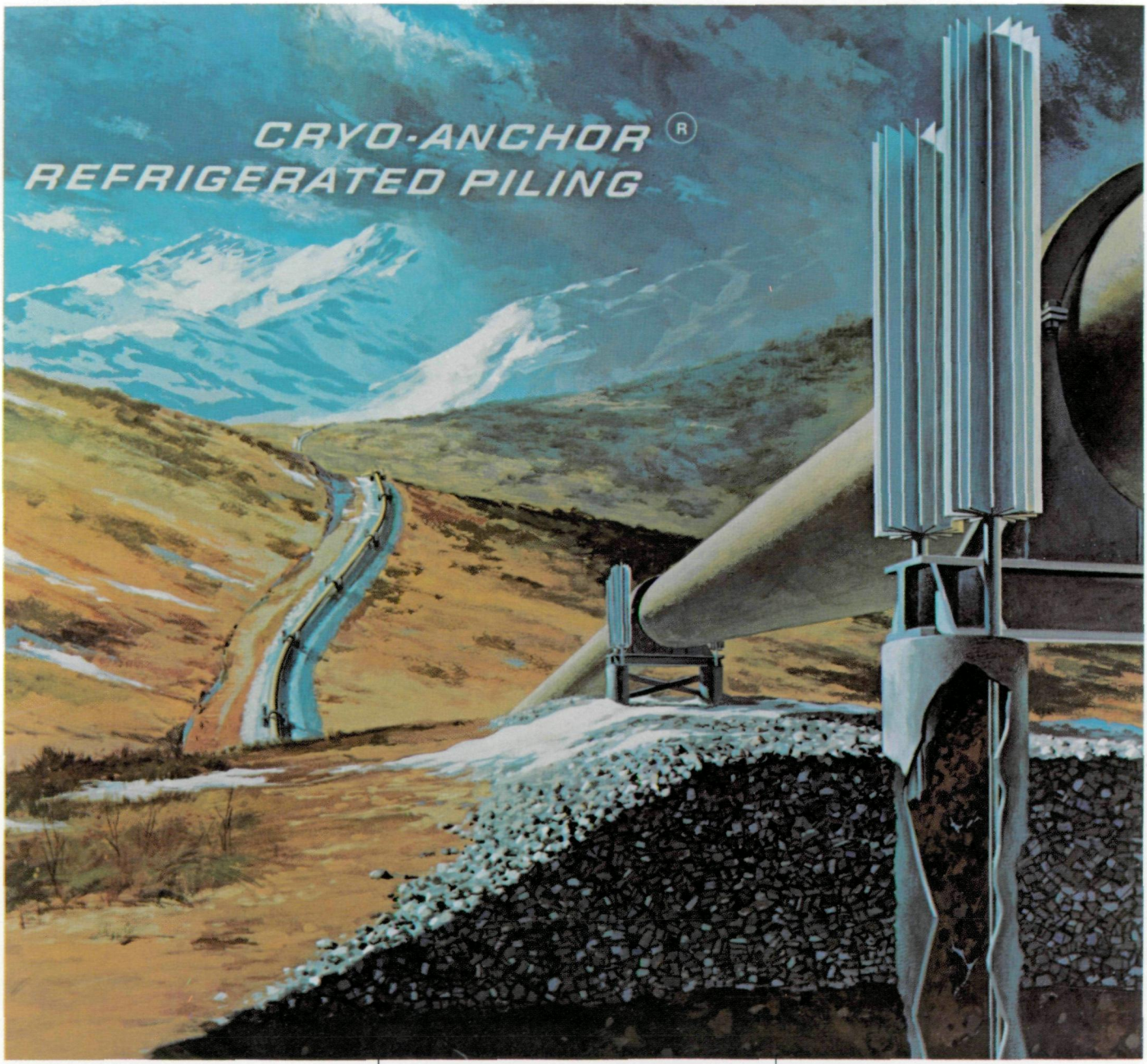
Director of Technology Utilization: James W. Wiggins
Phone: (205) 453-2224

NASA Jet Propulsion Laboratory (JPL)
4800 Oak Grove Drive
Pasadena, California 91103

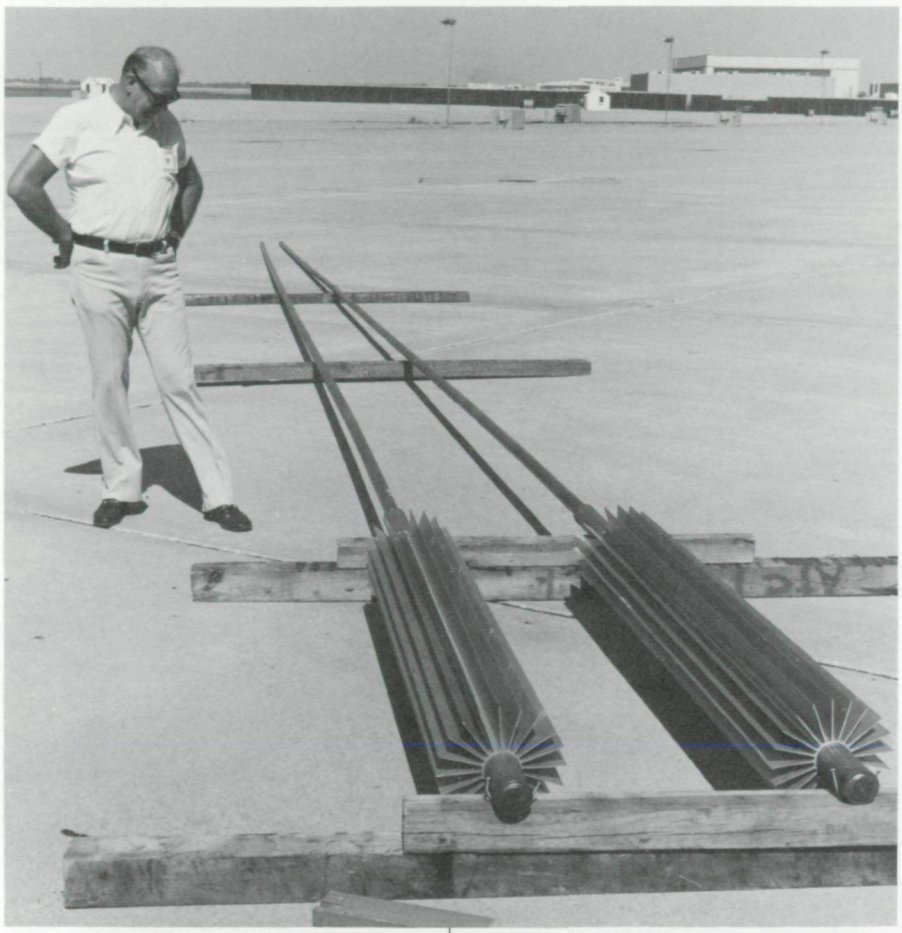
Technology Utilization Officer: John C. Drane
Phone: (213) 354-6420

Wallops Flight Center (WSC)
National Aeronautics and Space Administration
Wallops Island, Virginia 23337

Technology Utilization Officer: Gilmore H. Trafford
Phone: (703) 824-3411, Ext. 2201



Heat pipe technology developed initially for NASA's Skylab program has contributed significantly to solving the Alaska pipeline environmental controversy. This technology was developed by the McDonnell Douglas Corporation for the Alyeska Pipeline Service Company with the assistance of the Heat Pipe Center at the NASA Industrial Applications Center at the University of New Mexico.



At first glance, heat pipes used in Skylab would seem to have little bearing on the Alaskan pipeline environmental controversy. Yet the Skylab heat pipes contributed significantly to solving an Alaskan pipeline environmental problem.

Although the principles of heat-pipe operation were demonstrated during World War II, there was little concentrated R&D until the space program required a reliable device with highly effective thermal conductivity. Heat pipes contain no moving parts and use capillary action of a liquid in a sealed pipe to achieve thermal conductivity. They are used routinely in spacecraft to provide cooling for electronic packages, to maintain environmental control aboard satellites.

The NASA Industrial Applications Center at the University of New Mexico established a Heat Pipe Center to collect, organize, and disseminate heat-pipe technical information. The center publishes a continuing bibliography in the field and conducts heat-pipe short courses.

Engineers from Alyeska, the trans-Alaskan pipeline consortium, have attended the short courses and otherwise used NASA and other heat-pipe information gathered by the center. In addition, scientists at NASA's Goddard Space Flight Center worked directly with Alyeska in the heat-pipe design.

The NASA Industrial Applications Center at the University of Southern California was also involved in this effort. It provided technology services to Mechanics Research Corporation, which was selected by the Department of the Interior to review the design and monitor startup construction of the pipeline.

The pipeline will be supported above the Arctic tundra by thermal piles with internal heat-pipes extending many feet into the permafrost. Operating as a thermal diode, the heat pipes will help freeze the soil to full depth in winter when air temperatures are low. The heat pipes absorb heat from the ground and move it upward into the atmosphere. In the summer, thermal piles will be inactive, and the permafrost will thaw only near the surface.

By maintaining a solid mass of permafrost around each supporting pile, shifting of the soil will be reduced and pipeline settling avoided. Without this thermal protection, uncontrolled freezing and thawing of the soil could stress the crude oil line to the point of rupture. Protecting the tundra environment by keeping the permafrost frozen was a significant consideration in passing of the pipeline bill.

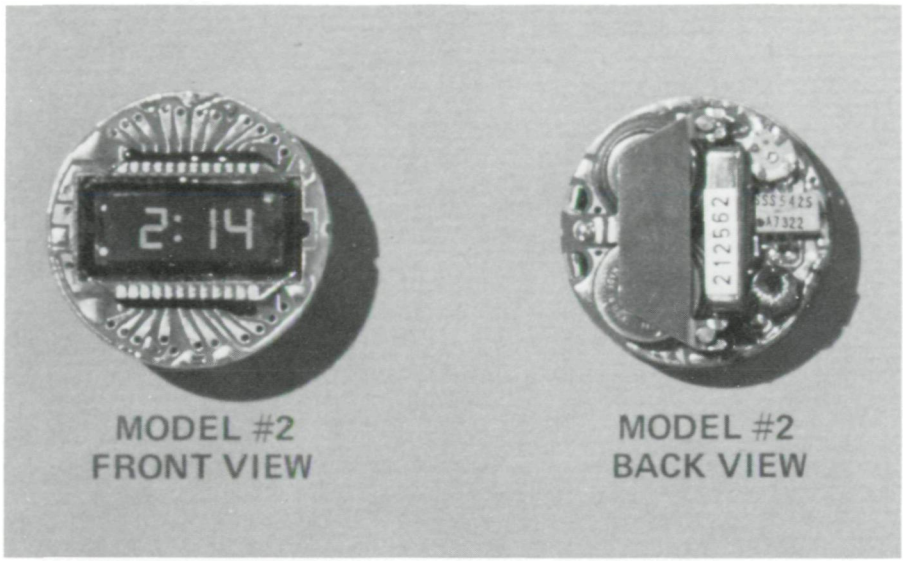
Some 110,000 heat pipes, using ammonia fluid, long steel tubes, and no moving parts, will be required. Accelerated life tests at high temperatures have shown the pipeline will last for at least 30 years.

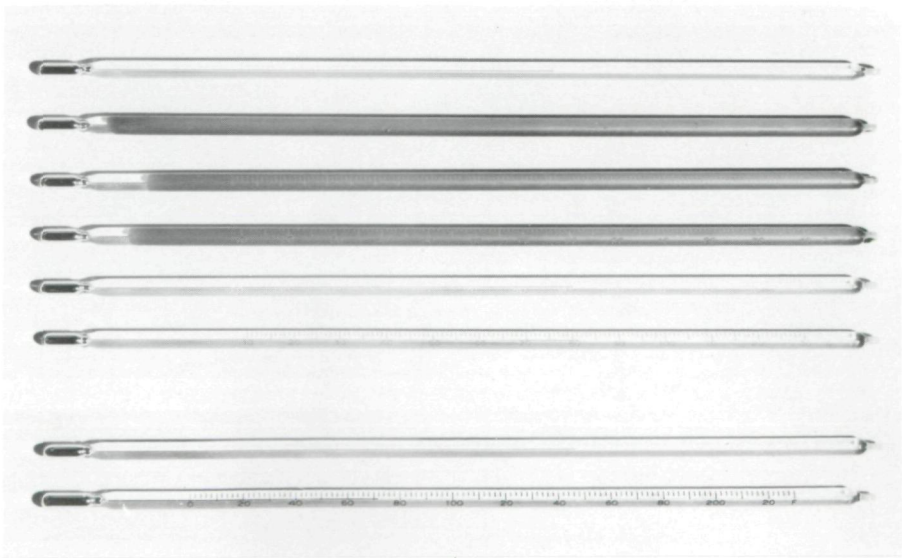
McDonnell Douglas Corporation, under contract to Alyeska, will produce the heat pipes for this vast

project which spans 798 miles from the oil field at Prudhoe Bay on the Arctic coast of Alaska to the marine tank ship terminal at Valdez, the ice-free port in the south-central part of the state. The 2- and 3-inch heat pipes, trade-named Cryo-Anchor Stabilizers, and using NASA developed technology, range in length from 30 to 60 feet. They will be fabricated at the Tulsa, Oklahoma plant of McDonnell Douglas for delivery beginning in January 1975.

Other examples of NASA/university center help to industry during the year are:

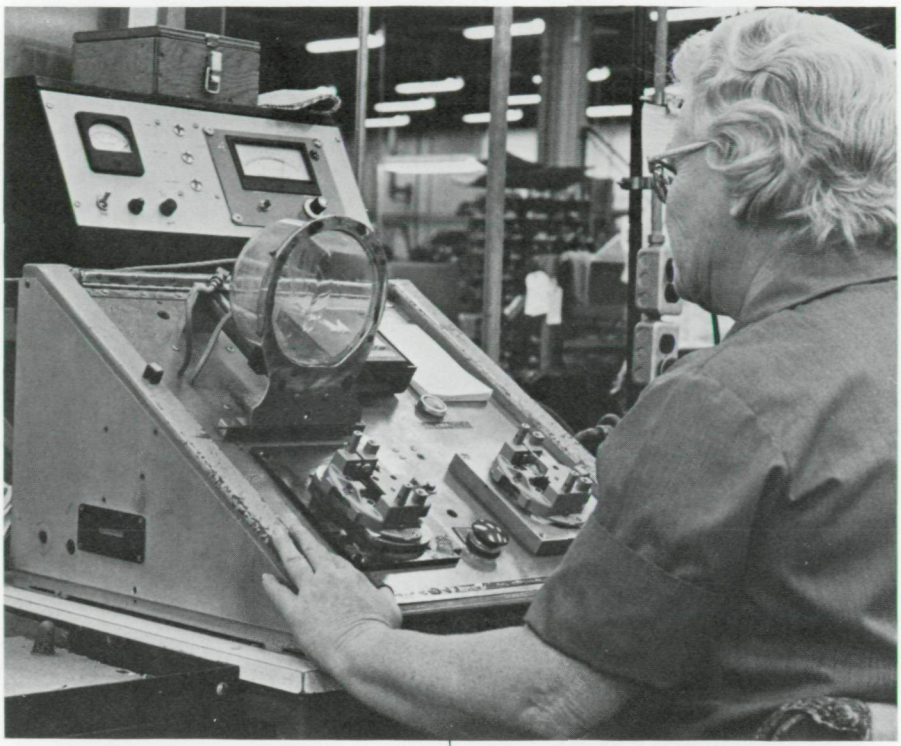
- When an electric field is induced in "nematic" liquid crystals or others having molecules arranged in small randomly oriented domains, the crystals become opaque, allowing for a digital display. The Microma Company of Cupertino, California, manufacturers of watches using liquid crystals, sought more reliable crystals than those conventionally used. The research director asked for help from the NASA Industrial Applications Center at the University of Southern California. The center, after conducting a technology search, suggested that benzoate crystals might be more reliable. Research performed by other industrial companies thus became the starting point for further Microma investigations into a series of benzoate compounds. Their use of the benzoates in the liquid crystal watches now saves the company about $50,000 a year. And the savings are expected to be multiplied several times in the next year or two.





Top:
Information on more reliable crystals for watches supplied by the Industrial Applications Center at the University of Southern California has resulted in significant savings for the Microma Company.

Above:
Thermometer NASA technical information on ceramic ink provided by the New England Research Applications Center assisted one firm in doubling its thermometer production last year. One six-step production process using etching and waxing was reduced to two steps using ceramic ink.



The life expectancy of manufacturing process equipment was increased significantly by the Duncan Electric Company by the use of information supplied by the Aerospace Research Applications Center at Indiana University.

- NASA technical information on ceramic ink provided by the New England Research Applications Center has assisted H-B Instruments of Philadelphia to double their thermometer production during the past year. As an example, NERAC provided information on ceramic ink technology. They now print on thermometers with ceramic ink, rather than using the more costly, traditional etching process which requires several additional production steps. The information made H-B Instruments competitive with manufacturers from Japan, Korea and Taiwan for the first time.

- Recommendations on improving the reliability of electromagnetic coils supplied by the Aerospace Research Applications Center (ARAC) at Indiana University enabled the Duncan Electric Company to increase the life expectancy of its manufacturing process equipment by nearly 1400 percent. A letter from the firm indicates that, with a minimal expenditure for ARAC assistance that first year, savings are likely to approach $150,000.

- The Drip Irrigation Supply Company in Florida, working on an extruded, linear fresnel lens to concentrate solar energy on pipe, requested a literature search by the NASA center at the North Carolina Science and Technology Research Center (NC/STRC). As a result of information uncovered by the center, the company has applied for a patent preparatory to commercializing a new product.

  Information on laser technology applicable to a new process for sealing plastic films was supplied by the NC/STRC for the Cryoval Division of W. R. Grace & Company. The company has developed the process utilizing research already available and expects to market a new product.

Space flight could never have been achieved without computer technology. NASA pioneered in the development of highly complex computer programs or software in information storage and referral, reliability assurance as well as for inventory and control and research budgeting. These are in addition to the more familiar program in structural analysis and trajectory optimization. Since these programs have wide application in industry, NASA established a special nonprofit center called COSMIC at the University of Georgia which makes all of these programs available to U.S. industry at very nominal prices.

COSMIC, or the Computer Software Management and Information Center, collects all of the computer programs NASA has developed (and also some of the best programs developed by the Department of Defense and other government agencies), verifies that they operate properly and then adds them to their inventory of software available for immediate use by industry. The price of the program depends upon its size and complexity, but generally ranges from $500 to $1,000. Program documentation is available separately so that a prospective purchaser may fully evaluate the software and ensure that it will meet his needs.

Documentation usually costs less than $25. To announce the availability of each program, COSMIC prepares an abstract which is published in a catalogue of NASA software called the *Computer Program Abstracts Journal*. The *CPA Journal* contains abstracts of all the 1400 plus computer programs in COSMIC's inventory and is available from the Technology Utilization Office.

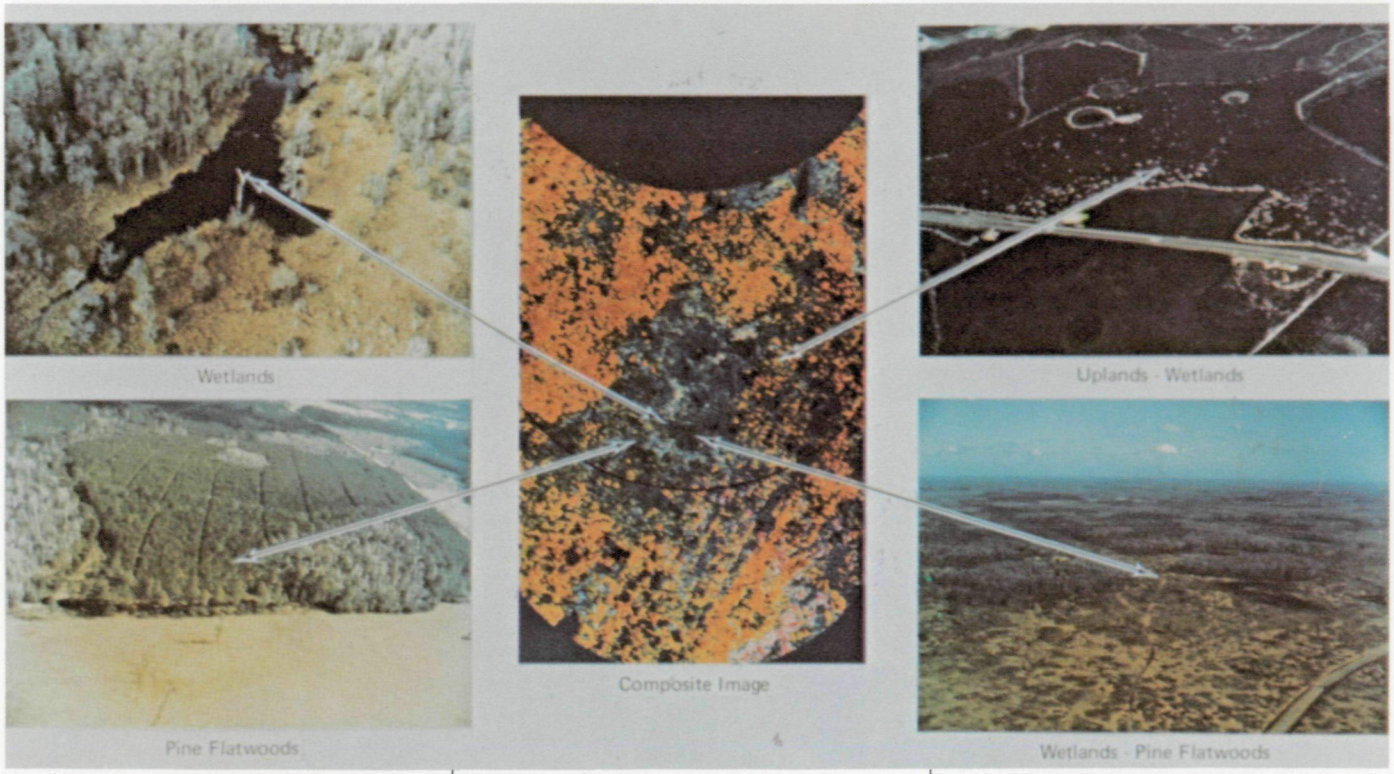
A few of the more popular software packages available from COSMIC, which help demonstrate the diversity of the inventory, include:

- NASTRAN. The NASA Structural Analysis Computer Program widely used in industry with hundreds of different applications and multimillion dollar savings.
- SLACMON. A general purpose utility program enabling a user to monitor the hardware and software performance of his entire installation over a given time period. A series of 11 reports and a summary provide information on areas of low utilization and performance bottlenecks.
- PROGLOOK. Another general purpose program, similar to the one described above, for making detailed measurements of any particular program while it is running to determine the action necessary to improve that program's performance. SLACMON and PROGLOOK have been very widely used in the banking industry but are applicable to any IBM OS/360 MVT installation.
- Automated ECG Analysis System. A program, developed by the Veterans Administration, for automatic analysis of electrocardiograms, including wave recognition, measurement, and the calculation of the posterior probabilities of each diagnosis.
- ECAP. An electronic circuit analysis program which aids an electrical engineer in the design and analysis of electronic circuits. The system can produce AC, DC and/or transient analyses of electrical networks based on parameters selected by the engineer. ECAP allows a circuit designer to economically and efficiently examine the performance of a circuit during the various stages of its design, by using a computer rather than a breadboard.
- The Fortran Analyzer. The Fortran Analyzer recently acquired through an international exchange of computer programs with Japan. It is capable of transforming programs written in Fortran for one machine for use on another. Such transformations can be made between IBM, CDC, GE and HITAC computer hardware.

There are hundreds of other software packages available from COSMIC with thousands of potential uses. Of course, many of the programs have rather specific aerospace applications but, as demonstrated above, there are also many which are valuable to non-aerospace, nonscientific organizations. Whatever business a firm is in, if it utilizes a computer, there is likely to be a program in COSMIC's inventory which could improve efficiency, help solve a problem or satisfy a software need. COSMIC will assist a customer in the selection of programs which appear useful.

In one COSMIC example, a U.S. Geological Survey hydrologist used his expertise and computer processed NASA photography to help bring about an unusual and successful settlement between developers of Florida's green swamp area and state ecologists. The green swamp area is undergoing rapid change as a result of its position between Orlando, Disney World and Tampa, three of the fastest growing areas in the state. Environmentalists and state agencies are becoming increasingly alarmed over the development of the area, both because of its critical importance to Florida's water supply and the variety of endangered species residing within it. The Florida Attorney General filed suit last fall against land developers who were beginning to implement plans to develop 16.5 square miles of the green swamp.

Rather than go to court, however, the Attorney General and the defendants asked the hydrologist to draw on his experience and NASA computer processed remotely sensed data to try to come up with a solution which would benefit both parties. The hydrologist's evaluation of the computer processed photography indicated that there was a way to develop the land while still protecting the environment, by, in the hydrologist's words "...showing the developers how to follow the contours of the land, shaping the development to the land--not the land to the development." The result was avoidance of costly litigation by a settlement which protected the interests of the state of Florida in protecting its natural resources while at the same time protecting the interests of



The colors produced by the computer shown in the composite image are not real colors, but are arbitrarily assigned to designate land-water categories; actual photographs are shown to demonstrate the relationship. The color code is as follows:

UPLANDS

Orange -*Citrus, sandhills, extractive earth (gravel pits etc.), residential areas and transportation*

Black -*Unclassified*

WETLANDS

Blue -*Water, lakes, streams and ponds*

Light Blue -*Fresh water marshes and bogs*

Turquois -*Bayheads, marshes and bogs*

Light Green -*Cypress heads and sloughs*

Purple -*Mixed wetlands, bayheads, bogs, and flood plains with mixed hardwoods and palms*

PINE FLATWOODS

Green -*Mixed palmetto and natural rangeland*

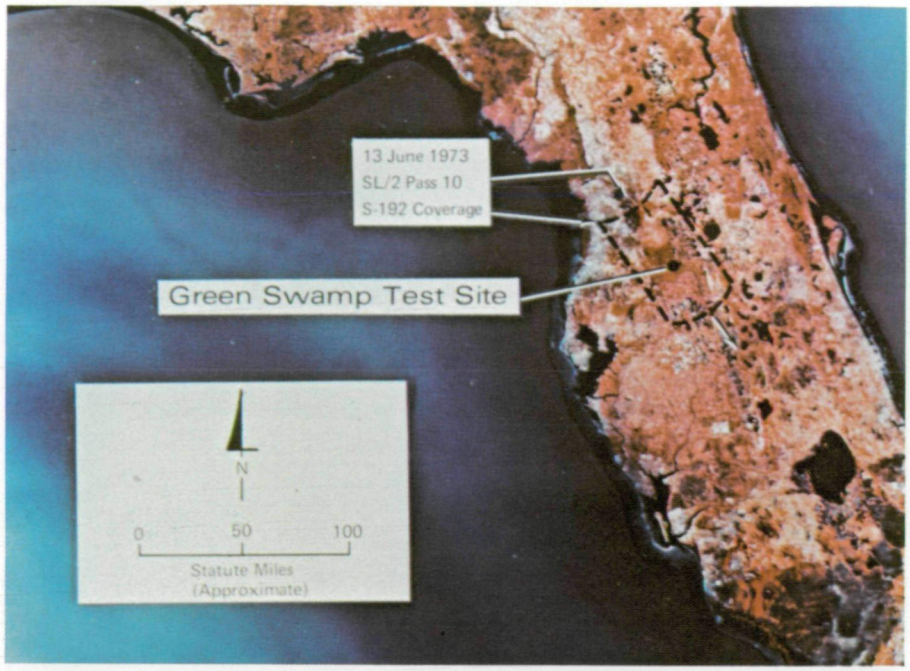
Dark Green -*Improved pasture, managed rangeland, and sod farms*

Yellow -*Managed and reforested pine*

the developers. The size and complexity of the area would have made such an environmental appraisal unfeasible by conventional techniques.

Understandably, both the publications and industrial applications efforts reach selected segments of possible users of technology. However, surveys and studies indicated that a much larger audience would respond if only the message could be delivered to tell potential users how to get this information. In 1974, four seminars were held in Boston, Jacksonville, Chicago and Salt Lake City to let interested people know more about the availability of NASA technology and patents. The reaction to these seminars was so enthusiastic that they will be continued in other U.S. cities in 1975.

