VOCATIONAL REHABILITATION SERVICES

OVERSIGHT HEARING

BEFORE THE

SELECT SUBCOMMITTEE ON EDUCATION

OF THE

COMMITTEE ON EDUCATION AND LABOR

HOUSE OF REPRESENTATIVES

NINETY-THIRD CONGRESS

SECOND SESSION

ON

FUTURE DIRECTIONS OF THE REHABILITATION SERVICES ADMINISTRATION

Part 3

HEARING HELD IN WASHINGTON, D.C., MARCH 8, 1974

Printed for the use of the Committee on Education and Labor

CARL D. PERKINS, *Chairman*

Best Wishes

Your Congressman

U.S. GOVERNMENT PRINTING OFFICE

WASHINGTON : 1974

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VOCATIONAL REHABILITATION SERVICE

FRIDAY, MARCH 8, 1974

House of Representatives,
Select Subcommittee on Education
of the Committee on Education and Labor,
Washington, D.C.

The select subcommittee met at 10 o'clock a.m., pursuant to notice, in room 2175, Rayburn House Office Building, Hon. John Brademas [chairman of the select subcommittee] presiding.

Members present: Representatives Brademas (presiding), Landgrebe, and Hansen.

Also present: Representative Clawson.

Staff present: Jack G. Duncan, counsel; and Martin LaVor, minority legislative associate.

Mr. Brademas. The Select Subcommittee on Education will come to order for the purpose of conducting a hearing regarding the application of technology in meeting the needs of handicapped Americans.

The Chair should point out that H.R. 8070, signed into law last year as the Rehabilitation Act of 1973, provides for research funds, and requires that 25 percent of moneys appropriated for research in 1975 be expended to establish and support engineering research centers.

It is our purpose here today to learn more about new developments in biomedical research in improving the lives of handicapped persons. We hope also to explore the benefits which the handicapped might derive from research and engineering devices sponsored by such agencies as the National Aeronautics and Space Administration and the National Science Foundation.

The Chair should point out his understanding that NASA has studied the relationship between weightlessness and mobility and NASA's work has made a significant contribution to understanding the mobility problems of handicapped persons.

So we are hopeful that we may today learn more about the future benefits of such work supported at rehabilitation engineering centers.

As you may know, this subcommittee has jurisdiction over a wide variety of human services programs, including programs that serve the elderly, very young children, and programs that serve handicapped children. Even now, we are in the midst of hearings on legislation to provide Federal grants to the States for reimbursing local school districts in order to meet the excess costs of educating handicapped children.

So our discussion today is in line with the continuing concerns of this subcommittee.

Our witnesses this morning will include Mr. Mike Gorman, consultant, United Cerebral Palsy Association; Mr. Leonard Goldenson, president, American Broadcasting Co., Inc.; Dr. William Berenberg, Children's Hospital, Boston, Mass.; Dr. James Reswick, director, Rehabilitation Engineering Center, Downey, Calif.; Dr. Erwin R. Tichauer, director, Division of Biomechanics, Institute of Rehabilitation Medicine, New York University Medical Center; Dr. Theobald Reich, Institute of Rehabilitation Medicine, New York Medical Center; Dr. Lee Arnold, director, Guggenheim School of Aeronautics, New York; Dr. Irving S. Cooper, director of neurosurgery, St. Barnabas Hospital, Bronx, N.Y.; James Burress, Acting Commissioner, Rehabilitation Services Administration, Social and Rehabilitation Service, Department of Health, Education, and Welfare; Dr. James Garrett, Acting Commissioner for Research and Demonstration, Rehabilitation Services Administration; and Mrs. Joan H. Miller, Deputy Assistant Secretary for Welfare Legislation, Department of Health, Education, and Welfare.

Mr. GORMAN. Mr. Chairman, may I add one more witness? He is Dr. Robert W. Mann, professor of engineering, MIT.

Mr. BRADEMAS. Fine. Mr. Gorman, I understand you have an opening statement. You may proceed with that, then we shall next hear from Mr. Goldenson.

I am especially pleased to be able to welcome you before the committee as one who has done as much as any American I know to draw this problem to their attention.

Mr. Gorman, you may proceed.

STATEMENT OF MIKE GORMAN, CONSULTANT, UNITED CEREBRAL PALSY ASSOCIATION

Mr. GORMAN. I have a brief statement.

Mr. Chairman and members of the committee, I have a brief statement as the moderator of this panel of the most distinguished experts in the country in the field of the application of technology to the severely handicapped. To list their curriculum vitae would take some 40 or 50 pages, so I will spare the Chairman in that regard.

We are deeply grateful to this committee and to its sister Committee on the Handicapped, headed by Senator Jennings Randolph in the Senate, for their increased attention to research technology and its potential for restoring thousands of severely handicapped individuals to productive living.

In your oversight hearings on this problem last year, Mr. Chairman, you noted that the administration's proposal for research in fiscal 1974 was about the same as the amount appropriated by the Congress in 1972.

We are, therefore, somewhat heartened by the fact that the bill passed by the Congress in September, H.R. 8070, 1973 authorizes $25 million for the current fiscal year and a like amount for fiscal 1975, which begins on July 1, and that the legislation further states:

> There is further authorized to be appropriated for such purpose for each such additional sums as the Congress may determine to be necessary.

The bill also specifies that of these sums authorized, 20 percent in the current year and 25 percent in fiscal 1975, which is of course the last year of the bill, shall be devoted to the establishment and support of rehabilitation engineering research centers to, "develop innovative methods of applying advanced medical technology, scientific achievement, and psychological and social knowledge to solve rehabilitation problems through planning and conducting research, including cooperative research with public or private agencies and organizations, designed to produce new scientific knowledge, equipment, and devices suitable for solving problems in the rehabilitation of handicapped individuals and for reducing environmental barriers."

I will not make too many ad libs, but the top amount we can receive is $6 million under the 25 percent formula for fiscal 1975.

However, since the final appropriation for research was only $20,596,000 for the current year, there is only approximately $4 million available this year for rehabilitation engineering research centers. Several witnesses on this panel here today are directors of these centers, and they are in a position, a much better position to testify to the crippling inadequacies of these appropriations.

We were therefore stunned, Mr. Chairman, when Mr. James Dwight, the administrator of Social and Rehabilitation Services, appeared before the House Appropriations Committee last year—that was on the general supplemental—and testified before Chairman Flood that, "there is some question as to whether the level that is required by the law can be effectively utilized." He was there talking about the $4 million. That has caused us anguish and I am taking more sleeping pills. There are only five rehabilitation engineering research centers in existence at the present time, and last year they were awarded the staggering sum of $1.7 million in a total vocational rehabilitation budget of approximately $700 million.

Mr. Chairman, I believe that this panel will prove to your satisfaction that there is a tremendous fund of technological know-how which can be applied to the rehabilitation of the severely handicapped. For example, many of the witnesses here today have worked on an informal basis with the National Aeronautics and Space Administration. For example, cooperating between technology and medicine, in a recent memorandum to Dr. Howard Rusk, who is the god of rehabilitation and rightly so, Dr. Theobald Reich put the thrust of these problems in a nutshell when he wrote about areas where NASA technology could be applied right now in a number of projects which he listed. I cannot go into a long list but just to quote one paragraph:

> Suitable technology for solution of all of these problems exists in the NASA coffers. The difficulty is that NASA has not developed the personnel who can translate technological know-how into the biomedical setting * * * NASA is woefully unaware of what is needed in the biomedical domain, and on the other hand, biomedical scientists and clinicians have too little knowledge of what NASA has to offer. The existing method of disseminating information is dilettantish and totally ineffective. It seems to us that better communication between NASA and the biomedical community is necessary and that one way to accomplish this would be for biologists and clinicians to survey NASA's technological domain and for NASA to have some of its people exposed to our environment.

Meaning the medical environment.

While this statement is restricted, Mr. Chairman, to NASA, there are so many areas beyond NASA where this can be applied. There is a two-way street between medicine and technology but certainly NASA is an important factor in this problem.

We, therefore, applaud your 1973 committee report on H.R. 8070, which requires the Secretary of HEW to, "conduct a comprehensive study, including research and demonstration projects, of the feasibility of methods designed to prepare individuals with the most severe handicaps for entry into programs under this act who would not otherwise be eligible to enter such programs due to the severity of their handicap, and to assist individuals with the most severe handicaps who, due to the severity of their handicaps or other factors such as their age, cannot reasonably be expected to be rehabilitated for employment but for whom rehabilitation could improve their ability to live independently or function normally without their family or their community." That is from the committee report of 1973.

Mr. Chairman, we are aware of the fact that the present Vocational Rehabilitation Act will expire in fiscal 1975, and that the research allocation in the present bill is limited again to only $25 million, but with the proviso previously referred to, that the Congress in its wisdom can appropriate such additional sums as it deems necessary. We, therefore, propose that in the new legislation which you are contemplating, and you have to contemplate it pretty soon, that the authorization for research be doubled, that is a modest estimate, to at least $50 million a year with an appropriate percentage allocated to the rehabilitation engineering research centers.

We also respectfully urge that language be included in the new legislation requiring that the Rehabilitation Services Administration be mandated to use the contract and grant mechanisms to carry on collaborative projects with the National Aeronautics and Space Administration with strong input on the technological side. Thus we are confident that we will bring about a new day for thousands and thousands of our severely handicapped citizens.

Thank you very much.

Mr. BRADEMAS. Thank you very much, Mr. Gorman.

We shall now hear from Mr. Goldenson.

STATEMENT OF LEONARD H. GOLDENSON, PRESIDENT, AMERICAN BROADCASTING COMPANIES, INC.

Mr. GOLDENSON. Mr. Chairman and members of the committee, my name is Leonard H. Goldenson. I am chairman of the board and chief executive officer of American Broadcasting Companies, Inc., and cofounder and chairman of the board of United Cerebral Palsy Association.

UCP's interest in technology applied to medicine started in 1971 quite by accident. My wife sat next to Dr. Lee Arnold, an advisor to NASA in the space program and the chairman and professor of the Department of Aeronautics and Astronautics, New York University. She complained about the lack of development in wheel chairs and the whole field of orthopedic equipment. He stated NASA had developed a lunar walker originally in their space program because they felt man couldn't walk on the lunar surface, but abandoned this idea later. He said, however, we should look at the lunar walker developed by Aerospace Lab at Downey, Calif. We flew out to see it. A young boy of 12 took this 8 by 6 foot mock-up lunar walker up stairs, down stairs, through mud, over rocks, through sand and shallow water. We immediately felt if, through research, this could be put into a miniature form for a handicapped person, we could free millions of handicapped and elderly people who had become immobile, get them out of their bedrooms and out into society.

We talked to the Secretary of Transportation, Mr. Volpe, about this. He said if this could be accomplished they would put hydraulic lifts in buses and even trains, so all such handicapped could truly get out into society and perhaps even earn a living instead of being public charges or a burden on their families.

Dr. Arnold then suggested United Cerebral Palsy should send him out to NASA's Ames Research Center at Moffet Air Base, Calif., to see what other developments had been initiated by NASA that could be used for the handicapped.

Upon returning, he suggested there were many developments that should be investigated and suggested United Cerebral Palsy sponsor a conference inviting NASA, Veterans' Administration, Health, Education, and Welfare, National Institute of Health, Department of Defense, Department of Transportation, Housing and Urban Development Department, National Science Foundation, Academy of Science, Academy of Engineers, MIT, Harvard Medical School, Duke, California Tech, Stamford, and a total of 14 other leading medical and scientific universities.

After talking with NASA they said they would like to jointly sponsor such a conference with United Cerebral Palsy. This was held on September 8–10, 1971 attended by approximately 80 doctors and scientists. Out of this conference developed many exciting possibilities. Here are but a few.

First, as you know, if a brain failure occurred to an astronaut on the Moon, it is possible to control that astronaut from Mission Control Center in Houston. This is the master and slave technique developed by NASA. If a person wearing a similar space suit in Houston moves his arm in any direction, or makes any number of movements, the astronaut on the Moon would have to do exactly the same.

This technology gave rise to the possible development of a lighter moon suit, which could be used by a therapist. Let's say that 50 people, who have suffered strokes, were put into similar suits. As a therapist moved her arm, all 50 people would involuntarily have to do the same, though voluntarily they could not. Or, when she moved a leg, they would all follow involuntarily. Thus, paraplegics, people who have suffered strokes, cerebral palsy, or infantile paralysis victims, arthritic victims or those with other nervous disorders could all receive therapy from one person.

In the discussions, it was suggested that it might be feasible to program each individual with his own computer. As an example, if the right leg was paralyzed, a formula could be put into the computer which, when a button was pushed, would cause that leg to go forward.

The only problem would be one of stabilization. This is the same problem the Wright Brothers encountered when they first flew an airplane—that of keeping it from flopping over. Through research, therefore, scientists would have to find a stabilizing force to prevent the person from falling over when stepping on a paralyzed leg. This, the scientists at NASA felt, could be overcome with research.

Another example was an electrode implant when the kidneys became paralyzed. This causes euremic poisoning and certain death within 48 hours. As a result of research, however, it is now possible to implant an electrode at an appropriate level of the spine and kidney. By pushing a button this activates a small transmitter. This in turn activates the implanted electrode causing the bladder to function.

It is also felt an electrode can be placed near the ocular nerve in the brain enabling a totally blind person to see light and shadows.

There are many other NASA discoveries to help the blind (such as the opticon), the handicapped and the stone deaf which will revolutionize their lives. I am sure this will be covered by other witnesses today.

The amount of $35 billion was spent on research to get men to the moon. It seems to me only logical that an additional amount of money, whether it be $1 or $2 billion, should be invested to further NASA's research to make many of these things available to those on earth. The public would then begin to appreciate the space program for its impact would be felt by over 10 million families in this country.

In addition, as I understand, it costs about $65 billion annually to maintain the 10 million handicapped in this country. If we could make many of them self-sufficient as suggested here through research we could cut that maintenance by billions of dollars. I would think this is a good investment on the part of our Government.

One of the big problems in having NASA pursue these medical technological research programs is cutting across Government agency lines. When we first brought up the idea of the conference at Ames, the National Institute of Health was not even aware of the medical technological research being done by NASA. The Department of Transportation, as an example, probably has the responsibility not only for mass mobility but individual mobility. If the lunar walker is to be developed in a miniature form for use by the public in their homes, the expertise to do the research is at NASA. It would appear to me it should be mandatory that the Department of Transportation and NASA should be forced to work on this together.

It would also appear that the National Institute of Health and NASA should be working hand in hand. Certainly the doctors would have to get their guidance in technology from NASA and from other scientific schools, of course. By the same token, NASA should get their medical input from the National Institute of Health as to their needs. I dare say the Department of Defense has researched many areas of technology that might be applicable to medicine, but here again I am sure the Department of Defense operates in their own ivory tower but I am sure would be delighted to cooperate with the National Institute of Health or the Department of Health, Education, and Welfare if the proper liaison could be set up between these Government agencies.

I might be presumptuous in making these suggestions, but it appears just good common sense and good business for this committee to recommend the machinery to enforce this crossover between Government agencies.

In closing, Mr. Chairman and members of the committee, I take the liberty of expressing my admiration for your display of humanity, your farsightedness and openmindedness in initiating this hearing. The merger of technology and medicine, by utilizing some of the discoveries of NASA and other scientific schools, is truly the frontier of the future. A firm commitment by the Congress is essential to effectively implement the research already started by NASA so as to make it available and applicable to the handicapped. I firmly believe we have it within our grasp to make fantastic strides forward in the very near future through such research.

Thank you very much for bearing with me.

Mr. Brademas. Thank you very much, Mr. Goldenson and Mr. Gorman, for two very exciting and informative statements. I say exciting because they make a serious attempt to enable us to cope far more effectively with the problems which affect hundreds of thousands of handicapped people.

