THE NASA ROLE
IN MAJOR AREAS OF HUMAN CONCERN

(NASA-CR-139656) THE NASA ROLE IN MAJOR AREAS OF HUMAN CONCERN: HEALTH CARE (Denver Research Inst.) 18 p HC $4.00 CSCL 05K
N74-33398
Unclas
G3/34 17147

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HEALTH CARE

This document was prepared under the direction of the Office of Industry Affairs and Technology Utilization, National Aeronautics and Space Administration, as part of the Transfer Research and Impact Studies Project supervised by James P. Kottenstette at the University of Denver Research Institute. Principal authors included James E. Freeman, James P. Kottenstette, and Jerome J. Rusnak. Research support was provided by Joanne M. Hartley, William F. Hildred, F. Douglas Johnson, Onyike J. Onyike, and Eileen R. Staskin.

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HEALTH CARE

- Prepared for -

Technology Utilization Office
National Aeronautics and Space Administration
Washington, D. C. 20546

Contract NASW-2362

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February 1973

PREFACE

Understanding the social significance of America's civilian aeronautics and space effort has become increasingly difficult during the past five years. Whereas the missions of the National Aeronautics and Space Administration once figured prominently in discussions of public issues, increased interest in other national priorities has come to compete with, and often to dominate, concern about those missions. The study which generated this presentation was undertaken to facilitate more thoughtful discussion of NASA's activities by exploring how the achievement of mission objectives has contributed to beneficial changes occurring in six areas of major national interest: communication, transportation, environmental quality, safety, health care and work.

This statement focuses attention on the area of health care. After introducing some of the general factors that have affected progress in this area, NASA program elements are examined to illustrate relevant points of contact. Interpretive steps are taken throughout the statement to show a few of the more important ways people's lives have been affected as a result of the work of NASA and other organizations functioning in this area. The principal documents used and interviews conducted are identified after the conclusion of this statement.

This statement, it should be noted, is incomplete in many respects, primarily becuase it reflects only a small number of the technical, economic, and social forces affecting American life. Taken as a summary statement, however, it hopefully will provide a useful basis for better understanding NASA's role in the national attempt to improve the delivery of health care services.

HEALTH CARE: EXPANDING THE BIOMEDICAL TECHNICAL BASE

Good health is one of the most widely sought, yet least permanent, conditions man strives to attain. The National Center for Health Statistics reports that seven out of ten Americans visited their physicians at least once during 1971, and that approximately one in ten were hospitalized at least once.[1] The cost for the country's health services totaled some $83 billion, roughly 7.6 percent of the nation's gross national product; by contrast in 1960 the nation's health bill came to $25.9 billion, or 5.2 percent of GNP.[2] Despite such massive and increasing expenditures, major health problems remain unresolved. Cancer, heart disease, sickle cell anemia, mental disorders, drug addiction, and aging plague millions. An estimated 81,000 professional workers were engaged in medical and health-related research in 1972 to develop more powerful means of solving these and other serious health problems.[3]

Health care requirements are extensive and costly.

Public participation in health care programs has changed greatly since World War II.[4] In the late 1940's, new group health insurance plans offering financial protection against illnesses and health care came to be viewed by many as being almost exclusively the treatment of injury, sickness, disease. Recently, however, the idea of health care has been broadened to include health maintenance through proper nutrition and physical fitness and periodic examinations for early disease detection with a renewed interest and emphasis on preventive medicine.[5]

Health care now means maintenance as well as cure.

Specialization and the high costs of medical care have been major forces behind the widening commitment to health maintenance. So, too, have improvements in preventive medicine.[6] By developing disease profiles and routinely analyzing physiological processes, predictive medical techniques have emerged as powerful influences for health maintenance. There is now sufficient evidence, for instance, that a strong link exists between cigarette smoking and lung cancer.

Many forces support health maintenance.

Today's expanding population has high expectations for good health fueled by rapid medical advances and by the emerging feeling that good health is a right rather than a privilege. That the subject has become one of intense public interest is clearly evident in the fact that five major health care proposals are now before Congress. The scope of these proposals is indicated by the estimate that, by 1975, the most comprehensive of these plans could cost taxpayers about $67 billion annually.[7]

Public expectations are forcing action against health problems.