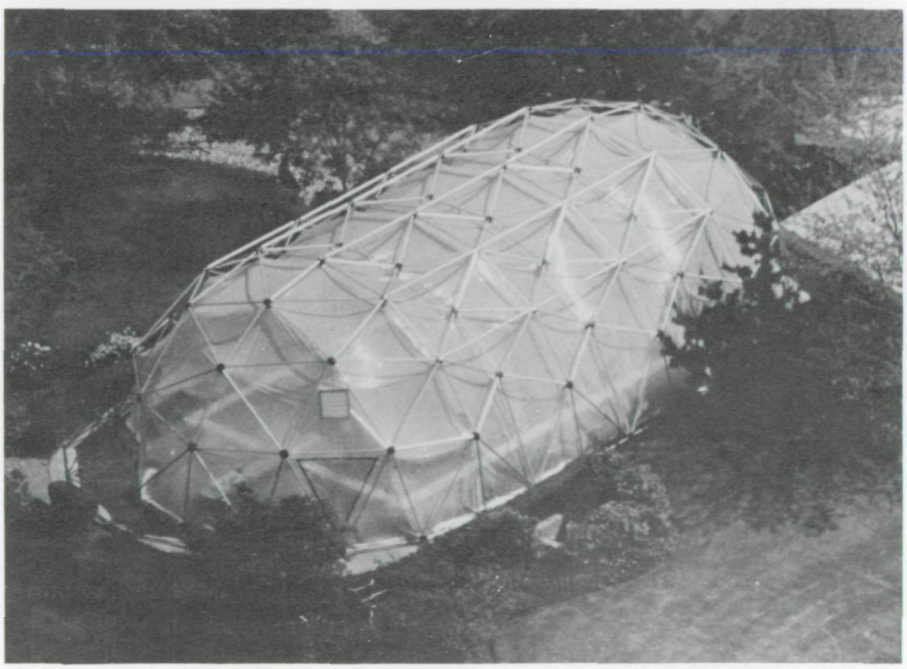
Not too surprisingly, the majority of people attending represented small business enterprises, whose requests for additional information encouraged a more rapid expansion of these seminars than was originally planned.



Above right:
Location of the Green Swamp in the Florida Peninsula.

At right:
Reviewing computer-produced image of Green Swamp area on TV-monitor.

Construction of the Scattergood Steam Plant Unit 3, shown at left, was halted until KVB engineering used its expertise and NASA's Chemical Equilibrium Calculations computer program to make operating changes so that it could comply with strict nitric-oxide emission standards set by Los Angeles County. The plant is scheduled to produce almost ten percent of Los Angeles' electricity next year.



Dome East Corporation is using a NASA Geodesic Structure Design Program to construct large swimming pool covers like this one, and for other structures such as greenhouses, classrooms, tennis courts and warehouses. Completed structures and do-it-yourself kits are produced.

NASTRAN is the NASA Structural Analysis Computer Program. Originally developed to help design aircraft, non-aerospace industrial users have reported hundreds of different applications and multimillion dollar savings attributable to NASTRAN's use.

The construction industry is a major user of NASTRAN, from skyscrapers such as this one in Chicago to a new sports stadium in Seattle.

The Department of Transportation is using NASTRAN to improve the design of railroad tracks and their supporting bed, and Pullman-Standard used it to design a new line of freight cars.

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Technology Applications

Effective application of aeronautics and space developments to significant public problems in medicine, health care, environment, housing and public safety often requires extensive problem definition and technology demonstrations with user participation.

In applying NASA capabilities and technical know-how to public problems the Technology Utilization Program has developed: (1) multidisciplinary teams to assist in user problem definition and application requirements, (2) demonstration projects which adapt, modify and test specific technology to users' problems, and (3) a special program to share these technological resources with state and local governments and minority businesses.

Applications Teams

NASA-sponsored Applications Teams working with appropriate federal, state and local agencies with specified mission responsibilities, seek to match identified problems in selected areas of concern in the public sector with potential solutions based on existing aerospace technology. Through established working relationships with NASA Field Centers, they couple NASA technology with these public problems.

Biomedical Application Teams

Currently there are four active Biomedical Application Teams: Research Triangle Institute (RTI), Southwest Research Institute (SwRI), Stanford Medical School, and the University of Wisconsin, Madison.

The objective of the RTI team, which began operations in 1966, is to define the problems encountered in health care delivery problems at major medical schools and in the National Institutes of Health and to identify relevant technology for solving those problems. Their sphere of operation is the eastern United States.

The SwRI Team, also established in 1966, has as its objective the definition of problems encountered by medical researchers and practitioners in medical schools, hospitals, clinics, and rehabilitation centers. This team is directly associated with the Life Science Program of Johnson Space Center, Houston, Texas. Through this active association many benefits are realized from prior research directed at manned space flight.

The Stanford Medical School Team, established in 1971, works with the Ames Research Center, Moffett Field, California. The objective of this team is to assist in the transfer of NASA aerospace technology, by means of a close-working relationship with scientists and engineers of NASA Ames and the Stanford Medical School. Emphasis has been placed in the area of cardiology and neurophysiological diagnostic and monitoring instrumentation.

The University of Wisconsin began its association with NASA/TU in July 1974. Their thrust is to optimize the application of technology generated by aerospace research and development efforts to the fields of family and general practice, small hospitals, and clinics in the northern midwest region. In addition, their previous background in emergency medical services will now take advantage of much of NASA remote health care diagnostic capabilities.

Technology Application Teams

Currently, there are three active Technology Application Teams, Stanford Research Institute (SRI), Technology & Economics, Inc., and Public Technology, Inc. (PTI).

The SRI Team, which began in 1969, has as its objective the transfer of aerospace technology to the solution of important technological problems in public transportation. Transportation includes railroads, highways, mass transportation, and shipping.

The Technology & Economics, Inc. objective is to identify technical needs and opportunities in the housing and urban construction area. This is directly associated with the Urban Systems Project Office of the Johnson Space Center.

The PTI Team was established as the result of a meeting in 1970 at which representatives from 79 cities and one county expressed their desire to work cooperatively with NASA and PTI in the identification and solution of common technical problems of major concern.

Applications Engineering

Application projects result from the matching of public problems, identified in cooperation with user agencies, with existing aerospace technology. These projects are designed to achieve maximum utilization of available NASA-developed capabilities and hardware through adaptation or modification to meet performance specifications provided by user organizations. Such projects result in development of hardware

prototypes which are made available to the user agencies for field testing and tangible application in the public environment. Extensive efforts are made to ensure commercialization of these demonstrations for widespread utilization of the technology. The details of these projects follow in the next section of this report.

Technology Sharing to State and Local Government and Minority Business

As part of a continuing program to bring technology to bear on state and local problems, NASA has assigned a number of its technologists to work, both part- and full-time, with municipalities to accomplish a number of objectives. The overriding objective is to apply NASA technology to problems of state and local governments which lend themselves to technological solutions. As this program evolved, it became increasingly clear that technology sharing on the municipal level presented some very unique challenges, particularly in the area of understanding, and effectively using, the mechanism of transfer. To this end, the program was structured so that an integral part of the technologists' activities focused on working within this mechanism. Another objective is the development of a communications network to link the technologists for the purpose of exchanging experiences to the mutual benefit of all members. Not only does the network enable members to be kept aware of successful and unsuccessful applications of technology in other areas but also from the interchange of ideas, new projects can be undertaken when it has been demonstrated that the projects have widespread application.

Some notable examples of current technology transfer activities to state and local governments are:

- Fireman's Breathing Apparatus demonstrated in three cities.
- TELECARE used in two states and under consideration by others.
- Silent communications alarm network installed in many schools.
- Image enhancement of illegible wills and deeds.
- Improved road patching material evaluated in many states.
- Use of satellite photographs for land use planning.

In early 1974, NASA and the Department of Commerce, Office of Minority Business Enterprise (OMBE) executed an interagency agreement to encourage minority enterprise development through the use and application of aerospace technology. Under this agreement, the Technology Utilization Office works directly with OMBE and the NASA Office of Equal Opportunity Programs in the planning and implementation of regional minority business seminars. A principal objective of these seminars is to encourage the utilization of NASA-developed technology by qualified entrepreneurs in the minority business community. A pilot seminar was conducted at College Park, Maryland in June 1974, and six additional seminars are planned. The next one will be held in January 1975 at Los Angeles, California.

The NASA-OMBE Agreement also fosters a close working relationship between NASA, OMBE and well established manufacturers. One outgrowth of this interaction in 1974 has been the adoption by a major retailer of a NASA-developed product which they plan to add to their inventory. A minority vendor will perform the fabrication necessary to convert this new product to the retailer's requirements Other examples of the adoption of NASA technology by minority firms are expected during 1975.

Two important elements of the applications program are significant enough to warrant special mention.

Interagency Cooperation

The Technology Applications Program involves a significant amount of governmental interagency cooperation and joint funding of projects. Formal or informal cooperative ventures are under way with the Department of Health, Education and Welfare; the Department of Housing and Urban Development; the Bureau of Mines; the Department of Transportation; the Environmental Protection Agency; the Law Enforcement Assistance Administration; the National Bureau of Standards; the National Science Foundation; the Veterans Administration and others. Also, more than 75 medical schools and health-care institutions are involved, as well as such widely disparate groups as the New York State Urban Development Corporation, the National Academy of Engineering, and the New York City government.

Patent Policy

Important to industrial participation in the Applications Program is the recent change in NASA patent policy which permits accelerated commercial use of space-related inventions or technology by granting exclusive licenses in a shorter time period than was previously possible. Specifically, NASA can grant exclusive licenses in appropriate cases as early as nine months after the patent application has been filed and announced as available for licensing. If NASA decides to grant an exclusive license, the prime consideration will be whether such a license is necessary to bring an invention to practical application.

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

NASA PATENT COUNSELS

Leonard Rawicz
Assistant General Counsel
for Patent Matters
NASA Headquarters, Code GP
400 Maryland Ave., S.W.
Washington, D. C. 20546
Telephone: (202) 755-3932

Darrell Brekke
Patent Counsel
Ames Research Center
Mail Code: 200-11A
Moffett Field, CA 94035
Telephone: (415) 965-5104

Robert F. Kempf
Patent Counsel
Goddard Space Flight Center
Mail Code: 204
Greenbelt, MD 20771
Telephone: (301) 982-2351

Marvin F. Matthews
Patent Counsel
Lyndon B. Johnson Space Center
Mail Code: AM
Houston, TX 77058
Telephone: (713) 483-4871

James O. Harrell
Patent Counsel
John F. Kennedy Space Center
Mail Code: AA-PAT
Kennedy Space Center, FL 32899
Telephone: (305) 867-2544

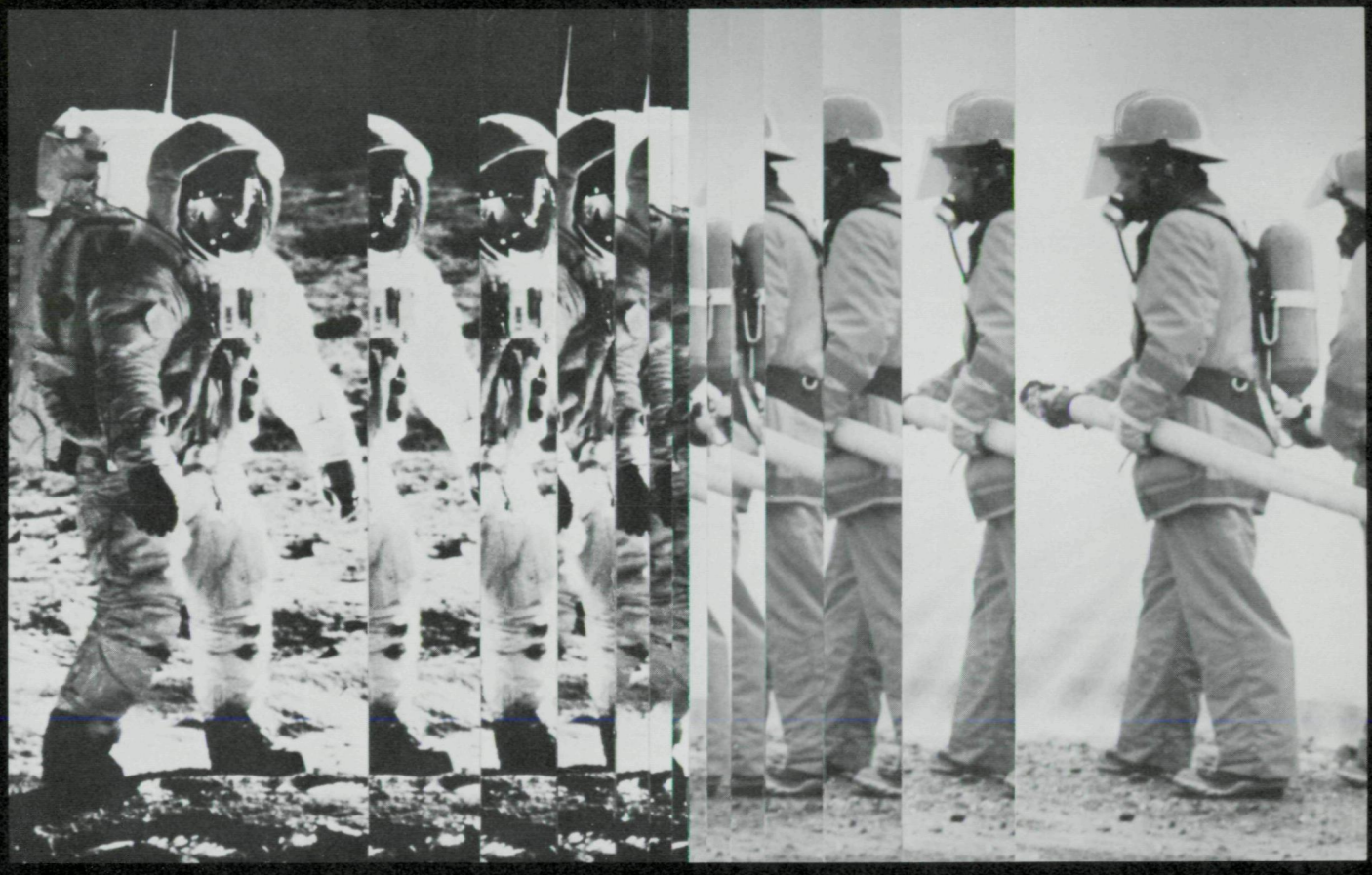
Howard J. Osborn
Patent Counsel
Langley Research Center
Mail Code: 313
Langley Station
Hampton, VA 23665
Telephone: (804) 827-3725

Norman T. Musial
Patent Counsel
Lewis Research Center
Mail Code: 500-113
21000 Brookpark Road
Cleveland, OH 44135
Telephone: (216) 433-6346

Leon D. Wofford, Jr.
Patent Counsel
George C. Marshall Space
Flight Center
Mail Code: CC01
Huntsville, AL 35812
Telephone: (205) 453-0020

Monte F. Mott
Patent Counsel
NASA Pasadena Office
Mail Code: 180-601
4800 Oak Grove Drive
Pasadena, CA 91103
Telephone: (213) 354-2700

Public Sector Projects



Urban Construction and Safety

Fire Fighter's Breathing Apparatus

Selected fire fighters in New York, Houston and Los Angeles started using and evaluating, in late 1974 and early 1975, a new breathing apparatus based on the NASA portable life support systems technology. The field evaluation is the culmination of a three-year development program and is scheduled to last six months. NASA will monitor the performance of the fire fighter's breathing apparatus during this period. Also, it will train the fire fighters in its use, provide maintenance support and, if required, design modifications.

Upon completion of the field evaluation, specifications for the apparatus will be made available to potential manufacturers and users. Manufacturers will be ready to start producing an improved version of the current apparatus based on the NASA system. It is expected to be available to fire departments in 1975-1976 time frame.

The development of an improved fire fighter's breathing apparatus started in response to the strongly expressed need by the nation's fire departments for improvements in such devices. NASA had acquired the relevant experience some years earlier, during the development of portable life support systems used by the Apollo astronauts on the Moon. Many fire fighters avoid use of currently available breathing apparatus because they are cumbersome and tend to restrict the fire fighter's mobility and vision.

A lightweight, longer duration breathing apparatus developed for fire fighters' use by NASA is shown during a test at the Johnson Spacecraft Center.

The NASA program to develop the improved equipment started in the spring of 1971, in cooperation with the Fire Technology Division of the National Bureau of Standards and Public Technology, Inc. Public Technology, under NASA contract, polled cities on their needs and then organized a User Requirements Committee, made up of fire chiefs, city managers and a representative of the National Bureau of Standards Fire Services Program. In addition, fire service organizations, such as the National Fire Protection Association, the International Association of Fire Fighters, and the International Association of Fire Chiefs, have periodically reviewed the program.


APOLL

At its first meeting--held in June 1971 at the Johnson Space Center--the Committee identified the principal problems of the currently used systems. The main deficiencies included: insufficient duration of air supply, excess weight and size, protrusions, and lack of an adequate alarm to warn fire fighters before the air supply ran out. The User Requirements Committee helped NASA define their breathing system performance requirements and cost goals.

NASA then undertook the development of a more efficient breathing apparatus. Johnson Space Center engineers decided on the development of an open-circuit demand system with a composite pressure vessel--an air bottle--made of an aluminum liner wrapped by resin-impregnated glass fibers. This was considered the best approach, based on cost, durability and safety. Also, the composite pressure vessel helped reduce the weight of the entire system by about 30 percent.

Other recommendations included making the system more compact and providing it with an air-depletion warning device. The apparatus includes an improved helmet, and the air bottle is carried on the hips, rather than the shoulder, making it more comfortable to wear and easier to put on or take off. All these changes helped to improve the system's utility.

The User Requirements Committee approved the proposed design and in early 1972 contracts were awarded to Structural Composites Industries, Inc. and Martin Marietta Corp. to build two lightweight pressure vessels. One was for a longer duration than is now commonly used, the other for a slightly shorter duration. Scott Aviation received the contract to build the other components of the breathing apparatus.

The last of twenty prototype units was delivered to NASA by the end of 1973. The units were subjected to an intensive checkout and test program before the start of the field evaluation.

The User Requirements Committee, at its most recent meeting in December 1974, reviewed the initial results of the field test program. The new system was also reviewed by the National Institute of Occupational Safety and Health and the pressure vessels by the U.S. Department of Transportation.

The new breathing apparatus must be charged with an air compressor with a higher pressure than is now commonly used. Anticipating the early availability of the NASA-developed breathing apparatus, a number of municipal fire departments--large and small--have already purchased the higher pressure air compressors.

Flat Conductor Cable for Building Wiring

During 1974, there were three important test installations of aerospace-derived flat conductor cable systems. These applications brought the cable significantly closer to commercial readiness as a method of reducing the constantly rising cost of installing electrical systems in new and renovated buildings. This ongoing project was developed from flat-conductor-cable technology extensively used in aircraft and spacecraft electrical systems. However, the flat conductor cable requires new components prior to its adaptation to the mass-housing market.

The conceptual design as well as some prototype hardware development is being undertaken at the Marshall Space Flight Center. In a contract with NASA, a complete baseboard wiring system and a breaker panel for flat conductor cable are being developed.

Two types of installations have been made. These are under-carpet installations for commercial applications, and baseboard installations, primarily for eventual residential application. The first installation was in Sunnyvale, California and was a joint project between AMP, Inc. and Western Electric. In this installation, a Western Electric facility was wired with flat cable under the carpet for both telephone and 110-volt power. Another installation was in a conference room at NASA's Marshall Space Flight Center. This was a prototype of 110-volt baseboard installation. The third important installation will be a baseboard installation by the Urban Development Corporation in late 1974 or early 1975 in six garden apartment units in Yonkers, New York.

A protective strip is laid over the flat conductor cable prior to carpet installation at Western Electric.

At least five future installations are planned. The first will be an under-carpet joint project of AMP, Inc. and Western Electric in Indianapolis late in 1974. The second is planned for January 1975, a joint project between AMP and the General Services Administration in a GSA building. Also, both AMP and Western Electric plan installations in their own buildings in 1975. A solar-heated test house at Marshall Space Flight Center and a demonstration house at NASA's Langley Research Center will both utilize the residential version of the system.

Baseboard installation of flat conductor cable by the Urban Development Corporation in garden apartment units in Yonkers, New York.

Marshall engineers are working with the New York State Urban Development Corporation to ensure that hardware designs meet National Electrical Code Specifications. A favorable preliminary Underwriters Laboratory report is expected in late 1974.

Even after these test installations and the Underwriters Laboratory review there will still be a significant obstacle in the path of successful commercialization of flat conductor cable. This is the current lack of both performance specifications and production standards for the components of the system. Discussions are now under way between the Department of Housing and Urban Development and the National Bureau of Standards to develop a program to establish performance requirements for electrical systems and an initial set of standards for flat conductor cable hardware.

Short-Range Radio Communication Equipment for Fire Fighters

Municipal fire departments have submitted to Public Technology, Inc. a high-priority requirement for improved short-range communications equipment for use at fire scenes. Fire departments employ two-way portable radios at the fire ground for command and control of fire fighting operations. Fire fighters are deployed throughout the fire ground either in small teams or individually to rescue victims, apply water, ventilate the burning structure and investigate the general situation. Timing and coordination of these fire fighters' operations are crucial to effective, safe fire fighting. But the hostile environment, high ambient noise levels and restricted visibility often hinder or preclude normal voice communications. The situation is further complicated if the burning structure is a high-rise building with fire fighters situated on different floors of the building. Thus, there is a need for improved, reliable, convenient short-range voice communications equipment.

The currently used hand-held portable two-way radios suffer from several drawbacks. A major problem is high unit cost. The prices of the most popular portable radios range from $750 to $1300, depending upon operating frequency and performance features. While portable transceivers priced as low as $350 are available, these units offer reduced performance. Thus, high unit price coupled with limited fire department budgets in cities throughout the country often limits communication equipment distribution to chief officers and selected company officers.

In 1973 Public Technology, Inc., under contract to NASA established a User Requirements Committee to advise on the development of a solution to the above problem. Committee members include fire chiefs, fire department communications supervisors, budget officers,and city managers from large and small cities throughout the country.

At an initial meeting in June 1973 the Committee defined some general performance requirements for improved short-range communications equipment. The Committee established the following order of importance for these constraints: low cost, high performance, small size and low weight, configuration and ease of operation, and resistance to harsh environment and rough handling.

While user requirements were being defined, Public Technology contacted the NASA Field Centers and searched the NASA technical literature to determine if suitable technology was available. This effort uncovered a patented NASA technology, described as an inductorless electronic circuit design developed at the NASA Goddard Space Flight Center. This unconventional circuit design approach replaced inductances and coils in radio frequency circuits with combinations of low cost transistors, resistors and capacitors. This substitution produces several benefits:

- It reduces circuit size since high-quality RF inductances occupy 10 to 50 percent of circuit package.
- It improves electrical performance by making tuned circuits with quality factors three to five times better than conventional inductance designs.
- It reduces cost of circuits by allowing use of low cost, discrete components or integrated circuits and by reducing manufacturing labor.
- It improves durability by allowing smaller package design, which in turn makes equipment more compatible with firemen's clothing.
- It improves maintainability by making integrated circuit, modular construction more feasible.

Because these benefits coincide with the needs of the fire service, NASA and Public Technology decided to pursue the development of improved equipment using this design technique. The project objectives were to determine the technical and economic feasibility of the NASA inductorless technology and to work toward commercialization of the technology. One project task was to develop engineering prototype models of short-range portable transceivers, using the NASA technology. Two of these were designed to operate in the VHF (150-170 MHz) public safety radio band, and the other two in the UHF (450-470 MHz) band.

In May 1974, the User Requirements Committee met to review the electronic designs of the engineering prototype transceivers. The Committee observed electronic tests of "breadboarded" (laboratory model) inductorless RF circuits to be used in these prototypes, re-examined the equipment performance specifications, and provided guidance on the shape, size and internal construction of these units.

In August 1974, the User Requirements Committee again met to examine two completed engineering prototypes incorporating the NASA technology. Laboratory tests indicate these units offer electronic performance comparable to that of the best conventional commercial equipment available.

Furthermore, preliminary cost estimates for these units show that a low priced radio can be built. Because of the favorable consensus regarding the prototype performance and low cost, the Committee went on to identify general requirements and constraints for a future field test program. The group also reviewed the market data previously collected by Public Technology and discussed procurement practices in local government.

In 1975 Public Technology under contract to NASA will build approximately 25 field test units incorporating the electronic designs evaluated in the engineering prototypes. These units will be tested in several municipal fire departments during actual fire fighting operations. At the same time, Public Technology will seek out manufacturers interested in making production models to provide for commercialization.

Development of Wood Based Fire Resistant Structural Panels and Veneers

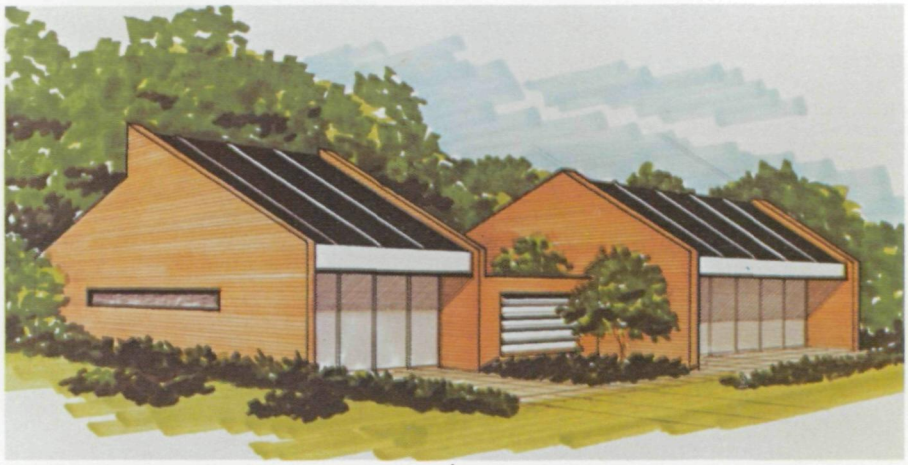
Researchers who have developed fire-retardant materials for aircraft at NASA's Ames Research Center, are now putting their expertise to other fields. They are working on fire resistant structural panels for use in high-rise buildings and in low-cost housing, such as mobile homes. Specifically, they are evaluating fire-retardant coatings and wood veneer which would be used to cover resin-bonded composite wood boards and plastics.

The spectacular growth in composite board manufacture lends particular importance to the development of fire-retardant coatings. In a September 1974 article, *Business Week* magazine reported on the expansion of two companies in their field, saying that it "could herald the greatest material-saving innovations since the development of particle board some 30 years ago."

Fire-retardant materials designed for aircraft might find application in fire resistant structural panels for use in high-rise buildings and in low-cost housing.

The development of new manufacturing processes is significant because wood-products manufacturers are under increasing pressure to use every scrap of raw material brought in from the forests. Yet, even today, ordinary plywood will utilize only about 40 percent of a log. Making these composite panels fire-retardant could make them even more attractive for construction uses.

High-temperature polymers, such as bismaleimide and epoxy-boroxine, as well as expandable (intumescent) coatings developed by NASA researchers, will be fabricated into test panels and veneers. The panels will then be tested to see how they stand up under heat, in fire, and other adverse conditions. The initial tests are expected to be completed by early 1975. The results of those tests will serve in launching a development program to produce a product of enormous market potential.



The NASA Technology House

NASA plans to design and construct a Technology House at the Langley Research Center to demonstrate the application of NASA aerospace technology to advance the residential building industry.

