ADVANCEMENTS IN MEDICINE FROM AEROSPACE RESEARCH

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Introduction

The world has recently viewed the dramatic successes of a space effort, which chose a difficult goal and then carefully developed the technology necessary to reach that goal. This paper discusses a program which is designed to find second applications in the field of medicine for the technology developed to achieve the nation's space goals. The program is the outgrowth of the congressional charter included in the Space Act of 1958, which directed NASA to find second applications for the technology which resulted from NASA's Research and Development (R&D) programs.

For several years NASA has sponsored a program which has, at its core, multidisciplinary teams of scientists and engineers called Application Teams. Such a team is located at each of three not-for-profit research institutes (the Research Triangle Institute of North Carolina, the Southwest Research Institute of Texas, and the Midwest Research Institute of Missouri) and one medical school (Stanford University). The teams seek to provide an interface between two diverse fields: aerospace and medicine.

The medical profession has awakened in the past decade to the need for advanced technology in medical research and health care. This awakening alone is not enough. Some effective avenues for the flow of information, ideas, and technology between the physical and medical sciences have been established, but more are needed. This program provides one such avenue.

Methodology

"Technology utilization" is the term applied to the task of finding second applications for technology. Many of the methods for implementing the concept of technology utilization are largely passive in nature; passive, in this case, means the information is provided to those who seek it and thus the physician must understand the information system in order to use it. One of the unique features of the Application Team program is that the method is active. Active, in this sense, means that the problems and solutions are actively sought.

This search for problems is carried out by the members of the multidisciplinary team. Team members visit major medical centers (the National Institutes of Health and medical schools) where suitable medical problems are identified with the aid of a consultant. The consultant, a medical center staff member, helps to ensure that the problems selected meet certain minimum requirements. In general, our team accepts only those problems which (1) have no solutions available on the commercial market, (2) are discrete and can be defined in specific terms, (3) impede the progress of priority efforts of the physician, and (4) appear amenable to solution by aerospace-related technology. We impose these requirements because this program is designed for problem solving, not just for information searching.

If a problem meets these requirements, it is defined by the physician and team member during one or more meetings. Problem definition can probably best be explained by an example: arthritis is a crippling disease which can result in the destruction of the ball-and-socket joint of the hip. One method of treating this disease is to replace the human hip ball-and-socket joint with an artificial material. An orthopedic surgeon asked the team to find an improved material. The team quickly determined that the basic problem was that existing materials have inadequate friction and wear characteristics. The team looked for improved low friction-bearing materials which were biocompatible and not just for prosthetic hip joint materials. Thus, the search could be broadened to areas unrelated to medicine.

After a problem is defined, a solution is sought using several approaches. First, a computer search of the NASA document bank is performed, which covers approximately 700 000 documents. The bibliography and related documents are analyzed by the physician and the team member to determine whether an adequate solution is available.

A second approach used in finding solutions is to request suggestions from NASA personnel by circulating concise written problem statements to the NASA field centers. These documents are circulated by the Technology Utilization Officers (TUO) who are located at each center and who have a detailed knowledge of the research activities at their centers. The TUO provides a vital link between the teams and key NASA personnel.

A third approach is to contact field center personnel or NASA contractor personnel directly when the teams are aware that these personnel have knowledge about particular problems. These contacts, coordinated with each TUO, allow the teams to rapidly obtain advanced technological information.

After an idea or individual has been identified by these searching procedures, both direct and indirect contacts between physicians and NASA personnel are arranged. In the former case, physicians have visited NASA centers for discussions; in the latter case, the team members have provided the contact by visits and correspondence. Always the idea is to provide the physician with fresh insight into his problem from a discipline he does not normally encounter.

The team then acts as a catalyst to provide implementation of the ideas. Although the primary responsibility for implementation of the technology lies with the physician, the team assists in engineering consultation and in recommendations for ways of applying the technology. In addition, in a few instances, NASA has initiated feasibility studies directly when it is clear that no other avenues are open to the physician and when the necessary expertise is available only within NASA. At all times, the team feels that success comes only when utilization has occurred.