Against the background of forces affecting health care, another major problem has arisen. It concerns the difficulty of improving the quality of health care while trying to meet a sharply increasing demand for such care. It is this quality-quantity problem arena that NASA programs have made largely unanticipated contributions. The combination of medical research, particularly in new areas of physiology and biology necessitated by space flight, together with systematic development of means for the remote acquisition, monitoring, and interpretation of physiological processes during flight, have contributed some of the technology needed for improving both the quality and the quantity of health care. The technical innovations, some of which are described below, provide the Nation not only new or improved health care tools, but they also provide greater assistance for more people concerned with maintaining or regaining a healthy condition.

NASA programs help improve both the quality and quantity of services available.

Discovering the Healthy Man

Major interest in the total physiology of healthy persons had its beginnings in military flight training.[8] The combination of aging individuals, expensive equipment, and urgent situations forced new attention upon the physiological and psychological aspects of man under stress. Solving such problems as pilots blacking out under high gravity forces or becoming unconscious or disabled with lack of oxygen became essential to safe and effective military aviation. The questions multiplied as aircraft performance was improved, as the number of older pilots increased, and as commercial aviation became more important in the American way of life.

Military programs stimulated interest in the healthy individual.

With the advent of manned space flight, it became crucial to define precisely an individual's optimum health state, physical and mental, in order to assure adequate performance in environments outside the Earth's atmosphere.[9] This requirement has helped broaden medical research from a primary focus upon diseases and corrective procedures to include a deliberate study of good health with clear definitions of what man's normal functioning specifically entails.

Space flight generated the need to define the healthy condition.

One of the most significant outcomes from this research is found in a new understanding of the influence of severe environments on human functioning. Most physicians study the response of abnormal individuals to normal environments, while flight surgeons study normal individuals to abnormal environments. Often, abnormal environments rapidly induce symptoms and characteristics of a wide variety of diseases and disabilities in healthy individuals and healthy organisms.

In recent years, there has been growing concern that the sedentary aspects of modern industrial society may predispose many Americans to cardiovascular diseases.[10] Many studies have demonstrated a strong relationship between the intensity, duration, and frequency of physical activity performed by an individual and mortality from heart disease: ordinarily the greater the activity, the lower the mortality rate. The consequences of prolonged bed rest can include muscle atrophy, brittle bones, circulatory difficulties, kidney stones, blood clots, and pneumonia; all of these threats are clinically recognized so that early ambulation of the recuperative patient has been emphasized more and more in the last 25 years.

The relationship of inactivity to disabilities concerns researchers.

Manned space flights have demonstrated that a certain amount of physiological adaptation occurs during prolonged weightlessness that may have adverse effects when reentering the Earth's atmosphere.[11] With weightlessness and loss of gravity, for example, there is a redistribution of body fluids which may alter acutely or chronically the sensors regulating blood distribution in the body. On returning to Earth, this problem may create readjustment difficulties for the astronaut. Just as congestive heart failure may disrupt the functioning of cardiac receptors, prolonged weightlessness or complete inactivity may cause alteration of the mechanisms responsible for maintaining the proper circulating blood volume.

Gravity effects have been related to body processes.

Scientific understanding of this condition and its treatment owes a great deal to research performed in aerospace medicine on the mechanics of circulation related to gravity effects on the human body. Scientists at NASA's Ames Research Center, for example, in cooperation with the National Institute of Health and researchers at Stanford University and the Mayo Clinic, have developed computer techniques to present a visual display of the contracting heart.[12] The computer input is obtained by injecting an X-ray opaque dye into the heart and converting the resulting X-rays into digital data. The new computer technique is being used in selected research centers around the country to evaluate the effects of blocked coronary vessels in heart patients. This new diagnostic method enchances the use of angiocardiography and holds promise for better diagnosis and understanding of cardiovascular diseases.

NASA, Stanford, and the Mayo Clinic jointly have studied cardiovascular activities.