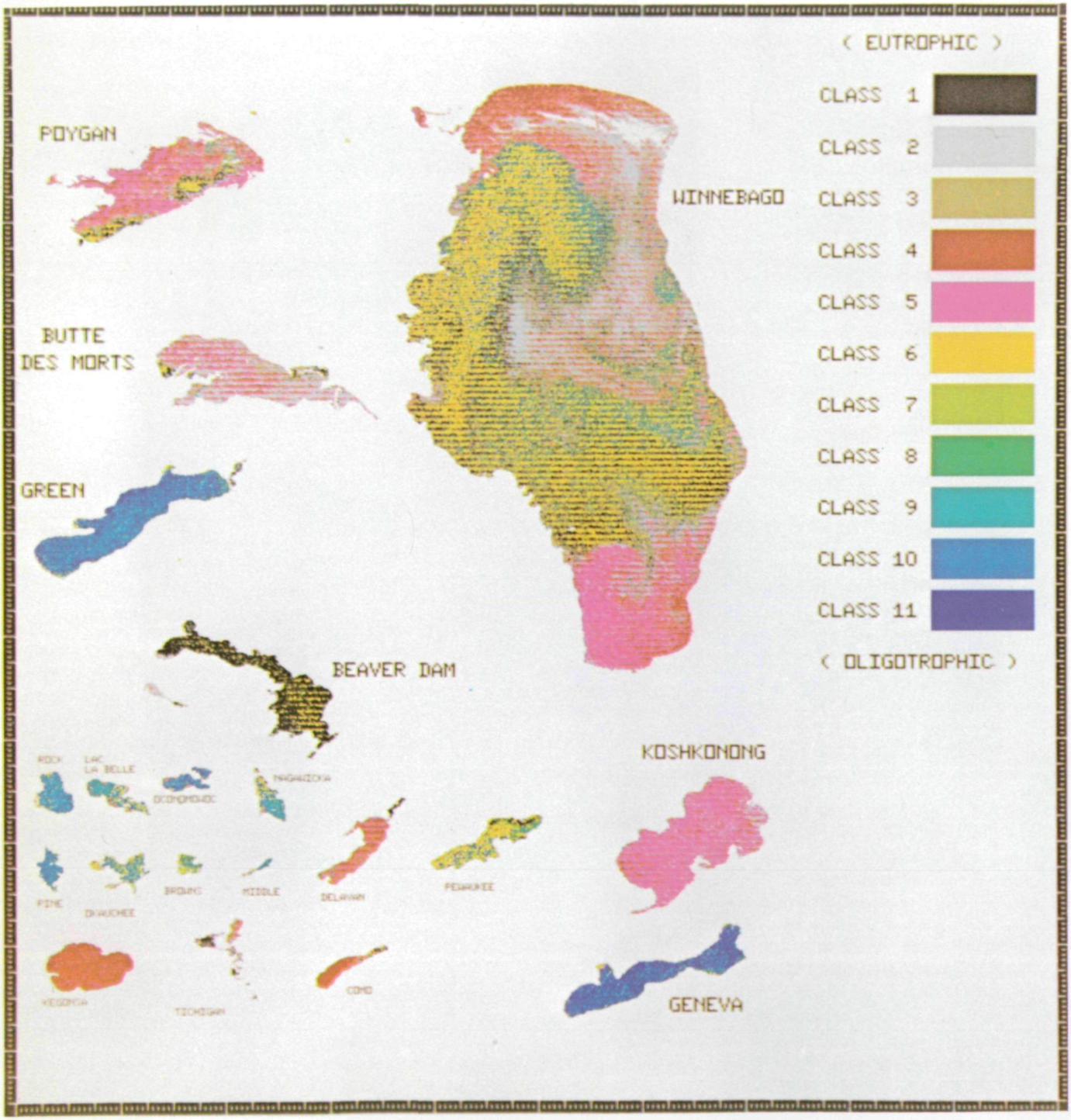
During the next two years a house will be designed and constructed at the Langley Research Center to demonstrate the application of NASA aerospace technology to advance the building industry in residential construction. The major considerations include resource conservation, safety, security, and low cost. Aerospace generated technology will be utilized in areas such as materials, tools, systems, management and construction techniques.

Only ideas and innovations will be included that could be commercially available within five years. The initial approach will be to evaluate related ongoing work efforts and equipment availability in fire and accident safety, on solar and wind energy collectors and converters, water and waste treatment systems, and advanced systems for heating, cooling, water heating, lighting and other systems for a single family residence. Systems, materials of construction, and construction techniques will be chosen based upon the appropriate, most resource efficient and cost-saving system that is available. These will incorporate the latest current technology and use some custom-made components and materials which have a high likelihood of market availability.

All the NASA Field Centers will be requested to review their past and present research and provide technology, equipment, management techniques or ideas that will contribute to improvements over present practice. The construction of the living quarters and its environment will be modeled on a digital computer. An integrated heating, lighting, cooking, water, and waste system will be included in the model. Parametric studies of various combinations of systems, heat sinks, and construction will be performed.

The current target schedule includes completion of NASA and university studies and selection of the energy efficient systems, fire safe materials, low-cost construction techniques, and technological innovations to be used in the house by July 1975 with complete construction by July 1976.

Environment

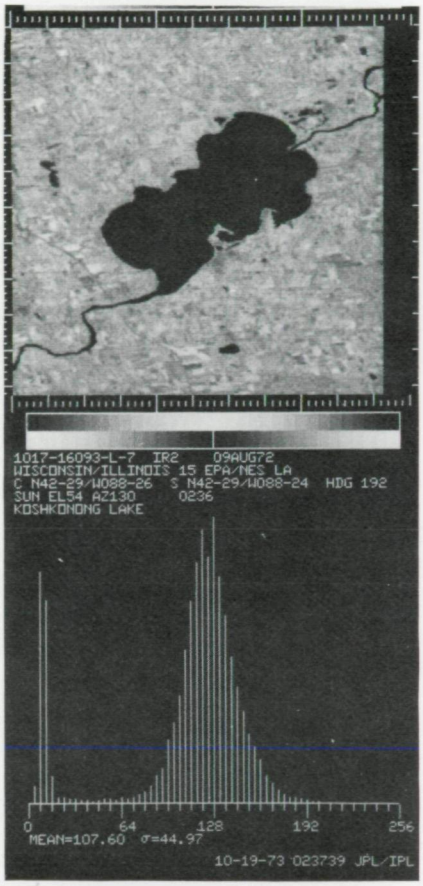


Computer Analysis of the Trophic Status of Inland Lakes

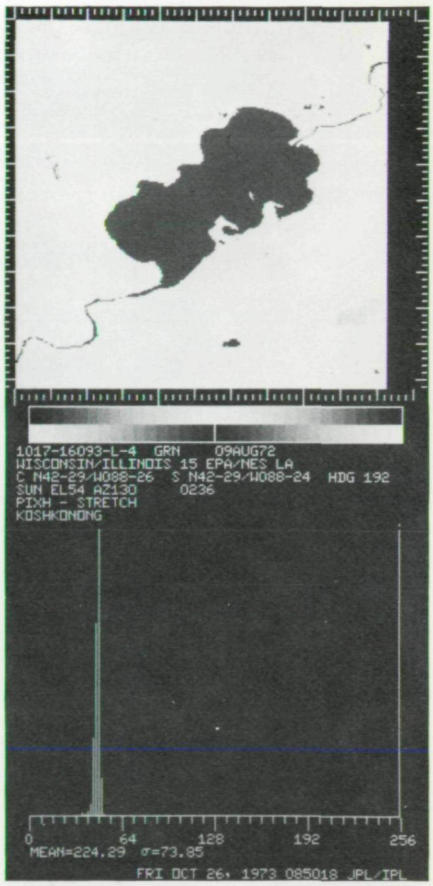
The feasibility of using aerospace-derived computer-image processing and multispectral data analysis techniques to classify lakes as to their trophic level is being studied by the NASA Jet Propulsion Laboratory. The methods and techniques used have previously been used to produce high-resolution, high quality images relayed by unmanned NASA spacecraft.

During the summer of 1973, a joint study between the Environmental Protection Agency, National Environmental Research Center at Corvallis, Oregon, and the NASA Jet Propulsion Laboratory was undertaken to examine the feasibility of using the NASA Earth Resources Technology Satellite Multispectral Scanner (MSS) data as a means of characterizing the water quality in lakes. The lakes studied were chosen from approximately 450 water bodies sampled by EPA's National Eutrophication Survey during 1972 and 1973. In order to establish a comparison base, NES helicopter-borne limnologists sampled the selected lakes on or about the day of the ERTS-1 overpass.

This project involved several different activities: (1) acquisition of the required ERTS frames coincident with the time and geography of the lakes to be examined; (2) extraction of the lake data from the ERTS digital tapes and isolation of the water body itself from surrounding land features; (3) multivariate classification of the water body on the basis of the NES gathered water-quality data in order to rank the lake in terms of its relative trophic status; and (4) classification of each picture element within the lake according to NES rank using the ERTS-MSS data.



Picture of a lake extracted from an ERTS frame and a histogram showing the range and relative distribution of grey levels contained within the picture. In the right hand picture land features have been removed.



A multitude of schemes have been conventionally used to ordinate and classify lakes. The result of most classification efforts is the application of one of four labels to a lake--oligotrophic (clean or low in nutrients), mesotrophic (moderate in nutrients), eutrophic (high in dissolved nutrients), and in some cases dystrophic (dead water; more extreme than eutrophic).

The six trophic indicators chosen for incorporation into both ordination and clustering efforts are: chlorophyll *a*, Secchi disc transparency (inverse), conductivity, total phosphorus, total organic nitrogen, and productivity as measured by an algal assay-control yield.

At left:
Lake classification picture.
The chart indicates the relative proportions of each water class within each lake.

The system under study works this way: ERTS, NASA's first Earth Resources Technology Satellite, was launched in July 1972 into a near polar orbit at an altitude of 910 km (547 nmi). It circles the Earth 14 times a day acquiring images of about 168 scenes per day. The multispectral scanner returns images in four spectral bands. Since each lake is sampled in four different regions of the spectrum, it is possible to take advantage of the fact that different materials, such as water, will have different spectral signatures. Indeed, even water of different colors will show different spectral signatures.

The picture of each lake area under study is first extracted from the ERTS digital tape and then with digital image-processing techniques the land features which surround the lake are eliminated.

Eventually, each lake--now represented by four separate images (one for each of the four ERTS-MSS bands)--will be grouped into a chain and classified into one of the NES-developed water quality categories.

As was expected, each lake contains more than one class; in fact several of the lakes exhibited all the classes. However, the positive aspect of the results is that the major class of water found in each lake is in most cases the same using the ERTS data for classification as that found by using the NES water quality ranking. For example, the multivariate analysis performed by EPA indicates that Beaver Dam is a highly eutrophic water body. Using the ERTS data, the lake was classified as containing 70 percent class l, or eutrophic water. The remaining 30 percent of the water within Beaver Dam was found to contain lower percentages of classes 2, 3, 4 and 6.

These results, while preliminary in nature, are very encouraging. If, for example, project planners determine that ERTS multispectral scanning data can be used effectively to classify inland water bodies, the cost-effectiveness of lake monitoring for environmental purposes will be enhanced.

Future activity will be focused on examining temporal changes within lakes as well as closer examination of the specific response of the satellite system at the point where water quality samples are obtained.

Computer Analysis of Multispectral Leaf Photos

A system to measure the extent of leaf damage due to environmental pollution is being developed at NASA's Jet Propulsion Laboratory. It is based on the computerized multispectral analysis techniques originally developed for the processing of multispectral images obtained by the Earth Resources Technology Satellite (ERTS).

The NASA researchers undertook the project at the request of the Environmental Protection Agency. EPA wanted to find out whether it would be feasible to automate the detection of plant diseases. Once the study is concluded in February 1975, the Jet Propulsion Laboratory will assemble a device for the automatic diagnosis of plant diseases. The device will include a mini-computer and EPA will operate it at a central site. EPA technicians will evaluate multispectral photographs of various leaf species received from ecology monitoring stations all across the United States.

This work is motivated by an increasing concern over the quality of our environment. The concern in this case is centered on the effects of air pollutants upon plant physiology. The examination of these effects is complicated by the presence of many interrelated environmental factors.

An experienced observer can usually judge the extent of injury to a given plant specimen, but it is a time consuming, tedious process and tends to be subjective. The systematic approach under study by the NASA scientists will provide an efficient means of data gathering and evaluation. This will assist in determining what actions must be taken to protect the environment.

In the initial study, five different plant species are being grown and will be exposed to selected pollutants. The species are soy beans, lettuce, corn, rhododendron and ponderosa pine. They will be treated with such pollutants as ozone, sulfur dioxide, peroxyacetyl nitrate, and the air of the Los Angeles basin.

The plants will be grown under controlled conditions at facilities provided by the Los Angeles Arboretum and the University of California at Riverside. The plant leaves which had been exposed to pollutants will be photographed through each of four different spectral filters, using 35 millimeter panchromatic film. The selection of the filters is based upon the reflectivity characteristics of healthy and injured leaves in the various species.

The four black-and-white color separation transparencies taken of each leaf are optically scanned. The information they contain is transformed into digital form which can be processed by computer. The computter generates a composite gray scale

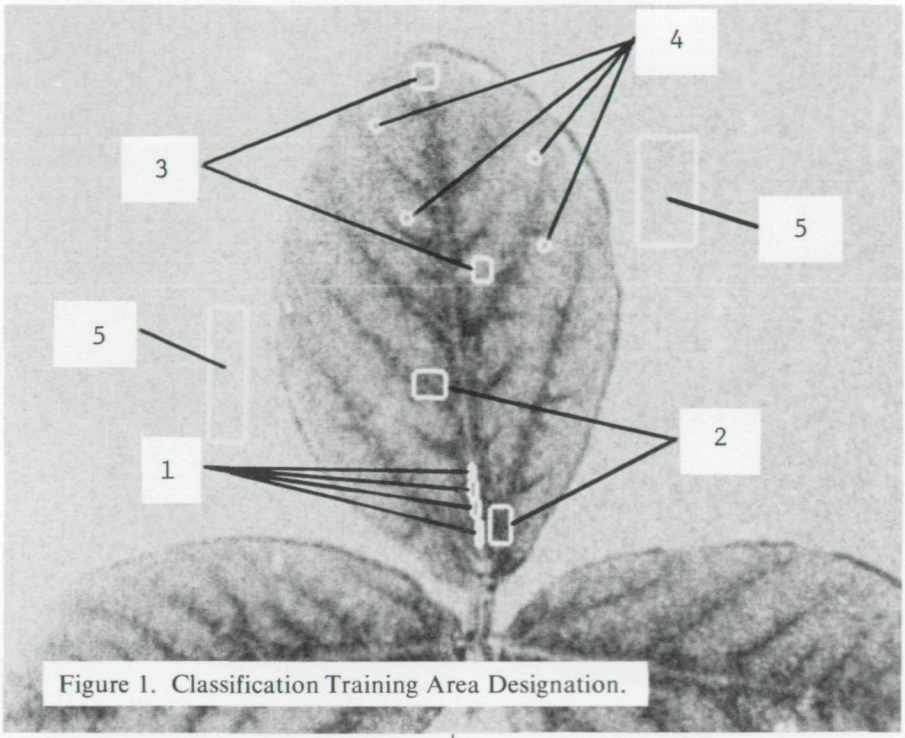


Figure 1. Classification Training Area Designation.

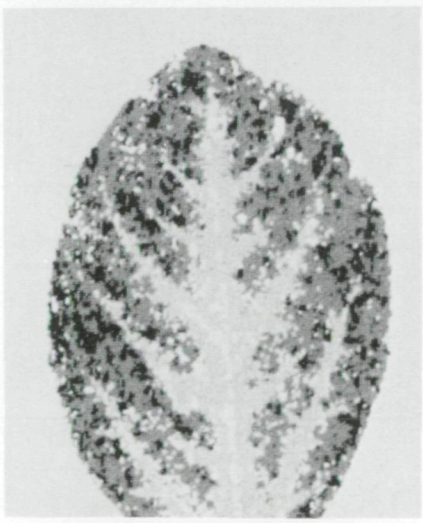


Figure 2. Classification Map of Soy Bean Leaf.

Figure 1 is a print of an injured soy bean leaf on which are displayed five training areas. Areas 1 and 2 represent two distinct healthy regions, area 3 represents a yellow chlorotic region, area 4 represents a red stipple lesion region and area 5 represents background. These training areas, or classes, were selected with the aid of a reference color print in which the five regions appear clearly distinct. Figure 2 shows the corresponding classification map resulting from the multispectral classifier. The statistical output indicated that 67 % of this leaf was damaged; that is, 52 % of the classification map is coded dark gray and 15 % is coded black. This leaf was photographed after the originally healthy soy bean plant had been exposed to a one part per million concentration of ozone over a six-hour period.

display of the leaf. From each display, so called "training areas" are designated. Each training area is a small sample representing a distinct region on the leaf's surface. The computer matches these training areas against pre-designated standards and classifies them according to those standards. It uses the same program that is being used for the classification of multi-spectral images acquired by the Earth Resources Technology Satellite. The computer also produces a statistical display.

Atmospheric Pollution Monitoring Programs Using LIDAR and Balloons

NASA LIDAR (laser-radar) and balloon-mounted instrumentation technology is being used to aid environmental 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's Langley Research Center for measuring haze particles in the lower atmosphere and to detect clear-air turbulence effects.

The LIDAR environment study, sponsored by the California Air Resources Board, is aimed at obtaining information on the vertical distribution of aerosols--fine suspended particles--near the ground. The overall objective of this project is to demonstrate LIDAR's ability to provide data for air pollution research. The measurements using the LIDAR system will provide the spatial and temporal distribution of particulate pollution in the Earth's mixing layer, the transmissivity or

visibility in the layer, and the longitudinal variation of the atmospheric aerosol. The temporal and spatial variations will then be correlated with meteorological phenomena and aerosol characteristics obtained from the overall program.

The State of California Air Resources Board, through their contractor, Rockwell International Science Center, has embarked on a major effort to conduct an air-chemistry study to increase the understanding of man's contribution to the trace constituents in the atmosphere. The study represents a pioneering effort to conduct major air chemistry investigations with the joint participation of industry, universities, and state and Federal government.

The NASA Mobile LIDAR facility was modified to meet the requirements for participation in the air-chemistry studies to be conducted by the California Air Resources Board contractor. The test site selected was located at Azusa, California and the LIDAR was shipped to that site for tests which were conducted in October 1972. Five-hundred data shots were made of the inner atmosphere to provide the aerosol mixing profile and to measure the top mixing layer. The reduction and analysis of the LIDAR data showed that laser-radar offers a valuable technique for measuring the atmospheric mixing of pollutants.

The development of a compact laser-radar system, utilizing a dye laser, has begun and is expected to be in operation in mid-1975. Laboratory

LIDAR and related instrumentation developed at the Langley Research Center is being used to aid environmental analysis of atmospheric aerosols.

tests have revealed that the dye laser is suitable for this application and work is proceeding to fabricate a compact system, based on the LIDAR techniques for air pollution studies.

NASA Langley Research Center is also cooperating with the Virginia State Air Pollution Control Board in an investigative program to determine air quality at various locations throughout the state. The LIDAR system has been installed at a site in Norfolk, Virginia and tests have begun there.

In a related program with NASA support, the University of Wyoming is studying aerosols by using instrumented tethered balloons from the NASA Langley Research Center. The project uses Langley Research Center Laboratory equipment such as the electron probe and a particle-measurement computer. The instrumented packages can measure three aerosol size intervals, temperature, pressure, ozone concentration, and wind speed and direction, telemetering the data to the ground simultaneously. This simultaneity permits the exact altitude and time location of variations in the data.

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 re-distribution 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 were conducted by the University of Wyoming during 1974 and a data-acquisition system tailored for the air pollution analysis mission will be delivered in early 1975.

Air Pollution Detection

An air pollution detection program, jointly developed by NASA and the Environmental Protection Agency, is based on technology originally developed for the detection of contaminants in space cabin atmospheres.

New cars equipped with the legally required catalytic converters to control exhaust emissions are creating a new and different potential pollution problem. While the catalytic converters reduce hydrocarbons and nitric oxides in the exhaust, they seem to release increased amounts of formaldehyde. This chemical not only irritates the eyes but also contributes to the formation of smog.

Because of the lack of satisfactory measurement techniques, the role of formaldehyde in these reactions is not yet precisely understood. NASA and EPA hope to learn more about them by applying aerospace microwave spectrometry techniques to measure formaldehyde in the auto exhaust fumes and in the air around us. A reliable, fast, non-wet chemical technique is being sought in place of today's time-consuming and cumbersome methods.

The Atomic Energy Commission's Lawrence Livermore Laboratory received a contract, funded by NASA and EPA. Working under the direction of the NASA Langley Research Center, the AEC scientists developed a microwave cavity tube spectrometer for the analysis of formaldehyde in the air. It can detect formaldehyde in quantities as low as one part per one million parts of air.

The formaldehyde-monitor prototype was delivered to EPA for evaluation in mid-February 1974. The instrument has shown excellent sensitivity and selectivity for formaldehyde vapor detection, but due to a combination of adsorption and polymerization effects the response time must be improved. The test results indicated that with further development a portable field monitor or a device that can detect and measure two different gases can be obtained.

Two new projects which the EPA has funded jointly with NASA include techniques for remotely measuring flow rates of polluting exhausts of automobiles and smokestacks to providing an automated system for measuring particle size of emissions from exhaust stacks. Both development projects were initiated in late 1974 at the Marshall Space Flight Center.

Pollution regulations are based upon the monitoring of mass flow rates of pollutants from their sources. Air pollution standards require monitoring the content of pollutant samples plus the flow rates of the sources. The monitoring of the flow rates of these sources has required insertion of an instrument into the flow such as pitot-static tubes. The insertion of these devices can be a difficult operation in the case of high flow rate smokestacks and many times interrupts the normal operation of the unit.

NASA developed technology for monitoring aircraft vortex flowfields and clear air turbulence can be readily applied to view the smokestack flowfields and give flow rate data. Flow rates can be remotely measured with a laser velocimeter and greatly reduce many of the problems associated with monitoring the pollutant flow rates from these sources. The remote monitoring of these flow rates with a laser velocimeter will not require the submergence of monitoring instrumentation

into the stream and thus should be a much more rapid, less difficult operation. Monitoring will be from an arbitrary distance away from the source in the case of the smokestack.

An automated system for measuring particle size of emissions from exhaust stacks is also required. Particle size distribution is directly related to the harmful effects of inhaling particulate matter into the human body. Very large particles are generally trapped and expelled from the body before causing any physiological damage. Very small particles tend to flow through the body with inhaled and exhaled air. Particles whose sizes vary between these extremes are often trapped in the lungs and cause respiratory problems.

Particulate size distribution of smokestack emissions are presently measured by physically sampling the emission; i.e., by immersing a filter in the emission and later analyzing the particulate matter trapped in the filter. A more convenient method of monitoring the size distributions of emissions from smokestacks will utilize the laser Doppler principle. The laser Doppler technology has been developed by NASA/MSFC for remotely monitoring aircraft trailing vortex flow fields. A laser beam could be aimed at the smokestack and the Doppler signal of the scattered radiation could be recorded. By programming a statistical measurement of the number of Doppler bursts of a specified amplitude over a given period of time, the number of particles present of some specified size could be determined for the time interval. Various amplitude signals could be correlated with the particle size distribution. This technique could be used to remotely determine the size distribution of the particles coming from the stack emission.

The Avco pilot plant which separates valuable nonferrous metals from scrap salvage.

Ultraviolet Measurements of Sulfur Dioxide

A program to measure smoke stack effluents using video techniques has been underway in 1974 at the NASA Langley Research Center.

This technique is based on analysis of the absorption of sky light by the stack effluents. In visible wavelengths, this absorption is negligible for the "clean" modern power plants of today. But at ultraviolet wavelengths, the absorption of the gas SO_2 becomes significant enough to measure for SO_2 concentration. The video technique uses an ultraviolet TV tube, an ultraviolet telephoto lens, and various optical filters. The technique was originally developed to identify hydrogen fires in hydrogen tank storage areas. The video technique allows the measurement to be made with minimal alignments, the information can be videotaped for future analysis, and video analysis techniques can be used to render accurate concentrations. An extension of the technique is planned for the future to obtain effluent velocities from the slow-motion aspects of video-tape recording. The effluent velocity, coupled with the concentration, will permit measurement of the total amount of SO_2 emitted by a stack.

The system is now being reviewed by the Philadelphia and New York City environmental protection agencies.

At left:
Demonstration of a video technique to measure stack effluents developed at the Langley Research Center.

Nonferrous Metal Separation for Recycling

A nonferrous metal separation system based on the results of a NASA applications project and useful to scrap salvage is now available commercially from Avco Systems Division of Lowell, Massachusetts. The Avco DIAL-A-DENSITY™ process separates valuable nonferrous metals such as aluminum, zinc and copper present in automobile shreddings, machining chips and turnings, mixed industrial wastes, municipal solid wastes, ore concentrates and other solid mixtures. Avco maintains a pilot demonstration plant at its Lowell facility. It is currently being used to separate titanium machining chips under contract to Pratt & Whitney, under sponsorship of the Air Force Material Laboratory. Also, the plant is being demonstrated for automobile scrap separation.

Using newly developed techniques based on the properties of magnetically responsive fluids known as ferrofluids, NASA supported the development of a prototype device to separate previously-wasted nonferrous metals from scrap materials in a commercially feasible 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 denser materials will sink in the ferrofluid. Therefore, to sep-

arate 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 ferrofluid, solid objects of densities that differ by ten percent can be made to selectively float or sink by varying the 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 Systems Division 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 recovery of nonferrous metals from automobile scrap promises to be a cost effective way to reclaim such material.

Mobile Domestic Water and Waste Treatment System

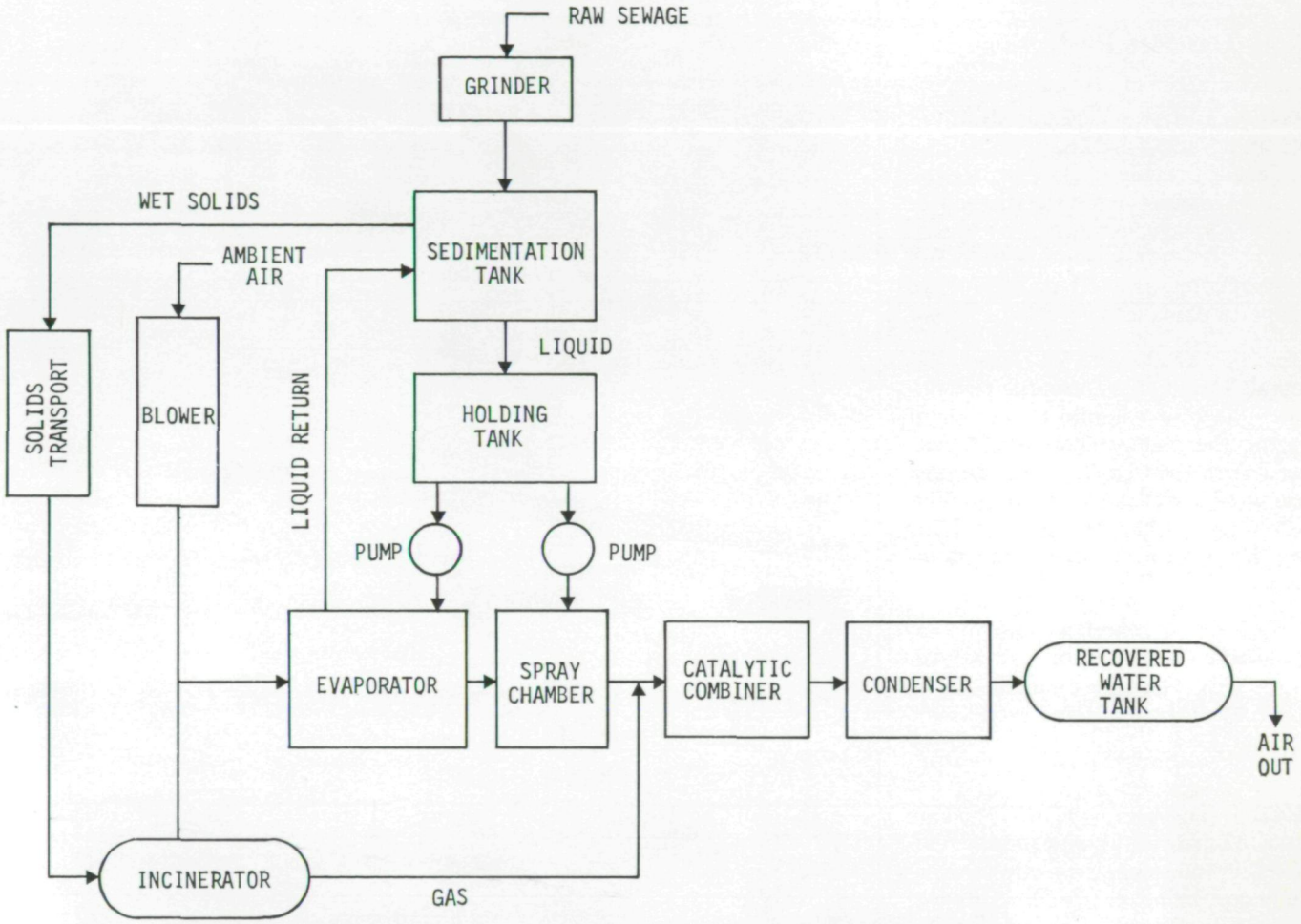
Getting rid of solid and liquid wastes in the household is one of the most pressing environmental pollution problems. During the past decade, NASA's Langley Research Center developed technology to recycle waste water and handle solid wastes aboard manned spacecraft on long-term missions. This technology was developed to the point where it could serve as an effective domestic water and waste treatment system, but still had to be demonstrated in actual prototype operation. Using this technology, the prototype should operate essentially maintenance-free, conserve energy and not pollute the environment.