Program Analysis

Because the transfer of technology in this active mode is a unique venture, significant efforts are made to analyze the transfer process so that improvements in transfer methodology can occur. The analysis phase of the program has disclosed several important facts about the problem of finding second applications for space technology. First, although the searching of document files is one key aspect of the program, it is not the most important aspect. Most information systems are designed to retrieve information directly related to a subject. Information that is indirectly related to a subject cannot be easily retrieved unless the searcher has some initial clues. A search for methods of rapidly heating blood, as an example, would probably not include semiconductor fabrication as a search term unless the searchers were aware that microwave heating is a vital aspect of semiconductor fabrication processes. Thus, search results are limited by the experience of the searcher.

The second important lesson learned from this program is that personal interaction is vital when two diverse disciplines are attempting to interact. In fact, disciplines do not really interact, but people do. This interaction between two diverse disciplines really results when two people sit down to talk. If we simply give a physician an engineering document, the results are usually quite low. Consider two examples: (1) The physician cannot begin to realize the significance of modern communications technology to his method of dispensing health care, and (2) the engineer cannot recognize the significance of his cryogenic technology to leukemia therapy until face-to-face and repeated interaction occurs. Personal interaction between all elements of the team program (physician, team member, and aerospace engineer) has been found to be of major importance for success.

Examples of Results

In order to illustrate both the methodology and the results of the Application Team, examples of particular problems will now be discussed.

A prototype of a prosthetic urethral valve is shown in Figure 1. This valve is designed to meet the needs of patients with urinary incontinence or the inability to voluntarily control urination. In addition to the obvious social and hygienic implications of incontinence, this inability to control urination can result in tissue deterioration, infection, kidney damage, and eventually death. Previous attempts to solve this problem using electrical stimulation have not been satisfactory.

One problem in attempting to use a valve in the urinary system is that urine causes an incrustation that fouls most valves. This problem was posed to NASA engineers at Lewis Research Center who proposed the use of a flexible membrane valve. A team engineer proposed a check valve that, together with the bulb shown in Figure 1, forms a bistable valve which controls the urine flow. This device is now undergoing testing in experimental animals, and if it is perfected, an estimated 15 000 patients per year could benefit from this device.

The next example concerns the need for careful monitoring of leukemia patients who, not uncommonly, die of shock — as opposed to some cause more directly related to the proliferation of white blood cell forming tissue. In order to prevent these deaths, the National Cancer Institute asked the team to find a means of monitoring blood pressure without significantly disturbing the patient. Conventional blood pressure measurements require an occlusive cuff which is clearly unsuitable for frequent, round-the-clock monitoring.

A direct contact with NASA's Ames Research Center revealed that an ear oximeter had been developed for measuring oxygen content of the blood of astronauts in ground testing. This device, shown in Figure 2, was also sensitive to relative changes in blood pressure. Although previous ear oximeters required that blood flow in the ear be occluded in order to measure blood pressure, this new NASA development removed this requirement and the resulting discomfort. At the present time, the NASA ear oximeter is undergoing clinical trials at the National Cancer Institute. Successful conclusion of these trials could result in savings of hundreds of lives annually.

A third example of an application of aerospace technology resulted when the Environmental Protection Agency (EPA) wanted to study the effects of low levels of carbon monoxide on automobile drivers. A search revealed that a NASA scientist at Langley Research Center had developed an instrument, shown in Figure 3, which measured the coordination and reaction time of astronauts exposed to contaminants in spacecraft. This instrument was loaned to EPA and is now being used for the planned study. Although the new application of the equipment is not significantly different from the basic NASA use, it is interesting to note that EPA had planned to develop such an instrument on contract so that a significant savings in tax dollars resulted.

A fourth example is shown in Figure 4. This is a radiation dosimeter probe, developed under NASA sponsorship for nonmedical purposes, and is now being used to measure the radiation level absorbed around cancerous areas in order to determine the position of administered radioisotopes. This allows more precise definition of cancerous areas and prevents damage to surrounding healthy tissue.

The final example of a transfer concerns the need for an improved electromyographic muscle trainer. When muscles of the hand become damaged or atrophied, an electromyographic muscle trainer is employed to determine whether or not a specific muscle is being used. The trainer consists of two electrodes, an amplifier, and a speaker which allows the patient to hear when a specific muscle is being used, but the bulky electrodes previously employed were too large for proper results.