I would like to think it may prove to be the case that our discussions here may stimulate interest across the country and in the Congress as to the needs of the handicapped.

Let me put some questions to you both, if I may. I was struck by the statement, Mr. Gorman, in your paper where you quoted Dr. Reich who is with us this morning, as stating NASA is woefully unaware of what is needed in the biomedical domain and on the other hand, biomedical scientists and clinicians have too little knowledge of what NASA has to offer.

Mr. Goldenson, you made a similar point when you remarked that when the proposal to have a conference at Ames was launched, the National Institute of Health was not even aware of the technology work being supported by NASA.

I wonder if you have suggestions as to how we can link NASA and the medical community?

Mr. Gorman. I will take a brief shot at that. We did talk and had a number of meetings with persons at NASA. I was astounded that they had no knowledge of many medical developments. Then on the other hand, the medical community has no knowledge of what the technological community is doing. There is absolute polarization, the feeling that we are doing our thing, we are over here, you are there, the Department of Defense is over there, you keep your cotton pickin' hands out of our thing.

So that is one of the major thrusts, Mr. Chairman, of what we were trying to say. I hope Mr. Goldenson will say without prompting, because I do not want to prompt the president of ABC to say anything, that in addition to cooperation which I like, along with motherhood and free beer, there be more money allocated to the engineering centers. At the present time there are only five. I think that is the thrust of it and maybe Mr. Goldenson wants to elaborate, particularly the cooperative portion of it.

Mr. GOLDENSON. We went to see Dr. Fletcher at NASA and outlined where we thought there were existing areas in which NASA could concern itself, making their research applicable to humans. He was unaware of this joint meeting we held between the doctors and the technological group at Ames, even though 20-some-odd people were there from NASA. We asked him if he would put down on paper the various things they had in their inventories that could possibly through research be made available to humans. We asked him first how long it would take to research each of those things and how much it would cost.

I think it is highly desirable this committee get Dr. Fletcher to make such a presentation as to the things they have in their inventory, how long it would take to research them and how much it would cost to do the job. I serve on the Space Applications Board. I was appointed by the National Academy of Science. It was only yesterday I prevailed upon them to have at least one or two doctors sit on this committee. They recognize the very fact that this is highly important and is something they should concern themselves with. Our problem with NASA at the moment is that they are still concerning themselves with satellites and the variations thereof and usage of satellites for various purposes. I think they have a great vista open to them which they really have not concerned themselves with. Therefore, I think it is a stimulation which must not only come from the private sector but from the Congress to get NASA interested in the project.

Mr. BRADEMAS. I appreciate that response because, as my colleagues here know, one of the justifications always given us for voting substantial budgets for NASA is that the benefits of their research can be applied to the problems we have here on Earth. What you said this morning seems to be quite an adamant indictment of the failure of NASA to take seriously this responsibility.

I am aware, as you may be, that in the committee report of this committee on the Rehabilitation Act of 1973, this committee urged the Secretary of Health, Education, and Welfare to cooperate with the National Science Foundation in supporting research under the act. But in view of what you, Mr. Goldenson, and you, Mr. Gorman, have said here today, that NIH, NASA, DOT, and perhaps other agencies of the Federal Government all have some support activities which might make an impact on handicapped programs it seems to me we may well have to consider dropping sermons and writing some mandates into the law. These mandates would require the other departments of the Federal Government to talk to each other and to work together. I think it is shocking that NASA has apparently demonstrated so little awareness of what has been going on in these other areas.

Do I take it, to put my question more bluntly, Mr. Gorman, that what I have just suggested is what you had in mind in the final paragraph of your testimony? That is, that language be included in the new Rehabilitation Act to require that the Rehabilitation Services Administration be mandated to do collaborative work with NASA, with strong input on the technological side. I should think it would be well to make that a two-way street and not confine that requirement to NASA, but other Federal agencies as well.

Do you have any comment on that?

Mr. GORMAN. Since the meeting Mr. Goldenson and I had with Dr. Fletcher when we presented the problem last December, or whenever it was, I have talked to I do not know how many people at NASA. I feel I am a qualified astronaut from the number of telephone calls I have made over there to NASA.

I do not want to use the word "runaround" or the word "indifference," but some of the people over there said, "Our budget used to be $5 billion and now we are down to $2 billion or thereabouts and people are saying why are we spending so much money on space shuttles and Soyuz."

They were telling me they had a public relations problem. I suggested they should show people they are doing other things than just presenting space spectaculars. I think, Mr. Chairman, that is at the heart of the problem. I am sorry to say this but I think they have to be mandated to cooperate.

Except for Dr. Berry, there is nobody else who showed any real interest there. Maybe this should be off the record, Mr. Chairman, but I am a very unwise Irishman. If I would show you what they sent me as to what they could do, I would not want to see it in the printed record. It was done by fourth echelon people who said, "You just toss off something because he has written a letter and he went to see Dr. Fletcher."

So when Dr. Barry came back from Houston, I told him that I had gotten two Mickey Mouse memos which said nothing about the enormous potential of NASA, such as Mr. Goldenson referred to. He looked at these things and called me back and said, and I think I can quote him directly, he said, "Oh, my God, is that what they sent you?" I said, "It said NASA at the top of the letterhead."

He was busy with Skylab at the time, which really tied him up. So we really have gotten nothing further from them. I thought a long time before using the word "mandate," but I see nothing else. I have made the effort, made the trips over there, have talked to everybody over there. On the one hand, they say, yes, we want to apply what we know to humans, we are in desperate need for a better public image. It can be noted that the last splashdown of Skylab, Skylab 2, it was mentioned by the NASA people, I did not mention it, they mentioned it was not covered on television. I said, "Here is a chance to show that you care and that you can use your technological knowhow and it is in the law."

Mr. GOLDENSON. I believe, Mr. Chairman, if I may, that NASA is so oriented to the utilization of satellites to determine what is on the ground, the minerals that lie beneath, the determinaion of meteorology, the determination as to agricultural development and things of that nature that they just are not oriented. They could get somebody in NASA that I would say had been schooled in this biomedical field to really stimulate them from within. I think that is highly important. Perhaps Dr. Fletcher should be brought before this committee and let him tell what they have and why that should not be utilized. I think they must be stimulated.

Mr. BRADEMAS. I just have one more question before yielding to my colleague from California. You observed there are only five rehabilitation research centers. Could you give us some idea as to the combined budgets and how much they could effectively use in the way of funds?

Mr. Gorman. We have two directors of the five centers here today, and they would be in a much better position to give you that information. They certainly could use more money.

Mr. Brademas. We are very glad to have sitting in with us a Member of the House of Representatives, Mr. Clawson.

Mr. Clawson. I have no questions, but I came here as an interested party. That is the reason I am here. I hope to make the appropriate introduction for a very distinguished constituent of mine.

Mr. Brademas. Thank you very much, Mr. Goldenson and Mr. Gorman. Your testimony has been very illuminating, and I would like to think it will be effective.

We shall next hear from a panel of seven physicians and engineers. I would suggest if the witnesses who are coming forward at this time have colleagues with them, that they bring their associates with them and arrange yourselves along the table.

The panel consists of Dr. William Berenberg, Dr. James Reswick, Dr. Erwin R. Tichauer, Dr. Theobald Reich, Dr. Irving S. Cooper, Dr. Robert Mann, and Myron Youdin.

Dr. Berenberg, why don't you go right ahead.

STATEMENT OF DR. WILLIAM BERENBERG, PROFESSOR OF PEDIATRICS, HARVARD MEDICAL SCHOOL

Dr. Berenberg. Mr. Chairman and members of the committee, I am privileged to appear before you in support of the need to apply space-age technology for the alleviation and rehabilitation of the severely handicapped. I have had a professional lifelong concern for the handicapped, dating back to my participation in the care of poliomyelitis victims since 1945.

Officially, I do represent the United Cerebral Palsy Association as its vice president for medical affairs and chairman of its Research Advisory Committee. It is a voluntary health organization concerned with the affliction of cerebral palsy in approximately 1 million individuals in this country.

As a past president of the American Academy for Cerebral Palsy, I can speak for the concern of the medical profession who have labored. often with frustration, toward improving the lot of the severely disabled. As a member of the Committee on the Handicapped Child of the American Academy of Pediatrics, I can assure you that the pediatricians of this country share in this vital concern for the severely disabled child.

As the project director of the Harvard Medical School component of the Harvard-Massachusetts Institute of Technology Rehabilitation Engineering Center, I can give testimony to the commitment of both of these institutions to gather every possible source of energy and expertise in a collaborative effort toward achieving the goal of maximal habilitation of the child and rehabilitation of the adult disabled.

I pause to point out there are those who really need to be rehabilitated because they never have been able to do things, and there are others who need to be rehabilitated because they once did and no longer can.

If the Chair would permit, not only in the interest of time, but in the interest of avoiding repetition, may I depart from my written testimony and address the committee informally?

Mr. BRADEMAS. Yes, and I would be grateful if your example could be followed by each of your colleagues. If you would try to summarize all of your statements, then all of them will be included in the record. That would be helpful.

Dr. BERENBERG. I am deeply aware of the problem. We are all concerned, and I would not again reiterate the huge numbers of handicapped in this country. I know these figures are familiar to you.

I would, however, want to emphasize that we are dealing with a growing problem, not a shrinking problem. Medicine is a peculiar profession. Every once in a while we are lucky enough to have a poliomyelitis virus vaccine or German measle virus vaccine and thereby eradicate the disease in one fell swoop.

I am sure we are seeing more paraplegics returning from Vietnam than from other conflicts. The increased skill of the surgeon, of taking a man riddled with machinegun bullets and taking pieces of his liver out to protect his life, or getting into his heart to get a bullet, all of that has developed so much. We have this growing pool of people that have to be dealt with.

A number of years ago, a great number of cases of retardation were prevalent. These resulted from problems in RH blood grouping. We have almost put that to bed where it is no longer a major problem. But prematurely it is on the increase. The incidence of cerebral palsy, including prematures, increases to 80 percent when you get to children born of 4 pounds or less. We are saving a great number. I think infant mortality is not increasing in this population, hopefully. But many of them are going to remain in the population as individuals with whom we must deal.

I have seen in my lifetime a great number of handicapped children, have worked with a great number of medical groups and it has only been recently I have had a chance to get in and talk to the medical engineers. But we are beginning to communicate. We are anxious to work together. I hope that others will join in the development of the opticon.

Mr. Goldenson made a comment this morning about the spinal cord. Let me expand on this for a moment, if I may. Most of the paraplegics in the Veterans' hospitals, most have spinal cord injuries of those who are in bed today. They are eventually not going to die because of being a paraplegic but because of urinary bladder control and the reflex action in the kidney. When I see the potential and see physicians working with engineers who look as though they are about to solve this problem, it becomes an awfully exciting possibility.

I can name other needs. But I would like to turn the technical end, the biomedical presentation of my presentation over to Dr. Mann.

[The prepared statement of Dr. Berenberg follows:]

STATEMENT OF DR. WILLIAM BERENBERG, PROFESSOR OF PEDIATRICS, HARVARD MEDICAL SCHOOL

Mr. Chairman and Members of the Committee:

I am privileged to appear before you in support of the need to apply space age technology for the alleviation and rehabilitation of the severely handicapped. I have had a professional life long concern for the handicapped dating back to my participation in the care of poliomyelitis victims since 1945. Officially, I do represent the United Cerebral Palsy Association as its Vice President for Medical Affairs and Chairman of its Research Advisory Committee. It is a voluntary health organization concerned with the affliction of cerebral palsy in approximately one million individuals in this country. As a Past-President of the American Academy for Cerebral Palsy, I can speak for the concern of the medical profession who have labored, often with frustration, towards improving the lot of the severely disabled. As a member of the Committee on the Handicapped Child of the American Academy of Pediatrics, I can assure you that the pediatricians of this country share in this vital concern for the severely disabled child. As the Project Director of the Harvard Medical School Component of the Harvard-Massachusetts Institute of Technology Rehabilitation Engineering Center, I can give testimony to the commitment of both of these institutions to gather every possible source of energy and expertise in a collaborative effort towards achieving the goal of maximal habilitation of the child and rehabilitation of the adult disabled. We do have the conviction that innovative application of advanced medical technology can be successfully applied towards solving these problems through cooperative research. As the Medical Director for the Children's Hospital Medical Center of Boston's Unit for Cerebral Palsy and the Chairman of its Committee on Rehabilitation and Handicapped Children, I can assure you that, that Hospital shares in its commitment towards the same objective.

The scope of the problem is broad and includes many disabilities under its broad umbrella. Among others, it includes individuals afflicted with cerebral palsy, mental retardation, learning disabilities, birth defects, muscular dystrophy, multiple sclerosis, head injuries, spinal cord injuries, brain tumors, strokes, spinal cord defects and myelomeningocoele, amputation—both congenital and acquired, blindness, deafness, paraplegia, arthritis, a variety of traumatic injuries, and the multiplicity of degenerative diseases of the elderly.

In the past, medical research and its applications have resulted in the conquest or near conquest of a number of conditions resulting in severe disability. One needs only to look towards the isolation of the poliomyelitis and German measles viruses along with the subsequent production of effective vaccines to appreciate the major reduction in the toll by the near elimination of poliomyelitis and the hopeful erradication of German measles in pregnant women and its ravages in their offspring. In the past, difficulties resulting from incompatibilities in the Rh blood group resulted in one third of all of the cases of cerebral palsy in the country. Today, the spectre of this disease as a cause for cerebral palsy has been reduced from 30% of the cases of cerebral palsy to 1% or less.

Despite these achievements, the numbers of individuals in this country with severe disabilities, continues to grow and even increase. Let us look at cerebral palsy as an example of this enigma. Thirty years ago, the incidence of cerebral palsy in this country was one per one thousand surviving live births. Despite the fact that the solution of the Rh problem all but eliminated one third of the patients with cerebral palsy, we are faced with an incidence of approximately one per 750 infants who survive after birth. The explanation develops when we examine a number of other contributing factors. Premature birth, today, accounts for at least one third of patients with cerebral palsy. The incidence of cerebral palsy rises to 80 per 1,000 surviving live births in those children born with birth weights below four pounds.

The success of fertility experts has resulted in the large number of women being able to conceive and give birth to children but a significant percentage of these pregnancies still result in premature delivery. The improved ability of the physician in the care of the newborn has resulted in a significant decrease in the mortality of newborn infants but the morbidity associated with prematurity rises along with this success story. This is not to be deplored since we must remember that although 80 out of 1,000 prematures will be afflicted, the remaining 920 will be normal individuals who would not otherwise be with us. However, the disability in that 80 per 1,000 remains as a group not only to be prevented but also to be helped. Thirty years ago, no one with tuberculous meningitis ever went on to develop severe disability since all of these patients died. Today, almost all will survive, but a significant number may remain severely disabled. Sometimes, medicine makes progress with a giant step such as the poliomyelitis vaccine and on other occasions, it makes progress one step at a time.

The increased number of automobile accidents has also served to increase the number of patients suffering from brain and spinal cord injuries adding a further dimension to the pool of the severely disabled. With recreation explosion and the advent of backyard pools, we witnessed a dramatic increase in the number of drownings and near drownings. The latter are frequently associated with residual massive neurologic disability.

Medical and surgical skill has advanced to the point where we now are able to deal successfully with the life and death problems of numerous traumas. Many of these individuals would have died in years past, but today we are able to operate successfully or treat successfully. On the other hand, too often there are near successes with residual disabilities. Numerous soldiers and some unfortunate civilians have suffered from bullet wounds which would have been fatal in the years past. Today, we have a huge number of paraplegics and serious spinal cord injuries as the residual of such insult.

These examples and numerous others have in great measure increased the number of severely disabled individuals in the country who deserve and require new, innovative, and different approaches to their problem as well as continuation of the existing methods of treating it.

I have the deep conviction that the sciences of medicine and engineering working together have the potential for providing much of the help which is so urgently required.