General Electric received a contract in June 1972 to design, fabricate and test a domestic water and waste treatment system, using the NASA-developed technology wherever possible. Under the technical direction of Langley Research Center engineers, General Electric developed a system to process the daily liquid and non-metallic solid wastes produced by a family of four. It was designed to be connected to the sewer line of a household which contains water conservation features. The system consists of an evaporator to separate liquids from solids, an incinerator to reduce the volume of the solids, and a catalytic oxidizer to eliminate noxious gases generated during the evaporation and incineration processes.

All wastes are passed through a grinder which crushes the solids and deposits them in a settling tank. The liquids are transferred through a filter into a holding tank. The filter must be cleaned periodically. From the holding tank, the liquids are sprayed into an evaporator. The resulting vapors are scrubbed by the catalytic oxidizer. The same device cleans the gases coming from the incinerator where the solid wastes are burned and reduced to ash. The system also provides for the recovery of water and any latent energy that might be generated.

Functional and acceptance testing of the domestic water and waste treatment system was completed during July 1973 and a final report received during March 1974. The system's feasibility was proven by evaluating performance under various operating conditions. It operated free of odors, produced a clear water effluent and completely incinerated all solid wastes.

An integrated water and waste treatment system of this type potentially could be used in homes, aboard ships and pleasure craft, on oil drilling platforms and at highway rest stops. A mass-produced unit is estimated to sell for $2000. That price would compare favorably with the cost of installing a septic tank or connecting the home with the municipal sewage system in some areas. The system might provide a rational alternative to local building bans where sewage treatment is a limiting factor.



Schematic diagram of a prototype domestic water and waste treatment system developed by General Electric under the direction of Langley Research Center.

Transportation

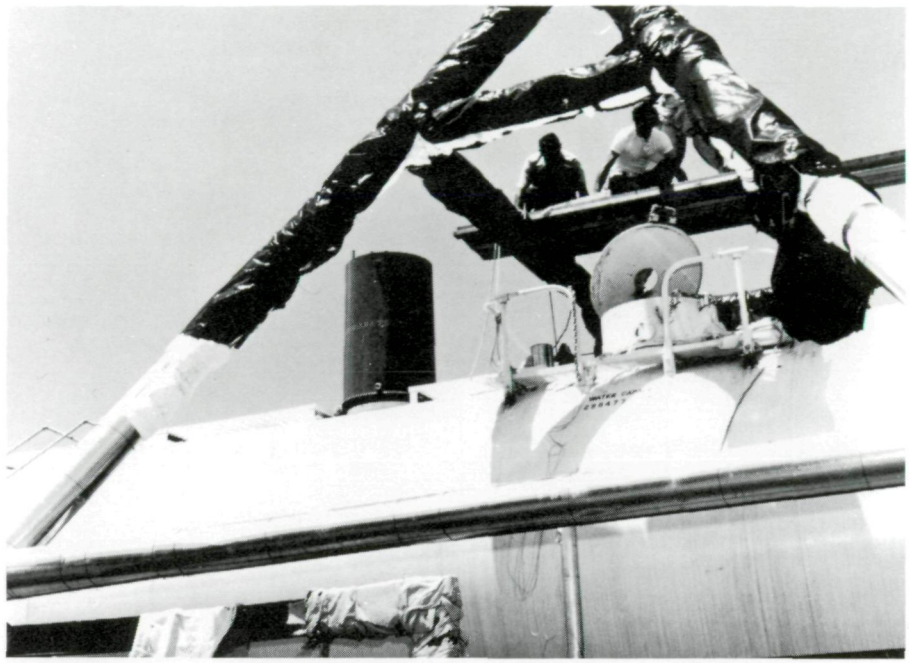
Tank-Car Fire Protection

NASA and the Federal Railroad Administration are cooperating in a project to provide rupture protection to rail tank-cars carrying flammable liquids. When such cars are exposed to fire they often rupture, causing loss of life, as well as expensive property damage.

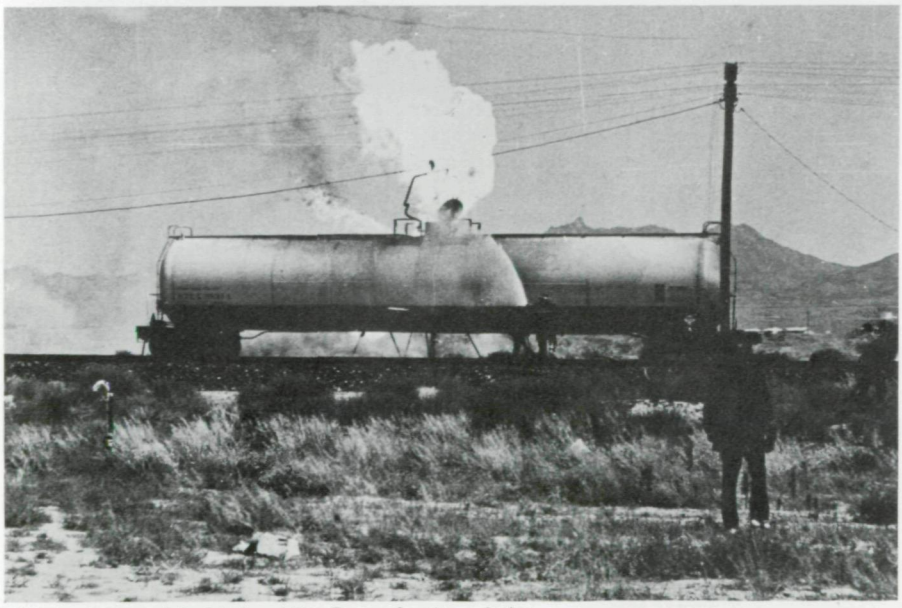
Chemists at the NASA Ames Research Center have conducted considerable research and development in the thermal protection of structures such as aircraft. They are now trying to see if the same, or similar, techniques could be employed for the fire protection of railroad tank-cars.

The Ames researchers set an instrumented tank-car on fire in August 1973. The data obtained during this realistic test was analyzed.

Currently, the various fire environments are being analyzed, and fire testing facilities which duplicate these environments and permit realistic thermal shield protection assessment are being designed. This will allow selection of fire protection materials which will prevent the catastrophic rupture of railroad tank-cars.



Ames Research Center scientists set an instrumented tank-car on fire and analyzed the data as part of the tank-car fire protection project.



Photos courtesy of the National Fire Protection Association.

Tank-car fires such as those shown here cost lives and considerable amounts of property damage in 1974. NASA is cooperating with the Federal Railroad Administration on tank-car fire protection.

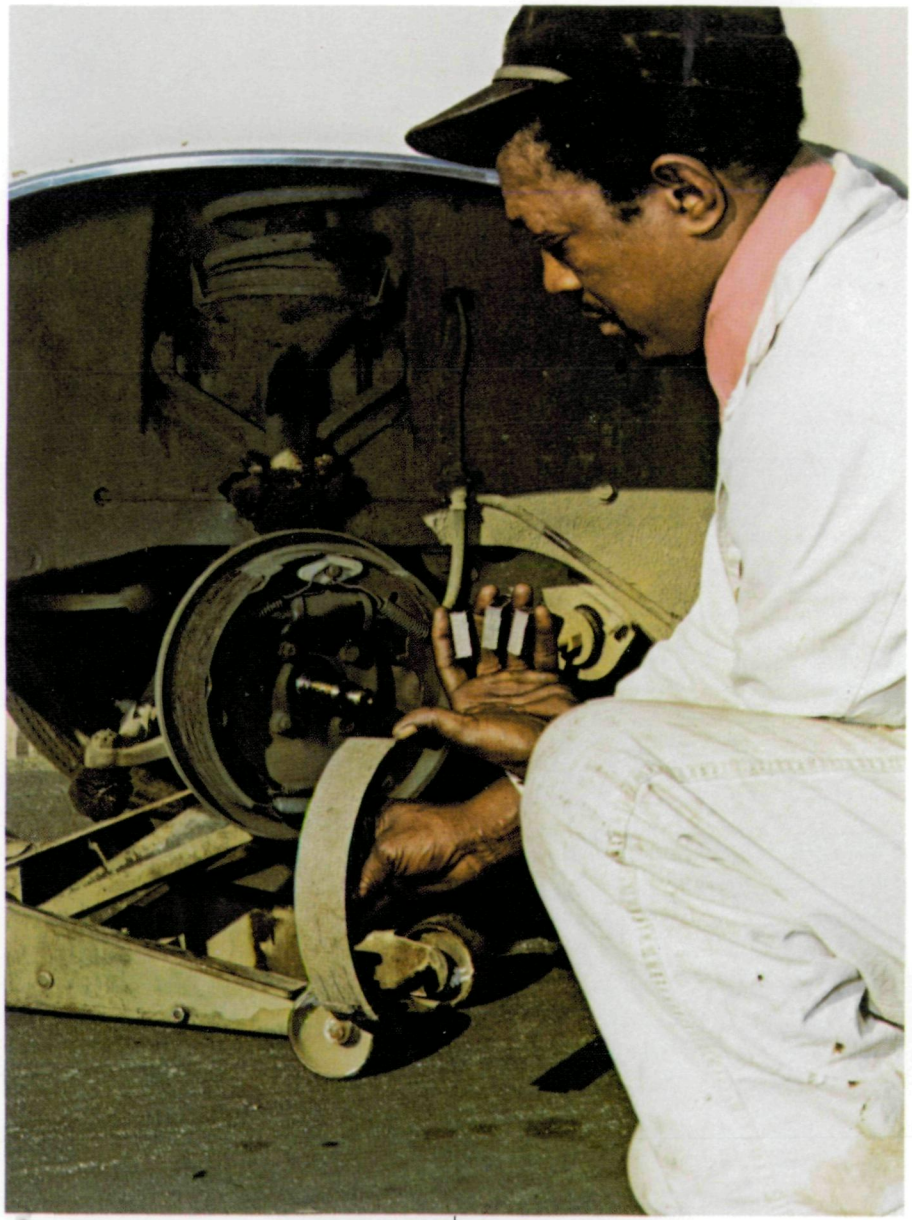
Improved Vehicle Brake Linings

There is a strong need for improved brake-lining materials to reduce maintenance and replacement costs in public vehicles. Increased safety is always a concern with brake design and materials. The recent directive to the trucking industry to increase brake capability by the National Highway Traffic Safety Administration has helped stimulate interest in this area.

The NASA Ames Research Center Chemical Research Projects Office has developed a broad competence in the technology of materials for high temperature environments to satisfy the thermal-protection needs of high speed flight. Technology from this research and development is considered potentially useful in the development of new automotive brake lining materials.

Current friction materials for automotive and light truck brakes are complex composites containing generally crysotile asbestos fiber, modifiers to maintain friction levels and some kind of organic binder. NASA's Ames Research Center, working with Bendix, is evaluating various materials for use as substitute binders, friction modifiers and fibrous materials. Bendix is fabricating varying combinations of these materials and evaluating results.

A program was initiated to develop the optimal formulation. However, instead of one formulation, two were optimized: one oriented toward maximum property improvement where cost is a secondary consideration; and the other based on cost-effective materials having improved properties.



The best low-cost formulation exhibits an essentially constant coefficient of friction with temperatures to 650° F. The average coefficient is approximately 0.34. The wear is equal to the standard at low temperatures and 32 percent better between 400 and 650° F.

Technology developed at the Ames Research Center related to materials for high temperature environments has potential for use in improved brake-lining materials.

These improvements were achieved through the replacement of asbestos by a potassium titanate fiber and through formulation adjustments from the optimized standard. Optimization is not now complete. While the toxicity has not been completely evaluated, currently available evidence suggests that the material acts as an inert substance and does not exhibit carcinogenic tendencies.

The second type of substitution is more expensive because the standard phenolic binder is replaced by a more stable but costlier counterpart which has the potential of providing improved properties. However, the binder is sufficiently distinct from phenolics that the first step of fabricating a satisfactory composite requires substantial experimentation, and further processing work will be required before a satisfactory composite is formed. Nevertheless improved wear rates at high temperatures have been obtained, and the friction coefficient is comparatively high in both the high temperature regions and, importantly, in the lower temperature region. High friction at low temperature is important because the binder serves a basic function of the modifiers, and the possibility of reducing or eliminating standard modifiers is significant in reducing fabrication problems. Part of the difficulty accompanying the use of the new binder has been that its higher required cure temperatures seriously degrade the standard organic modifiers. Current work is following the line of modifier reduction.

The series of full-scale dynamometer tests will be completed in early 1975. A decision will then be made on testing on an instrumented lightweight vehicle.

Improved Pavement Striping for Road Safety

It is difficult to drive safely at night on a rain-soaked highway. Rain decreases the visibility until the lane marking stripes become obscured, posing an additional hazard.

The Federal Highway Administration (FHWA) has been looking for new materials that would make road markings visible even under the most adverse conditions. FHWA turned to NASA for help and the Goddard Space Flight Center has a possible solution.

Goddard scientists, in the course of their research into planetary life detection systems, acquired considerable expertise in bioluminescent light emitted by living organisms. The FHWA has funded a research program at Goddard to determine the feasibility of using bioluminescent or chemiluminescent materials for self-illuminating highway markers that could be seen by motorists on wet roads at night. Chemiluminescent materials emit light as the result of a chemical reaction.

In the start of this project it was recognized that three criteria must be met. First, the marking must be water activated; second, it must be compatible with a solid matrix (asphalt, concrete); and thirdly, it must be cost effective (considering application, maintenance costs).

In the conduct of the program bioluminescent materials were first considered because of NASA's experience with luminescent properties of living matter. However, in time it was recognized that chemiluminescent materials held more promise. At present several candidate substances are being investigated. Siloxene was considered the most promising, however current research indicates that an oxilate ester material may be the best solution. Research will continue to ascertain if oxilate ester or other materials are best suited for highway application.

Track-Train Dynamics

In view of the large number of derailments on the nation's railroads a project has been initiated by the Federal Railroad Administration and NASA to study the behavior of hopper cars. Hopper cars frequently become derailed due to erratic behavior at various speeds, loads and train positions.

The Federal Railroad Administration funded the project through NASA's Marshall Space Flight Center because of MSFC's expertise in dynamic and static modeling which is directly relevant to this problem. This project is part of a large test program being conducted by the Association of American Railroads.

An 80-ton hopper car has been furnished by the AAR and the Louisville and Nashville Railroad in order to perform static and dynamic tests. The dynamic tests include vertical and lateral motions. These tests involve both the truck and the car loaded and unloaded and will be completed in 1974.

A math model will be developed in order to simulate the car's behavior. The math model will eventually be

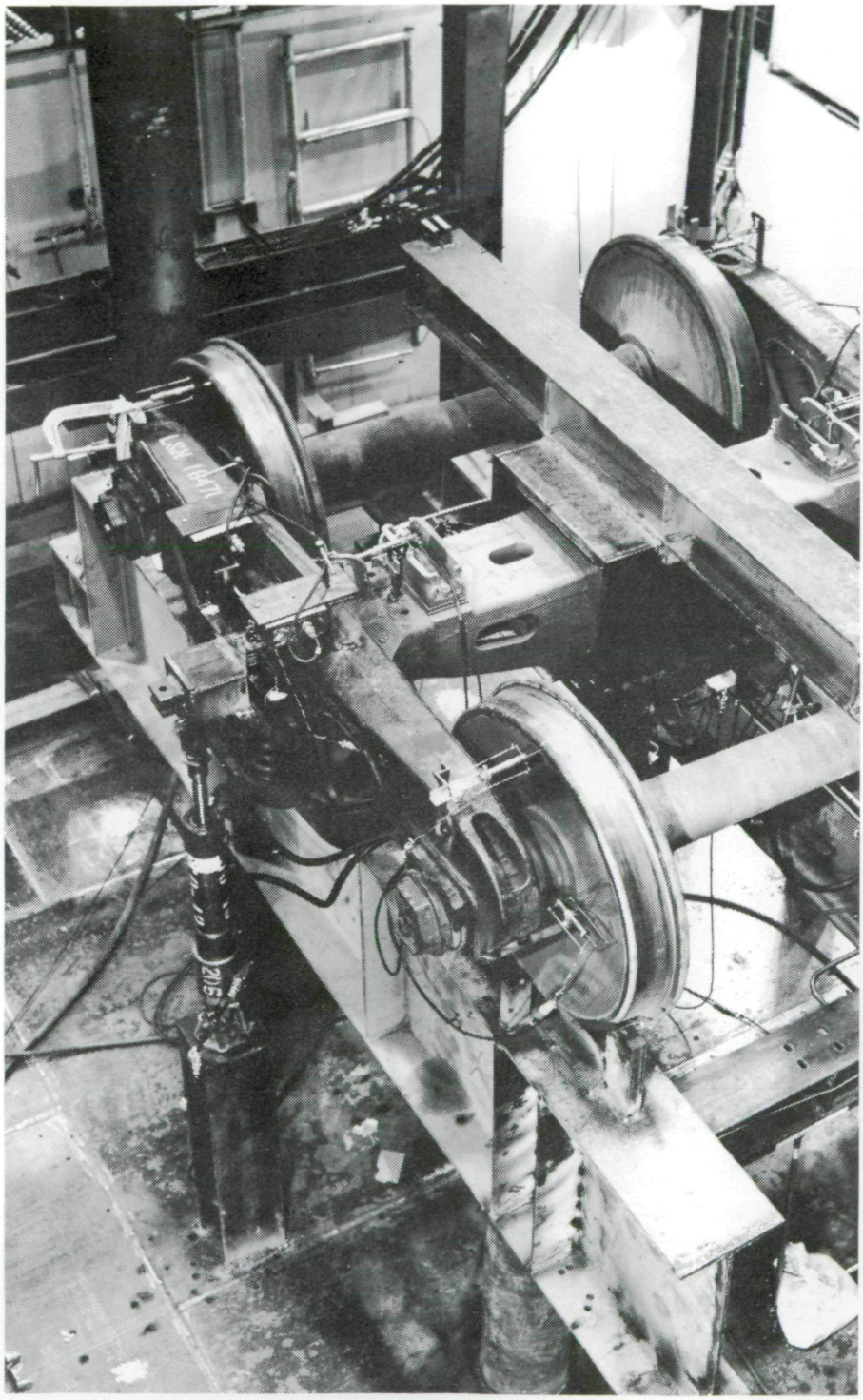
compared to the actual performance of the car. Once the model has been verified as representative of the behavior of the truck and car it will be used as an experimental tool to determine unusual and dangerous situations in which the whole car can be involved. Thus situations that normally would lead to a real car accident can be simulated in the math model. With the information gained from the model experience, modifications can be made to the car to prevent hopper car derailments.

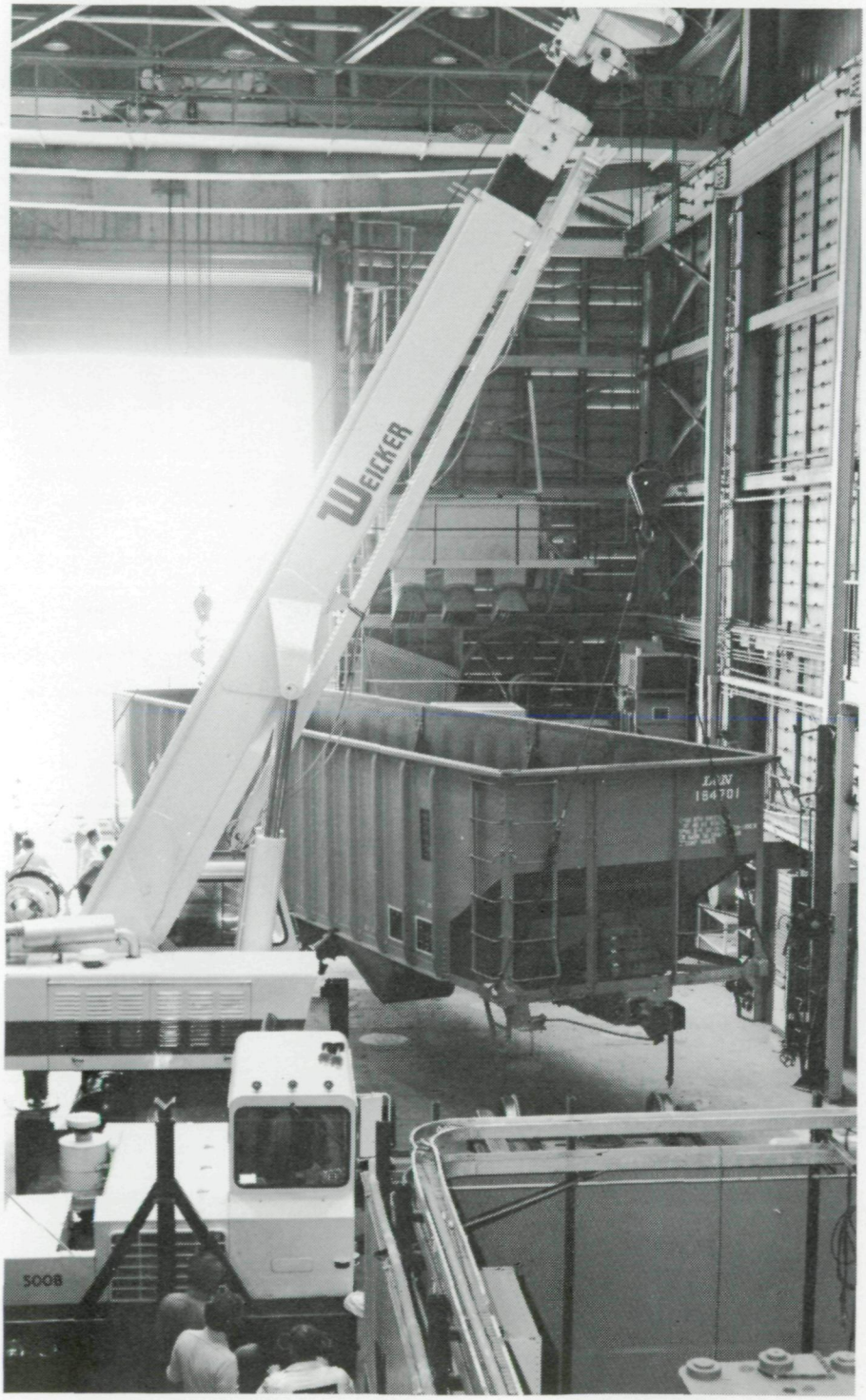
The Martin-Marietta Corporation, under contract to NASA and with the direction of MSFC, is performing this work. The math model validation will begin in February 1975, while an eight-month test program under operating conditions will begin in April. A final report is expected to be prepared by December 1975.

At right and opposite: Marshall Space Flight Center expertise in dynamic and static modeling is being used in a Federal Railroad Administration funded project to study the behavior of hopper cars and their derailment.

Computerized Bridge Safety Inspection

The collapse of the Point Pleasant Bridge over the Ohio River in West Virginia might have been prevented if the so-called Randomdec system had been available. Randomdec, developed jointly by the NASA Ames Research Center and the Federal Highway Administration, is used to detect structural deterioration in bridges.





The system was derived from the aerospace technique of analyzing by computer structural flutter fatigue in wind tunnel model aircraft. Material fatigue is also an equally significant bridge safety problem.

Strength degradation can be caused by long-term effects, such as corrosion and metal fatigue, or short-term, single events, such as collisions, fire, or extremely heavy wind gusts. Currently, there is no reliable, inexpensive way to detect damage. The most common technique is careful visual inspection, which has obvious shortcomings. No matter how careful the search for defects and strains may be, many flaws remain undetected because they are hidden by paint or cover plates. Clearly, a method of continuous scientific monitoring is needed so that changes in the bridge's structural characteristics can be detected long in advance of any catastrophic damage.

The Ames Research Center, in the course of its research on aircraft structural dynamics, developed a way to measure the effect of random forces or influences on structures. This method is being used to detect failure due to structural fatigue in aircraft and rocket components.

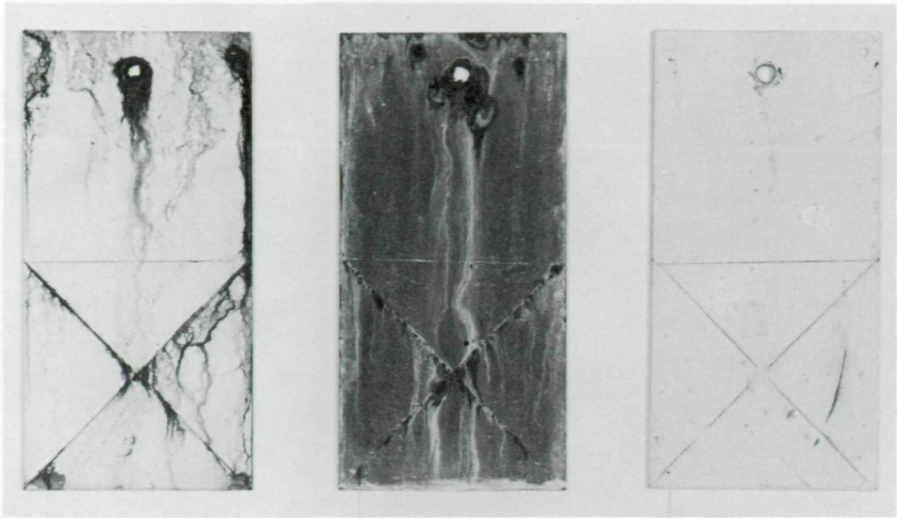
The Randomdec system applies the NASA experience to detect deterioration in steel girders. Engineers at the Fairbank Highway Research Center subjected a ten-foot rolled steel girder to random jolts by an electrodynamic shaker. The data from that test is being analyzed by a computer at the Ames Research Center.

At the same time, a highway bridge near the Ames Research Center has been equipped with a sensor to monitor vibrations from traffic and the

effects of the weather. The data is being matched against earlier analyses of the bridge to determine the rate of degradation that may be occurring.

Preliminary results from the two tests are so promising that NASA and FHWA will have a follow-up program. Its objective will be to further evaluate the technique on a variety of actual bridges. These tests will further verify the feasibility of the Randomdec technique.

An engineer checks the installation of Randomdec, a method of detecting dangerous defects in highway bridges based on aerospace-derived techniques for mathematically analyzing structural fatigue in aircraft.



A potassium silicate zinc dust coating developed by a Goddard Space Flight Center scientist might provide improved corrosion protection for coastal bridges.

Bridge Corrosion Protection

Bridges in coastal areas, with their constant exposure to salt spray, require more corrosion protection than is needed for inland bridges. Currently available zinc coatings provide only a few years of protection for coastal bridges. Inland bridges, coated with the same material, are protected for as many as fifteen years.

A scientist at NASA's Goddard Space Flight Center developed a potassium silicate zinc dust coating for the corrosion protection of launch structures located on the sea shore. NASA made the material available for testing to the Alaska Department of Highways and the California Department of Transportation when the two agencies sought help for their coastal bridge corrosion problem.

Both states agreed to test steel plates covered with the potassium silicate zinc dust coating. Tests in the California salt-spray chamber were concluded in October 1974 after 5,308 hours of exposure. The steel plates suffered no degradation. The test results indicate that the NASA-developed coating equals or exceeds in quality anything that is currently available.

The space agency is now disseminating information on this NASA-developed rust-proofing material to potential commercial manufacturers. This coating is expected to be cost-competitive with other materials now used.

Nickel-Zinc Battery for Electric-Powered Vehicles

The current energy-environment crises generated urgency to improve air quality, fuel supply and to abate noise pollution has stimulated interest and research in the use of electric-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. This high energy density makes this battery suitable for use in electric vehicles. Unfortunately, because of zinc electrode problems such as slumping, dentritic growth and separator degradation, rechargeable nickel-zinc batteries have not been commercially developed.