Confinement and relative inactivity are other specific examples of common patient environments in which the normally occurring physiological effects have much in common with specific effects induced by weightlessness. Recognizing similarities between these conditions has stimulated important advances in patient care. For example, in long-term bed rest studies supported by NASA and the U. S. Public Health Service, new treatments have evolved for osteoporosis, the thinning of bone structure due to calcium loss. During these investigations, researchers developed the first method for predicting the susceptibility of a patient to osteoporosis.[13]

Inactivity and weightlessness produce similar effects.

Over the past few years, NASA's development of new and better means of continuously measuring human physiological responses has injected the Agency into the mainstream of preventive and predictive medicine. The investigation of healthy individuals has thrown new light, for instance, on the nature of the body rhythms. It has long been known that normal body temperatures decrease by one or two degrees during the night and then rise to a peak during the afternoon. NASA research clearly documented the constant changes occurring in other physiological and biochemical life processes. With the onset of many illnesses, bodily rhythms often fluctuate unexpectedly. Understanding the broad range of normal physiological rhythms, therefore, is clearly important to predictive medicine. Previously, isolated clinical tests provided only a glimpse, whereas long-term examinations of bodily functions by improved physiological tests and timed biochemical analyses are providing major insights into man's physical nature and his dynamic responses to constantly changing environments.[14]

Continuous monitoring includes body rhythms in patient profiles.

A basic thrust of recent cancer research has been to analyze the nature of rapid, uncontrolled cell growth and the propagation of this condition through the body; these two conditions characterize cancer. As part of their space research mission, scientists in the NASA Langley Research Center Molecular Biophysics Laboratory have been investigating the effects of radiation on cell division for several years.[15] Their research has shown that the occurrence of cell division is associated closely with the electrical potential of cell surfaces: division is more likely to occur with lower electrical surface potentials. From these results, Langley researchers have been able to formulate and test a theory of cell division. Several university research teams are conducting independent investigations based on this theory. If it is substantially verified, the theory should make a major contribution to the understanding of cancerous cell behavior and should help move the nation one step closer to an ultimate prevention or cure of the disease.

Cell-division studies by NASA scientists are tied to cancer research.

One of the most familiar diagnostic tools used in routine medical practice today is the electrocardiograph. This device measures the electrical activity accompanying the rhythmic behavior of heart muscles. Interpretation of the ECG is always related to what is physiologically normal. When the Public Health Service (PHS) began work in 1957 to automate the analysis of ECG records, the first requirement was to establish normalcy patterns. Working with the Air Force initially, thousands of healthy servicemen were examined, and a computer-based processing and analysis system was developed. This concept was refined by the Public Health Service, the Air Force, and NASA over the next decade. One of the principal refinements was to make possible real-time computer analyses of ECG recordings.[16] This advance may become particularly important in major surgery, for example, where knowledge about sudden changes in a patient's condition can mean the difference between life and death.

Automation is employed to speed use of diagnostic information.

Late in the 1960's, the technology had progressed to the point where a new industry for local analyses of ECG's came to life.[17] More than 500,000 people have had their records screened automatically, thus establishing a new benchmark in the early identification and treatment of heart disease.[18, 19] This thrust toward automatic analysis of health records has been strongly supported by NASA's research on normal individuals, research that involved both the development of instrumentation and methods for total medical information management.[20]

Maintaining Adequate Health

Improving physiological measurements is essential for long-term advances in the quality and quantity of medical care, and it is here that NASA-supported research has made a significant contribution. Better measurement, however, translates into more advanced equipment and larger systems of data and research management. As the Nation's current, large-scale attack on major health problems intensifies, tools for performing tests faster and more accurately must be developed; new testing methods and instruments will be required; and, finally, the capability to interpret and act on the information generated must be improved.

Tools for prediction and prevention are needed for health maintenance.

Activities to maintain adequate health are supported internationally by organizations such as the United Nation's World Health Organization and UNICEF, private organizations such as CARE, and through numerous bilateral and multilateral government aid programs. Within the United States, the Public Health Service, the National Institutes of Health and other agencies within the Department of Health, Education and Welfare are involved across the whole spectrum of maintaining adequate health, from nutrition and health education to diagnostic screening programs; in addition, the Department of Agriculture has had a long-term major role in the revolutionary increases in productivity of American agriculture.