Figure 5 shows the use of small electrodes devised from NASA-developed spray-on electrode formulations. With these electrodes no further attachment mechanism is needed for the wires, and the electrodes provide extremely satisfactory results. The improved access to the muscle being exercised permits improved rehabilitation procedures for a significant number of patients. The technique is already in use in several rehabilitation centers.

Conclusion

This paper has described a new and exciting approach to the process of finding new applications for space technology. NASA has taken the lead in implementing the concept of technology utilization, and the Technology Utilization program is the first vital step in the goal of a technological society to insure maximum benefit from the costs of technology. Experience has shown that the active approach to technology transfer is unique and is well received in the medical profession when appropriate problems are tackled. The problem-solving approach is a useful one at the precise time when medicine is recognizing the need for new technology.

It is significant that the decade which heralded the space age is also the decade that signaled the awakening of medicine to the need for technology. Whether the coincidence is directly related, indirectly related, or unrelated can be argued by philosophers. But this simultaneous occurrence cannot be ignored, and this program is one step in the many that are needed to fulfill medicine's needs. Thus, the Application Team program clearly fits the purpose of this conference which is to discuss "Space for Mankind's Benefit."

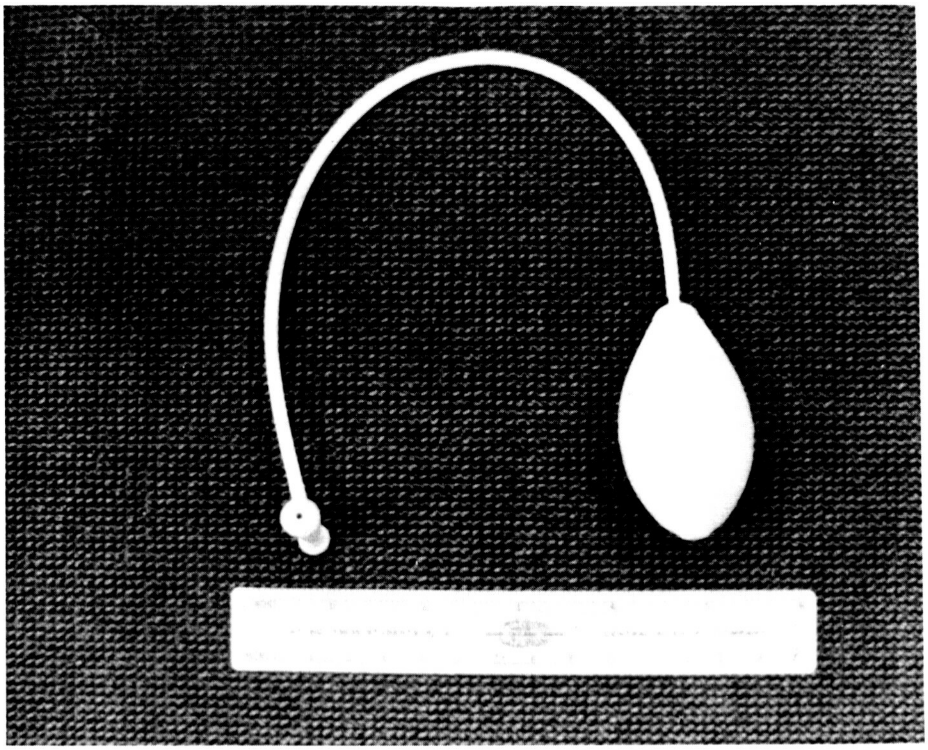

Figure 1. Prototype prosthetic urinary valve.

Figure 2. Ear oximeter.