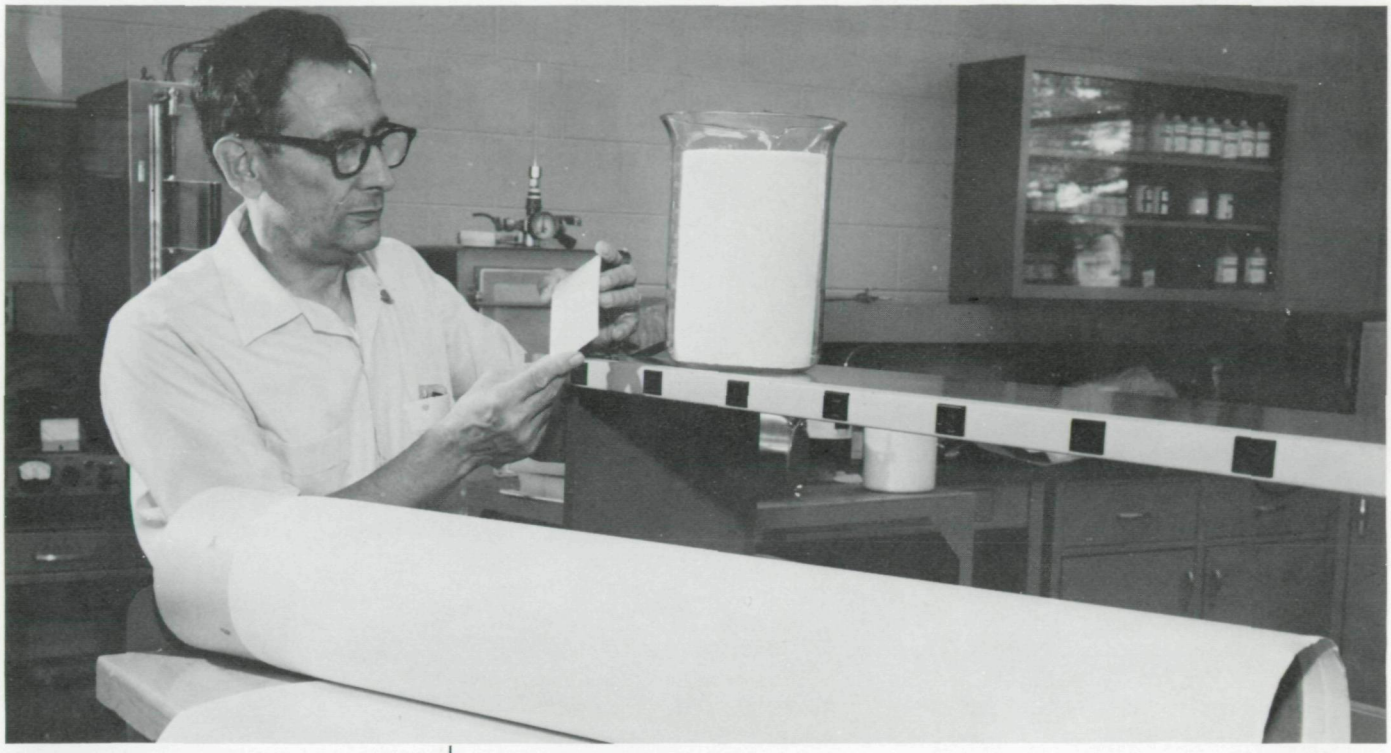
NASA's Lewis Research Center has an extensive background in battery technology, developed in the course of its research on silver-zinc batteries for space-vehicle electric power supplies. It was found that the above zinc electrode problems could be controlled in silver-zinc batteries by using an inorganic separator developed by McDonnell Douglas and NASA Lewis. Use of this separator also increased rechargeability of silver-zinc batteries by more than a factor of four.

Based on these silver-zinc results, tests were made on nickel-zinc cells using inorganic separators. As a

Lewis Research Center engineers updating their data on the operation of a zinc electrode battery for electric vehicles.

Above right:
This battery testing facility can be programmed to run tests of hundreds of cells with different charge-discharge cycles.

Prototype nickel-zinc batteries developed at the Lewis Research Center will be evaluated in a Postal Service vehicle similar to the one shown here in late 1975.



result of encouraging results an additional program was recommended and funded. Test cells of 300 ampere hour capacity suitable for use in test vehicles will be developed for United States Postal Service vehicles. The ultimate objective is to transfer this technology to a competent nickel-zinc battery manufacturer who will produce the battery for the commercial market.

Prototype batteries are projected for delivery in December 1975. They will then be placed in a vehicle provided by the Postal Service for extensive in-service testing.

Roll of inorganic separator for battery cells was experimentally machine produced. Continuous coating process will make possible mass production of inorganic separator material important for longer life of nickel-zinc batteries.

State and Local Governments

Ballistics Identification

Electro-optics techniques developed at the NASA Johnson Space Center may soon be adapted into a new law-enforcement technique for the high-speed, preliminary classification and identification of bullets, augmenting conventional techniques. This project will determine whether using optical Fourier transforms can be applied to police ballistic technology, how accurately an individual bullet can be identified, and what would be involved, by way of cost, in the development of a practical system.

A bullet fired from a gun has distinctive markings made by the lands and grooves in the barrel. Forensic scientists usually identify or match a bullet with a particular gun by using a comparison microscope. This traditional technique, which has been in use since the 1920's, is a slow process involving considerable set-up time for optical alignments and visual comparisons. Only a few bullets per hour can be compared. The system does not lend itself to mass sampling. Thus, a system which could take the Fourier transform of the individual bullet "signatures," store the information in a general-purpose computer, and then correlate a new signature with those in the computer library could be most useful.

Using similar technology, a number of techniques for processing fingerprints have been studied, and several prototype systems are now in use. The optical techniques include comparisons of interference fringes between the Fraunhofer diffraction patterns of two sample transparencies as well as optically-matched filters using either holographic or standard Fourier patterns. In each of the optical processing systems a film transparency containing the unique matched filter is compared with transparencies previously recorded in a library. The digital processing techniques are similar except a computer compares the digitized information on magnetic tape. The cross-correlation of two samples can be calculated, with a threshold criteria (degree of correlation) determining whether the samples match.

A bullet identification technique similar to those used for fingerprints appears feasible. But there are additional complexities to be overcome. While fingerprints remain virtually unchanged, the characteristics of firearms change constantly with use. The current program is aimed at developing a system for use on a city or state-wide level rather than a centralized national bullet identification file. The library search file would be limited to 10,000 entries. The computer algorithms would have to be compatible with general-purpose computers commonly found in large-city police departments. Also, the processing system must have a capability for varying the threshold value for the correlation. It would not be necessary, nor desirable, for the system to make a positive match, since the final identifications or comparisons will be made by a ballistics expert using a comparison microscope.

To determine the feasibility of adapting these techniques to police ballistics, a contractor was chosen by JSC engineers in September 1974 to perform the following tasks:

- Develop and define a preprocessing system for programming optical Fourier transform data into the computer.
- Develop the necessary algorithms for correlating and comparing the bullet signatures.
- Undertake a test program to determine the feasibility of using the computer processing system under simulated "real" conditions.
- Define the computer interface requirements, the optical preprocessing system, readout and necessary equipment. These tasks will be completed in April 1975.

Several law-enforcement agencies have been invited to participate as advisors to the project and to supply sample bullets. These agencies include the FBI, Law Enforcement Assistance Administration, New York City Police Department, Houston Police Department, New York City Criminal Justice Coordination Council, New York State Division of Criminal Justice Service, Texas Department of Public Safety and Texas Criminal Justice Council. The New York City Police Department has agreed to set up a system as a practical laboratory when the system is developed. Also, the International Association of Chiefs of Police has agreed to participate both as advisor to the project and as communicator of progress in the project to the law-enforcement community.

Photos courtesy of The New York Times.

Liquified Natural Gas Safety

NASA's experience in handling volatile rocket fuels storage is being applied to a problem of increasing public concern--the safe handling and storage of liquified natural gas used for heating and lighting fuel, a substance being stored in increasing quantities near coastal urban centers. A tragic fire at a liquified-natural-gas storage tank on Staten Island in 1973, which killed 40 people, dramatically highlighted the need for increased attention to this problem.

In the wake of the Staten Island disaster, New York City Fire Commissioner John O'Hagan asked the NASA Technology Utilization Office for assistance. NASA and New York City had already cooperated successfully in a number of other efforts to adapt aerospace technology for solution of public sector problems.

A meeting was set up in New York City to review NASA expertise relevant to the Fire Department's problems. As a result, projects related to liquified natural gas safety were begun at three NASA Field Centers with periodic review meetings conducted in New York City. They include:

- Development of a risk-management system for all phases of design, construction,

operation and maintenance of liquified natural gas and other technologically advanced facilities. Emphasis is placed on hazards identification, control and elimination. The program is based on NASA's Kennedy Space Center launch experience gained in the management of risk situations including manrating, facilities certification and hazard identification.

- Development of a liquified natural gas safety manual. There is at present no total compilation of liquified natural gas safety information. This program is a follow-on to widely respected NASA-prepared compilation efforts such as the Hydrogen Safety Manual developed at NASA's Lewis Research Center.
- Development of a model regarding liquified natural gas spills on water. The model will be used to develop assessments of liquified natural gas vaporization and spreading which can lead to situation control. It is based on extensive research into cryogenic and fire safety performed at the Ames Research Center.

The first project began in late 1973 while the latter two started in the fall of 1974. The NASA Lewis Research Center has let a contract to the National Bureau of Standards to collect, analyze and evaluate safety related liquified natural gas literature. This information is being prepared for input to the NASA Aerospace Safety Data Bank. When a sufficient volume of data has been received, it will form the basis for the preparation of the liquified natural gas safety manual.

The NASA Ames Research Center has begun its study of the hazards and accidents of storage and transport of liquified natural gas with particular emphasis on large quantity spills on water. This should lead to a model which, on completion, would be of practical benefit in reducing the explosive and/or fire hazard of liquified natural gas spills. The objective of this program is to calculate the characteristics of fuel/air "clouds" (plumes) formed from a select few realistic accidental spills of liquified natural gas in New York Harbor. The work consists of (1) determining the probable types, sizes and locations of spills, (2) determining the local atmospheric conditions which will affect plume formation, (3) surveying and selecting the most applicable from among the available computer programs, and (4) calculating the properties of three test case plumes.

Engineers at the NASA Kennedy Center are completing a prototype risk-management technique for use by the New York City Fire Department in following liquified natural gas plant development and operations. This technique was designed for widespread use in the assessment and minimization of risks at hazardous facilities such as liquified natural gas plants, nuclear power plants and naphtha plants. The technique is presented in the form of an instruction document to guide the user in operating the risk management system. Also, it will provide a means of identifying risks and developing risk-analysis techniques and a follow-up reporting system.

Another portion of the Kennedy Space Center effort was a technical analysis of the New York City Fire Department *Regulations for Manufacture, Storage, Transportation, Delivery and Processing of Liquified Gas.* This analysis led to recommended changes in the regulations, many of which were accepted by the Fire Department.

The New York City Fire Department is now in the process of incorporating the Risk Management System into its operating procedures. They are also evaluating its incorporation into the new computerized Fire Department Management Information System--now in the planning stage.

The tragic fire in a liquified natural gas storage tank on Staten Island shown here killed 40 people. NASA is applying its expertise in several programs to the safer handling of LNG.

Mine Safety

Fire resistant coatings are being developed at the Ames Research Center for mine tunnel coverings.

Applications for Fire-Retardant Materials Technology to Mine Safety

Materials used to fireproof airplanes and spacecraft may help solve a mine safety problem. Urethane foams, presently used as mine tunnel wall covering to eliminate hazardous dust, are hazardous in themselves and must be covered to prevent their burning. The U.S. Bureau of Mines would like to have a fire resistant covering which retains all the desirable properties of urethane, such as moisture resistance, rigidity and ease of application, but will be flame retardent. Proper tunnel coatings can also reduce air turbulence permitting better ventilation as well as reduce wall stress and subsequent rock falls. Newly developed materials must be able to be used by themselves as well as cover existing polyurethane.

NASA scientists and engineers, particularly at the Ames Research Center, have acquired considerable experience in the development of fire retardant polymer foam systems for use in spacecraft and airplanes. NASA and the Bureau of Mines are now jointly sponsoring a project to demonstrate the reduced flammability and flame spread characteristics of the NASA foam in a simulated mine fire.

The Monsanto Corporation has been selected to furnish the foam panels to be tested. The Bureau of Mines expects delivery of the panels by 1975. If they prove to be satisfactory as fire retardants and pass the Bureau's requirements, an ambient cured foam will be developed under a second phase of the program.

Study of the Onshore Lease Management Program

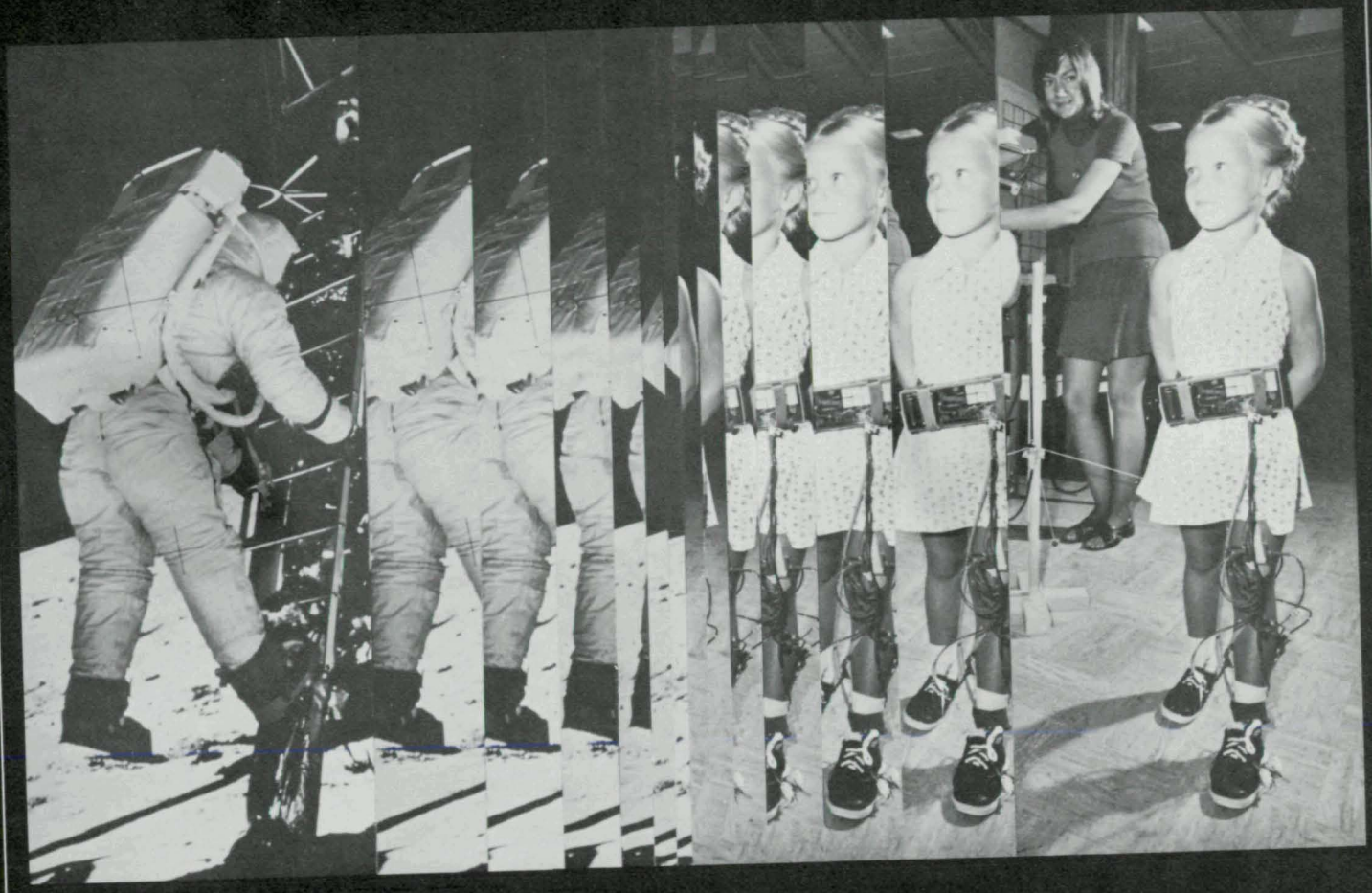
The Onshore Lease Management Program supervises and regulates extraction of mineral resources from about one-third of the land of the United States. For almost 50 years, the people in this program have supervised development of mineral resources on Federal land with relatively little attention from the public. In recent years, however, under the impact of new environmental, safety and freedom of information legislation, and an increasingly aware and politically active public, the program has found itself operating in an entirely new, and often critical, climate. Also, as the impending mineral shortage materializes and as the energy crisis continues, onshore lease management performance will become even more crucial to the national welfare.

In recognition of its need to modernize and improve its supervisory capability, the U.S. Geological Survey of the Department of the Interior requested an independent study of its supervision of operations authorized by mineral leases on Federal and Indian lands.

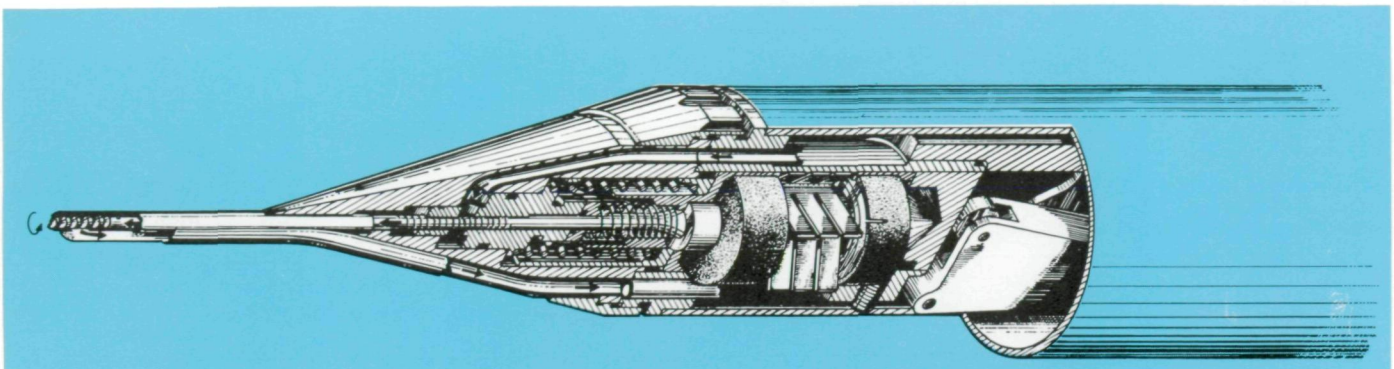
The management study was made under the leadership of Mr. J. Pemblefield of NASA, with contracted assistance from the Martin Marietta Corporation. The results of the critical but constructive study were heard and analyzed during a recent two-day session of self-appraisal by management and supervisory personnel.

Agreement was reached that steps must be taken to overhaul existing procedures and approaches to cope with the increasing dimensions of the Government's problem of meeting the demands for resources while maintaining environmental quality.

Biomedical Projects



Detection, Diagnosis and Treatment



OPHTHALMIC MICRO—SURGICAL LIQUEFACTION PUMP

Cataract Surgery Technique

The high-speed cataract removal instrument was developed to rapidly remove cataract material from the eye through a very small incision. As a result operating and recovery times will be greatly reduced.

A new surgical instrument for the quick and safe removal of cataracts has been developed jointly by the initiator of the project, William J. McGannon, M.D., an eye surgeon in Cleveland, the Retina Foundation of Boston and NASA's Lewis Research Center. A cataract is a condition in which the lens of the eye becomes opaque, reducing the vision and leading, eventually, to total blindness. The vision can be restored only through the surgical removal of the lens. Within the United States alone, approximately 400,000 people per year require surgery for the correction of cataracts.

The traditional cataract surgery technique for removal of the whole lens requires a 180° incision in the eye. As an incision of this size requires a large number of sutures to close and because of the risk of infection, patients are usually kept in the hospital for ten days after the surgery. The intent of the newly developed instrument is to perform the operation through a small incision, requiring only one suture to close. This procedure permits the patient to leave the hospital in less than a day after the operation.

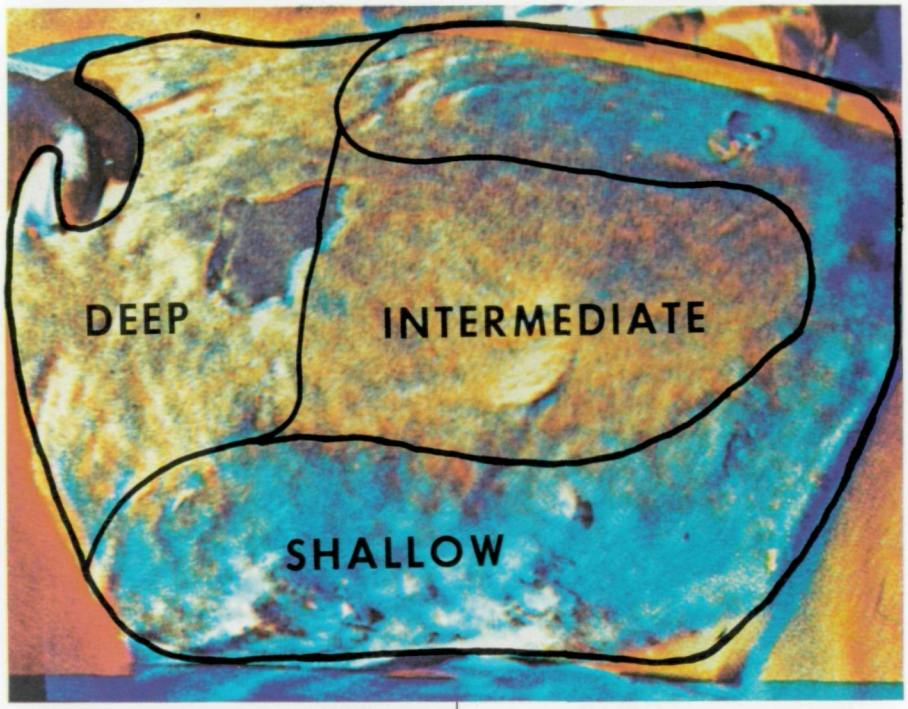
The NASA-McGannon cataract surgical tool is a tiny cutter-pump, which liquefies and pumps the cataract lens material from the eye through a small incision. The cataract removal tool, which can be used on the hardest cataract lens, is inserted through a single incision in the cornea, about 3.2 millimeters in length. The tip of the tool is about 1.25 millimeter thick, 2.8 millimeters wide and 15 millimeters long. This tip houses the cutter-pump rotor driven by an air turbine at about 200,000 revolutions per minute, as well as two passages for a saline solution. The liquid inflow passage is connected to a pressure regulator to maintain essentially constant pressure within the eye. The outflow passage from the tool is connected to an air-driven pump to aid in the rapid removal of the fragmented lens material and fluids.

Work on this project, under way for over two years, has resulted in a thoroughly tested design with an excellent potential for improved cataract surgery. The design, fabrication and assembly of the device have placed great demands on advanced technologies in such diverse fields as fluid mechanics, high-speed rotating machinery, pumps, seals and bearings, and miniature mechanisms.

Laboratory work to evaluate the tool and develop the exact surgical procedure has been under way for over a year. The Retina Foundation anticipates that the instrument will go into clinical use by early 1975. NASA has applied for a patent on the instrument and will license a commercial firm to manufacture the device.

Computer Aided Diagnosis of Thermal Burns

Techniques developed for the analysis of Earth Resources Technology Satellite photographs are being used to assist the treatment of burn victims. These techniques will facilitate



Computer enhanced thermal burn profiles of same victim indicating areas of deep to shallow thermal penetration. Availability of such data to the admitting physician would permit a clearer delineation of destroyed tissue for removal.

A young victim of hot water burns several days after admission for treatment.

the early differentiation of viable and non-viable tissue and reduce the risk of infection and the area of tissue requiring grafting. Medical experience indicates that it is to the advantage of burn victims if the irreversibly destroyed tissue is removed as early as possible. Its removal reduces the risk of infection, the growth of scar tissue, and the loss of function to the damaged limb. It also appears to provide the best surgical results in the shortest time.

In many cases, however, it is impossible to differentiate between the tissue which has been destroyed and the tissue which would spontaneously heal with time. Treatment of these questionable areas then depends quite heavily on the intuition and experience of the physician. Even though the physician has many diagnostic tools at his disposal, at the present time the only positive detection method is the healing process itself. Only after the start of the healing process does it become possible to determine what tissue has suffered irreversible damage. Should the physician decide to remove tissue before a precise diagnosis is available, the patient may suffer from having insufficient or excessive tissue removal. In the case of incomplete removal of dead tissue, the remaining dead tissue becomes a source of sepsis--infection--and may ultimately require additional surgery, pain and expense. In the event excessive tissue is removed, the patient would suffer by losing viable tissue which could have assisted in the vital healing process. Removal of living tissue would also increase the risk of sepsis by enlarging the wound area. Moreover, it would reduce the supply of viable tissue which may be required for grafting. Delay or inaccuracy in the diagnosis of the irreversibly damaged tissue increases the danger of sepsis, which is the most common cause of death for the burned patient.

Physicians at the Los Angeles County - University of Southern California Medical Center burn ward are working with volunteer patients to evaluate the technique developed by researchers at NASA's Jet Propulsion Laboratory (JPL) for determining whether an area of burn tissue has suffered irreversible damage. Several days after admission, a series of photographs in the visible and the infrared portion of the spectrum are taken of the burn wounds of selected patients. Then the photographs undergo computerized image processing at the Jet Propulsion Laboratory. The image processing programs being used are derived from the multispectral analysis developed for the Earth Resources Technology Satellite program.

The diagnoses of the very deepest burns appear to be accelerated by using infrared photographs with

enhanced images. During the current year, the researchers have been working on the development of a method to extend the diagnostic process to all burned and normal areas. Due to the extremely complex nature of the problem, only a few observations can be offered.

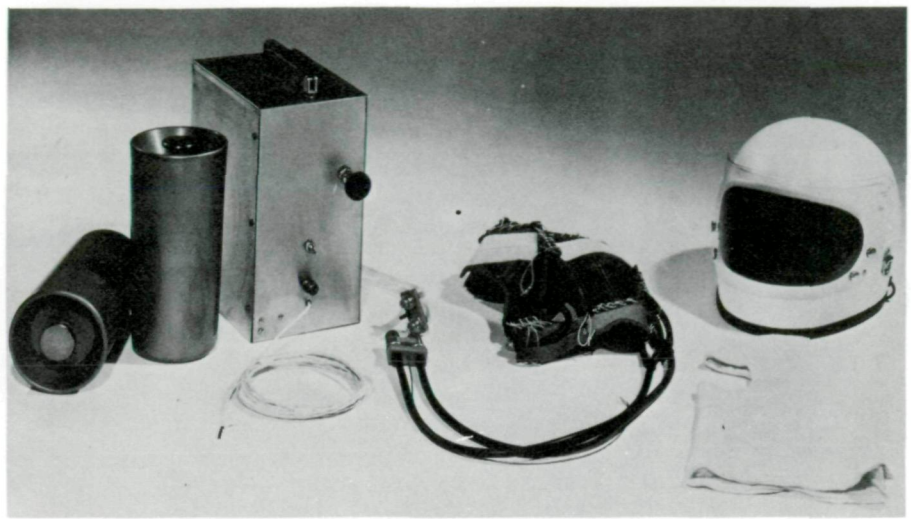
The accompanying photographs show an example of what may eventually become a clinically useful diagnostic process. While they represent the present state of development, they are not meant to present the final conclusive form for a new diagnostic procedure.

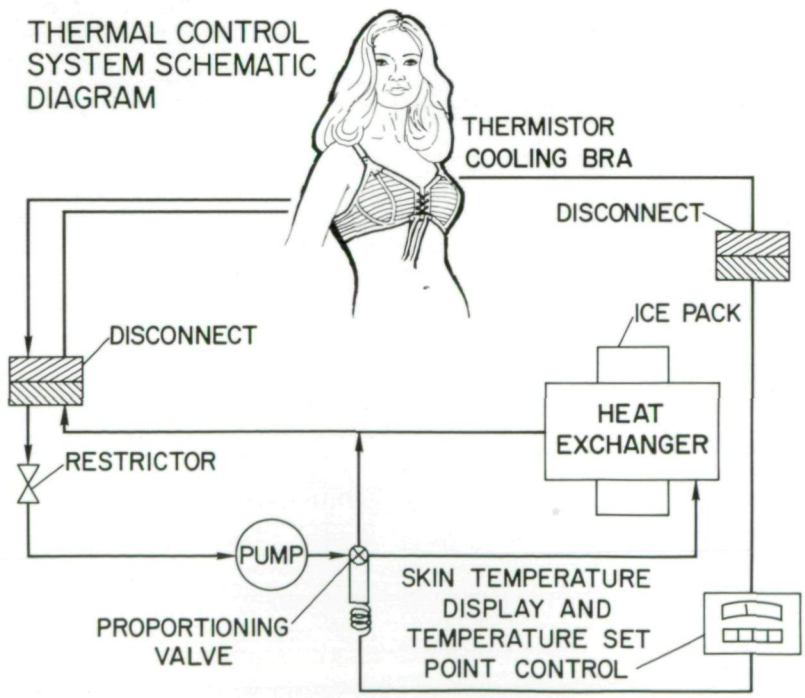
Further work is underway to compare burn histology--tissue structure--with the data from analysis of the infrared and multispectral photographic images. A primary objective of this phase of the experiment is to determine what makes it possible to use infrared photography for the diagnosis of deep burns in man.