In the production of food, new technology has played a fundamental role. Fertilizers, pesticides, and "miracle" strains of wheat and corn have increased production potential many-fold in the last few decades. Now satellites and aircraft are coming into use to identify crop diseases, discover new arable land, and improve weather forecasts used in planning for planting and harvesting.[21, 22] Food preservation techniques, so essential for good nutrition, also have been improved significantly in recent years.[23] The food processing industry, in developing foods to NASA requirements for use on long-term space missions, has generated much new information on food processing, preservation, and nutritional value which is being used for consumer products. To sharply reduce the chances of food-borne infection on space flights, for example, firms that have produced foods for NASA have established special controls and procedures in food production. One such control is the use of "clean rooms," isolated areas where contamination is minimized, to prepare food. Clean room technology has been

Remote sensing and contamination control tools help improve food production and distribution.

significantly advanced by NASA, the Department of Defense and the Atomic Energy Commission. The use of a contamination free environment could lead to elimination or reduction in the need for thermal processing, which often destroys nutritional value, flavor, and color; it could also lead tion in the incidence of food-borne diseases, which is still a public health problem. Other NASA work on food technology which has general applicability includes identification of dietary requirements to avoid bone demineralization (a problem with bed-ridden patients), contributions to the use of radiation for food preservation, and a low cost method of determining the vitamin content of food.

Multiphasic health screening is demonstrated.

Adequate health is maintained not only by proper nutrition, but also by frequent diagnosis. In the past decade, automated and computer-created health screening centers have been organized, particularly in support of paid health maintenance programs and large medical institutions.[24] For instance, the Kaiser "Multiphasic Health Checkup" was screening 25,000 patients annually in 1965 at a cost of about $35 per patient. The screening provides an instantaneous computer summary of more than 40 medical measurements obtained during a 2-1/2 hour examination.

NASA was an early contributor to the technology of automated health screening. At the Manned Spacecraft Center in Houston, for example, a program for multiphasic analysis of clinical patients has been operated since the Center was established in 1961.[25] Some 5,700 people have been screened routinely during the decade. This work also has affected medical procedures by standardizing results, reproducing tests, defining normals, and developing computer software for records management and data analysis. Among other things, an operational, computerized medical-record system called MEDATA emerged from this work.[26]

New developments can make many tests routine.

A technique developed at the Goddard Space Flight Center to detect life on other planets is being adopted by researchers at Johns Hopkins University Hospital in Baltimore to help identify urinary tract infection, a malady affectirg 1,000 Americans.[27] The first step, nearly complete, has been to establish the reliability and repeatability of the technique by comparing its results with those obtained through the standard technique in which cultures are prepared from urine specimens. Results, the second step, also nearly concluded, involves the construction of an automatic apparatus that completes the test in 20 minutes as opposed to the 3 to 5 days involved in the standard test. This apparatus literally makes a diagnostic test routine that formerly was undertaken only after other symptoms of infection indicated the advisability of specific confirmation.

Social problems relate to health problems.

The Whittaker Space Sciences Division of the Whittaker Corporation has used diagnostic and optical instrumentation technology it developed under a NASA contract to build a new instrument for screening potential lead poisoning victims.[28] Lead poisoning is particularly problematic in inner city areas where lead-based paints still take a terrible social and economic toll by causing brain damage in young children. Whittaker has introduced a portable instrument that can rapidly and economically detect the presence of lead in the blood.

At Baltimore City Hospital, the Whittaker unit was used during the past two years to screen approximately 1,000 children; 12 percent were found to have abnormally high levels of lead in their blood.[29] Children with a reading above 60 micrograms of lead per 100 grams of blood are placed in convalescent facilities; those above 80 micrograms are placed in intensive care. Use of the machine at Charleston, South Carolina and at Harrisburg, Pennsylvania showed that the tests could be performed rapidly and with few personnel, and that costs were reduced to about $1.00 per test from the $15.00 per test using the usual atomic absorption method. It has been suggested that 12 percent of all ghetto children have a reading of 50 micrograms or greater. After a person's level reaches 60, it can rise very rapidly and cause irreparable harm to the central nervous system. In St. Louis, a demonstration model of the Whittaker instrument was used on about 200 children; 11 percent had a high level of lead indicated, while another 15 percent showed positive readings without lead indicating other serious problems such as sickle cell anemia, poor nutrition, etc.[30] Use of the unit is faster than conventional methods and greatly reduces testing trauma. The technologies of power supply, fiber optics, photo-detection, and miniaturization were combined with the laboratory fluorimeter's capabilities to provide this valuable diagnostic tool.