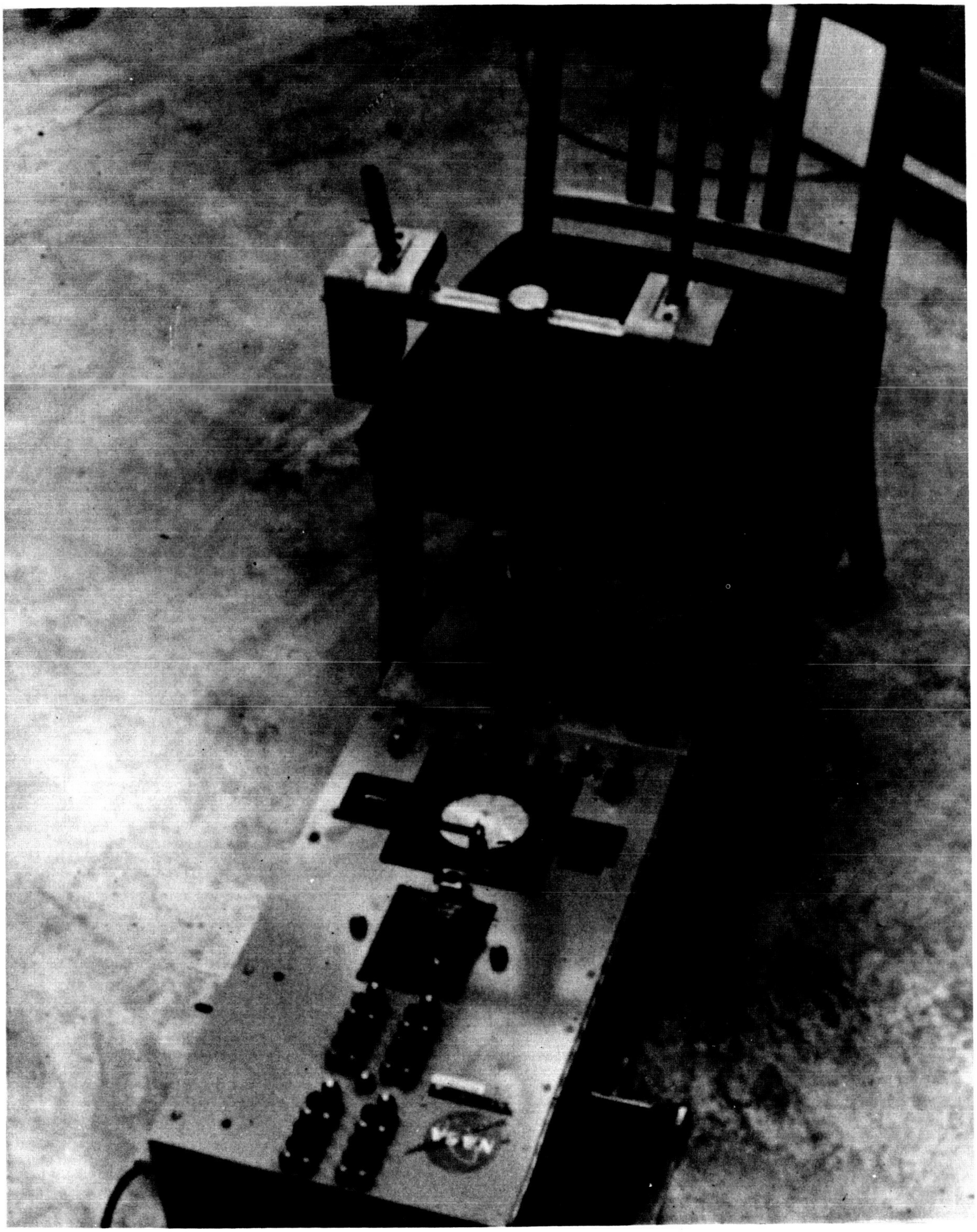

Figure 3. Complex coordinator.