Applications of Body Temperature Control Systems

Personnel working in elevated temperature environments perspire heavily, lose body weight, become fatigued more rapidly and are less efficient than workers in a normal environment. These adverse conditions were experienced by military helicopter crews until the introduction of a body cooling technique developed by NASA's Ames Research Center. The materials developed for this task are now manufactured commercially by the ACUREX Corporation.

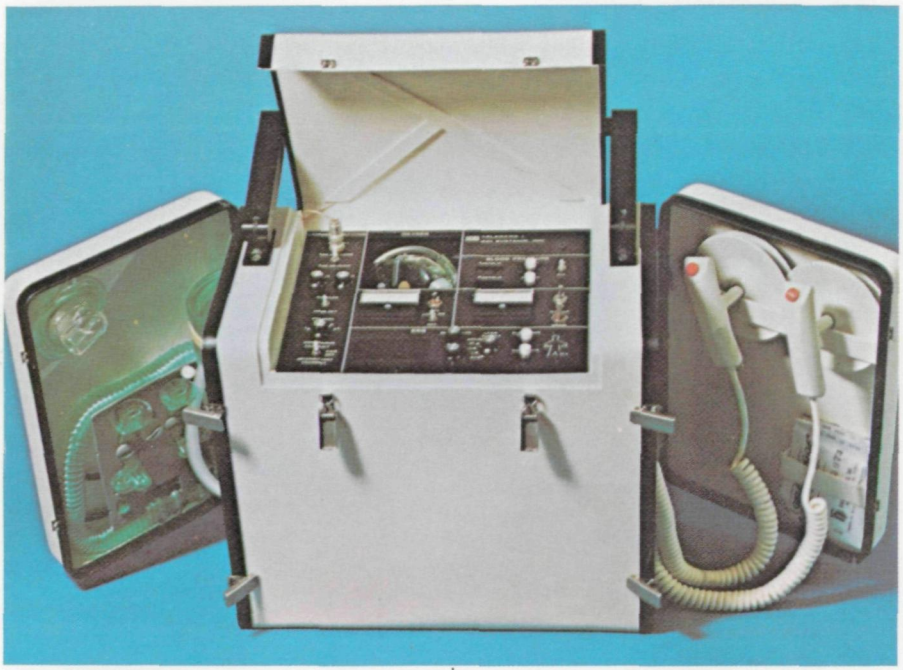
Flexible thermal liners, made from a very thin poly-urethane material, were fabricated to the contour of the





Top: Richard Petty's auto race helmet contains a built-in temperature control system. Lowered head temperature reduced his fatigue, loss of body weight and permitted him to be more mentally and physically alert during the long grueling races.

Above: Schematic of proposed tissue cooling system to enhance infrared photographs used for breast cancer detection.



TELECARE, a portable self-contained cardiac and respiratory treatment device. This equipment is currently being used by ambulance and rescue personnel in the diagnosis and treatment of victims.

head and fitted within a standard U.S. Army helicopter aircrewman helmet. Chilled water was pumped through manifolds of cooling channels within each liner segment, which was arranged to provide maximal surface coverage on the head-neck area.

The system shown above left is a civilian application manufactured for and worn by Richard Petty, winner of the Daytona 500 in 1973 and 1974. By controlling the helmet temperature normal race weight loss is reduced by two-thirds, body temperature by one-half, and visible perspiration is virtually eliminated. These factors reduce fatigue and improve driving comfort.

Another application of this technology holds great promise for the early detection of breast cancer. It has been confirmed through other clinical evaluations that infrared photography can detect shallow tumors prior to the advent of a discernible lump. As tumors receive a much greater flow of warm blood than the surrounding normal tissue, cooling of the suspected area prior to recording an infrared photograph permits the reflux of warm blood in heavily perfused tumorous areas to be highlighted in the photograph. A sequence of such photographs would reveal all areas of abnormally high concentration of blood flow and permit a more detailed examination of the indicated areas.

This work will be carried out by NASA's Ames Research Center and the University of Oklahoma Medical Center.

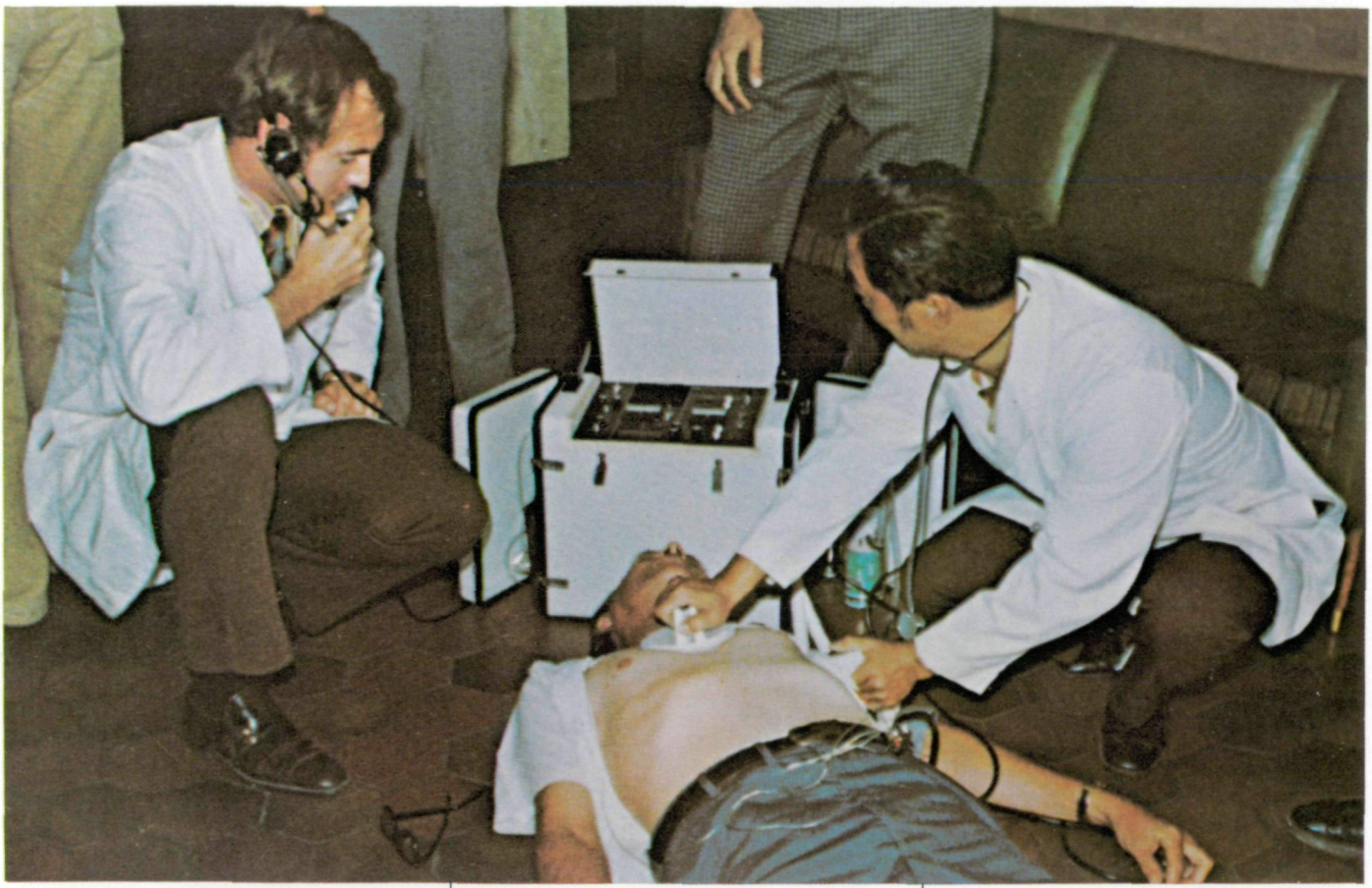
Emergency Ambulance Cardiac Care System

The remote biomedical monitoring and treatment technology developed by NASA for the manned space flight program is used widely in emergency medical systems. The city of Houston, Texas provides a case in point. Several factors are cited by the city as reasons for the reduced traffic fatality rate despite a 12 percent increase in the total number of major accidents in 1973 over 1972. The cited improvements responsible for this saving of lives include better trained ambulance personnel, more ambulances strategically located throughout the city, and the introduction of a new life-saving device called TELECARE.

TELECARE is a completely self-contained, portable cardiac diagnostic, therapeutic and communications system developed in conjunction with the NASA Johnson Space Center. Used aboard ambulances and rescue vehicles, the suitcase-size TELECARE unit weighing approximately 40 pounds is easily carried to a patient's side by an emergency medical technician.

Communications facilities are vital elements of TELECARE, and enable the physician in the hospital to evaluate the patient's electrocardiogram in real time and to talk with the rescue personnel. The simultaneous ECG and voice transmissions may be sent over an ordinary telephone. If no phone is available, a radio link can be established between the TELECARE unit and the hospital, with the rescue vehicle serving as a relay station.

Each unit contains a solid-state oxygen supply canister, capable of deliv-



ering six liters of oxygen a minute, for at least 15 minutes; and a defibrillator--to regulate erratic heartbeat--adjustable up to 400 watts per second and powered by its own separate rechargeable battery. A phosphor screen oscilloscope, used to monitor the patient's electrocardiogram (ECG), has a 1.25 by 2.75 inch screen of the long-persistence P-7 type. The standard equipment of TELECARE includes a fluid aspirator to aid breathing, a laryngoscope to examine the patient's throat, and a well-stocked drug kit. In addition, TELECARE may be equipped with a semi-automatic blood pressure measuring device, an electroencephalogram to measure brain waves, and a tape recorder to make permanent medical records.

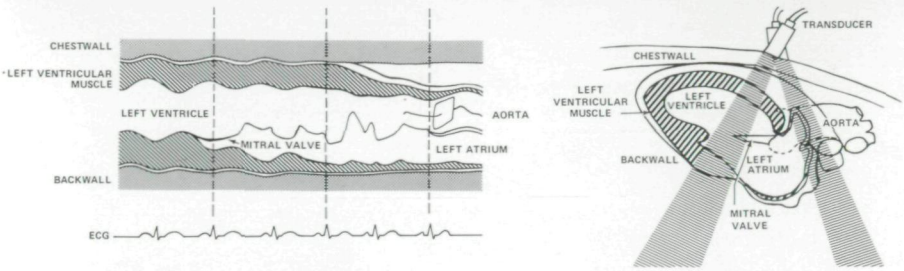
Acting upon telephonic instructions from the physician, trained personnel are administering emergency treatment to a heart attack victim.

Portable Ultrasonic Echocardioscope

A prototype ultrasound device designed by NASA Ames Research Center to study the heart and cardiovascular system is being evaluated by the Stanford University Medical Center. This device is electrically safe, portable, and easy to operate.

Examination of patients to determine cardiac size and abnormal patterns of cardiac valve motion previously has required bulky and sometimes electrically hazardous equipment. In an effort to permit wider use and acceptance of ultrasonic echocardioscopes, this new device, using state-of-the-art technology has been developed.

A three-part program under way at the medical center uses the NASA-developed instrument to validate the simplicity, portability, and diagnostic accuracy in the performance of non-invasive diagnostic studies. Two of the three projects in progress involve a series of pediatric and adolescent patients with a variety of cardiac abnormalities. As the patients are in the newborn nursery and



Ultrasonic transmissions permit the physician to note the condition of the heart from any angle in real time with an instantaneous display. Note the display schematic is offset by 90° from that of the ultrasonoscope.

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 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 on a patient, this battery-operated ultrasonic device is ideal. The physician can obtain ultrasonic information on the patients with very small hearts, while life support systems continue their function. The first completed project confirmed that Polaroid photographs of the oscilloscope screen and strip chart recordings of the same event are virtually identical.

The second project involves the use of the instrument on an emergency basis in the evaluation of acutely ill patients with congestive heart failure due to probable congenital heart defects. In this test, the accuracy of the ultrasonoscope is assessed in relation to the known congenital defect and studies of the same patients with commercially available equipment. This test compares the accuracy of both ultrasonic devices with respect to the patterns thought to accompany the anatomic defects. This program will be continued until the results of sufficient patient examinations prove the feasibility of relying on ultrasonic information rather than the more extensive invasive procedures such as cardiac catherization and angiography.

The third project that will be performed at the Stanford Medical School Experimental Cardiology Laboratory will use the instrument in conjunction with lower-body negative pressure (LBNF) on patients with cardiac disease.

Results to date of the total program are very encouraging, and preliminary discussions have been held with two major medical instrumentation manufacturers concerning their potential marketing of the instrument. Both companies have expressed interest and are doing marketing studies prior to making a firm commitment.

Biological Isolation Garment

A garment derived from the design used to biologically isolate Apollo astronauts quarantined on their return to Earth from the lunar mission, is providing a portable, sterile environment for cancer patients undergoing chemotherapy.

The Apollo biological-isolation garment was adapted for cancer patients as an extension of the pioneering use, by the National Cancer Institute, of cleanroom techniques to provide a sterile environment for patients. This isolation is necessary because the various drugs used in the treatment of diseases, such as leukemia, severely reduce the number of white blood cells and the patients' protection against and resistance to infectious diseases. Another benefit, as yet unexplained, is that patients

living in the sterile environment can tolerate much higher doses of drugs than they normally could.

For several years, the National Cancer Institute has treated adults in sterile laminar-flow rooms with great success. In these rooms, the highly filtered internal air is maintained at a pressure greater than that outside the room to reduce the possibility of infection from a variety of airborne particles (aerosols). Recently, the Institute started using the laminar-flow rooms for children. Because confinement to one room is psychologically less tolerable for younger patients, a method was sought to enable children to leave the laminar-flow rooms for periods up to several hours while remaining within the protection of a sterile environment. This would enable the patient to move freely about the hospital, for recreation, additional tests, or radiation therapy.

As a result of an inquiry from the National Cancer Institute, the NASA Johnson Space Center loaned a copy of the biological isolation garment to the NCI for evaluation. The garment was designed to be worn from the time of exit from the Command Module until arrival in the portable quarantine facility aboard the recovery ship to preclude contamination of the Earth's environment in the event the astronauts were carrying unknown microorganisms from the Moon.

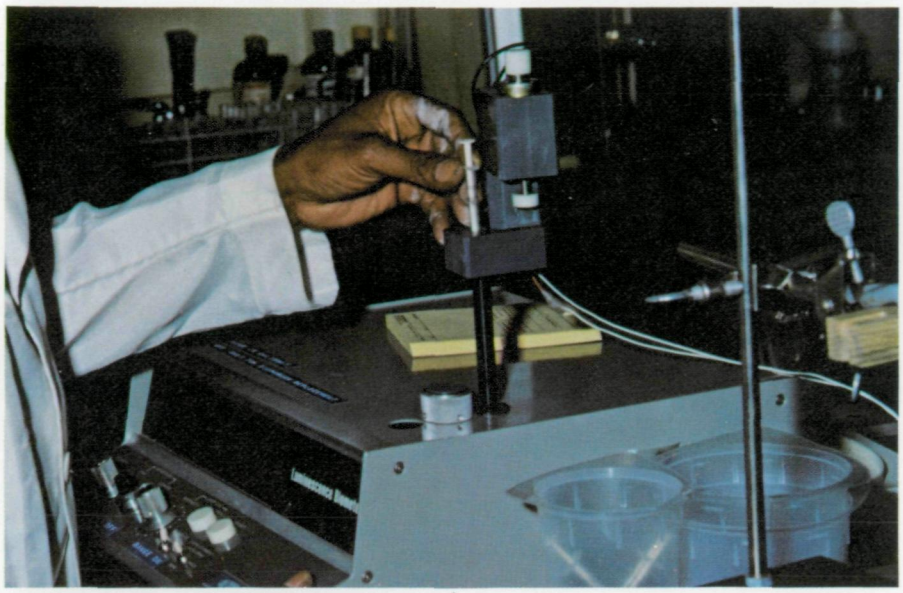
National Cancer Institute researchers, redesigning the garment to better fit their needs, added a positive-pressure, portable air supply, not only to reduce heat and weight, but also to assist in contamination control. Because many contaminants are found on the surface of the patient's own body, a directed air flow from the top of the head downward reduced the danger of self-contamination. It also permitted a reduction in the sealing requirements by allowing the use of a simple Velcro fastener rather than the more complex and heavier pressure-sealing zipper.

A small leukemia patient whose immunity to disease has been greatly reduced by chemotherapy is being assisted into a Biological Isolation Garment for his protection, mobility and comfort outside the sterile treatment room.

After fabrication of the child-sized garment and necessary modification by an NCI contractor, the suit was tested for biological effectiveness and approved for use on a child. The garment, which proved an overwhelming success, allowed the patient to wear it frequently. The patient can leave the room for recreation with other members of his family as well as to travel about the hospital for tests and therapy.

A recent article by D. G. Poplack, W. Z. Penland and A. S. Levine (*Lancet*, p. 1261, June 22, 1974) discussed this new technology for the protection of patients susceptible to infection.

Future use of the biological isolation garment is expected where laminar-flow cleanrooms are specified for chemotherapy patients or for others with immunological deficiencies. The National Cancer Institute is already using such rooms extensively, and other hospitals are now building similar cleanrooms to further investigate their utility.



Above:
Urine sample in photometer being injected with luciferase, an enzyme derived from fireflies.

At left:
Concentrated urine specimen ready for processing in the Rapid Bacterial Detection System.

Laboratory technician preparing a culture for bacteria growth. Results from such procedures are not normally available for 48 to 72 hours.

Rapid Bacteria Detection System

A technique under development at NASA's Goddard Space Flight Center for the rapid detection of bacteria in fluids may soon benefit hospitals, clinics, and physicians, as well as a host of food, beverage, and other industries requiring sterile manufacturing conditions. The technique stems from research originally performed in support of NASA's life-detection missions to other planets. During this earlier effort, bacteria common to Earth were used to evaluate the sensitivity of the systems under development. Because of the sensitivity and rapidity with which bacteria could be detected, it became evident that the technique has significant implications for the detection of bacteria in the clinical laboratory.

The system offers a quick indication of the presence and quantity of bacteria by registering the amount of light emitted by the reaction between adenosine triphosphate (ATP - found in all living matter) and luciferase, an enzyme derived from fireflies. The more conventional method for determining the presence of infection and the amount of bacteria present, using a culture, requires 48 to 72 hours. This new technique reveals the required information within 15 to 60 minutes.

Beyond bacteria detection, recent studies indicate that the ATP assay technique permits the examining laboratory to determine within three to five hours which antibiotics are most effective. This knowledge would help to rapidly prescribe the most effective antibiotics--reducing the need to try a broad variety of drugs on the patient. Rapid correct treatment can produce more rapid recovery, reducing hospitalization and resultant costs, as well as freeing hospital facilities for other patients. The system could also be advantageous to clinics for mass screening programs.

Evaluation of the technique, under way at Goddard Space Flight Center, is also currently being performed by the New England Medical Center in Boston, Hahnemann Medical Center in Philadelphia, and Delaware State College to determine the most effective procedure for widespread clinical use of the technology.

Instrumentation

Figure 1:
The lethal effects of intravenous injection of detergent-solubilized DEHP, a plasticizer used in vinyl plastic products, on the lungs of rats. Center lung is of rat injected with detergent vehicle alone.

Toxicological Effects of PVC Plasticizers

Stemming from the discovery that the special optics of unmanned space vehicles became fogged with a substance later identified as a plasticizer, additional research was authorized by NASA's Goddard Space Flight Center (GSFC) to determine other effects on the spacecraft and its equipment. Research at GSFC and at the Department of Environmental Medicine of the Johns Hopkins School of Hygiene and Public Health produced some interesting and disturbing information concerning the physical characteristics and effects of one specific plasticizer.

To impart pliability to vinyl plastic, a plasticizer, di-2 (ethylhexyl) phthalate (DEHP), used in the formulation of the finished product accounts for 30 to 40 percent of its total weight. DEHP insoluble in water can be solubilized by preparation in a solution of nonionic-detergent,TWEEN-80. When intravenously administered to rats, it causes death due to the development of pulmonary exema and hemorrhage. An LD_{50} was determined to be approximately 250 to 300mg/kg.

In Figure 1 are shown the lungs of rats given detergent-solubilized DEHP. On the left of the figure is the lung of a rat which was given an intravenous dose of 250mg of DEHP/kg and sacrificed after 60 minutes. On the right is the lung of a rat that died 15 minutes after a 300mg/kg injection. In the center is the lung of a rat given the detergent vehicle alone. This center lung does not grossly differ from that of a non-injected control animal. The lungs of the two treated animals are clearly enlarged, engorged with blood and hemorrhagic. Recent experiments have shown significant engorgement of the lung with blood at doses of DEHP down to 50mg/kg, which doses begin to approach that inadvertently given to man. In Figure 2 are shown light microscopic pictures (750x) of the vehicle-injected lung on the left and the DEHP-treated lung (250mg/kg) on the right.

The thickening of the interalveolar septa and engorgement of the septa with blood cellular elements can be readily seen.

Though still under investigation, it is interesting to note that the method and form of the DEHP relates to the effect of DEHP on various parts of the body. Orally administered DEHP appears to be metabolized in the gastrointestinal tract. The metabolites are then either excreted directly with the feces or into the urine following intestinal absorption. Because of its documented low level of toxicity in oral feeding experiments, the Food and Drug Administration has sanctioned the use of DEHP in vinyl film for use as food packaging. This low level of toxicity is considered to be attributable to the almost total metabolism of the DEHP in the

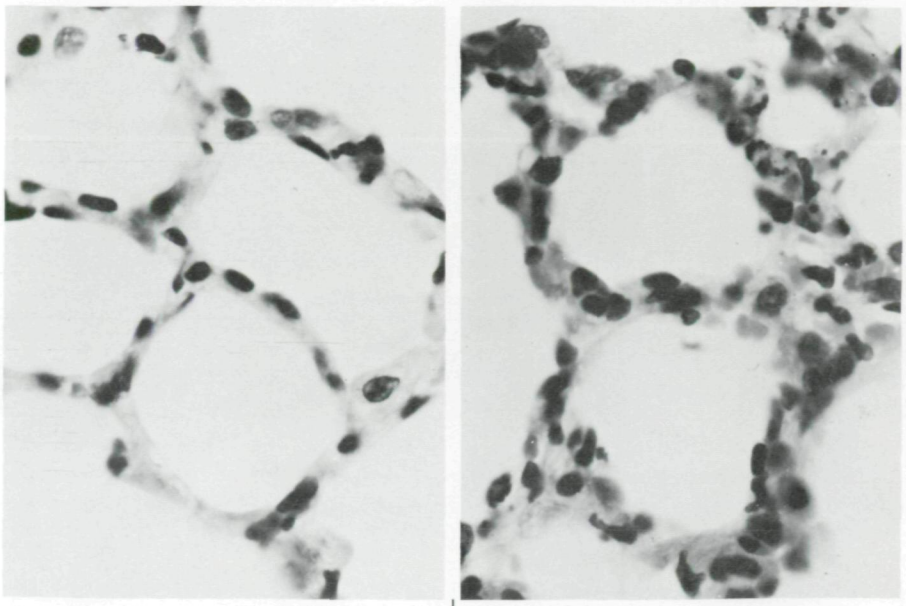


Figure 2:
Light microscopic pictures of interalveolar septa of a vehicle-injected lung on the left and a solubilized DEHP-treated lung on the right.

gastro-intestinal tract. However, the FDA, having clearly recognized the potential for migration of the plasticizer into fatty foods, has limited its use to packaging of foods with high water content.

It appears that the blood banking industry has adopted the use of phthalate plasticized vinyl bags based on the FDA's approval of such material for food packaging.

However, a distressing phenomena has been observed with the use of vinyl plastic bags to store human blood. A migration of the DEHP into the whole blood is 0.25/100ml blood/24 hours of storage. This is of even greater concern when one realizes that at present about 100 percent of the blood in America is stored in plasticized vinyl bags as is a variety of other blood-derived products. Concern heightens even more when it has been determined that migration of DEHP into stored platelets ranges as high as 38mg/100ml plasma/24 hours--about 100 times greater than with whole blood. Current investigation tends to indicate that once the plasticizer interacts with blood cellular elements, a physical change occurs within the blood cells to trigger a sequence of reactions resulting in pathological damage to the lung tissue.

It should be recognized and understood that not all plastics contain plasticizers, nor do all plasticized plastics contain DEHP. However, most plasticized vinyl plastics contain phthalates. To give one perspective, the annual U.S. production of phthalate esters is about one billion pounds. The industrial handling of such vast amounts of phthalates and the ubiquitousness of plasticized vinyl products give rise to almost unlimited potential for environmental exposure of the American public.

Topography of Aortic Heart Valve

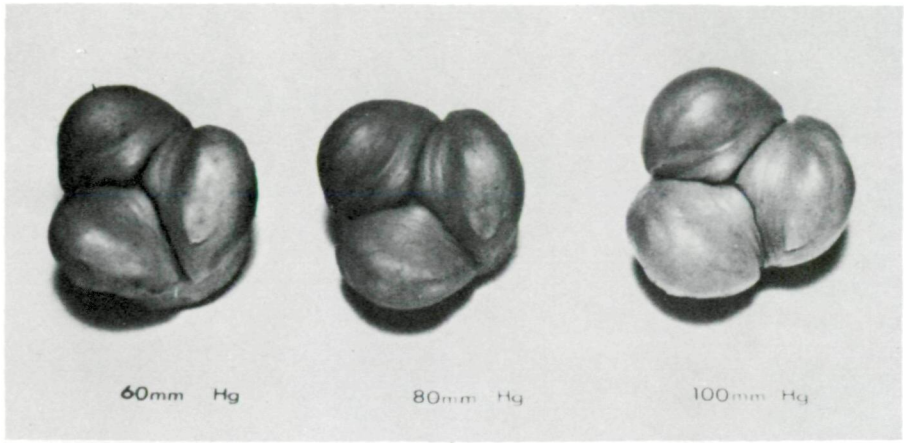
Stereophotogrammetry - a precision stereophotographic "mapping" technique similar to that used to map the surface of the moon - is being used to gather data needed for the development, design and fabrication of a new artificial tri-leaflet aortic heart valve. The new prosthetic valve will be a central flow device, similar to the actual human valve, rather than the present central occluding-device which have less than satisfactory hydrodynamics with resultant blood degradation and thromboembolic phenomena. Tens of thousands of persons who have had their aortic heart valves replaced with the central occluding valves are required to continue the use of anti-coagulants, which can have undesirable side effects.

The aortic valve is a one-way check valve between the left ventricle (chamber) of the heart and the aortic artery which carries blood to the entire body. The valve is composed of three, approximately crescent-shaped, flexible leaflets which open and close as the heart pumps. When the natural valve is damaged by disease, such as rheumatic fever or injury, it does not close properly, thus reducing the heart's efficiency. To correct this situation, the damaged valve is replaced by a synthetic valve.

The design of an artificial tri-leaflet valve is a demanding task requiring a design capable of withstanding many years of flexing with each heartbeat millions of times a year as well as minimizing the turbulence of blood flow through the valve. The collaborative design and development effort has involved NASA, the

University of Illinois at Urbana, and the Division of Cardiothoracic Surgery at Washington University in St. Louis, Missouri. A complete multiphasic study was performed which involved (1) the careful definition of the normal anatomy of leaflets in-

Surface deformations of certified tri-leaflet aortic valves are evaluated at different internal pressure levels to better comprehend the many complex aspects of heart valve design and fabrication.



cluding surface characteristics, thickness variations, and composite nature of the internal structure; (2) uniaxial stress-strain data on leaflet tissue describing the anisotropic and nonlinear behavior in the very low stress region; (3) a numerical-graphic analysis of the opening characteristics of the aortic valve detailing the magnitude and relations of bending, shear and loading stresses; (4) a detailed analysis of the distribution of in-plane stresses was made through the use of close-range stereophotogrammetry which defined the asymmetric shell surfaces in global coordinates; (5) a computer based finite element method of analysis was used to obtain principal stress resultants over a physiologic pressure range; (6) ultra-pure polyester resin was made and extruded into fiber and woven into a multilayered fabric to yield variation in thickness, mechanical behavior and surface characteristics superior to previous devices.