Efficient equipment developments can meet specific needs.

Sanders Associates in Nashua, New Hampshire is marketing a medical data management system that embodies technology developed from the Saturn V prelaunch checkout system.[31] The medical data system has been tailored to link all map parts of hospital information networks, including laboratories, treatment rooms, admissions, accounting, and dietary kitchens.[32] The Kaiser Memorial Hospital in San Francisco uses this system in its pediatric center where 24 cathode ray tube displays provide interactive data links. The Mayo Clinic in Rochester, Minnesota installed the system about two years ago in its Admissions and Records Department where 130,000 line items per day are processed. These examples illustrate the technological basis behind improvements in measurement and data management affecting large numbers of people. Population screening is a trend in health care delivery that is clearly in its infancy. Screening will continue to grow as a force in health care because it is much less expensive--socially and economically--to correct potential problems than to treat major disabilities.

Data management systems link hospital units.

Correcting Health Problems

The impact of technology in health care is perhaps most graphically demonstrated in the treatment and rehabilitation phases of a patient's recovery. Open heart surgery, organ transplants, and cancer therapy, to cite just three examples, require advanced technology of the type embodied in heart-lung machines and in high-energy X-ray generators. The availability of such expensive equipment sometimes overshadows the fact that less costly instruments, equipment, and appliances that can play such an important role in health care are not generally available.

Serious medical equipment shortages exist.

About four years ago, the National Academy of Engineering recognized that a clear discrepancy existed between the problems in health care delivery and the number of devices available to meet these problems.[33] The Academy established the Committee on the Interplay of Engineering with Biology and Medicine to determine why the discrepancy existed and what could be done to correct it.

The National Academy of Engineering recently studied this problem.

The committee learned that one of the factors behind the discrepancy was the fact that certain devices, while highly desirable, need only be manufactured in small quantities; for other devices, the markets are fragmented, isolated, and difficult to predict, with the result that no manufacturing activity occurs. The committee suggested that one way to close the gap might be to create an agency with primary responsibility to develop and stimulate deployment of biomedical engineering technology.

The NAE committee's recommendation gives an appropriate perspective for viewing the operation of NASA's Biomedical Application Program.[34] Three teams, comprised of engineers and scientists and operating from nonprofit research institutes, attempt to match technology generated through space-oriented research and development with patient needs identified in medical research or field practice.

NASA BATeams help develop needed devices.

Some 77 medical facilities across the country currently participate in this program. In addition to providing information, the application teams oftentimes oversee the development of prototype devices for field evaluation.

An example of a recent collaborative effort between the National Cancer Institute (NCI) and the three Biomedical Application teams illustrates the problem definition and solution process.[35] Dr. Edward S. Henderson, head of NCI's Leukemia Service, asked the Biomedical Application Team at the Research Triangle Institute (RTI) in North Carolina to assist in a search for a new way to detect the onset of shock in critically ill patients.

NCI and NASA are testing a new device for early detection of shock.

If not recognized in the initial stages, shock can rapidly prove fatal. Dr. Henderson had determined that conventional methods for detecting initial drops in blood pressure were either unsuitable or unduly disturbing for critically ill patients. A promising solution to the problem was discovered recently when an RTI team member visited NASA's Ames Research Center. An Ames engineer proposed the use of an ear oximeter that measures the oxygen content and pressure level of blood by employing an infrared absorption technique. Impressed with the oximeter's potential, Dr. Henderson and his staff are working with the NASA Application Team to adapt the instrument for shock measurement use.

NASA's research in planetary quarantine, the life sciences, materials, and instrumentation has produced a number of contributions to treatment and rehabilitation technology. Areas of NASA concern for space missions such as contamination-free environments, miniaturized instrumentation, remote sensing of physiological processes, and closed-cycle life support systems are directly related to basic problems in the medical community and, as a result, have been particularly useful in medical applications.[36] Despite strict controls in hospitals to minimize the possibility of infection, for example, as many as five percent of all surgical patients become infected.