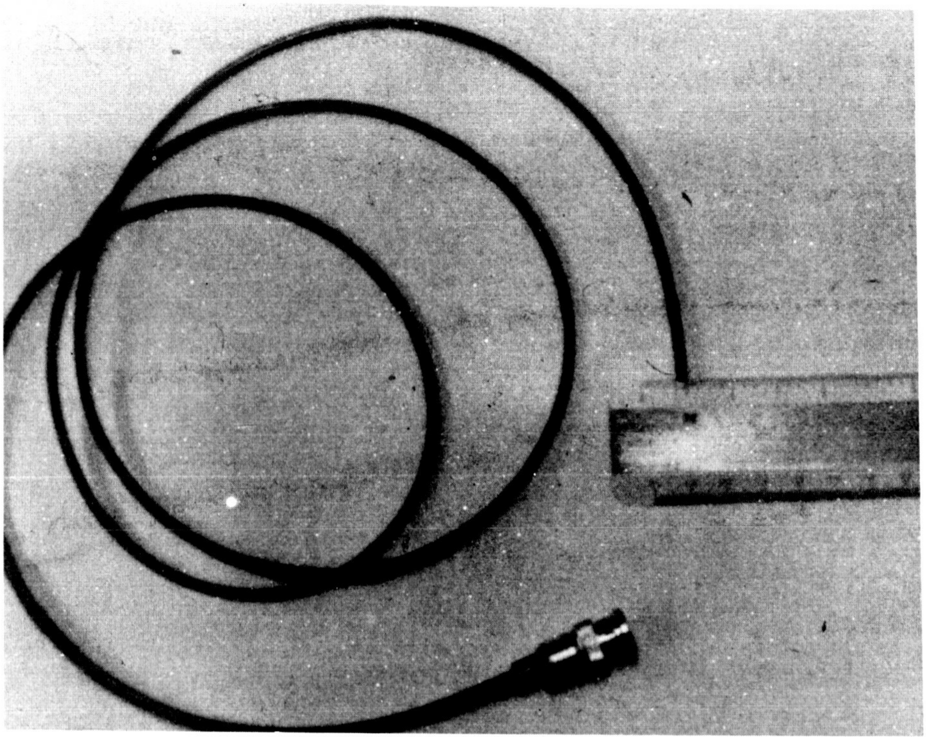

Figure 4. Radiation dosimeter.

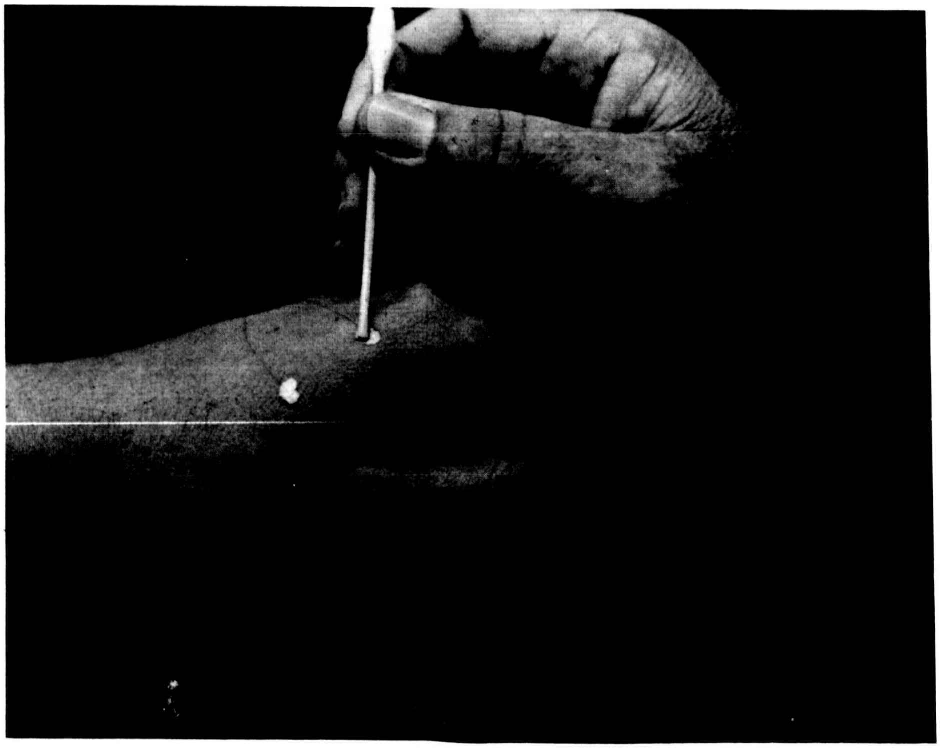

Figure 5. Electromyographic electrodes.