The two sciences will need to develop a vocabulary of understanding, a collaborative team approach and work together towards translating technology into clinical care for the severely disabled. I have yet to meet a physician working with the disabled who is not totally anixous to participate with the engineering sciences and all of my recent contact with members of the engineering community convinces me that the same attitude prevails there. It is inconceivable that an all out effort on the part of both groups will not result in a large number of important and meaningful aids for the severely disabled.

We already have witnessed a number of such exciting advances and I do hope that time will permit a description of many of them.

The Optakon is a device which permits the blind to read through vibratory tactile stimulation of the skin. With this newly designed instrument, we have seen blind people who can read between 80–100 words per minute. It permits the blind to read the telephone book, today's newspaper and the typewritten letter. A great number of spinal cord injury paraplegics will die because of paralysis of their urinary bladder and subsequent retrograde reflux resulting in kidney disease and infection. Implants have been carried out experimentally which place minute electronic devices into the spinal cord below the level of injury and on radio signal will result in complete emptying of the bladder in a controlled fashion.

The dramatic development of prostheses such as the Boston arm, is a prime example of the success for which so many of us yearn. New orthotic developments are available which hopefully will do away with the very heavy and antiquated mechanical braces used by so many disabled individuals. The newer materials are much more attractive, comfortable by comparison and very light weight. The basic design of the wheel chairs has not altered in many decades and is in striking need of revision to include changes in weight, mobility and the development of power driven systems. There is a crying need for new systems which will permit the deaf to hear and especially those with nerve deafness for whom hearing aids are not applicable. The speech and mobility problems of stroke victims as well as the children with cerebral palsy are multiple and hopefully capable of solution. The list of examples of accomplishments to date and the long list of needs for the future is indeed so long that I shall not enumerate them at this time.

I am pleased to introduce my distinguished colleague from the Massachusetts Institute of Technology, Professor Robert Mann, who is the father of the Boston arm and widely recognized as one of the world's foremost experts in the field of Rehabilitation Engineering. I do hope that Dr. Mann will have the opportunity to address this committee and that you may wish to call on him for answers to specific questions.

The advanced technology which was capable of sending man into space and at the same time monitoring and controlling his body movements and functions must be applied towards the welfare of the severely disabled here on earth. In

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many instances, this may require adaptions of what has already been designed and in other instances, it will require research and new clinical applications. There already exists a pool of interested and trained individuals but there is major need for training of other individuals who work in this same area. Research will require significant support at both a basic as well as applied level. Contracts will need to be issued towards goal oriented objectives. The rehabilitation engineering centers deserve and require expanded resources in order to achieve their objectives.

The millions of disabled individuals in this country look to you for help. The scientists stand ready to participate. I have no particular knowledge of economics but do have the belief that apart from the humanitarian aspects of the problem, the economics hopefully will be such that many severely disabled individuals currently requiring financial support by the government will be able to return to gainful employment and will become productive and taxpaying members of society. The problems are multiple and many but a great number of the goals can be achieved. I have every confidence that with the medical profession and the engineering sciences working together, solutions to many of the problems of the severely handicapped are in sight, if adequate and appropriate federal funding is made available.

Thank you very much.

STATEMENT OF DR. ROBERT W. MANN, PROFESSOR OF ENGINEERING, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Dr. Mann. I appreciate the opportunity to make a few remarks and I will attempt to make them very brief and compact.

I am very sympathetic to the comprehensive view that Mr. Goldenson presented as to the urgency and necessity of coupling the high technology components of our national system as exemplified in NASA, DOT, et cetera, any area of technology as it relates to the physically handicapped. I say that as a consultant and a grant recipient from all those agencies, NSF as well and I say that as a career engineer educated on the GI bill from a vocational high school as a result of the Second World War, and I say that with the, hopefully, appropriate humility.

The gut issue as I see it is, in order to do effective technology, to rehabilitate humans, one must create an environment in which knowledgeable goal oriented physicians, engineers are brought together in an appropriate clinical environment. This is so there is a clear understanding of what the human goals are and the sources needed in the attainment of these goals.

I am interested in NASA and their exploitation of space satellites. I do not want to impair that, but I would also like to see them work in areas related to human rehabilitation. They will not be able to do that if they do not involve themselves with physicians and patient populations that are germane.

The heart of the centers involved in the rehabilitation services program under H.R. 8070 is in fact that principle of bringing together the engineers and physicians in the appropriate clinical context to understand what the problems are and address them in a direct and forthright way.

I thought I would complete my remarks with just a few succinct examples. I want to illustrate the relatively primative state in which technology can even now be brought to bear on this problem of rehabilitation.

About a decade ago, I became aware of some very sophisticated investigations which determined that blind persons mobile with a long cane, had great difficulty with the shabby, non-durable collapsible canes which were then on the market and still are. Utilizing some of the technology available to them, NASA developed this collapsible cane which is now on the commercial market. It has become the most popular cane used by blind persons. We became aware, through the Director for the National Center of the Deaf and Blind, of the severe communication problems encountered by deaf and blind persons. They do not have the benefit of speech, sound, signals, nor do they have the benefit of individual signs, the lights, the information which comes from their visual senses.

For the workshop and residences of the National Center for the Deaf-Blind on Long Island, N.Y., the MIT Sensory Aids Evaluation and Development Center developed the TAC–COM communication system. Smaller than a pack of cigarettes, the device is carried in a shirt pocket or apron of a deaf-blind person. This personal, portable receiver is coupled electro-magnetically to a localized radio transmitter arranged to transmit coded information in the workshops for coffee breaks, shift bells and the paging of individuals and in the residences for door bells, oven timers, et cetera. When the radio link is activated the personal receiver vibrates very vigorously, thereby communicating to the deaf-blind person through the cutaneous sense, one of the few remaining sensory channels available to the deaf-blind individual.

A cane only reaches a step or two ahead. A blind person ought to be able somehow to be the beneficiary of technological work in radar and sonar, which we all know makes it possible to land planes at Dulles under zero–zero conditions. It also makes possible the location and identification of underwater hazards.

Here are a couple of devices which have been developed. Here is a sonar detector carried by a blind person which provides him with audible cues as to obstacles in his path which might be beyond his ability to reach with a cane. The technology is not nearly as sophisticated as it could be. This could be made pill size if the technology skills and know-how at NASA were brought to bear.

Here are the so-called sonic spectacles. There are two receivers for the left and right field of the traveler, which are fed into their right and left ear. Differences in the amplitude or loudness of the reflected signals provide clues on the direction from which the reflection originated. With head motion, both left and right and up and down, a wearer of these sonic spectacles can search his environment and establish the position and distance to objects of interest, or obstacles in his path. In my view, as a career engineer, they could be much more effective and applied to a much wider range of blind persons.

Let me complete my remarks by making a statement as to the reading problems of the blind. The Opticon is a contribution from California, a product of Stanford University. It permits a blind person using a lipstick-case-size camera in one hand, which he or she passes over copy with one hand while the index finger of his opposite hand lies in a cradle in the device where it is stimulated by an array of vibrators. These vibrators generate a facsimile of the printed materials scanned by the camera. Blind persons after reasonable instructional time learn to interpret the patterns and with this experience increasing their reading speed and competence. By this technique, the blind person has direct and immediate access to printed and written material, to television displays, to instruments, to charts and graphs and what have you. It is a superb example of how technology can be brought to bear on the problem when a problem is defined and when there are committed technologists in association with clinical people who work intimately and collaborate with motivations.

I hope I do not embarrass her, but there is a young lady blind who, with enormous facility, is taking notes in braille of the discussions of this hearing. Now, I do not want to go into a long dissertation on braille, but the task she is performing is extraordinary. Braille to begin with is a code. It is a foreign language. So she is translating from English to braille. The combinations, one by one, are punched onto paper with a stylus, because she can only make dots that go in, she has to make those braille figures upside down and backwards. She is Leonardo da Vinci, if you will, in braille. There is no reason in the world why that lady could not be provided with a cassette recorder which with a few convenient keys would permit her to take that recording like the stenotypist over there. The technology to do that exists.

We really need the will to apply and the REC concept is a way to go and a primary way to go, because it forces a configuration, a constellation of technologists and clinicians grouped around client oriented problems and I very much appreciate the opportunity to speak.

Thank you.

[The prepared statement of Dr. Mann follows:]

TESTIMONY OF DR. ROBERT W. MANN, PROFESSOR OF ENGINEERING, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

"The application of technology to specific rehabilitation goals for the severely physically handicapped is in its infancy but there are already clear indications that 'rehabilitation engineering' can make handicapped persons capable of activities heretofore impossible. By means of these aids the self-reliance and self-respect of physically impaired persons is enhanced, employment possibilities increased, and they become less dependent on others, and/or the society.

For the purposes of this discussion I will limit my examples to cases within my experience where technological feasibility has progressed to the point where clinical applications are in progress with very positive indications of the prospects for successful wider-scale application.

Let me first comment on recent developments in artificial limbs for amputees. The radical improvement here is the coupling of information resident in the human's normal biological system to the command of an artificial joint. The 'Boston Arm' elbow prosthesis has shown that bioelectrical information naturally associated with the contraction of skeletal muscles can be used to continuously and proportionately control the machine manipulating the artificial joint.

A program at the Massachusetts Institute of Technology and the Massachusetts General Hospital supported in part by the Social and Rehabilitation Service and the Liberty Mutual Insurance Company has demonstrated the feasibility of this concept and has produced several design iterations resulting in an elbow prosthesis fitted to several score of amputees. This limb has been enthusiastically accepted and routinely used in normal everyday life and in a variety of vocational situations over periods as long as several years. This example of "rehabilitation engineering" would not have occurred without the close and continuing collaboration of engineers, physicians and prosthetists utilizing the full resources of premiere technological and medical institutions, coupled with the interest and support of both the federal government and private enterprise.

The techniques demonstrably successful on the elbow are now being shown in the laboratory to be equally applicable to much more complex prostheses for the upper extremity, replicating the many possible motions at the shoulder, elbow and wrist. Another investigation at M.I.T. coupling the remnant muscular, and therefore bioelectric activity, in the leg amputee's stump to a knee prosthesis is likewise demonstrating, thus far in the laboratory, the synergism which can be created between a human and a prosthesis machine.

Research in our laboratories and elsewhere is also demonstrating the necessity for, and techniques whereby, the amputee can sense touch, warmth and force through transducers on the machine which communicate in an intelligible fashion to human sense organs and thence to the central nervous system. These advanced prosthetic research investigations demonstrate both the feasibility, and the achievability of cybernetic prostheses which link the human and the machine in an intimate fashion with the human central nervous system communicating naturally and directly to the machine and the machine in turn feeding back sensory information into the human.

The research results and practical demonstrations of devices for amputees is relevant to other areas of severe physical handicap. Trauma, disease and/or congenital defects deprive humans of motor control via muscles and of sensory feedback from the extremities and from both. The spinal cord injury victim—quadraplegic or paraplegic—the hemiplegic stroke victim, the cerebral palsied infant or adult, the spastic child, all these and others will benefit from the merging of technology and human rehabilitation.

Humans deprived of that overwhelming source of sensory information—vision—are being significantly helped today by technology applied to the specific goals of sensory aids for reading and mobility.

One truly dramatic device, as portable and convenient as a cassettte tape recorder, provides the blind person direct access to the wealth of written, printed, and graphical material which normal humans utilize every day of their lives. Books, magazines and newspapers become directly and immediately readable without an intervening human reader or a translation process into braille or recorded speech. The privacy of certain communication is maintained since the blind can read their personal correspondence, their bank balances, bills, etc. Forms of 'reading' so routine to normal humans, such as determining the value of currency, reading can labels in a supermarket or on the pantry shelf become manageable for severely visually impaired persons.

The 'Optacon' (OPtical to TACtile) reading device utilizes a miniature lipstick-case-sized 'camera' which the blind person scans over the copy with one hand while the index finger of his opposite hand lies in a cradle in the device where it is stimulated by an array of vibrators. These vibrators generate a tactile facsimile of the printed materials scanned by the camera. Blind persons after reasonable instructional times learn to interpret the patterns and with experience increase their reading speed and competence. Some five hundred Optacons are now in use world-wide, contributing to the education of students, strengthening the occupational competence of computer programmers and others, and in general giving the blind person a 'new window' on the world.

Text reading rates for the Optacon are relatively low compared to visual reading or speech ; the best subjects are approaching 100 words per minute compared to say 180 words per minute for normal speech and up to several times that for fast visual reading. But the vital, qualitative difference is that with this device the blind person previously completely cut-off from his own personal, direct acquisition of information now has that door opened again. Technology made this possible.

The program which developed the Optacon was centered at Stanford University. Motivated by the needs of his blind daughter, Professor John Linvill, head of the electrical engineering department, and James C. Bliss, engineering student at Stanford and M.I.T., and later collaborator with Linvill at the Stanford Research Institute, with substantial support from the U.S. Office of Education, applied the sophisticated electronic technology and human perceptual studies to the creation of this new capability. Without these knowledgeable, skillful and enlightened technologists, familiar with the clinical problem, and immersed in an environment with resources capable of applying the finest 'state of the art' in engineering the rehabilitation promise of this remarkable device would not exist.

Braille, the embossed paper matrix sensed with the fingertips, has been, along with recorded speech, the primary access of the blind to the world of print. While the Optacon provides direct access to print while braille and speech required the intercession of other humans, braille will continue to be a major information source to the blind due in part to the increase in reading speeds of two or more which braille permits.

Up to fairly recently, the process of translating ink print copy into braille symbols was performed exclusively by specially trained human translators. However, over the last decade research exploring the feasibility of computer translation of English into braille has progressed to the point where now several organizations routinely employ this automated technique to supplement the trained braille translators.

Efforts, primarily at M.I.T., the MITRE Corporation, the International Business Machines Corp. and the American Printing House for the Blind in Louisville, Kentucky, have contributed to the development of computer programs for the translation of English into braille equal in quality to, and extraordinarily more responsive to reader needs than that produced by human translators. Of a number of organizations utilizing the M.I.T. program, the Atlanta Public School system is a good example. Braille readers in the Atlanta area were doubly disadvantaged when the regional branch of the Library of Congress storing braille materials was consumed in a fire. Technology literally came to the rescue in the form of the M.I.T. MITRE program. With support from IBM personnel on the IBM computer used for administrative and fiscal purposes in the Atlanta Public School system, and with help from the Computation Center of Georgia Tech, Atlanta now has a computer-based braille system which meets the needs of the city and surrounding counties with both voluminous and quick service.

Computer programming and computer data management represent a potentially attractive employment field for blinded individuals, provided they have the equivalent of a teletypewriter for computer printout of alphanumeric information. Complementing its braille translation efforts, the M.I.T. group, with S.R.S. and private foundation support, brought into existence a braille producing typewriter compatible and interchangeable with the teletypewriter and other ink-printing computer terminals. With this example of technology applied to handicapping conditions, blind and severely visually impaired students and professionals have competed on a peer basis with their sighted colleagues in computer instruction and on computer applications. Blind M.I.T. students have used the 'Braillemboss' in regular M.I.T. coursework and then have borrowed terminals for summer and subsequent professional employment. Blind computer professionals with NASA, the Department of Transportation, the Internal Revenue Service, university libraries, and computation centers, and even Rolls Royce in England and the Hebrew Braille Institute in Jerusalem have employed this terminal to produce braille copy.

But the utility of this form of technology is not limited to computer professionals. Employment opportunities extend to the broader and more accessible areas of customer representatives for the reservation industries, banking and credit, etc. A typical successful application has been in the Internal Revenue Service where an M.I.T. Braillemboss terminal on the I.R.S.'s regional computer equips a blind person to serve competatively with the sighted as a 'Taxpayer Representative.' When a taxpayer calls the Little Rock, Arkansas office his respondent may be a blind Taxpayer Representative who accesses the I.R.S. computer information bank via a typewriter keyboard and then reads the response via braille on the Braillemboss. The success of this interactive braille program has stimulated the I.R.S. to consider its replication at 50 or more installations nation-wide. The concept has also caught the interest of the Social Security Agency and other potential federal employers of handicapped persons.