Hospitals are beginning to use contamination control techniques originally applied by AEC and NASA.

Clean rooms that practically eliminate airborne bacteria from a room in minutes embody contamination control technology originally developed for the assembly of delicate instruments used in aerospace and atomic energy. To reduce the risk of infection, at least 25 hospitals in the U. S. now apply such technology both in operating rooms and in facilities reserved for patients undergoing radiation and cancer chemotherapy or who have received organ transplants.

In the field of biomedical instrumentation, several NASA developments have found medical application.[37] Biotelemetry units developed to monitor the physical condition of astronauts in flight have been adapted and incorporated for use in patient monitoring systems that simultaneously monitor several patients from one nurses' station. Devices originally developed at Ames Research Center and Manned Spacecraft Center allow telemetering of blood pressure, temperature, electrocardiograms, and electroencephalograms without encumbering the patient with lead wires. A NASA-developed sensor for monitoring the breathing of animals now performs the same task for infants suffering respiratory difficulties. The sensor monitors the pace and intensity of the baby's breathing. Information is telemetered to a nursing station where any unacceptable change in the child's breathing sets off an alarm. Engineers at NASA's Lewis Research Center have designed a control system for an experimental artificial heart operated by the Cleveland Clinic; they also have designed a small, inexpensive analog computer to monitor heart patients' blood pressure and cardiac output at St. Vincent's Charity Hospital in Cleveland.

Many NASA-developed instruments are finding medical application.

Space materials technology also has found medical application. Carbon composites developed originally for rocket nozzles are being used by researchers as implantable splints, heart valves, and other devices. The carbon material appears to be more compatible with the human body than any other known material and can easily be fabricated into complex shapes.[38] Several major medical centers, such as Rancho Los Amigos and the University of California in Los Angeles, are involved in developing applications for the material. Lightweight epoxy composite materials are being tested for use in a variety of prosthetic devices and appear to hold promise of significant reductions in the weight and bulkiness of such items. Foam material, originally developed for advanced airline passenger seats to counteract crew discomfort on long flights, is being used experimentally as a decubitus ulcer prevention aid in bed pads, as lining materials for prostheses, and as padding material for burn victims.

Various materials first used in space vehicles are applied in several different medical areas.

A significant new system for correcting health problems involves the use of a satellite to bring medical aid to remote areas. In 1971, Lister Hill Center for Biomedical Communications, initiated an experimental program in Alaska using NASA's ATS-1 satellite.[39] The program, which serves 20 villages in the remote Tanana region, provides direct voice communication on a daily basis between physicians in the district medical center and the resident paramedic in each village. These contacts provide medical information of an educational nature for the resident paramedics along with specific directions for procedures in emergency situations. Recently, for example, two emergencies occurred simultaneously in different villages; by using the satellite, a district physician was able to instruct each paramedic so that in both cases lives were saved.[40]

NASA's ATS-1 satellite brings medical aid to remote Alaskan villages.

Biomedical Engineering Improves Health Care Delivery

New developments in health care are helping to bring a longer and better life to millions of people, yet illnesses and deaths that could be prevented by more adequate health care must number in the millions. Many issues must still be addressed in understanding the nature and causes of disease, in maintaining adequate health, and in correcting health problems. Technology, however, contributes not only to solving the purely medical aspects of these problems, but also with wider application to the long-run reduction of medical costs, improvements in food supply and distribution, and advances in preventive medical care through such means as mass health screening programs.[41]

Technology provides a basis for better health care.

In a surprising number of program areas, NASA's activities have contributed substantially to the reservoir of knowledge that is being drawn on to improve both the quality and quantity of health care. Satellites have been used to bring medical advice to remote communities; research in life sciences has contributed to the basic understanding of man's physiology; the physiological monitoring and life support of astronauts has found direct application to health problems on earth; and advancements in the fields of instrumentation and materials technology have helped produce badly-needed improvements in health care.

NASA strongly supports the technology generation effort.

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