Based on the stereophotogrammetric outputs provided by three series of studies (a total of 18 molds), stress analysis was conducted by the structural group using a thin shell finite element model. The design and manufacture of the prosthetic valve is based on the results of the stress analysis and the corresponding strength provisions, on the geometry and dimensions provided photogrammetrically, as well as information provided by other studies in the project. Extensive laboratory tests have been successfully performed on the new valve design, and it is expected that a usable valve will be ready for testing in primates early in 1975.

Ultrasonic Transmission Imaging

The increasing potential of ultrasound in medicine is gaining widespread recognition in the medical community. This application involves sending high frequency sound waves into the body, and the subsequent analysis of the transmitted sound patterns provides an indication of the condition of various tissues. Ultrasonic imaging provides a non-destructive testing technique which, unlike x-ray, poses no known radiation threat.

Current predictions are that within ten years, the medical applications of ultrasound will equal or surpass those of x-rays. This explosive growth has also prompted the recognition that the knowledge of tissue characteristics as measured by ultrasound may not be able to keep pace with the demand as new uses are found for this method.

In recognition of the vast potential and the need to coordinate developmental efforts, the National Science Foundation (NSF) sponsored a series of studies conducted by the Alliance for Engineering in Medicine and Biology. Task groups assessed and established priorities for research on four aspects of ultrasound imaging: the interaction of ultrasonic energy with biological structures, ultrasonic transducers, displays and scans, and signal processing.

NASA's Jet Propulsion Laboratory (JPL) has been actively working in these areas for several years. This interest, combined with the space agency's expertise in signal processing and related technical areas, is rapidly extending the state-of-the-art in medical ultrasonic technology.

The JPL goal in medical ultrasound has been to translate some of the advanced signal processing concepts into techniques which can produce clinical results acceptable to the medical profession. In providing this needed technological base, JPL has developed newer methods of ultrasonic imaging for medical diagnosis

Intensive investigation into the characteristics of body tissues and organs is being conducted at the Jet Propulsion Laboratory using ultrasonics. Widespread use of such characteristics or signatures are anticipated by the medical profession in diagnosis and treatment.

and conducted investigations of the characteristic signatures for healthy and diseased tissues. NSF has also given high priority to the development of such information.

Within the past year, several tissue signature indicators have been uncovered for use in tissue diagnosis. These include: verification of the earlier discovery that one type of brain tumor may be distinguished from healthy brain tissue because the tumor absorbs ultrasound at a much higher rate; the possibility that some tumors transmit frequencies differently than healthy tissue does; and the fact that cysts in the kidney have a transmission characteristic so strongly different from homogenous tissue that the cysts will show up in the whole kidney images.

JPL has determined these specific ultrasound signatures in addition to the cataloging of human tissue properties routinely obtained on clinically interesting specimens furnished by the University of Southern California School of Medicine.

The results of the tissue evaluation will be submitted by cooperating JPL and medical researchers to medical journals for publication.

Ultrasonic Microemboli Detector

A new ultrasonic instrument for use in monitoring gaseous and solid impurities--known as microemboli--in a patient's blood during open-heart surgery has been developed by a team of five researchers at Washington University, St. Louis, Missouri and the NASA Langley Research Center. The device, a continuous wave ultrasonic microemboli monitor, was cited as one of the 100 most significant, new, technical products of 1974 in the annual "I-R 100" competition sponsored by *Industrial Research* magazine.

Among the significant new features of this monitor are its compact size, ease of operation, and relatively low cost. These features were achieved by combining the signal enhancement of an ultrasonic resonator with the high sensitivity of a marginal

Microemboli Monitor, an instrument used in the detection of gaseous and solid impurities in patients' blood during open heart surgery, is being investigated for other applications.

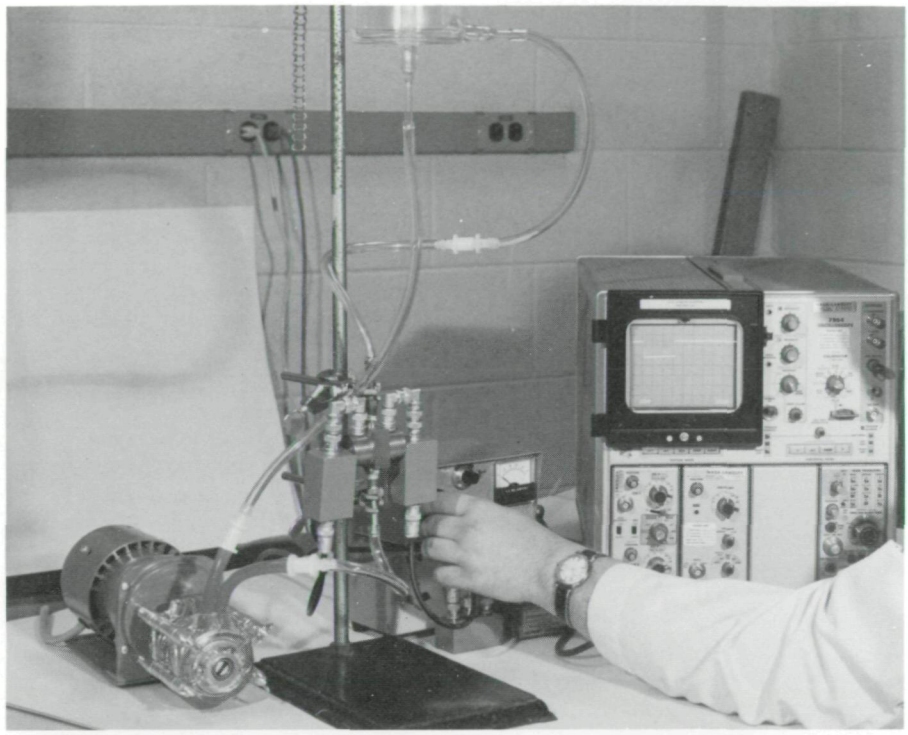
oscillator system, techniques which have been under development in the laboratory for ultrasonics for a number of years. The monitor is a simple and reliable method of detecting gaseous and solid impurities in blood which is circulated and oxygenated by the heart-lung bypass machine during open-heart surgery.

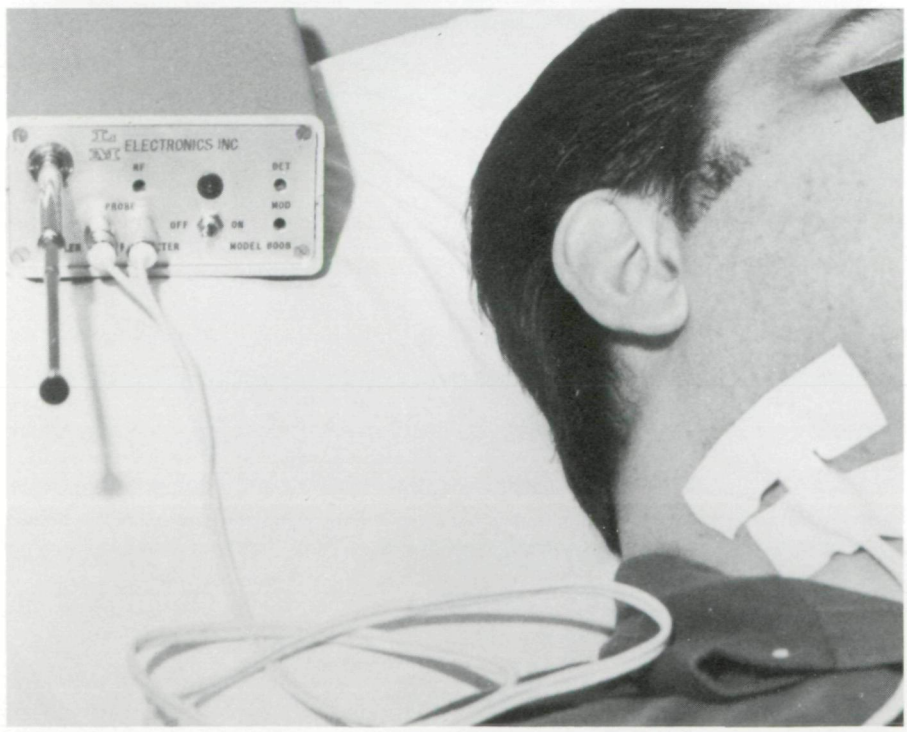
Although further testing and development are necessary before its full potential can be realized, the monitor already has been used to investigate the efficacy of blood filtration devices and the influence of the commonly used anticoagulant heparin. Other potential medical uses for the device are in hemodialysis (artificial kidneys) units, blood banks, and during blood transfusions. In addition, NASA Langley Research Center is investigating a wide range of possible non-medical applications involving contaminants in fluid-flow systems. Such systems could provide in-line monitoring of particulate matter in lubricating and hydraulic systems.

Ultrasonic Measurements of Cerebral Blood Flow

A NASA instrument for measuring blood flow on pilots undergoing centrifuge testing has been used to monitor the condition of patients with head injuries in hospital intensive care units.

It is extremely important that stroke victims and patients with head injuries receive an adequate flow of oxygen-carrying blood to the brain.





Inadequate cerebral blood flow can cause irreparable damage to the patient, depending on the portion of the brain deprived of the flow.

At present, no cerebral blood flow monitoring systems are available to assure that the flow is maintained. With a system to monitor cerebral blood flow, it would be possible to (1) observe the effect of cerebral blood flow on the natural progression of the disease, (2) monitor the stroke patient from the time he enters the intensive care unit until he leaves, thus permitting a continuous evaluation of his progress, and also to (3) observe the response of cerebral blood flow to different forms of therapy. This monitoring system could enable the physician to select the optimum therapy for each patient. The availability of such information would decrease the death rate among patients with widespread brain injury, as well as permit research into the pathophysiology of the progression of such injuries.

Direct invasive measurement of the cerebral blood flow is a risky procedure. Therefore, for ordinary clinical use, a non-invasive technique is required so the cerebral blood flow can be measured from the outside. For example, if the rate of blood flow could be measured in the internal carotid artery that transports the blood from the heart to the brain, and if it were possible to determine the diameter of the carotid artery without entering the body, these data could be used to calculate the rate of the cerebral blood flow.

Through the efforts of the Research Triangle Institute's Biomedical Applications Team and NASA's Ames Research Center, one of the Ames ultrasonic blood flowmeters and an appropriately shaped transducer were loaned for evaluation in the Stroke Intensive Care Unit at the Bowman Gray School of Medicine in North Carolina.

Preliminary clinical experiments indicate the device is capable of detecting the carotid artery pulse and measuring the blood flow through that artery to the brain. The early results suggest that this technology can be used to clinically monitor cerebral blood flow. The Stroke Intensive Care Unit at the Bowman Gray School of Medicine will continue using the ultrasonic Doppler system on patients to determine conclusively the suitability of the technique for long-term monitoring.

At left:
Using Doppler ultrasound cerebral blood flow can now be monitored non-invasively.

Automated Analysis of Coronary Angiograms

Doctors can more accurately study the functioning of the human heart as a result of computer programs originally developed at the Jet Propulsion Laboratory (JPL) to extract information from photographs of Mars. The space science technique was adapted for medical use by researchers at Duke University Medical Center seeking an automated method to analyze x-ray images of the heart in action, coronary angiograms, to determine the condition of the heart muscle.

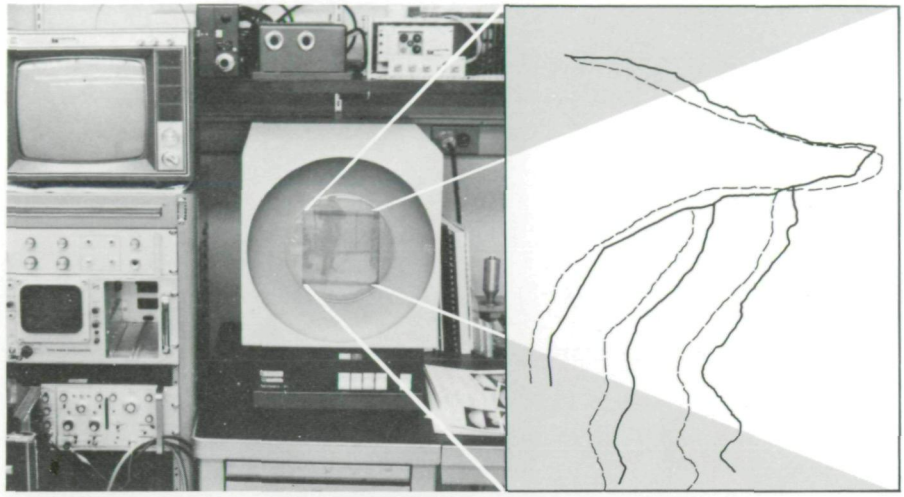
The technique adapted from space science is particularly useful in quantitating local changes in the ability of the heart muscles to contract and in determining both the advisability and effectiveness of surgery to improve the blood supply to regions of the heart muscle. By applying the technique both before and after surgery, the physician can see the changes in the condition of the patient's heart. X-ray images of the heart are taken following injection of a radio-opaque dye into the coronary artery. The dye shows up in the x-rays, making the coronary artery and its branching points - bifurcations - visible for use as reference points. By simultaneously recording a series of images--angiograms--from two different angles, it is possible to obtain the equivalent of a three-dimensional view. It also permits the precise measurement of changes in the distance between various bifurcation points in a region of the cardiac muscle. Subsequently, a series of angiograms taken throughout the cardiac cycle shows the effects from variations in the muscular contractability. The new technique permits these changes to be accurately measured.

Ordinarily, the acquisition and interpretation of coronary angiograms is a difficult and lengthy process. Two x-ray views are recorded simultaneously on 35-millimeter motion picture film, at a rate of sixty frames per second. This results in a large number of images to be marked, measured, and analyzed--another time-consuming process.

The Duke University researchers learned of the existence of the JPL computer programs and decided the techniques used to extract information from the Mars pictures could be adapted to the automated analysis of coronary angiograms. One member of the Duke team applied for and received a summer fellowship at JPL. During the summer of 1970 at the Jet Propulsion Laboratory, he learned the image processing procedures, worked out his own algorithm, and determined that the JPL approach could, indeed, solve the problem. Following his studies at

Image Scanning and Processing Equipment for automated analysis of Coronary Angiograms.

At right: Coronary angiograms of the placement, size, and movement of the coronary artery and bifurcations reveal the condition of the circulatory vessels within the heart wall.



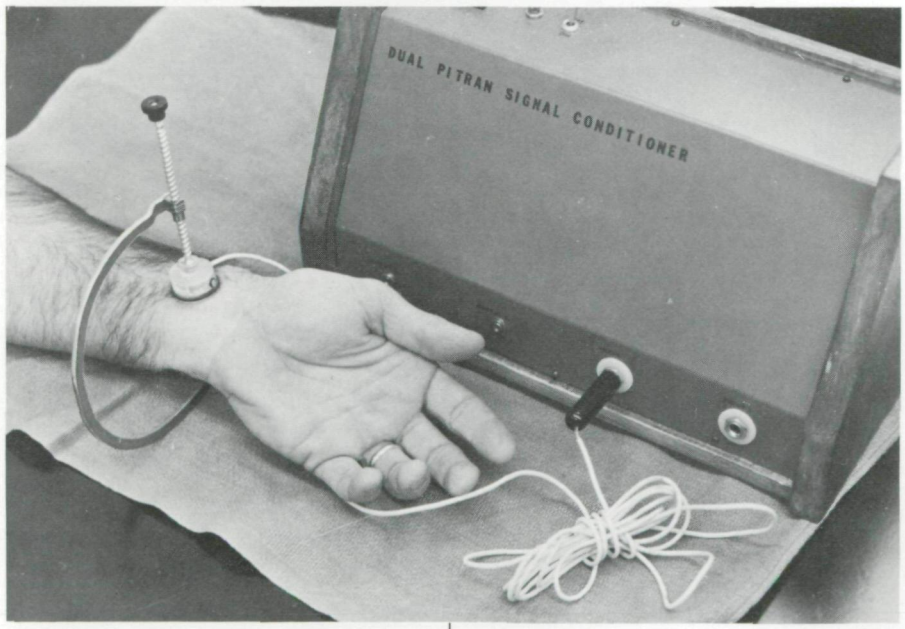
JPL, the Duke researcher designed a modified image-scanning and processing system, tailored to analyze cardiac angiograms and making possible the automated reading of the 35 millimeter x-ray filmstrips, providing information on the positions of specified arterial bifurcations.

The specific bifurcation points to be analyzed can be marked manually, with a light pen or a similar technique, on the first film frame. The film reading system automatically focuses on the location of the identified points in the subsequent frames.

Development of this technique for the automated measurement from coronary angiograms has progressed to the point where several complete heart cycles can be followed and measured by the automated equipment. The technique is ready for use in clinical research.

Arterial Pulse Wave Transducer For Hypertension Research

Research into hypertension - high blood pressure - is benefiting from a pressure-sensitive transducer system developed at GSFC summer institute. The pressure sensor has been coupled with a fluid-filled chamber to non-invasively monitor arterial pulsations generated by contractions of the heart. The device is called an Arterial Pulse Wave Transducer (APWT).



The Arterial Pulse Wave Transducer (APWT) used to record cardiac and arterial responses to anti-hypertension drugs.

NASA's Goddard Space Flight Center and the Hypertension Research Group at the Washington, D.C., Veterans Administration Hospital cooperated in the development of the APWT. The hospital is conducting a three-year evaluation of the device in recording the responses of the heart and arteries to drugs given to lower the blood pressure.

Placed externally over the artery to be examined, the transducer requires only a few minutes to obtain the desired data. The output of the APWT can be recorded by either an electrocardiogram recorder or on magnetic tape for computer analysis.

Although other transducers are also available for this purpose, the Hypertension Research Group believes the cost, size, weight and signal stability of the APWT far exceed the capabilities of other available devices. Weighing about ten grams, having excellent signal stability, and a mechanically simple design, the APWT can be built for a comparatively low cost.

The transducer has also shown significant value in the study of arteriosclerosis, the hardening of the arteries which may lead to the occlusion or blocking of the blood vessels. Since arterial occlusive disease is one of the most significant health problems in the United States, early detection of the disease is extremely important. Unfortunately, it is very difficult to detect arterial occlusive disease during its early stages when only little damage has occurred. Often the disease becomes extensive before it is detected. Advanced arteriosclerosis has severe consequences, frequently leading to the death of the patient with little advance warning.

Arteriosclerosis is a narrowing of the arteries and a reduction in the elasticity of the arterial wall. This restriction increases the vessels' resistance to blood flow, making the heart work harder and eventually leading to a reduction in the flow of blood through the involved arteries. As changes in the elasticity, or sudden changes in the diameter, of the arteries would affect the arterial pressure pulse and its transit time between two points along the artery, medical researchers have sought a sensitive technique for measuring these changes.

Since the effects of arterial occlusive disease on the shape of the arterial pressure pulse wave were not well known, the Arterial Pulse Wave Transducer proved useful to the study of those changes. The shape of the pressure pulse wave was measured at two points along the artery, and the transit time between the two points was recorded. A change in the shape of the wave between the two points was an indication of possible changes in the elasticity and the diameter of the artery. By moving the APWT along the artery, local constrictions could be detected. Detection of a series of changes with increasing transit time over a number of segments of the artery could then be regarded as an indication of arterial occlusive disease.

Another interesting aspect discovered while researching this project is the presence of a secondary or "bounce" wave following each systole. The wave form of this secondary wave is believed to be another measurement of the arterial wall elasticity. Further evaluation will confirm the validity of this observation.

Moisture Resistant and Anti-Reflection Optical Coatings

Certain critical optical surfaces, such as halide crystal windows or plastic lenses used in scientific instruments, projectors, and cameras need protective coatings. Widely used halide materials, such as sodium chloride and cesium iodide, are extremely moisture sensitive. A number of approaches have been taken to protect such optics, but these approaches, often crude, have not always been reliable or particularly convenient.

Feasibility studies at NASA's Ames Research Center have already demonstrated that thin organic coatings of one micron or less, produced by plasma polymerization of fluorinated monomers in a low temperature gas discharge (plasma), exhibit a very high degree of moisture resistance. In the case of cesium iodide lenses, these coatings provided hundreds of hours of protection, whereas an untreated surface made of the same materials, would begin to degrade rapidly within a few minutes after exposure to moist air.

Another desirable property of these optical coatings is that their indices of refraction fall between that of halide and plastic substrates and air. Thus, the organic coatings not only offer moisture protection but improved transmittance as well. Further, the polymer coating is non-absorbing over the spectral range 0.4 to 50 microns with an exception at 8.0 microns, the expected absorption for C-F bonds in fluorocarbon coatings. The coatings, while completely transparent in the visible region of the spectrum, will improve the optical systems of scientific instruments as they behave as anti-reflection coatings in this region.

Experiments have shown that these coatings also are useful for coating plastic lenses used in movie or slide projectors and cameras. With the encouraging results already demonstrated, the plasma polymerization process is being developed to improve the mechanical strength, adhesion, abration resistance, and optical properties of the plasma coatings.

Rehabilitation

High Purity Carbon Implants

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 at the Rancho Los Amigos Hospital as developed by the NASA Marshall Space Flight Center.

Compared with other materials used for implantation, it is light in weight and hard enough to permit low-mass implants. This pure carbon has a low coefficient of thermal expansion, and a high resistance to body fluids because it does not corrode at body temperature. The non-metallic 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 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. Several design concepts for direct skeletal attachment systems for prosthetic devices have been evaluated. The current 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. The device shown in Figure 1, manufactured by the Kennedy Space Center, was implanted in a male amputee in March 1974 with very encouraging results to date.

Permanently implanted percutaneous connectors of pure carbon have been used successfully to relieve pain via direct electrical stimulation and to exercise muscles which have begun to contract involuntarily.

Nine patients have implanted buttons which successfully relieved chronic back pain. LTI and vitreous carbon are employed with two design variations and several connector systems. On most pain patients the amount of pain medication used has greatly decreased. Also, a format for recording the reduction of pain and the actual mechanical condition of the button has been developed to permit validation of research data.

The number of patients with transcutaneous carbon for muscle stimulation has increased. Implanted buttons are being used by other services in this hospital. Subjectively, it seems the carbon implants are better tolerated than any others available. These are being used on both upper and lower extremity contractures with intermittent stimulation.

Long range goals for carbon encompass many and varied problems. If standardization of carbon button implants for low back pain becomes a reality, theoretically this could benefit thousands of patients across the United States. Thus far, the results with pain relief from electrical stimulation have been impressive. Myoelectrodes and neuroelectrodes interfacing the skin with carbon devices have the potential both to straighten contracted muscles and ultimately to provide function where none had existed.

The skeletal fixation devices with carbon skin interface have the theoretical potential to provide artificial skeletal support for amputees. This has obvious advantages over current suspension and socket devices. An estimated one-third of the current amputee population might be fitted for these devices.

The functional, psychological and vocational aspects of the carbon projects become readily apparent. Pain control for low back patients may return them to gainful employment and an improved quality of life.

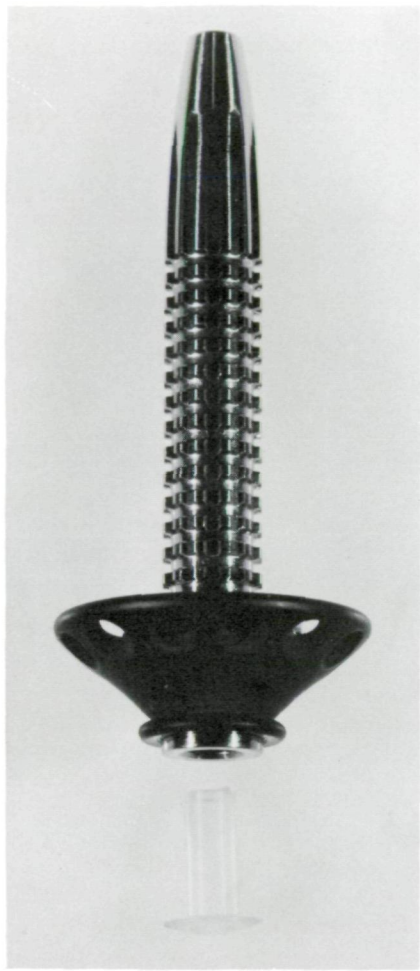


Figure 1:
Intramedullary skeletal fixation device is permanently implanted in the bone with the black carbon collar permitting chronic passage of the device through the skin. This device permits an artificial limb to be easily attached or detached by the patient.

Figure 2:
Patient wearing prosthesis developed at the Rancho Los Amigos Hospital in California.

Functional advantages of skeletal fixation devices versus standard prosthesis hopefully would be great. The carbon project encompasses solutions to many types of problems, all of which would hopefully improve function, return patients to gainful employment, improve appearance and certainly psychologically benefit patients.

Application of Teleoperator Technology to Aid the Handicapped

At present, nearly two million people in the United States are afflicted with varying degrees of paralysis with an annual incidence rate approaching one person in one hundred. Nearly two-thirds of these individuals have severe deficiencies in manipulative and/or mobility capabilities.

During the past several years, NASA has invested a significant effort in the development of teleoperator and robot technology for space-related programs, such as free-flying teleoperators for satellite servicing and retrieval in earth orbit. It appears that this technology can be applied to the benefit of the severely handicapped (e.g., quadriplegics) by giving them greater self-reliance and independence, and may offer some the possibility of leading productive lives.

A project jointly sponsored by the National Aeronautics and Space Administration and the Veterans Administration was initiated at JPL in July 1974. The primary objective of the project is to apply available teleoperator/robot technology to rehabilitate amputees and spinal cord injured patients with severe loss of motor, manipulative, and sensory capabilities in the upper and/or lower extremities. As a first step, during 1975, a powered, multipurpose manipulator will be developed and mounted on a standard wheelchair. The wheelchair mobility will be controlled through a conventional two-channel bidirectional chinswitch (not shown in the figure).

The manipulator is a six degree-of-freedom mechanism with the following motion capabilities:

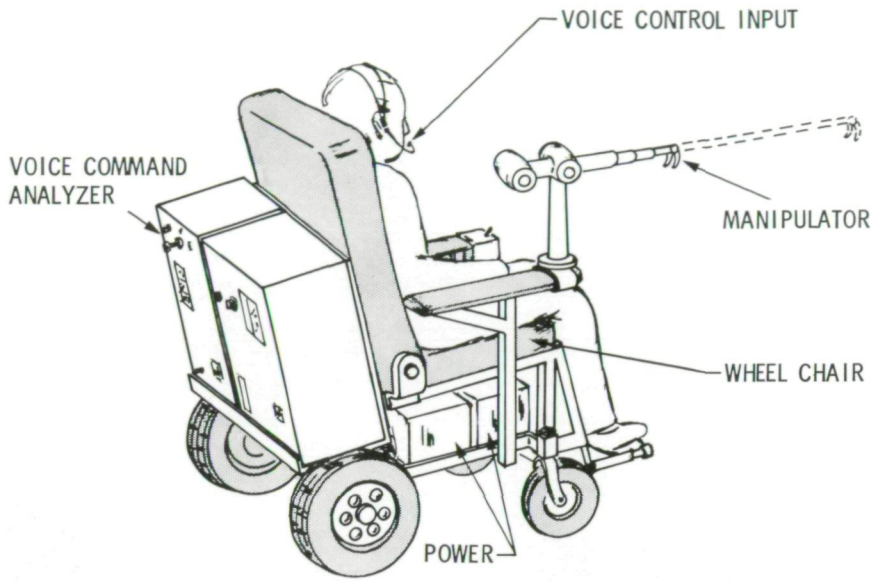
- Horizontal abduction and adduction
- Shoulder flexion and extension
- Telescopic extension
- Supination and pronation
- Wrist flexion and extension
- Grasping

These motions will be voice controlled, using an adaptive voice analysis and recognition system with approximately a 32-word vocabulary input. Appropriate coding will enable the manipulator to perform simple routine tasks. However, this will require a certain training period during which the voice recognition system adapts to the peculiarities of

the patient's voice and pronunciation, and the patient learns to speak the "language" the machine understands.

The available wheelchair is being redesigned to accommodate the manipulator and the voice command analyzer. A new manipulator based on an existing prototype is under construction, and the voice command analyzer has been ordered. The command language and the interface work is in progress.

The integrated system will be tested at Rancho Los Amigos Hospital prior to delivery to the Veterans Administration Prosthetics Center for clinical testing in the spring of 1975. Results of the clinical evaluations, with the help of severely handicapped patients and medical practitioners, will guide the JPL development of improved second-generation systems.