As part of our continuing program to demonstrate the feasibility of vocational opportunities, the M.I.T. group is working with the Massachusetts Commission for the Blind in demonstrating how this capability can open positions for blind persons in the hotel-motel, rental automobile, credit inquiry, etc. industries. In short, wherever information is computer stored, organized and retrieved, the existance of a braille producing terminal makes a blind person competitive for employment.

An increasing store of computer-coded information, including for example the by-products of computer typesetting in the publications industry, enhances the prospects for the rapid and economic translation of inkprint into braille. These same automatic processes enhance the use of computer synthesized speech for information transfer to blind and visually impaired and otherwise physically handicapped persons. Computer generation of natural sounding human speech has of course profound economic and commercial implications quite beyond the amelioration of the handicaps of humans with sensory losses. However, interestingly enough, the motivation of some of the most capable researchers in the field of speech synthesis derives directly from the potential for the blind and visually impaired. The group at Haskins Laboratory, affiliated with Yale University, is especially committed to this application. In this era of linkage of computers for commercial purposes and the emergence of cable television as a means of tying together households, it doesn't take much imagination to visualize a regional network using telephone lines and strategically placed computational facilities. Copy presented locally to automatic optical character recognition devices, or selected out of computer-coded type composition files, would be manipulated by the computer and represented at the local site either in braille or as synthetic speech at the behest of the physically handicapped person. Not only the blind, but the deaf and the motor impaired could benefit from variations of such a system. Modestly supported efforts thus far have demonstrated the feasibility of major components of such a concept. We lack but the will and commitment to carry it through.

Mobility ranks with reading as the major problem confronting the blind or visually impaired human. Here again technology, knowledgeably coupled into the clinical needs of the sensory impaired person, is beginning to make significant contributions. Even as simple a device as the long, light, usually white, cane employed by the blind traveller has benefited from a critical technological review. M.I.T. faculty and students, impressed by the utility of the cane as a transmittor of vibrational and textural information from the surroundings to the hand and the arm of the blind traveller, looked to the problem of how to make the cane collapsible, and therefore more convenient to the blind user, while at the same time not sacrificing its vibrational transmission capability, its durability, and its low cost. A student project at M.I.T. followed by a further effort at the M.I.T. Sensory Aids Evaluation and Development Center led to a cane design transfer to industry which has become the standard in the field.

But the technology which reaches through fog and obscuring clouds to successfully land aircraft, or locate and identify underwater hazards or potential enemies surely must be applicable to providing a blind traveller with information about his environment and obstacles beyond the one-step-reach of his cane. Again over the last several years, with modest support in part from the S.R.S., truly significant progress is being made.

The Pathsounder developed at M.I.T. makes it possible for a blind Boy Scout to follow the clear path between trees and shrubs along with his sighted colleagues. This same device mounted on the wheelchair of a legless and sightless veteran permits him to successfully navigate through hospital corridor or home avoiding and maneuvering around obstacles in his path. The Pathsounder floods the travel path with ultrasound above the hearing threshold of the human. The time-of-flight of reflections from obstacles is transformed electrically into distance and stimulates audible or in versions currently under development vibrational, cues which warn the traveller of obstructions up to several steps ahead.

A more sophisticated mobility aid, the Binaural Sensory Aid provides a blind traveller with not only distance information but also generates the azimuth or direction to environmental objects. Integrated inconspicuously into an eyeglass frame, an ultrasonic radiator floods the travel volume with signals at a frequency above the normal hearing limit. Two receivers detect reflections from the left and right fields of view of the traveller. Transformed into the audible range the reflections are presented through small ear phones to the wearer—the left field reflections to the left ear and right field reflections to the right ear. Differences in the amplitude or loudness of the reflected signals provide clues on the direction from which the reflection originated. Thus with head motion, both left and right and up and down, a wearer of these 'sonic spectacles' can search his environment and establish the position and distance to objects of interest, or obstacles in his path.

The Binaural Sensory Aid was developed in New Zealand but the major evaluation and training programs have been centered in Boston, for the last several years at M.I.T. As with the other devices I have described, the sustained involvement of knowledgeable engineers, immersed in a clinical environment suitable for the device under development, is mandatory if these useful devices are to be made widely available.

I'll close this testimony with but one more example of the way in which technology is making contributions to humans with physical losses. Deaf-blind per-

bridge of the nose, and the echoes from objects are received by two special microphones located directly above the miniature loudspeaker. The inaudible ultrasonic signals are converted into the audible frequency range by specialized electronics and are fed to the two ears by miniature earphones located in the temples of the glasses. The blind person hears these sounds and learns to recognize certain features of his immediate environment.

The sounds heard from the device depend upon the location of objects relative to the user. If there are no reflecting objects within the illuminated area, the device is silent. Each object that creates an echo creates an almost continuous tonal sound in the earphones, with a frequency (or pitch) that depends upon the distance. For example, an object at a distance of 10 inches will produce a signal with a pitch approximately that of middle-C. The frequency will rise by one octave every time the distance is doubled, until the object falls outside the range of detection of the device. As the distance increases the echo becomes weaker because the ultrasound waves spread out and are absorbed by the air. The range of detection depends upon the size and nature of the object, but may exceed 20 feet for large surfaces. Each separate object that is creating an echo will generate its own tonal sound in the earphones, hence several objects may create a chordal effect.

The two ultrasonic microphones are each deflected slightly outwards; one to the left, the other to the right. This causes the sounds produced by an object that is to the right of center to be louder in the right ear, and conversely, for an object to the left the sound is louder in the user's left ear. An object on the center line generates sounds that are equally loud in each ear. This binaural (or two-eared) effect gives the user an impression of the object's direction by the difference in loudness between the two ears, similar to the effects experienced while listening to a stereo recording on a pair of headphones.

Some information as to the gross nature of reflecting objects is contained in the quality or timbre of the sound. For example, a leafy bush will generate a sound that might be described as "mushy", while a window pane gives a clear tonal sound.

The Binaural Sensory Aid cannot detect step-downs or very low hazards in the user's path. For this reason it must be considered to be an adjunct to either the long cane or guide dog. Under no circumstances should it be used as an aid to mobility on its own in congested and unfamiliar areas.

For cosmetic reasons, and to provide a convenient method of wearing it, the device is built into a pair of glasses. A small box, approximately the size of a pack of cigarettes, containing the rechargeable battery and volume control, plugs into the glasses through a light, flexible cable. The battery may be removed from the control box for charging and replaced by another.

The device, in experimental form has been under evaluation in New Zealand, Australia, USA, and England since 1970. Since then more than 200 blind people have been trained in its use and have demonstrated improved confidence in mobility, a greater awareness of the environment; and an enhanced ability to avoid objects in the travel path, to travel in a consistent direction and to locate landmarks.

A production version of the device, shown in its proposed form in the photograph, is currently being developed for general introduction by Wormald-Vigilant Ltd. and will be available for release in mid-1974. This new device will incorporate the recommendations made by instructors and users during the evaluation study.

To ensure that users obtain maximum benefit from the device, it will be introduced only through agencies with personnel who have been fully trained in its use and the techniques of teaching blind clients. Plans are now in progress for courses for orientation and mobility personnel to be held when the new device is released.

For further information: Derek Rowell, Ph. D., Project Director, Binaural Sensory Aid Project, Sensory Aids Evaluation and Development Center, Massachusetts Institute of Technology, 77 Massachusetts Avenue (31–063), Cambridge, Massachusetts 02139; or Russell P. Smith, Ph. D., Manager, Sensory Aids Division, Wormald-Vigilant Ltd., P.O. Box 19545, Christchurch, New Zealand.

Study of Aerospace Technology Utilization in the Civilian Biomedical Field—Final Report—National Academy of Engineering, Washington, D.C.

INTRODUCTION

The overall objective of the Academy effort was to study means by which NASA capabilities may be more effectively utilized to improve the delivery of health care in this country. The study rested upon three assumptions:

(1) Health care delivery could benefit from a more extensive application of technology.

(2) NASA, through the performance of its primary mission, has developed a far-ranging and perhaps unique familiarity with certain technological areas which are related to current needs in the medical profession.

(3) Current efforts by NASA to contribute in health care delivery can be improved upon.

These operating assumptions were, in the view of this Committee, verified during the course of the Committee's work.

THE NASA TECHNOLOGY UTILIZATION PROGRAM

The technology transfer process involves information, devices, technological processes, and technological rationales for problem solving. The latter category includes such things as systems analysis and management and evaluation techniques; that is, schemes for problem definition and for organizing and managing the resources used in developing appropriate solutions.

Historically, there have been two approaches used in NASA's technology utilization program. The first has been characterized as solutions looking for problems. Technological solutions abound within NASA's technological base. In the process of solutions looking for problems, solutions are advertised on a very broad basis in the hope that those having a problem will find an applicable solution. The widespread dissemination of NASA Tech Briefs is an example of this process. Tech Briefs, at most a few pages in length, describe instruments, devices or processes resident within the NASA program. The hope is that somebody with a problem will happen upon the solution by perusing Tech Briefs. Other examples include the Scientific and Technical Aerospace Reports (STAR), the International Aerospace Abstracts (IAA) and the Regional Dissemination Centers, all of which are designed to make NASA solutions readily available; those with problems must come to find them.

The other major approach to transfer is, of course, that of identifying problems first and then looking for the solutions. NASA also has utilized this approach. It has established biomedical application teams, or BATeams, at a few nonprofit research centers around the United States. Staff members of the BATeams attempt to locate problems by talking with people involved in biological and medical research and health care delivery and by continual study of health care delivery processes. Once a BATeam has identified a problem, it uses its knowledge of the NASA technological repertoire to aid in working toward a solution. Early in the program (circa 1969) BATeams often only provided information to the user. Of late, the emphasis has switched to one of providing hardware, including some development when required, to achieve a transfer. NASA also has used other institutions such as university teams (and the Academy), under contract, to identify problems and match NASA technology to potential solutions.

There are several characteristics of the BATeam approach which merit consideration. BATeams attempt to assess the importance of an espoused problem by making estimates of the size of the national patient population that could be benefited by its solution. This estimate is used to judge the merit of supporting the transfer with additional investment of NASA resources. In the analysis, however, certain key questions are not addressed: Will the cost of the solution be acceptable to the health care providers? How many units can be sold for the estimated price? Is industry prepared to take the end product of the NASA development and carry it through to production with an effective sales and distribution program? The lack of an adequate market survey may mislead or impede private companies which might otherwise step forward to manufacture the device or process. The role of industry is critical to achieving most transfers in any meaningful sense. But the road must be well paved or the risks to private capital will outweigh the speculative promise of profits. Thus, BATeam efforts could be considerably enhanced if sound marketing data were also generated.

A second characteristic of the approach is that the time frame of BATeam transfer operations is generally short, on the order of a few months or less. Third, for the most part, little expenditure of funds other than that required to operate the BATeams has been involved. \$5,000–\$10,000 per transfer is a typical investment for hardware and development.

NASA has also supported hardware and software development both by contributing NASA personnel time and by contract with NASA vendors for particularly promising devices or systems. These efforts also are of a relatively small scale, generally in the \$25,000–\$50,000 class and one year or so in duration.

Each of the above techniques is a legitimate technology transfer operation, and each has its place in a comprehensive technology transfer program of an agency such as NASA.

An expanded transfer concept

It was the Committee's view that there is another technology transfer process which has not been utilized to date and it is this process which our Committee attempted to develop by means of demonstrations. The concept may be summarized as follows: In the area of health care delivery, there are rather significant and somewhat universal problems faced by those providing services and functions. Some of these problems may be alleviated by an appropriate use of technology. Further, if the problem is of sufficient impact, *it may well prove worthwhile to expend considerable funds and a considerable length of time to accomplish the transfer of the technology;* perhaps \$200,000 or more expended over several years of development, clinical trials and ultimate deployment.

Thus the study focused in part on: (1) identifying some significant problems in health care delivery rather universally faced by the medical profession that could be alleviated by NASA technology applications; (2) identifying the specific technology and delineating the specifications for further development and evaluation; and (3) developing the institutional relationships and collaboration required to accomplish that development and evaluation process.

The Committee was faced with having to select, rather arbitrarily, a few medical areas for concentrated study to demonstrate the expanded transfer concept. It also, of course, desired to maximize the probability that relevant NASA technology could be identified once significant medical problems were defined. Because of its outstanding expertise in instrumentation, the Committee felt that NASA technology held promise for at least two important medical applications: (1) the substitution of fast and precise physical measurements for slower and less accurate chemical determinations that are now a standard part of medical practice, and (2) the substitution of non-invasive measurements (using NASA developments in transducer technology) for invasive patient measurements.

Chosen for intensive study were the fields of acute pulmonary care and cardiovascular care. Patients in acute respiratory or cardiac distress are often subjected to the types of measurements referred to above. These two areas share the characteristics of being a part of common medical practice of long standing. In contrast and as a third area of study, the Committee chose a new, emerging concept in medical practice as yet only explored in a handful of isolated research and demonstration projects. This is the delivery of health care at a distance—remote health care—in which the practitioner is physically separated from the patient, connected by communications systems (e.g. voice and television channels). The potential of NASA technology for such systems is obvious; the Committee endeavored to determine what the NASA contribution might be to their development.

At the request of the agency, the last fifteen months of the study turned toward an extensive examination of the field of emergency medical services with the same objective in mind: What might be NASA's capability to aid in the current national thrust to improve the quality of emergency health care?

Finally, the Committee identified and pursued the application of one unique system—a urine bacteria detection method—to further demonstrate the concept of long-term development and funding of potentially very useful medical technology.

The pulmonary, cardiovascular, remote care, and emergency medical services projects revealed serious institutional impediments to the technology transfer process and, although varying degrees of progress were made on them, it cannot be claimed that any has yet yielded effective fruit as far as completing a meaningful transfer is concerned. The urine bacteria detector project progressed, with great difficulty, to the point where further Committee involvement would not be required.

In the pursuit of all of these efforts, much was learned about the process of technology transfer from a federal technological agency to civilian health care delivery. Here, perhaps, lies the ultimate value of the Academy's involvement, for institutional impediments are man-made. With courage, motivation, cooperation and rational management, they can be removed. Considerations of this nature are discussed in the next section of the report, with the hope that the managers of both the space agency and mission-oriented health agencies can derive some useful new concepts and procedures to accelerate and enhance the natural process of technology transfer.

Subsequent sections describe the course of the Committee's specific efforts in explicative fashion. Various Appendixes and supplements further summarize Committee findings and document Committee activities during the three-year contract period.

THE TECHNOLOGY TRANSFER PROCESS AND NASA TECHNOLOGY UTILIZATION MANAGEMENT

It has always been the hope of the Committee that in addition to revealing some generic characteristics of the technology transfer process, this study would serve to strengthen NASA's technology utilization (TU) program by both demonstrating an expanded, workable transfer concept and by establishing collaborative relationships between the space agency and mission-oriented health agencies.

The Committee has not been entirely successful in fulfilling these latter two objectives. It is felt that the problems encountered together with some recommendations for their alleviation would be of interest to NASA, to other technologically rich federal agencies concerned with technology utilization, and to the mission-oriented federal health agencies with which the Committee has interacted.

It should be understood that the comments in this section are not intended to convey criticism. Rather, they are included solely for constructive purposes for consideration by NASA management as it strives to improve the NASA TU program. Further, it is recognized that the experiences upon which these conclusions and recommendations are based were those of our Committee, Subcommittee, Ad Hoc Groups and staff. It is possible, although the Committee doubts it, that these experiences were unique and peculiar and that the problems encountered (to which the recommendations are addressed) are not, in fact, prevalent.

The technological agent and the user agent

Essential, in the Committee's view, to effective technology transfer in the health care field is the proper relationship between the user community and the technological source. In the realm of this study, the user community was the health care delivery system and the technological source was the technology resident within NASA and its contractors. Both the user and the technological source and a mission-oriented health agency (e.g., the Health Services and Mental Health Administration) or other institution (e.g., American Hospital Association) was to be the agent of the user. It is our Committee's opinion that neither agent can conduct the transfer process unilaterally. Rather, *both agents must be intimately involved in the transfer process from beginning to end*, particularly if the transfer requires an expenditure of a considerable amount of funds and resources to bring about a solution.

The first step in the technology transfer process is problem definition. This requires the insights, knowledge, and expertise of the medical scientist and medical practioner working with the user and the technological agent. During the problem definition phase, although the technological agent should play an important role, the user agent must take the lead. NASA does not hold a charter to operate unilaterally in the civilian health field, nor can it be expected to identify the existing problems and have broad knowledge of the characteristics of the real world of health care delivery. This can, however, be provided by a mission-oriented health agency or other broad representative body acting as the user's agent. The next step of the transfer process involves the searching for technological components which will lead toward a solution. Here the technological agent must assume the lead. Once these technological elements for a solution are identified, there follow development, test and evaluation conducted both in the engineering laboratory and in the clinical environment. Here both the technological agent and the user agent must work collaboratively to insure that the best technological solution is provided and to insure that the clinical objectives are met. Finally, once a solution has been evaluated and found to be useful, there remains perhaps the most important function of all; that is, the injection of the solution into the user community so that there remains not a one-of-a-kind system being operated as prototype somewhere, but rather a system which becomes an accepted component of the armamentarium of health care delivery.

This latter task falls to two groups. First is the user agent, for it has a far greater ability to influence the ultimate users and carry the results to the delivery system at large than does the technological agent. The mission-oriented federal health agency often has leverage through the use of funding control, ability to promulgate certain rules and regulations, and influence upon health operations and legislation not available to the technological agent to further this transfer process. The other type of user agent (e.g., American Hospital Association), while not a federal agency, is a body that has direct influence upon the user community and therefore is in an excellent position to serve as a distributor of the new technology application.

In the ultimate, it is the degree to which the solution is adopted throughout the user community that measures the success of the transfer process. Of critical importance, therefore, is the conviction of the user agent that the device, process or technique proposed for transfer is sound and worth distributing. *This conviction can best be achieved when the user agent participates with the technological developer throughout the transfer process,* thus identifying the resulting product as being as much his as that of the technological agent. It is a rare case, indeed, where the technological agent can unilaterally choose the problem, develop the technology, create the solution (e.g., a new "black box") and then create a strong motivation in the user agent to serve as the distributor.

The second necessary partner in the widespread transfer of technology is industry. Here, as elsewhere in the overall process, there have been problems. The NAE has considered this question in some detail. Among the chief conclusions derived from an in-depth survey of fifty companies involved in biomedical engineering were these: [1]

1. That industry faces several problems in becoming active, including lack of an identifiable market of sufficient size for new medical instruments and fear of legal repercussions which could result from misjudgment in an endeavor directly influencing human life.

2. That there is no informed consumer demand for better or new products or services.

3. That there is an absence of competitive cost pressures and incentives for cost reduction by new technology because of the historical development of hospitals along philanthropic lines and the presence of third party insurance companies to pay the bills.

The Committee believes that by engaging NASA, HEW, and private industry in a cooperative program, such as the one attempted in pulmonary care, some of these problems will be alleviated promptly. Reducing the remaining impediments, caused by uncoordinated methods of health care delivery in this country, must await other, bolder attacks.

The lending of intellect

In most attempts used so far to transfer technology and, indeed, in the model proposed above, there remains a delineation of two groups: the technological group and the user group. The process involves the transfer of information and hardware between these groups, collaborative activity between them, and people with experience in both. The Committee proposes that an efficient mechanism to bring this about is the transfer not only of information hardware and software but also the transfer of people: that is, assigning technologists well-versed in the technology deemed transferable to full-time, albeit temporary, positions in organizations of the user community faced with solving user problems. For example, NASA engineers could be assigned full-time duty in a hospital, a city communications department or a university project developing prosthetics for

[1] Committee on the Interplay of Engineering with Biology and Medicine, "An Assessment of Industrial Activity in the Field of Biomedical Engineering." National Academy of Engineering, Washington, D.C. (1971).

the handicapped. This could constitute a technological agent's sole contribution to a specific transfer process, the lending of intellect. When the task is complete, such persons could return to their regular duties. Not only would the user community benefit from such an arrangement; cross-fertilization would occur and the technologist returning to the space agency would bring a broader outlook and, perhaps, even new technological concepts that would accrue to NASA's benefit—technology transfer can be a two-way street.

TECHNOLOGY UTILIZATION MANAGEMENT WITHIN NASA

The Committee experiences lead it to offer several recommendations which could enhance the technology utilization (TU) program within NASA.

1. *Assignment of people.*—It was suggested that one effective means of transferring technology is the lending of intellect—the assignment of NASA employees to operate within the community that will be the ultimate recipient of the transfer. Because of current administrative constraints in the agency, this is very difficult to accomplish. It has been done in only a few selected instances such as assignments made under the Federal Intergovernmental Personnel Act of 1970. It is far easier for NASA to contract for a $75,000 technology transfer hardware development than it is to obtain approval to "lend" a $25,000 per year salaried engineer who, working in the user's community for a year or two, could accomplish equivalent, if not more effective, transfer functions. *NASA could strengthen its TU program considerably if constraints to assigning personnel to extra-NASA institutions and to internal technology utilization projects were reduced.*

2. *Strengthening interagency collaboration.*—Some problems that developed in this area came as a surprise to the Committee. In developing the contractual agreement between the Academy and the Agency to conduct this study, NASA consistently emphasized its desire for aid in developing mutual, collaborative programs between NASA and mission-oriented health agencies. Perhaps naively, the Committee did not anticipate serious difficulty. Yet in attempting to accomplish that end, the Committee often was frustrated by a seeming reluctance on the part of agencies to cooperate. This reluctance was found in the health agencies as well as within NASA. Some examples are in order.

In the pulmonary care project, the Committee has yet to be successful in developing funding support in either the National Institutes of Health (NIH) or the Health Services and Mental Health Administration (HSMHA). In this case, the reluctance came from those agencies, although obtaining a definite commitment from NASA as to what it would contribute in the form of hardware and engineering expertise has also been difficult. Having that information might have made approaches to the health agency more effective.

A lesson learned from that experience is the desirability of coordinating the offering of technology with the current priorities and thrusts of the health agencies. When the technology offered matches the user agent's needs, the probability of negotiating a joint program is greatly increased. Further, the health agency's priorities and thrusts should be excellent indicators of significant current problems demanding attention.

At the height of the pulmonary care project, for example, neither NIH nor HSMHA was placing heavy emphasis on pulmonary care hardware development; in fact, the National Heart and Lung Institute (NHLI) initiated a study of its own on technology needs in pulmonary care. Until that effort is complete and the agency moves toward implementation of its recommendations, NHLI is not very inclined to provide any substantial support.

In its health care technology transfer program, NASA should maintain close contact with the mission-oriented health agencies and other user institutions and stay apprised of continually changing and emerging program thrusts and priorities. Further, *when a collaborative transfer project is undertaken, a willingness on the part of all agencies involved to share management prerogatives as well as resources is a necessity.*

3. *Internal management control of technology utilization projections.*—Since the Office of Technology Utilization is a staff office in the agency while the personnel in the NASA Field Centers conducting TU programs are in line management, the Office of Technology Utilization has little management control of the projects is funds through or in the Field Centers.

The NASA commitment to technology utilization and transfer would be considerably strengthened if means were developed by top management that would permit direct headquarter management control of technology utilization projects originating in and funded by the Office of Technology Utilization.

A closing statement

The national technological resources could be beneficially exploited in a way that has gone heretofore untapped. NASA, other agencies of government and the private sector can all assist toward that end. Required are:

1. An expansion of the concept of technology transfer to include large, more imaginative development, evaluation and deployment schemes addressed to significant and universal problems.
2. True interagency and inter-institutional collaboration from problem definition to user acceptance.
3. A recognition of the needs and capability of American industry.

Computer Braille Translation of the Atlanta School System

SUMMARY

A system has been developed at the Atlanta Public Schools to translate and produce hard copy braille on an IBM System 360/Model 50. The purpose of this project is an attempt to make braille materials accessible to visually impaired students so that they may compete successfully with their sighted classmates. This paper discusses the different phases involved in the translation system, including problems, the personnel involved, the necessary hardware, and operation of the software packages.

COMPUTER BRAILLE PROJECT

The Atlanta Public School System has a multi-faceted educational program for blind students. All such students receive instruction in regular classrooms along with their sighted classmates under the guidance of a regular classroom teacher. This instruction is augmented by the services of a "vision teacher" who visits school on a rotating basis and works with the blind student and with his regular classroom teacher. When possible, textbooks are obtained from the American Printing House for the Blind and from the school system's own Library for the Blind. In those frequent cases when needed books are not available, a group of approximately twenty volunteers transcribes these volumes, working at their homes with braille-writers.

Materials for the sighted in the Atlanta Public Library System number approximately 700,000 volumes, excluding periodicals, newspapers, film strips, or other materials. The Atlanta Branch of the Library of Congress, Division for the Blind and Physically Handicapped has only 7,000 volumes on tape, on talking book records, and in braille. The discrepancy between the amount, kind, and availability of reading materials for sighted and blind students is one of the major weaknesses in the overall education program for visually impaired pupils and is an indication of the magnitude of the problem in obtaining a minimum of needed instructional materials.

The Computer Braille Project in the Atlanta Public School System, funded under Title VI of the Elementary and Secondary Education Act (ESEA) was designed to develop a program to alleviate this problem of limited reading materials by providing braille materials for the visually impaired via the computer. The project is bringing about increased accessibility of educational material in braille for blind students in attendance with their sighted schoolmates.

Under the present system books and other materials are copied onto either a typewriter-like device (ATS terminal) which is connected to a computer or a typewriter equipped with special characters which can be read by a document reader. The materials thus copied are proofread and corrected, then subsequently stored on magnetic tape. These tapes are then used as input to the braille translator. Next the output of the translator is embossed into braille by a high speed printer equipped with a specially made device. The printer speed is approximately 300 braille lines per minute or 200 characters per second. The entire system runs on an IBM 360, Model 50 Computer.

The braille translator, DOTSYS III, was developed by the Massachusetts Institute of Technology (MIT) under contract from the Atlanta Board of Education. The program contains extensive capability for text editing. Among these are tabulation controls, page and line formatting, poetry, and special braille symbols. It is capable of producing two types of braille as well as an inkprint proof copy for a sighted braille editor and punched card output to be used for compatability with other systems. The two types of braille are (1) a low quality braille produced on standard computer paper for use by computer programmers and (2) a high quality braille for the general reader produced on 90-lb. paper utilizing an interchangeable print train which works very much on the same principle as a braille-writer.

An interface program accepts the output of ATS, which consists of archives tapes, and converts them to a form compatible to the DOTSYS III program. This program makes use of certain features of ATS commands, DOTSYS III commands, teleprocessing characters, and rules of Standard English Braille.

Although experience with the software indicates a high degree of performance it is continuously undergoing modifications in order to improve the accuracy of translation and its flexibility within the environment for which it was designed. Both programs use complier-oriented languages. The ATS to DOTSYS III program is written in PL/1 and DOTSYS III in COBOL.

Experiments are being conducted with the use of a document reader as input to DOTSYS III. In this application, a service bureau is contracted to provide the input. The typist prepares the document on an IBM selectric typewriter using an optical character reader (OCR-A) type element. The pages are scanned and the output placed on tape. Since the output is in binary coded decimal (BCD), a simple interface routine is used to convert the information to extended binary coded decimal interchange code (EBCDIC), because DOTSYS III makes extensive use of the characters on the 029 keypunch. Many of these characters are not present in BCD. It then becomes necessary to use some of the little-used symbols on the typewriter keyboard as DOTSYS III editing symbols. The interface routine accommodates the conversion of these characters as well. The service bureau uses IBM selectric typewriters, a system/360, model 20 computer, and a Farrington optical scanner. Under consideration is the investigation of Control Data's Model 915 document reader which uses 8-bit characters. The use of this equipment would practically eliminate any character conversion and consequently the sacrificing of keys on the typewriter for editing symbols.

One of the chief goals for using an automated system such as has been described is the total elimination of the need to know braille by those persons within the system who must prepare the input. Although this goal has not been totally attained, it is within reach in the foreseeable future. One of the chief problems is the rather vigorous standards set forth by the rules of Standard English Braille including the unique formatting of braille publications. A partial solution to these problems will be the utilization of an input editor whose job will be to examine each publication to uncover any unique formatting situations and to look at the DOTSYS III printout for any major deviation from the braille rules. Obviously an input editor must have at least a partial knowledge of braille and braille book formats, and preferably a background in data processing in order to determine the cause of the errors encountered.

The progress of the project has been substantial but like any other, it has had its problems as well as its rewards. For example, some of the previously encountered problems were the correct formating of braille title pages, tables of contents, indexes, tables and charts, and test materials, as well as errors in translation. Solution to these problems was found by merely becoming familiar with the ATS and DOTSYS III editing commands and a little ingenuity in their application. The correction of errors in translation was not so easy. When received, the DOTSYS III program was not 100 percent operational. As translations were made, errors were found and corrected. Some of these involved modification to the dictionary and other modifications to the program itself.

Because of the specific requirements within a textbook environment certain additions became apparent. Among these were an inkprint page number in braille and double line spacing in textbooks produced for the primary grades. Due to the absence of a final documentation of the DOTSYS III program much time was spent in trial and error with dictionary changes and program modifications.

The project has presented many satisfying experiences. Among the first braille translations was the Ohio State University Psychological Test for a visually impaired student competing with sighted students for the Governor's Honor Programs. This enabled the student to take the test without outside help. One instance where computer braille proved helpful was the translation of an ecology book which permitted a visually impaired student to enroll in a newly organized oceanography course. Another highlight of the project was meeting the daily demands of the first visually impaired student-programmer to enroll in the Atlanta Area Technical School.

With the assistance of MIT, IBM, Georgia Institute of Technology, Georgia State Department of Education, and many others, the Atlanta Public School System has made a significant contribution toward automating processes of braille production. A system has been designed not for one particular agency but for anyone who has the necessary equipment. It is believed that modern technology and know-how have brought together such components and skills to make this the most thoroughly automated system presently available. It will prove to be a most powerful tool in the hands of its users and should usher in a new era in providing a better life for the visually impaired.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY,
SENSORY AIDS EVALUATION AND DEVELOPMENT CENTER,
Cambridge, Mass.

TACCOM—A COMMUNICATION SYSTEM FOR THE DEAF-BLIND

TACCOM (for "tactile communication") is a wireless remote paging system designed for the deaf-blind in particular, but with possible applications for the singly-handicapped deaf *or* blind.

The TACCOM pocket receiver is the core of the system; it functions like the pocket pagers carried by physicians in a hospital, but with one important difference: instead of beeping to alert its user, it *vibrates.* (It feels like an electric toothbrush running.) The receiver has the appearance of a tiny transistor radio and measures 2½″ × ⅞ × 5″. It weighs 6.3 ounces. It employs rechargeable batteries and is normally plugged into a battery charger at night when not in use.

Two primary applications are: (1) To provide an effective "doorbell" for a deaf-blind person who may be alone in his house; and, (2) To effect an alarm system (e.g., for fire, etc.) in an institution or other setting where a number of deaf-blind persons may be spread about and must all be summoned at once.