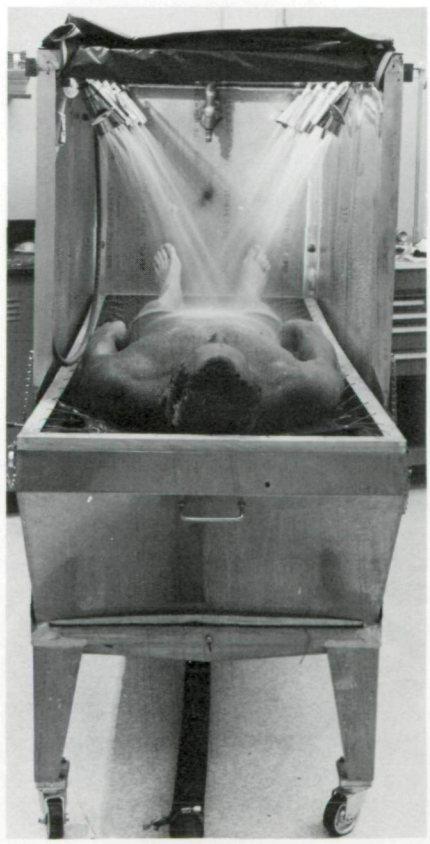
Wheelchair designed for persons having only cranially activated response. Operation of chair is by a chin-operated "joy stick," while the manipulator arm is controlled by voice command.

Horizontal Shower

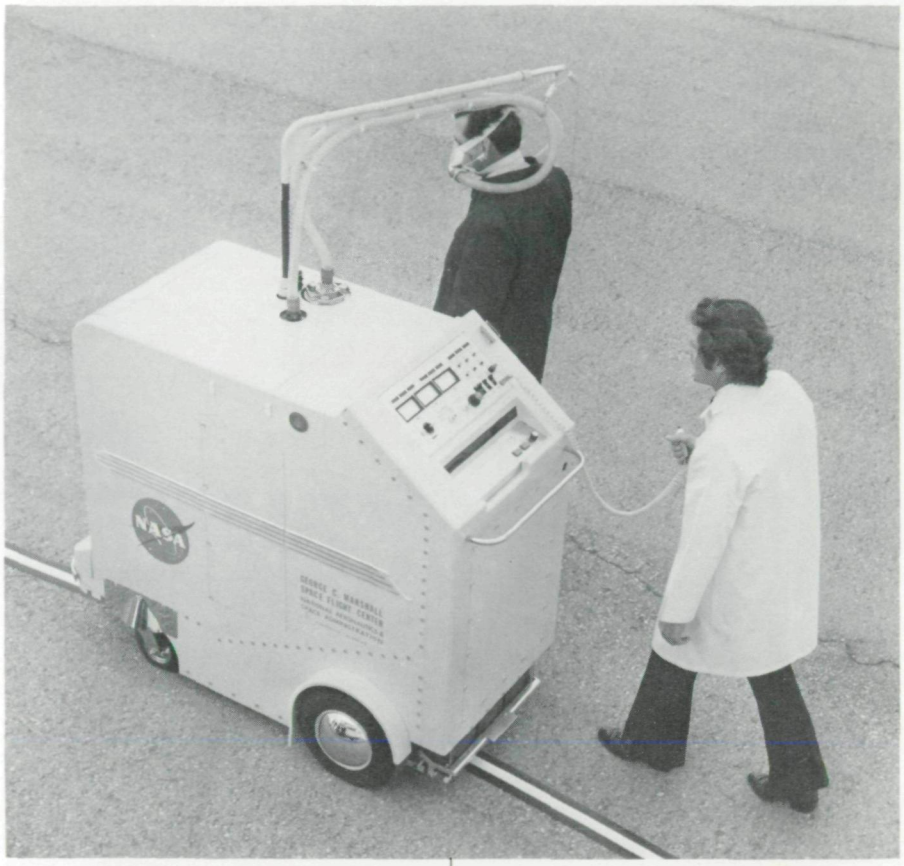
The bathing of bedridden hospital patients is now facilitated by a horizontal shower originally designed at NASA's Ames Research Center. The shower was initially used to bathe subjects in long-term bed rest studies who had to remain absolutely horizontal to simulate the effects of zero gravity which would be encountered in long space flights.

Conventionally, the thorough bathing of physically incapacitated patients is quite difficult, yet a complete cleansing and refreshing bath has considerable therapeutic value for the patient. When caring for wards full of such patients, nurses and attendants are confronted with a time-consuming task that often requires heavy exertion. In addition great care must be exercised when moving these patients to preclude additional discomfort while providing a thorough bath.

Horizontal showers based on the Ames design are being manufactured by Diamondhead Industries and General Teleoperators, Inc. The initial production units are being evaluated at the Stanford Medical Center and the Palo Alto Veterans Administration Hospital. The many advantages of the system should make it quite attractive for use in hospitals, rehabilitation centers, and chronic care facilities.



Incapacitated patient being bathed by series of shower nozzles in the horizontal shower.



The Mobile Automatic Metabolic Analyzer permits precisely controlled exercise and provides accurate and correlated data for the evaluation of patient assist devices and rehabilitation procedures.

Mobile Automated Metabolic Analyzer

Analysis of the amount of energy expended by severely disabled patients during exercise and rehabilitation training is being facilitated by a new, mobile, automated metabolic analyzer known as MAMA. The MAMA system is an outgrowth of instrumentation and techniques originally developed to monitor the metabolic activity of astronauts in the NASA SKYLAB program. Information provided by this system has been valuable in improving the design of patient-assist devices and for assessing the efficacy of various treatment procedures.

The NASA Marshall Space Flight Center instrumentation provides 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. Previously, 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 non-existent.

In a cooperative effort between a DHEW Social and Rehabilitation Services research and training center and NASA, a special motorized cart and an instrumentation system provided by MSFC enables physical therapists to gather accurate workload information. The instrumentation, consisting primarily of a portable mass spectrometer to analyze respiratory gas exchange and an electrocardiographic recording system, includes devices for measuring patient velocity. The motorized cart accurately controls the patient's velocity. The mass spectrometer provides 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, are also recorded.

Accurate velocity measurements are essential to meaningful workload data. Coupled with accurate physiological data, the 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 has been delivered to the Spain Rehabilitation Center in Alabama. Studies of amputees will include both semi-stationary and ambulating activities involving the use of lower-extremity prostheses, long braces, pneumatic braces, and wheelchairs. Further

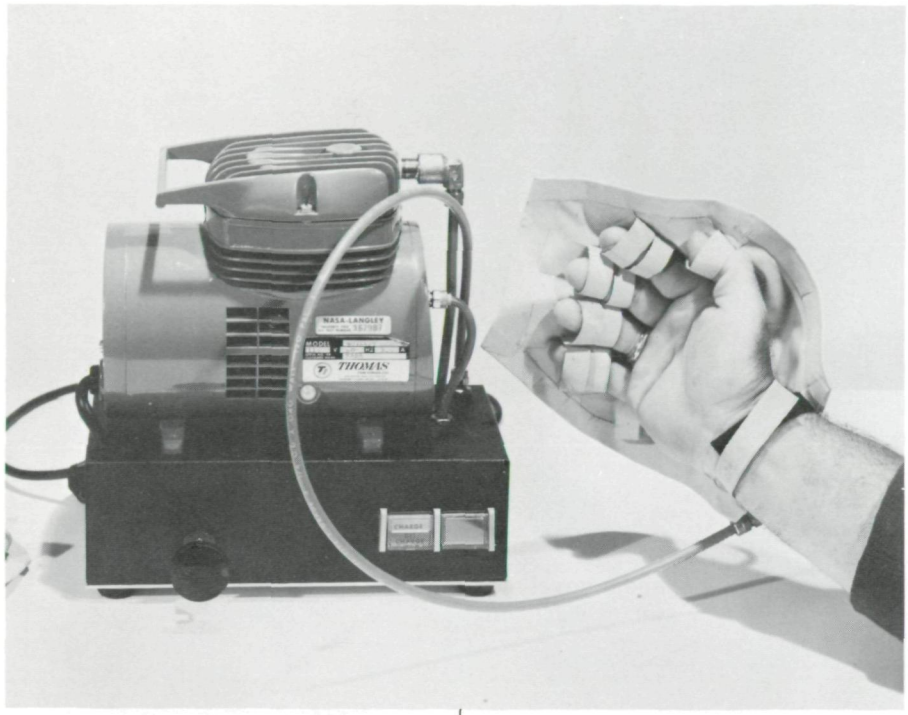
studies will include conditions such as cardiovascular disease, cerebral hemorrhage, spinal-cord injury, diabetes, hypertension, neurological diseases, peripheral neuropathies, nerve damage, vascular disease, and severe pulmonary diseases, such as emphysema and asthma.

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. Since its installation in Birmingham, the system has been used for energy expenditure tests using "normal" patients (no physical disabilities) to obtain baseline data. Tests with "real" patients with actual disabilities have been in progress since October 1974.

Hand Physiotherapy Assist Device

A new technique for providing physiotherapy to the seriously injured hand has been developed by NASA's Langley Research Center in collaboration with the North Carolina Memorial Hospital's Hand Rehabilitation Center.

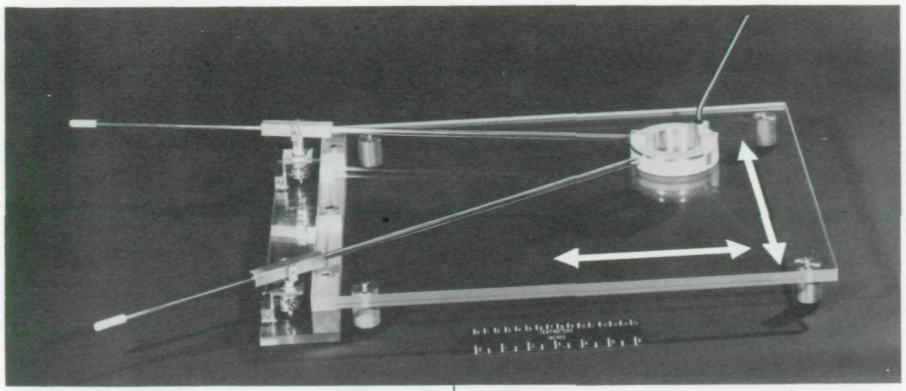
Most severe injuries to the hand (burns, cuts, frostbite) require that the fingers be immobilized for an extended period. While larger joints such as the wrist can be immobilized for four or five weeks with little adverse effect, a finger joint immobilized for one or two weeks may be permanently damaged. Consequently, a frequent task in hand rehabilitation is the preservation or restoration of mobility to the various finger joints. This task is complicated by the intense pain associated with joint movement, patient fear, and very fragile skin. The conventional treatment requires a skilled physical therapist to sit with a patient and manipulate the involved joints for periods of 20 to 30 minutes daily. Beyond inefficient use of skilled personnel, the conventional treatment procedure has several limitations: (1) since the patient is not in direct control, consistent maximal joint flexion is seldom obtained; (2) the degree of flexion varies considerably with each manipulation; (3) when the patient leaves the rehabilitation center, therapy often becomes ineffective, and ultimately considerable joint flexibility is lost.



Pneumatically actuated finger flexor device used for self-administered prescribed hand therapy.

Researchers at the Hand Rehabilitation Center of the North Carolina Memorial Hospital had developed a device which consisted of an inflatable section of a motorcycle innertube, a foot-operated pump, and a quick-release pressure relief valve. The deflated innertube was placed across the palm, and inflation of the tube forced the fingers outward from the palm. Although the patient was in control, neither the degree of flexion nor the control of the orientation of the pressure applied to the joint was satisfactory.

In response to a request for assistance, a systems engineer at NASA's Langley Research Center, who had worked for several years on the development of the LX-1 Space Suit, developed a hand physiotherapy assist device. Consisting of an inflatable mitt and a highly controlled portable pumping system, the device appeared to meet all requirements. But evaluation of the system at two hand-rehabilitation centers (North Carolina Memorial Hospital, Chapel Hill, North Carolina, and Jackson Memorial Hospital, Miami, Florida)



Grasping the almost vertical rod the neuromuscular patient guides the ringed reticle to trace a light spot projected on the plexiglass. Difference between input and output signals is a measure of the effect of therapeutic treatment.

revealed the need for further development.

The NASA engineer made several design changes which provided additional control, an automatic inflation-deflation cycle, and a novel mitt design. This new system was demonstrated at the Hand Rehabilitation Center, North Carolina Memorial Hospital, in January 1974. After several force distribution problems were solved using NASA-developed Temper Foam, patients were able to use the hand physiotherapy assist device for as long as 20 minutes with significant improvement in finger flexion. They developed no detectable skin irritation.

A four-month intensive clinical evaluation was conducted in which six patients used the NASA device each day. The patients demonstrated significant improvement in finger flexion, showed no fear of the unit, suffered no skin trauma, and could be left unattended during treatment. These results were presented at the Second Annual Georgetown University Hand Symposium held at the Georgetown University Medical School in Washington, D.C.

Widespread use of this NASA innovation is anticipated, and a well-established firm in the rehabilitation and physiotherapy field has expressed the desire to manufacture and market the unit.

Neural-Motor Control Evaluation

A system originally designed by the NASA Langley Research Center to measure pilot performance has been adapted for the study of neuromuscular disorders.

Many people suffer neuromuscular disorders that result in the loss or impairment of muscular control due to damage to the nervous system that controls the musculature. One symptom of this disorder is the uncontrollable random contraction and relaxation of the muscles. While modern therapeutic treatment allows many thousands of patients to improve their voluntary control over muscles, this treatment is hampered by the difficulty of measuring an individual patient's improvement during the course of therapy. One currently used measurement method involves the use of a drawing of a thin-lined geometrical pattern which the patient is asked to trace with a pencil. From this method, one can make only a subjective judgment regarding the degree to which a patient is able to control the movement of his hand. A more quantitative measurement of the effects of various therapeutic techniques would lead to improved techniques, which, in turn, should bring about more rapid and complete recovery for the many patients suffering from neuromuscular disorders.

The design of flight vehicles suitable for control by a human operator has been intensely studied by scientists at NASA's Langley Research Center for many years. Of major importance is the understanding of the motor and perceptual characteristics of the human pilot. To measure pilot characteristics, such as limb controllability, response time, rate of movement etc., these NASA researchers had developed a variety of tests and testing equipment as well as a mathematical model of the human pilot.

These tests devised to determine pilot characteristics have much in common with the requirements for testing patients with neuromuscular disorders. One test, for example, required an aircraft pilot to track an oscilloscope trace of a noisy signal using a joystick manipulator. This configuration permitted the recording of both pilot response and instantaneous error in tracking random disturbance. The tasks included control-stick and aircraft dynamics. At Langley, researchers suggested that the stick and aircraft dynamics be removed from the task in order to acquire a better measurement of the motor performance of neuropathic patients. This modified system has provided much quantitative information on human motor performance. A modified version of this manipulator was later used to make the test results less sensitive to the patient's perceptual performance. In

addition, NASA engineers built a unit for administering and analyzing the results of tracking tasks. This neuro-motor control system is being used in a clinical setting at Duke University School of Medicine.

Gait Analysis for Cerebral Palsy Research

Electrode sensors are being used to prescribe and evaluate physical therapy techniques for children with cerebral palsy. These sensors form the basis of a technique to measure the precise walking pattern of such children.

An exact description of the walking patterns, or gait, of children with cerebral palsy is essential to the prescription of physical therapy for individual leg muscles. In the past, it has been necessary to connect the patient by means of a bundle of wires to a recorder and a display to measure muscle movements. Young patients are often inhibited by the awkward tangle of trailing wires and the electrodes attached to the body. These factors and the jerky leg motions make it difficult to obtain clear, consistent readings by these methods.

An orthopedic researcher at the Stanford University Children's Hospital in Palo Alto, California, learning of the body sensors developed for the space program through a NASA *Tech Brief*, contacted a research engineer at the nearby NASA Ames Research Center (ARC) for assistance. At her request, the Ames researchers, utilizing their experience with electronics, EMG electrodes, telemetry systems and similar devices, developed a system to measure the gait of young cerebral palsy victims. L-M Electronics of Daly City, California, contributed some miniature amplifiers which were attached to muscle-sensing electrodes. The electrodes and amplifiers send impulses to a small transmitter worn around the waist of the patient. The transmitter relays the signals to a receiver in another room where the data is recorded. By this method, the patient no longer needs to drag around the cumbersome equipment and can walk in a more natural fashion. As a result, more accurate test results can be achieved.

R-F data transmission of neuro-motor commands now permits remote monitoring for gait analysis.

The unit, in use at Children's Hospital where the inquiry had originated, has been used to test over 30 children. The orthopedic researcher in reporting considerable success on her

Light weight leg brace made of graphite polysulphone thermoplastic.

patients, adds that she can now obtain undistorted gait data free of interference. It is anticipated that similar, simple, portable systems will be widely used to develop improved techniques for children with cerebral palsy.

Composite Brace Materials

Scientists and engineers in the Composite Materials Laboratory of NASA's Langley Research Center have built a leg brace of lightweight graphite epoxy composite material to replace the present orthopedic leg and pelvic braces, which are too heavy and impair the movements of the patient. The conventional braces are constructed of steel, aluminum, leather, wood blocks, and some form of padding. If the weight of these component materials could be reduced, the brace would be more useful.

In the new design, the strut members and waistband pieces of an ordinary brace were replaced by the composite material weighing less than half of the original metal components of the same strength. The Coastal Center for Mental Retardation at Ladson, South Carolina is evaluating the brace, which is being worn by one of the Center's patients. The composite material used in this one-of-a-kind brace was originally developed to fabricate high-strength, low-weight structural members for spacecraft.

The initial evaluation of the brace resulted in some valuable suggestions which encouraged the NASA team to design and fabricate second and third generation braces, and to modify the first brace. One of the most important design considerations was to make the fabrication of the lightweight brace as simple as possible, as a complex fabrication technique would complicate the future widespread use of the lighter weight brace materials.

Normal metal braces are adjusted by bending the metal struts in a jig, and brace height can be adjusted by moving the screws that hold the metal components together from one hole to another. With metal braces, these adjustments can be done quickly and without any difficulty. It was clear that a composite material brace should retain the adjustable characteristics. Therefore, another design consideration required the use of a composite material which could be adjusted to patient growth, or leg size.

The final consideration was to design leg braces with an overall systems engineering approach to reduce the total weight of the brace including the straps, padding, and shoes as well as the metallic structures. This approach produced a brace which permits a child to move more freely because of the reduced weight.

The second and third generation braces were made for a patient at the Mississippi Methodist Rehabilitation Center in Jackson, Mississippi. Braces of graphite polysulphone thermoplastic composite material (one that could be re-shaped) were fabricated with simple forming techniques which included a unique joint design. These design improvements hold the promise that a simply-made and clinically useful light-weight brace can be developed for economical widespread use.

The NASA team is also investigating materials and technologies for use in improving the characteristics of the non-metal brace components. For example, a new honeycomb material is being fabricated to replace the wooden block shoe filler in the first brace. This honeycomb material, too, was initially developed as a high-strength, light-weight spacecraft component.

The brace padding and the leather components of the leg brace may also be replaced with an equally strong but lighter material. The NASA team is studying nylon mesh materials for this purpose.

Systems Analysis and Planning

Video Requirements for Remote Medical Diagnosis

With the increasing commitment to provide quality medical care to all citizens and the scarcity of practicing physicians in certain rural and urban areas, several programs have evolved which use paramedical personnel to provide a first tier health screening service. Health programs have begun to utilize nurse practitioners and physicians' assistants in increasingly responsible medical support roles. The physician's skill is utilized only when required; supporting data gathering and treatment is handled by the allied health professionals qualified by training for primary assistance roles.

In addition to the use of paramedical personnel, the physician's efficiency can also be increased by the implementation of information systems utilizing present-day technology and systems engineering techniques. A television system providing for remote visual examination is rapidly becoming part of this telemedicine technology.

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 for many medical applications. The scarcity of available frequency spectrum space, bandwidth, and the economics of transmission systems make it 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 normal 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.

NASA was motivated to perform this study due to the related transmission and cost problems if telemedicine is to become a practical reality for both manned space missions and terrestrial applications. With the rapidly expanding usages for telecommunications, the RF spectrum has become very congested in many areas, and the cost of transmission is directly dependent on the data bandwidth requirement. Therefore, for medical-electronics planners and others who can implement only a minimal system for practical cost reasons, it is important to know the pictorial and diagnostic limitations as related to such technical characteristics as scene resolutions, motion rendition, contrast ratio dynamic range, colorimetry, and signal-to-noise ratio.

Over the past two years, NASA's Telemetry and Communications Division at the Johnson Space Center conducted a study to determine the minimal television system requirements for remote medical diagnosis. The first step involved making high quality videotape recordings of actual medical examinations conducted by a skilled nurse under the direction of a physician watching on closed circuit television. The recordings formed the "baseline" for the study. The videotape recordings were then electronically degraded to simulate television systems of less-than-broadcast quality. Finally, the baseline and degraded video recordings were shown (via a statistically randomized procedure) to a large number of physicians, who attempted to reach a correct medical diagnosis and to visually recognize key physical signs for each patient. By careful scoring and analysis of the results of these viewings, the pictorial and diagnostic limitations as a function of technical video characteristics were defined.

The primary objectives of this study were (1) establish the variability of visual medical information flow from patient to physician as a function of television design parameters, (2) establish the effect of that variability on the physician's ability to arrive at a proper diagnostic impression, and (3) establish the effect of that variability on the physician's ability to properly designate the patient for remote treatment or referral to a central medical facility.

There are different applications for telemedicine systems, and the requirements would be expected to vary. For example, telemedicine has been used for psychiatric therapy, speech therapy, hospital-to-hospital specialized consultations, continuing medical education, in-service training etc. The objective of this study was to determine what type or types of television systems are applicable when used to care for a wide spectrum of patients by a remotely located medical assistant (registered nurse skill level) and a general practitioner.

Theoretically a telemedicine system could be used to make entry into the health care system more accessible to patients at a location remote from physician-attended medical facilities. For the purposes of this study it was not considered essential for the telemedicine system to provide a capability for final diagnosis on every incoming patient. It is not reasonable to assume that the remote location would have adequate laboratory test facilities, treatment facilities, trained personnel etc. to gather a wide spectrum of medical data neces-

sary to completely treat complex medical cases. The requirement for the telemedicine system must be balanced with remote data gathering and treatment capabilities. The critical task for this telemedicine system is to provide capability for a medically-correct decision without direct examination by a general practitioner or specialist. In theory, the majority of incoming patients could be treated remotely, thereby eliminating the inconvenience, work time loss, and expense of traveling to a distant medical facility.

Photograph of zoom lens televised x-ray presentation of gunshot victim to physician. Small white areas represent lead bullet fragments.

Technology Support to Comprehensive Health Planning

In 1966, Congress passed Public Law 89-749 known as the "Comprehensive Health Planning and Public Health Services Amendments of 1966." The law declared that:

> "Fulfillment of our national purpose depends on promoting and assuring the highest level of health attainable for every person, in an environment which contributes positively to healthful individual and family living....
>
> "To carry out such purpose, and recognizing the changing character of health problems, the Congress finds that comprehensive planning (CHP) for health services, health manpower, and health facilities is essential at every level of government."

Although the Act assigned broad responsibility to local agencies for developing their own problem solving methodologies, no specific approaches to solving problems recognized by Congress were written into the Partnership for Health Act. This report summarizes how the Comprehensive Health Planning Council of Los Angeles County (COMP-LA) significantly improved its estimates of demand for health services by using technical assistance from the Jet Propulsion Laboratory.

As an outgrowth of earlier efforts in urban health systems planning, which produced a general concept for a more rational approach to health resources planning, JPL began to work more closely with COMP-LA. With this close support, JPL began developing new mathematical models for predicting the health service requirements of seven million residents of the Los Angeles area and planning the facilities needed to meet them. This developmental work consisted of providing systems analyses, economic analyses, computer programming, systems management, and related services. A similar, concurrent agreement was reached with a rural agency serving a population of less than 200,000 persons in northern California so that the predictive ability of the model for various geographic and economic distributions could be validated.

In its first specific task under the general agreement, JPL developed and applied two models to estimate the demand for physician services and facilities. The first model was then used to estimate the demand for physician services in each of nineteen health services areas. The second model was used for estimating (1) the number of general hospital admissions and (2) the hospital bed demand by type of service needed, such as pediatrics and surgery. The results were utilized in the COMP-LA Areawide Health Plan, which was subsequently approved by the State of California Office of Comprehensive Health Planning in August 1974.

Using the formula applied under the Hospital Survey and Construction Act of 1946 (Hill-Burton Act) pre-

Comparison of Hill-Burton and COMP-LA Estimates for Hospital Bed Needs

Hospital Service Area	Hospital Beds (Available - Needed) Hill-Burton	COMP-LA
1	+ 56	+ 86
2	+ 135	− 325
3	+ 496	+ 346
4	+ 49	− 198
5	+ 76	+ 214
6	+ 130	+ 6
7	+ 229	− 232
8	+ 236	− 181
9	+ 94	− 62
10	+ 79	− 141
11	+ 16	+ 323
12	+ 143	+ 128
13	+ 813	+ 3,586
14	+ 232	+ 63
15	+ 383	+ 208
16	+ 158	− 387
17	+ 429	+ 977
18	+ 66	− 465
19	− 62	− 328
TOTAL	+ 3,758	+ 3,618

cluded taking into account the changing demographic characteristics of the population. Conventionally, the Hill-Burton formula combines statistics on patients of all ages, both sexes, and those with varying requirements for health care. In contrast, the COMP-LA/JPL approach differs from the Hill-Burton formula in the following respects: actual demand for beds is derived from the actual population demography and on the basis of projected change in utilization; and the expected utilization rates are derived from the National Health Information Survey. Thus, the bed estimate is based on the actual projected health problems of the population in each health services planning area rather than on the gross population size exclusively.

In most hospital service areas, these approaches produce significantly different estimates of needed health resources. For example, the attached table shows that while the total country-wide bed surplus estimate appears nearly the same with both approaches, there are major differences between the methods in many hospital service areas. In over 40 percent of the areas, the Hill-Burton approach predicts a bed surplus, while the COMP-LA method indicates a deficit.

Clinical Laboratory Resource Allocation Model

As a consequence of an exploratory meeting between the Veterans Administration and the NASA Technology Utilization Office, an interagency agreement was reached for the Jet Propulsion Laboratory to perform a resource allocation study for the clinical laboratories of the VA hospital system.

Mathematical modeling and computer simulation techniques necessary to analyze large, complex systems such as those at VA Hospitals are an outgrowth of technology developed during the design and analysis of large, complex spacecraft systems (e.g. Mariner planetary spacecraft).

The study objectives are to develop models which allow 1) estimation of the resources required - primarily manpower and equipment - to accommodate a given laboratory workload; and 2) evaluation of tradeoffs between resources and future budgeting requirements. These study objectives are designed to address questions of the following type:

a) Given a projected demand for services, some constraints on the resources available, and some performance objectives, what set of resources are required to meet that demand in the most cost-effective manner?

b) Some of the resources available to the laboratory director can be traded for other resources. Often, the options include a trade-off between technical personnel and automated instruments, which influences the choice of procedures used in the laboratory. Which trade-offs lead to better laboratory performance?

c) With a specified set of resources (either current or anticipated) and a known (or projected) demand for services, how should these resources be used? To what schedules should personnel be assigned? Which tests should be sent to referral laboratories and which should be performed in-house?

d) Using the laboratory's current set of resources as a benchmark, what additional resources are required to meet current and anticipated demand in the most cost-effective manner? Or, stated more generally, what is the relationship between the performance of the laboratory and additional resources that might be sought?

To accomplish these objectives, JPL is developing two models of clinical laboratory operations:

l) The simplest, Model A, is a static model directed to the first project objective--It will estimate the total resources required to satisfy all requests for each kind of test in a typical day by referring to a compilation of the resources required to perform each test.

2) A dynamic simulation of clinical laboratory operation, Model B, is the second model that will be developed. Because this model will consider the fact that available resources are limited, it will estimate the costs and performance of the laboratory by simulating on a digital computer the assignment of actual resources, such as technician and instrument time, to each test request received during a typical day.

After thorough validation, the dynamic simulation model will be used to investigate carefully selected sets of alternative changes in the deployment of laboratory resources such as the choice of alternative test procedures, personnel schedules, and automation.

The models are being developed with the understanding that the individual clinical laboratory directors will be the prime users of the results. The result of this effort will be a documented computer software package for the Veterans Administration Central Office by summer 1975. Following this, the methodology and software will be applied to selected VA clinical laboratories for practical application.

Technology Applications Projects

Covered in Detail in Earlier Reports

Applications of Aerospace Technology in the Public Sector November 1971

Technology Applications Progress Report May 1972

Technology Applications Progress Report December 1972

Technology Applications Progress Report December 1973

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