The equipment involved includes the pocket receivers (one for each user), the centrally-located 115 volt transmitter, and a loop antenna which runs around the area to be covered by the radio signal. This service area can be fairly large—one hundred thousand square feet or more. The transmitter can be connected to push buttons at convenient locations, fire alarm boxes, time clocks—whatever suits the end purpose.

Ancilliary attachments make possible other TACCOM applications:

1. End-of-line indicator for brailler or typewriter.
2. Auditory cue indicator (phone ringing, baby crying, etc.)
3. Ambient light indicator.
4. Message system (Morse code signalling, etc.)
5. Teaching/training aid.

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Final Report—Development and Demonstration of Communication Systems for the Blind and Deaf/Blind, Braille Communication Terminals and Tactile Paging Systems

(By George F. Dalrymple, Sensory Aids Evaluation and Development Center, Massachusetts Institute of Technology, Cambridge, Mass.)

ACKNOWLEDGEMENT

It is appropriate that the Sensory Aids Center record the contributions to its work of the many persons who were generous in their counsel and cooperation toward our common ends. These range from the government official whose advocacy of our pursuits made the endeavor possible, to the teachers of the blind who assist in the deployment of the devices; acknowledgement is given herewith of the valuable help of each.

To Professor Robert W. Mann, Chairman of the Steering Committee of the SAEDC for his help, support and encouragement.

To the Staff of the Center, to Mr. Vito A. Proscia, former Director of the Center; Norman L. J. Berube, Senior Technician who constructed and helped maintain some of the devices used in this work; to Nancy Brower, Susan Sokalner and Evelyn Welch who kept the administrative aspects of the Center running smoothly.

To Mr. Lindsay Russell, Consultant in electrical engineering for his work with Taccom and Pathsounder and Mr. Murray Burnstine, Consultant in mechanical engineering.

To the professional persons who are using the Braillembosses in their regular employment: Dr. John Morrison, the Perkins Computer students, Mr. Alan Downing, Mr. Donald Keeping, Mr. Terry Hicks, Mr. Jack McSpadden, Mr. Michael Lichstein, and Mr. Phillip Hall.

To Social Rehabilitation Service of the Department of Health, Education and Welfare for their support, to Dr. Douglas McFarland, Dr. L. Deno Reed, Dr. James F. Garrett, and Mr. George Majors.

To the Massachusetts Commission for the Blind, to Mr. John Mungovan, Mr. Fred Greehan, Mr. P. J. Davis and Mr. John Robichaud for both their encouragement and assistance in Braillemboss placement.

To Perkins School for the Blind and Howe Press, to Dr. Edward Waterhouse, Mr. Benjamin Smith, Mr. Harry Friedman, Mr. Frank Staples, Miss Bertha Kasetta and Mr. Mike Minahan.

To Mr. Robert A. J. Gildea, of the MITRE Corporation and ACM SICCAP for his many suggestions and encouragement; to his colleagues at MITRE, Dr. Jonathan Millen, Mr. Joseph Sullivan, and Mr. W. Reid Gearhart who wrote DOTSYS III.

To the American Foundation for the Blind, to Mr. Louis Goldish, Mr. Leslie Clark, Dr. Milton Graham, and Dr. Carl Rogers.

To the National Braille Press, to Mr. Louis Dennis and Mrs. Janet Fields for their part in the demonstration of interactive braille.

To the Internal Revenue Service for their assistance in demonstrating a Customer Service function, that of a Taxpayer Service Representative; to Mr. Jerry Kleiman, Mr. Frank Braun, Mr. John Killingsworth, and Mr. Fred Moser.

To Mr. Fred Johnson of Little Rock for his help and encouragement.

To the Arkansas Enterprises for the Blind, to Mr. Roy Kumpe, Mr. Elmo Knoch, and Mrs. Billie Elder for their enthusiastic support.

To the National Center for the Deaf/Blind for their support and assistance with Taccom, to Mr. Harvey Spar, Dr. Peter Salmon, Dr. Robert Smithdas, Dr. Fred Kruger, Dr. Eugene Zumalt, Dr. Trevor Reader, and Mrs. Sally Silver.

To Rolls Royce (1971) Limited, to Mr. Dennis C. Boston and Mr. Terry Tate: to Digital Equipment Corporation, to Mr. John Norris, Mr. Steve Milkulski, Mr. Brad Dewey, and Mr. Ken Pierce for testing facilities and shipping the Rolls Royce Braillemboss and to Mr. Bob Lane and Mr. Jack Learson for help in interfacing to the AEB computer.

To Worcester Polytechnical Institute and Worcester Collegiate Computation Center, to Dr. Sondak, Mr. James Sistare, Dr. James Jackson, and Mr. William Swiger.

To the Vision Center of Columbus, Ohio; to Dr. Richard W. Schuricht.

To the Ohio State School for the Blind, to Mr. Philip Johnson and Miss Judith C. Harrison.

To the Jewish Guild for the Blind, to Mr. Edwin Goldberg, Mrs. Judith Rutberg.

To the Connecticut Institute for the Blind's Oak Hill School, to Mr. William Lyndon, Mrs. Ruth Gilchrist, Miss Sandra McClosky, Mr. L. Campbell.

To the University of Pittsburgh, Department of Special Education and Rehabilitation, Mr. Bruce Blasch, Mr. William A. Fluharty, and co-workers.

To the Greater Pittsburgh Guild for the Blind, to Mr. James A. Kimbrough, and Mr. Leon Reid.

To Boston College, to Dr. John Eichorn, Mr. Hugh Vigurso, and Mr. Paul McDade, Mr. John Burke, and Mr. William Walkowiak.

To the Department of Blind Rehabilitation at Western Michigan University, to Mr. Stanley Suterko, and Mr. Donald Blasch.

To the New York Association for the Blind, to Mr. Michael Petrizzi, Mr. Robert Lieberman, Mr. John Rocsin, Mr. Edwin Goldberg, Mr. William Gallagher, Mr. William Lord, and Mr. Robert E. Long.

To the Massachusetts Association for the Blind, to Mr. William Curtis.

To the Veteran's Administration, to Dr. Eugene Murphy and Mr. Howard Freiberger, to Mr. Russell Williams; to Hines VA Hospital, to Mr. John Malamazian, Mr. Jay Whitehead and Mr. Lee Farmer; to West Haven Hospital, to Mr. Paul D. Sheel, Mr. George Gillespie, Mr. Wilbur Kingsley, and Miss Jill D. Healey.

To Technology Community Association, to Mr. Steve Shladover, Ms. Helen Mitchell, Chairman of the M.I.T. Libraries Committee for Blind Students, Mr. Alan Downing, Miss Karen Navy, Mr. Bob Liu, Mr. David Taenzer, Miss Lila Kobylak, Miss Helen Manning and Miss Dorothy Becklenberg.

To Ray E. Morrison, of Sun City, Arizona, a telephone pioneer, for his interest and aid.

ABSTRACT

Described in this report is the Braillemboss, a braille page printer, which is useful as a short run braille producer and especially as an employment and education tool for the blind. Examples of the latter applications are given, including its use by computer programmers, students, taxpayer service representatives, and news broadcasters. The machine is, for blind users, a braille counterpart of the familiar teletype page printer used by the sighted.

Taccom, a wireless signalling device for the deaf-blind, is also described. Making use of a radio-activated pocket-size vibrator, Taccom permits remote

paging of deaf-blind persons and gives them a number of ancilliary capabilities: sensing of ambient sound and light cues, communication of simple messages from a distance, etc.

Also given is a status report of the Pathsounder ultrasonic mobility aid for the blind.

INTRODUCTION

The Sensory Aids Evaluation and Development Center has been exploring three devices to enhance the communication capability of the blind and the deaf/blind (d/b). The first device is the Braillemboss, a braille page printer, i.e. a braille producing teletype. The second is Taccom, a wireless communication and paging system for the deaf/blind. The third is the Pathsounder, a device that communicates to the blind traveler a blockage of the path ahead.

The Braillemboss has been demonstrated in two basic ways. One is an output device for a computer. The other is as a braille production device. There is overlap for example when the Braillemboss is used as the output device for a computer braille translation system.

The most significant use of the Braillemboss is as a tool used in routine day-to-day employment. It has been used as the communication device from a computer to professional computer programmers. It has also been to give customer service personnel access to computer data. Further it was used as a newswire printer to give a blind television newscaster access to that service.

The Braillemboss has been used in small-scale braille publishing activities. These have included several pamphlets, a chapter of a book, and a book. One pamphlet was done as a cooperative effort with the National Braille Press for one of their clients. Two other pamphlets are SAEDC Technical Description Sheets. The chapter of the book was done in cooperation with Technology Community Association and the M.I.T. libraries for the blind students at M.I.T. and other colleges in the Boston area. The book was done for the Library of Congress.

The Braillemboss was selected by the national IR–100 Industrial Research contest as one of the 100 most innovative and significant "products" produced in America in 1972.

Taccom is a wireless communicator for the d/b. Each user carries a small receiving unit that vibrates when signalled by inductive coupling (wireless). The system is effective in an area defined by the signal loops connected to a fixed station transmitter. Two installations are presently in use—one at the National Center for Deaf/Blind Youths and Adults, New Hyde Park, Long Island; and one at the SAEDC, building 31 at M.I.T.

BRAILLEMBOSS

The Braillemboss (Figures 1 and 2) operates in a similar fashion to a teletype, i.e. it converts coded electrical signals into embossed braille. The Braillemboss is constructed as an output device only and when used in an interactive role it must be used in conjunction with a device containing an appropriate keyboard.

The Braillemboss is the product of a long range M.I.T. program[1 2] involving many M.I.T. people, students, faculty, engineers working in the Mechanical Engineering Department, Sensory Aids Evaluation and Development Center and the Draper (Instrumentation) Laboratories. The development was supported at various times by the Office of Vocational Rehabilitation[3], Vocational Rehabilitation Administration[4 5 6], Social Rehabilitation Administration and the Social and Rehabilitation Service[7 8 9] of the Department of Health, Education, and Welfare, and by the John A. Hartford Foundation.[10]

The Braillemboss earliest beginning was in a design engineering course 2.671 as a result of a series of "Sensory Aids Discussions," a series of lunch time seminars. These seminars brought together members of the M.I.T. community, some of those who have worked with the blind and members of the blind community to explore the ways technology can help the blind. From the initial senior theses by Lichtman [11] and Eglinton [12] were written based on the design of a braille printer and typewriter input device for it.

The first operational braille embosser was built by Kennedy[13 14] as his masters thesis. This model was further refined and six units were built at the SAEDC. Two of these units were loaned to users; three were used by students for addi-

[Footnotes appear on p. 47.]

tional thesis projects; and one retained at the SAEDC for its use. It later served as a test bed for the changes incorporated into the Braillemboss.

The three student projects braille embossers were built into braille telecommunication terminals by Armstrong[15] as his masters thesis. One of the terminals was then incorporated in a computer Grade II braille system, by Greiner[16] as his masters thesis project and saw limited use at Perkins School for the Blind. The other two units were used in design improvement projects by Scott[17] and Sturgis.[18]

The SAEDC engineers and technicians in conjunction with an engineer and design draftsman of the Draper Laboratory re-examined the design and made changes to improve its reliability and accuracy and to reduce its cost of manufacture. As a part of this effort twenty Braillembosses were constructed.

As the Braillemboss is presently configured it used "brailler code"[19] as its input data. This code is an eight level or eight bit code. That is, there are eight yes-no elements, or bits, per character or data word. This code was designed to have maximum correspondence to the braille cell. If the eighth level, machine function, is a zero (no) then the first six levels are embossed in braille; i.e. level 1 data becomes dot 1; level 2, dot 2 through level 6, dot 6. If the machine function is a 1 (yes), then the codes in levels 1 through 7 determine the machine function to be performed. The functions are space, new line (carriage return), new page and line feed.

The Braillemboss was built to use the existing "standard" brailler code for braille equipment. It was recognized early in the development of the Braillemboss that maximum flexibility had to be built into the device as it was expected that uses for the Braillemboss other than remote production of literary braille via computer would be found. Provision was therefore made in the Braillemboss cabinet and electronics for an interface unit to adapt the Braillemboss to the desired application. The flexibility will not be needed if large numbers of Braillembosses are built for any given application as the control electronics can be optimized for the data transmission code used.

For most of the present applications of the Braillemboss three data transmission codes are used: 5-level newswire (TTY), 7-level EBCDIC, and 8-level teletype (ASCII). The most common interface unit used ASCII data transmission code and has input conversion equipment to permit the Braillemboss to operate in parallel with all of the present 8-level teletypes—Models 33, 35, 37, and 38 regardless of version be it Receive Only (RO), Keyboard Send-Receive (KSR) or Automatic Send Receive (ASR).

An interface unit for newswire (TTY) has seen service at a TV station. This interface unit includes a time buffer and format control circuitry to provide clear format material. Also an interface unit has been built for EBCDIC, the code used by IBM for its remote terminals. Preliminary testing of this unit is complete, but it has not seen field service.

Conventional English braille, either the letter for letter Grade I or the highly contracted Grade II forms are not directly usable with computers, as many of the symbols used in the ASCII or EBDIC character set are simply not defined in braille. Also several characters are ambiguous; i.e. "("and")" use the same braille symbol. Further, numbers are not directly defined in braille but use a number sign before the letters "a" through "j" to represent the numbers 1 through 0.

A new braille system was defined for use with the Braillemboss when used. Each symbol in the Fortran character set has a unique braille symbol defined in this system by computer programmers. This code, called "one-cell" braille uses the same pattern for the alphabet. It takes identical pattern for the numbers defining the same bit arrangement as "a" through "j" but using the lower four dots of the cell.

Then the most important symbols in the Fortran character set; i.e. =, +, −, *, /, (, and) are assigned the least ambiguous braille cells. Finally the remaining characters used in the ASCII (teletype) character set are arbitrarily assigned the remaining braille characters. This one-cell braille has a one-to-one correspondence between each printing character of the ASCII character set used in teletypes and the 63 possible printing characters in the braille cell. This allows any system based upon the ASCII transmission code to transmit Grade II braille since each braille symbol has a printing ASCII code to represent it. One cell braille has also been defined with the 5-level code with not all braille symbols

[Footnotes appear on p. 47]

represented. One cell braille is also defined for the 7-level EBDIC but with only 62 printing characters.

Interface units have been built to one-cell braille containing translators for each of these three codes. There have been special features included in some of these interface units, such as a data controlled on/off switch, and with a time buffer and format control circuitry for newswire use.

Time-shared computer programmer terminal

The Braillemboss is presently being used by programmers and system analysts with time-shared computers at a U.S. Government agency, two companies, three universities and a residential school for the blind. At each of these installations the Braillemboss is connected to a teletype such that both the Braillemboss and the teletype page printer produce the received material simultaneously.

This form of interconnection was selected for several reasons. First, it insures that the installation will not be restricted to blind users, but can also be used by the sighted. This provides maximum flexibility and usefulness of the terminal. Second, it limits the amount of special equipment at the terminal that must be maintained differently than the equipment used regularly. It also reduces the complexity of the Braillemboss.

Sensory aids evaluation and development center installation

The first Braillemboss built (Serial #10) was connected to a Model 35 teletype at the SAEDC and was first used by a graduate student in his ergometric studies. This first terminal was used chiefly with a CTSS, a time-shared computer system at M.I.T. based on an IBM 7090 computer. This particular Braillemboss is not presently in use, but could be upgraded easily and put back in regular service if desired. Two Braillembosses (Serial #26 and #27) have been and are being maintained on line at the Center for use of M.I.T. students and for computer braille experiments and demonstrations.

Dr. John Morrison, NASA/DOT, Cambridge, Mass.

The first Braillemboss (Figure 3) in the field was installed at NASA Electronic Research Center (ERC) here in Cambridge. The Braillemboss and teletype were installed in Dr. John Morrison's office during October 1969.

ERC was disbanded in June of 1970 and the facility transferred to the Department of Transportation. Dr. Morrison transferred to DOT's Transportation Research Center in the former ERC facility. In October of 1970 the Mass Commission for the Blind purchased a Braillemboss for Dr. Morrison's use and DOT installed a Model 33 teletype. At that time the SRS supported equipment was removed.

Dr. Morrison has written two reports on his use of the Braillemboss. They are included as Appendix I and II. It should be noted that the last service call except for lubrication was in early 1971 to install a convenience switch and to adjust the electronic timing to eliminate the occasional random dropping of characters. The Braillemboss and teletype have been moved at least twice by DOT and telephone personnel without assistance from the Center.

Programming Course, Perkins School for the Blind, Watertown, Mass.

For several years Perkins School for the Blind has offered a course in computer programming for students in the upper school during their junior and senior year.[20] The object of the course was best expressed by Mr. Benjamin F. Smith in a report to "The Blind in Computer Programming, an International Conference"[21] describing the reasons for use of a time-shared computer.

"Secondly, we concluded that this computer plan offered considerable promise as a tool in the classroom of some of the subject areas in our senior high school department. We felt that the application of the computer to classes in mathematics and science would be particularly effective both as a means of greater efficiency in the learning process and also as a means of motivating our students to greater interest and effort."

"Finally, since it had already been well demonstrated that blind people can be highly successful vocationally as computer programmers, we concluded that we should give our students experience on the computer with a view to exploring both vocational interest and vocational aptitude."

An M.I.T. Braillemboss was transferred to Perkins and was connected to a teletype previously rented by Perkins. The initial time-sharing computer service

[Footnotes appear on p. 47]

was provided by General Electric. The Babson College Hewlett Packard 2000C time-shared computer system presently is used.

The Perkins students are taught both how to use a time-shared computer and how to program with programming language. During the 1972–73 school year there are seven students, including five braille users in Computer I and five students, including four braille users in Computer II. The computer terminal room is now left open during certain afternoons and evenings each week for use of both students and members of a computer club.

The Braillemboss has operated reliably and efficiently with only two service calls in the period March 1970 through January 1973. Its performance and student acceptance has demonstrated that a reliable, maintenance-free braille terminal is an essential adjunct to teaching blind students computer programming via a time-shared computer.

Alan Downing, Systems Programmer, Honeywell Information Systems, (HIS) Cambridge, Mass.

Mr. Downing is an example of the importance of an interactive braille terminal to a motivated, intelligent blind student or computer professional. During his junior year at M.I.T., 1970–71, Alan took an introductory course in Fortran programming. He was not content to have other students read his output or proofread his input. He therefore arranged with the SAEDC to use one of the Braillemboss terminals at the Center as his terminal and arranged with the department offering the course to support his use of the IBM 360/67 time-shared computer at the M.I.T. computation center. This proved satisfactory and was continued during his senior year.

Mr. Downing obtained summer employment at Intermetrics, Inc., a "software house," contingent upon a braille terminal being available to him at their office. The SAEDC then agreed to loan him the terminal shown (Figure 4) until a cooperative agreement could be reached with the Massachusetts Commission for the Blind. The MCB, through a similar arrangement as that for Dr. Morrison, underwrote the transfer of a Braillemboss for Alan's use. A new Braillemboss was installed for his use and the temporary Braillemboss returned to the Center.

During his senior year Alan continued employment at Intermetrics on a two day a week basis and upon graduation he was offered full-time employment. He decided however that he would rather work on development of the operating system of a large scale computer and obtained employment at HIS. The Braillemboss has moved to his new location and has continued to give good service.

Mr. Donald Keeping, supervisor, programming course for the blind, University of Manitoba, Winnipeg, Manitoba

The Braillemboss was procured through a grant from the Canadian National Research Council for use of both teachers and students in the Programming Course for the Blind. The Braillemboss was shipped during October 1971 and was installed by University of Manitoba personnel during November. At the present time the Braillemboss is used only by Mr. Keeping, as all of the present students while legally blind have sufficient vision not to require braille.

The Braillemboss is used with a teletype as a terminal on an IBM 360/65 system using TSO (Time Sharing Option). Mr. Keeping estimates that he uses it 4 or 5 hours per week, chiefly before and after normal working hours and on weekends.

It is presently also being used in a small scale program to generate French braille for a group in Toronto. The programming associated with translating Grade I French braille is comparable to Grade I in English and much simpler than Grade II English Braille.

The University of Manitoba experience can best be summarized as follows:

"As you know, we have recently installed here at the University of Manitoba an M.I.T. Braillemboss. Outside of a few minor mechanical problems, we have found the system quite satisfactory. We have here a suite of conversational mode programs which are excellent on such a device." [22]

Mr. Terry Hicks, programmer, Bristol Engine Division, Rolls Royce (1971) Bristol BS12 7QE Great Britain.

A Braillemboss was transferred during March 1972 to Rolls Royce Ltd. for use by Mr. Terry Hicks, a blind programmer in their Bristol Engine Division. A letter from Dennis C. Boston, Head of Mathematical Services Department to Milton Graham of the American Foundation of the Blind describing their use of the

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Braillemboss is appended (see Appendix IV). This Braillemboss was converted to 117 volt 50Hz power and was tested on 50 Hz power at the Maynard Plant of the Digital Equipment Company (DEC). Since the Braillemboss is being used on the DEC PDP–10 computer at Rolls Royce, DEC crated, shipped and installed the Braillemboss.

Phillip Hall, student, Worcester Polytechnical Institute, Worcester Area Collegiate Computation Center, Worcester, Mass.

Through a cooperative agreement negotiated by the SAEDC between the Mass. Commission for the Blind and the New Hampshire Division of Blind Services, a Braillemboss owned by MCB has been loaned to WACCC. It is presently being used by Phillip Hall, a blind student at WPI from New Hampshire. The Braillemboss was installed by the staff of the SAEDC and is located in the terminal/keypunch room at WACCC.

It is connected to one of the four teletype terminals of the PDP–10 located in the main Center. This terminal is available to any of the users of the WACCC PDP–10 but it is the only one usable to Phil. He does not have absolute priority to this terminal but has to wait his turn if all the terminals are in use. When another terminal becomes free, the user of the teletype/Braillemboss terminal is asked to move the other terminal so Phil can use the Braillemboss.

For the second semester of the 1972–73 academic year Holy Cross College is planning to install a new teletype in the terminal/keypunch room at WACCC for the use of a blind HC student. The Braillemboss will be reconnected to this teletype. This will give the blind students a terminal that will give them absolute priority over all other users.

The WACCC serves a consortium of colleges and universities in the Worcester area. There are approximately 10 blind students in these colleges and WACCC is expecting 5 or 6 of them to make use of the teletype/Braillemboss terminal during the second semester this year. It should be noted that HC is not now a member of the consortium.

Customer service computer terminal

In the past several years the computer has become an important part of many non-technical jobs. One of these is that of customer service, where a customer's questions are answered. These questions can either be about their account or on company policies. Another type of job is the making and confirming or reservations, whether it be airline, hotels, motels, rental cars, etc. In many of these jobs the contact with the public is via the telephone. Some special equipment is required for a blind person to fill these jobs. Perhaps most important he must have access to the computer output. The Braillemboss is capable of being used as an output device with essentially any computer used in the customer service field. In certain cases telephone indicators may be required. The typical working blind person either has most of the additional equipment required or it is regularly supplied to him by existing rehabilitation agencies.

Jack McSpadden, taxpayer service representative, Internal Revenue Service, District Office, Little Rock, Ark.

The IRS has employed many blind persons as TSR's. The TSR function is to assist the public in obtaining information on the tax codes, rules and regulations, and to answer questions concerning the taxpayer records. Presently most of the some 40 Braille using TSR's are limited to answering questions on the tax code, rules and regulations unless they have sighted help to obtain the required data on taxpayer accounts.

In certain regions the taxpayer records are now available on the Integrated Data Retrieval System (IDRS), a large regional based computer. Each district office in the region with IDRS has Cathode Ray Tube (CRT), television like, displays on which lines of data are displayed for the sighted copy; i.e. a copy that can be saved when needed.

A Braillemboss (Figure 5) was connected to the RO teletype such that a braille copy as well as an inkprint copy can be made when requested. Mr. McSpadden, a blind TSR in the Little Rock office, now has access to the braille equivalent to the other TSR's hard copy in the office. His access to the data is only slightly slower than the other TSR's when they are not using the hard copy.

Mr. McSpadden is an enthusiastic Braillemboss user. He is reported by his supervisor to be performing all functions essentially as the other TSR's in that District office. It should be noted the Braillemboss has removed the restriction of sighted help or of limiting Mr. McSpadden's services to only answering tax code questions.

Newswire

A serious hindrance to the blind performing as radio or television newscasters is the absence of usable direct braille copy of the newswire service; i.e. United Press International or the Associated Press. The Braillemboss, with a suitable interface unit has demonstrated it can provide this service. To develop and demonstrate this capability several steps were accomplished.

The first step was to produce newswire braille in non-real time to determine the utility of the braille copy and to explore the system before a final design was undertaken.

The initial step (Appendix V, TDS No. 12) to demonstrate program feasibility required that the following be available: a newswire service with a tape reperforator, a 5-level TTY code to One Cell braille translator, a paper tape reader and a Braillemboss. The first items were available for a limited period at Electronic System Laboratory (ESL), a part of the Department of Electrical Engineering. They were performing some studies on computer storage and retrieval of news sponsored by the American Newspaper Publishers Association. Available to them was a UPI newsprinter and reperforator which could produce 5-level punched paper tape for our use.

The SAEDC had all the remaining necessary equipment with the exception of the translator. The translator was designed and fabricated by the Staff Engineer, and easily installed in one of the M.I.T. Braillembosses located at the Center. A pilot program was then initiated, punched tapes were acquired from ESL, brought to the Center, and translated into braille via the Braillemboss system.

The braille material produced by this method was distributed to three blind readers for examination and use. Approximately five hours of newswire services (produced on a daily basis), were converted into braille each day. The conversion of the newswire service information into braille tok approximately three hours on the system. The pilot study was performed during May and June 1970 and terminated when the UPI reperforator service was discontinued at ESL.

The next step was started when Paul Caputo (Figure 6) of Westfield, Massachusetts obtained a job as a television newscaster at WWLP, Channel 22, in Springfield, Massachusetts with the provision that the Mass. Commission for the Blind would obtain newswire braille for his use.

A Braillemboss was installed at WWLP–TV Channel 22 during May 1971. The interface unit for this installation had to be significantly different from the one used previously for the news demonstration.

In the news demonstration above, punched paper tape was used as a convenience but it also served as a timing buffer to accommodate the generally longer carriage return time of the Braillemboss. Using this method as an operational system is inappropriate since the paper tape adds another expendable (paper tape), as well as requiring a tape reader and tape punch. A full reel of paper tape lasts only 5 to 6 hours, while a box of braille paper lasts several days. This complicates the operation and requires much more attention by the user than is desired.

To simplify the system an integrated-circuit storage system was designed and built to provide the necessary timing buffer, eliminating the need for the intermediary paper tape. Two shift registers, both 128 words long with 8 bits per word, are used. While one register is being loaded from the newswire the other register is used to drive the Braillemboss. When the register being loaded is full, the system interchanges the registers. Sufficient time generally exists to unload a register into the Braillemboss while the other register is being loaded.

Included in the interface unit are format control circuits. A space counter and line control circuits are used to divide the 72 character line of the teleprinter at a space near the 38-cell length of the Braillemboss line. This generally eliminates dividing words randomly at the end of the line. Also paging control circuits were included to prevent embossing on the perforations.

This newswire Braillemboss installation was a cooperative program with the Mass. Commission for the Blind. The Center adapted a Braillemboss to the UPI newswire by designing and constructing the interface unit. The Mass. Commission supplied funds for the necessary hardware.

Unfortunately Mr. Caputo's relationship with WWLP Channel 22 was severed during October 1971. The Braillemboss performed well during the period and provided him with excellent braille copy that he could read rapidly and accurately while on camera.

There is some dropping of characters in the timing buffer used in the newswire interface unit when a long series of short lines are received. Developments of computer memory technology since the newswire interface unit was designed should permit significantly better buffer performance for approximately the same cost as the original buffer.

Interactive grade II braille production

A computer program for Grade II braille translation, DOTSYS III,[23] was written by the MITRE Corp. under contract to the SAEDC. (This contract was supported from a multi-sponsored M.I.T. account). The program is written in COBOL (Common Business Oriented Language) such that it can be transferred from one suitably equipped computer to another with minimal changes. 24, 25, 26

Additions have been made to DOTSYS III to use the Braillemboss as an output device. This modified program is called DOTSYS III and is stored in the time-shared computer of Interactive Data Corp., in Waltham, Mass., a commercial computer facility.

A teletype, connected by telephone line, is used as the input/output device of the computer. The Braillemboss is connected via an interface unit to the teletype.

The material to be brailled is typed into the computer where a data file is created. This file can be proofread and corrections made. Then by a single command the material is translated by the computer and brailled on the Braillemboss.

The initial interface units did not include a computer controlled brailler on/off switch such that they could be used with the computer translation program. A redesign of the Model 33/35 interface unit permits the Braillemboss to be used as a time-shared computer terminal for a blind programmer or by throwing a switch, be used as the braille output for DOTSYS III.

National Braille Press Demonstration.—The first substantial use of DOTSYS III by the SAEDC was the brailling of an IRS publication for a client of NBP in December 1971. The material to be brailled was typed into the computer using the necessary format controls thereby forming the input file. The input typing was done by personnel of both NBP and the SAEDC. As sections of the input file were completed, these sections were individually translated, brailled, and proofread. Typographical errors in the input file were corrected and small changes were made in the translation table of the program to remove program braille errors. After the input file was completed and all known errors corrected, the entire publication was translated, embossed by the Braillemboss, bound by NBP and delivered to their client.

This system shown in Figure 7 was demonstrated to a large group of possible employers and workers for the blind on January 31, 1972. An employee of NBP produced several pages of braille. Following the typing and correction of the input file the remote computer translated the material which was then brailled on the Braillemboss.

"*In Darkness.*" On January 5, 1972 Howe Press of Perkins School for the Blind issued a purchase order "* * * to do a single copy at M.I.T. of the novel *In Darkness* using a paper tape prepared by computer and to provide Howe Press with a paper tape to drive the sterograph machine * * *" Scheduling commitments with the above demonstration at NBP delayed the start of the work until February 1, 1972. The same steps were employed in the translation as at NBP including two proof readings except that a punched tape was prepared when a copy was being produced by the Braillemboss. The proofreading was performed by NBP personnel under a purchase order on a time available basis.

The unbound braille copy was delivered to Howe Press on April 12, 1972. The SAEDC then worked with Howe Press personnel in testing, adjusting, and repairing the APH paper tape driven sterotype. The SAEDC staff then operated the sterograph and otherwise assisted in producing the embossed zinc plates for press braille production. This sterotype's reliability could be improved by replacing the relay control system with solid state logic, as used in the Braillemboss.

The experience gained by the regular staff of the SAEDC, supplemented by proofreaders, has demonstrated that the existing computer program and equipment can produce computer translated braille. It cannot be done efficiently, however, unless the work is performed by an organization fully and completely committed to braille production. The overall national production and timely

[Footnotes appear on p. 47]

availability of braille would be improved if several regional computer braille production facilities were established to supplement the work presently being done by The American Printing House, the many volunteer agencies and the braille libraries. These regional facilities could be either new organizations or extensions of existing braille agencies.[27]

Technical description sheets

Two TDS's have been translated by DOTSYS III and are stored in punched paper tape form such that copies can be produced on demand.

The first one translated was TDS #2, the Braillemboss, a Braille Page Printer (Appendix V). In inkprint it is two full single spaced type-written pages and in braille it is six plus pages. A typist with some previous experience typing in material for DOTSYS spent approximately an hour typing the material, proof reading and correcting the input file that was produced. It then took 20 minutes of terminal time to translate and braille the material.

A total time of 80 minutes was required for a person familiar with the DOTSYS format control convention (Appendix V TDS No. 11) to produce this report. It was not necessary for that person to know Grade II braille; however, the user should have some knowledge of braille to check for obvious operator, computer transmission or terminal error.

TDS #1, Folding Canes (Appendix V) has also been translated by DOTSYS III. It is a little shorter than TDS #2. It is five and one/half braille pages long and took 45 minutes to produce.

Both of these TDS's are available in braille or request to the SAEDC.

The social beaver

The SAEDC in conjunction with Technology Community Association (TCA), the M.I.T. Libraries, and Howe Press has embossed 25 copies of *The Social Beaver*, a chapter of HoToGAMIT (How To Get Around M.I.T.) HoToGAMIT is a paperback student guide to M.I.T. as well as the Boston area. The chapter entitled *The Social Beaver*, is a guide to enjoying yourself in and around Boston and is applicable to all, not just M.I.T. students.

Through a fortunate set of circumstances catalyzed by Steve Shladover of TCA this braille volume was made possible. Lindsay Russell volunteered to produce the braille coded punched paper tape necessary to produce the copies of braille economically on the braillemboss.

The Braillemboss has been used previously to produce braille materials from manually prepared punched paper tape. In the work described in Appendix V TDS No. 7, the punched tape was prepared by a professional braillist using a modified Perkins Braillewriter connected to a paper tape punch.

The Center has a special teletype, modified by Mr. Ray Morrison, a telephone pioneer, that produces braille coded punched paper tape directly from its keyboard. This teletype contains all the Grade II braille symbols in its character set.*

Bertha Kasetta of the Howe Press and two blind young people presently or formerly M.I.T. students proofread the material. The book was then brailled by the Braillemboss operated by TCA volunteers under the direction of the Center Staff.

The M.I.T. Libraries undertook the distribution of copies of the finished volume to other universities and colleges in the Boston area. A copy has been given to each blind student at M.I.T. The libraries also underwrote the cost of binding the volumes by the Howe Press.

Rehabilitation Agency, Arkansas Enterprises for the Blind, Little Rock, Ark.

A Braillemboss was made available to Arkansas Enterprises for the Blind to be used in their rehabilitation and training programs. It was installed during September 1972. AEB has obtained a minicomputer and paper tape equipment to be used with the Braillemboss.

AEB's applications include training of IRS TSR students on the IDRS system. They will also use the Braillemboss to train other students in computer interaction. The minicomputer can be used both as a simulator of the larger IRS IDRS or as a small computer for actual operating and programming experience by other AEB trainees.

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*This teletype is similar in concept, but different in detail, to the Tyco brailler developed previously by Woodcock.[28]

[Footnotes appear on p. 47]

Another AEB application of the Braillemboss is the braille duplication of instructional materials. A paper tape punch/Perkins Braillewriter combination was borrowed from Howe Press to support this effort. The Howe Press equipment was used by an expert braillist to produce a punched paper tape which is then used to operate the braillemboss to produce as many braille copies as desired. This same paper tape equipment was used at an earlier time M.I.T. to produce a pamphlet for Perkins upper school students to establish the accuracy of reproduction by the Braillemboss (Appendix V, TDS #7).

TACCOM

Taccom (for "tactile communication") is the name given a system of signalling to deaf, blind, or, most importantly, *deaf-and-blind* persons. The focal device of the system is the Taccom pocket receiver—see figure 8—a six-ounce instrument which vibrates in response to a radio signal. Carried on the person, in a shirt pocket typically, the receiver functions as a pager, not unlike the pocket pagers in common use by physicians in a hospital or executives in an office building. Instead of beeping in response to a call, though, the Taccom receiver vibrates; held in the hand, when it is activated it feels rather like an electric toothbrush running.

Two purposes established the initial scope of the TACCOM project, both related to needs of the deaf-blind:

(1) To develop something to serve as a fire alarm;

(2) To develop something to serve as a doorbell.

The financial support for this project has two roots: an initial purchase of hardware by the National Center for Deaf-Blind Youths and Adults * with a view primarily toward fulfilling the above two needs; later, support over a three-year period by the Social and Rehabilitation Service of the United States Department of Health, Education and Welfare, with the objective of augmenting and broadening the usefulness of TACCOM beyond this initial rather limited scope.

Background

To summon a person who is both deaf and blind, to alert him that there is a fire, or that he is wanted elsewhere, or that a particular moment has come (e.g., end of lunch hour) is not an easy thing unless one is close enough to touch him and communicate by physical contact. A person who is blind but hears normally can be altered in the usual auditory ways: doorbell, fire gong, even by calling out to him. On the other hand, a deaf person, if he has sight, can be signalled visually by the turning on or off of a light or in any other way that will catch his eye. In the case of the double handicap—deafness and blindness together—there seems to have long been a need for some scheme that could call a person from a distance without needing either his eye or ear. Such devices have been used as stamping on the floor or starting an electric fan (to create an air current) but they have obvious limitations in range and dependability.

Although it is this *double* handicap to which Taccom is primarily addressed, there come to mind ways in which a person afflicted with deafness or blindness alone could make use of a vibratory signaller. A deaf person can be alerted by turning on a lamp, but only if it is assured that he will be looking where the light can be seen, a difficult requirement, perhaps, when he is in his yard. A nonauditory signal could be useful to a blind person under many circumstances one could envision: when a soundmaker would embarrass him, annoy others nearby, drown out other sounds he must hear, etc. Thus while the need of the deaf-blind are the main objective of Taccom and its (by now) many adjuncts, there has been attention given that potential benefits to those with either single handicap do not pass by our view unheeded.

Technical description

Radio frequency induction is the signalling means of the Taccom system. Technically this is not true radio communication; indeed it is a form of signally that historically antedates radio. The transmitted signal is a 25 kilohertz alternating magnetic field set up by energizing one or more loop antenna splaced typically on the walls of the building or rooms to be covered. Figure 9 shows the transmitter proper, an all-solid state unit housed in the kind of cabinet used for audio amplifiers or small public address systems.

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*Referred to subsequently in this report as the "National Center," it is located at 105 Fifth Avenue, New Hyde Park, N.Y., and administered by the Industrial Home for the Blind, Brooklyn, N.Y.

Creation of the ringing field is accomplished by pressing a button on the front of the transmitter. "Short Ring" is a momentary-contact pushbutton; "Long Ring" evokes an activation of fixed duration, tyically set at five seconds. The latter feature is primarily for insurance against missed calls due to an over-brief button push on the part of the caller. Pushbuttons at other locations can be wired to terminals on the back of the transmitter so that it can be activated from a remote location if more convenient.

Five small jacks on the front of the transmitter are outlets for recharging batteries within the Taccom receivers; this is done each night-thus five receivers can be recharged simultaneously.

Receiver

The characteristics of the TACCOM pocket receiver are as follows: Weight, 6.3 ounces; size (approx.), 2½ x ⅞" x 5"; battery, Four Burgess "CD–3"; Ringing time, 45 minutes starting fully charged; Listening time *, 150 hours starting fully charged.

The components are all in a small aluminum case, except for the loop-stick receiving antenna, which is potted in silicone rubber at the bottom. When the transmitter is activated and a ringing field established, a weak 25 kilohertz signal is induced in this loopstick; it is amplified by circuits within the receiver, detected, and if above a certain minimum threshold, causes to be energized a tiny electric motor within the instrument. The vibration is brought about by a tiny eccentric on the motor shaft. The mechanical inertia is low, and the vibration starts and stops within milliseconds of the starting and stopping of the ringing field.

Transmitting loop antenna

All installations to date make use of transmitting loops in vertical plans, so that the magnetic field lines therefrom will be substantially horizontally oriented in the service area. The receiver loopstick will normally be oriented more-or-less horizontaly oriented in the service area. The receiver loopstick will normally be oriented more-or-less horizontally too, for example, in the pocket of a sitting or standing person, so that its alignment is appropriate for the exciting field. If this exciting field were generated by a single loop antenna, however, a null direction would exist where the loopstick, thought horizontal, would be perpendicular to the magnetic flux lines. (Anyone who has rotated a transistor radio in his hands will have observed corresponding nulls that it, too, exhibits in certain directions).

To avoid the risk of missed calls due to a user's possible unfavorable orientation when being paged, a second loop is used, also connected to the same transmitter, but whose exciting current is in time quadrature with that of the first loop, and whose physical placement is at right angles. This arrangement effects essentially null-free coverage, since the null direction of one loop's field will be nearly at the maximum of the other's, and the time quadrature relating the two will prevent destructive interference at intermediate angles.

Why magnetic induction?

A word or two ought to be said regarding the choice of this low frequency induction scheme, especially considering that there are true radio systems as alternatives. For example, why not use Citizen's Band channels or possibly even private frequencies of one's own assigned by the Government?

Easily the most negative feature of the induction system chosen is the need for the transmitting loops; for strong coverage the wires comprising them must run the length and breadth of the coverage area. Whether this factor makes the installation of a Taccom system troublesome and expensive depends on the building involved, whether the wires must be totally out of sight, and so on. There are ways of avoiding some of these problems, about which more will be said in the next few pages.

The positive features are technical simplicity and freedom from radio interference problems (false rings, etc.). The receiver uses only five transistors, and its simple circuit lends itself to substantial further miniaturization should such an end be sought. The noise level at its detector is more than 50 decibels below

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*"Listening" means the quiescent situation where the receiver is switched on to be able to respond to a call, but is not actually being called. There is very low battery drain (compared with "ringing"); hence the many hours of life when the receiver is on but not activated.

the signal present upon receiving a ringing signal; the transmitter, with only several watts output, provides considerable "overkill." In short, there is a high strength or safety factor in this system; only the most rare and unlikely circumstances could be envisioned wherein it would interfere with or suffer interference from other radio services.

Installations to date

Taccom signalling systems have been installed in four separate buildings:

(1) The M.I.T. Sensory Aids Center at 292 Main Street, Cambridge, Mass.

(2) The M.I.T. Sensory Aids Center at 77 Mass. Avenue (Building 31), Cambridge, Mass.

(3) The Headquarters of the National Center for Deaf-Blind Youths and Adults, New Hyde Park, N.Y.[29]

(4) The apartment of a deaf-blind National Center staff member at Kew Gardens, N.Y.

The M.I.T. installations

The Taccom installations at M.I.T. (two, because the Sensory Aids Center moved from its old to its new location in 1971) were set up not only to prove out the system in an initial way, but to gain the experience of many months of continuous operation—a designer's life-test, so-to-speak. Both installations were accomplished without difficulty; the coverage area in each case was about 4000 square feet, and it was null-free. The one transmitter involved has run about three years and has been without breakdown. It can be keyed (to page receivers in the area) by pressing a button either at the Director's desk or that of his secretary. One staff member has for several years made it a habit to keep receiver in his pocket at all times while at work; to gain him a secondary benefit (besides the main one of life-testing the equipment involved), the transmitter has been wired to the Center's telephone switchboard so as to signal incoming calls, and to an "electric doormat" to signal that someone has entered the front door. Since the reception area and switchboard are unattended at off hours, the arrangement permits him to work in remote areas of the Center without missing incoming calls or visitors.

The new Hyde Park installation

This Taccom system was installed at National Center Headquarters and put in operation in July, 1970. A semi-institutional setting wherein a number of deaf-blind clients are served in various rehabilitative and sheltered work programs, it has been here at the National Center that the bulk of experience has been had with the kinds of handicapped people Taccom is designed to serve.

The system is in use at this Center as a fire or evacuation alarm (initially for testing and demonstration, but now for "real") and has been wired to a time-clock to signal each hour's rest break and return to work. The system has functioned as it was designed to do, although a number of problems have turned up: the main ones and their solutions are summarized as follows.

1. *Vibration amplitude.*—Many clients find a severe startle factor in the Taccom stimulus. This is not surprising; experience across a broad front suggests that a person deprived of one or more senses is startled by a relatively minor stimulus in a remaining sense, especially when the stimulus comes on suddenly. Thus, the Taccom vibration, which seemed just adequate to its designers for being reliably felt through a layer or two of clothing, was excessive to most deaf-blind people, and many objected to wearing the early receivers for that reason. The problem is easily corrected by reducing the rotor mass eccentricity in the receiver's motor; a number of receivers were recently so-modified on a trial basis for the National Center by M.I.T.

2. *Inadequate pocket retention.*—A second problem was that receivers dropped out of users' pockets with considerable frequency, sometimes being damaged on striking the floor and needing subsequent repair. The early units had pocket clips more suitable for securing a pencil than a 6 ounce receiver; the retaining method was improved some by cementing abrasive patches to press against the pocket wall, but even the improved units had only marginal retention. On the basis that each receiver would probably get dropped sooner or later anyway, more rugged mounting means were arranged for the batteries and motor inside, which were the components that generally got dislodged from a bad drop. Each

[Footnotes appear on p. 47]

receiver returned to M.I.T. for repair was sent back not only fixed, but with more secure internal construction. The problem, then, while not solved completely on a hard-and-fast basis, was considerably alleviated. Further work should include a stronger clip yet, perhaps special pockets sewn on the clothing of users for whom nothing else will work, possibly mounting on a belt or other similar strategem. Finally, miniaturization of the receiver would make the task easier no matter what the scheme of mounting.

3. *Instllation of loops.*—A third Taccom system attribute needful of improvement is the nuisance factor (and possible cost) of installing the transmitting loop antennas. The number of loops needed and their placement depend on the geometry of the service area, and it is not feasible at present to prepare a blanket manual of instructions. The magnetic flux paths are not straight lines but curve away at some distance from a loop, so that, for the moment, engineering judgment is needed to prescribe for a particular setting. For this reason, and with a limited number of installations envisioned at present, it has seemed a wise policy for the Sensory Aids Center at M.I.T. to examine each setting and suggest an antenna arrangement. A way has been found to simplify the loop requirement now, and is described further on (see "Horizontal loop").

4. *Miscellaneous improvements.*—Several things of a more minor nature were suggested by National Center personnel—improvements which would diminish nuisance value and result in greater convenience to the deaf-blind users.

One would be a short-stop button on the receiver; pressing it during a ring would terminate or abort the remainder of that ring. A timeclock signal, for example, might last ten seconds; the user who "got the message" during the first second could press the short-stop button and not be subjected to nine seconds' additional vibration.

Also desirable: a more convenient recharging method than the present one of connecting the small charging plug to the receiver. Perhaps the electric toothbrush scheme could be used—the receiver would merely be dropped into a slot or receptacle and recharged by magnetic induction—no connections needed.

Kew Gardens (apartment) installation

A "doorbell' installation was put in use on a test basis at the apartment of a National Center deaf-blind staff member. The transmitter was placed atop a refrigerator in the kitchen and two loops were affixed to kitchen walls at right angles. The coverage was adequate in most of the two-bedroom apartment, though just marginal at extreme ends of the furtherest rooms. The loop arrangement was responsible for the marginality; it was a compromise which avoided time-consuming work of an electrician in snaking wires through walls, etc. The transmitter was actuated by the apartment front-door intercom "beeper" by means of a sound switch (described further on) placed against the tiny intercom loudspeaker in the user's livingroom. Results of this Taccom setup were reported to be satisfactory; it was taken down, though, when the user moved to a new location.

Ancilliary Taccom devices

A considerable part of the S. R. S.-supported Taccom work was the study of ways to augment Taccom's usefulness beyond the simple paging or calling function that was its initial task. A number of techniques were studied and devices designed to that end; many of the studies resulted in working hardware, and some of this hardware was placed into service with deaf-blind clients (at the National Center) during the period of the contract. These subsidiary studies are described as follows:

Standby battery

An emergency standby battery pack was developed for the 115 volt transmitter to enable it to continue running in the event of power failure. If the Taccom system were used as an emergency or fire alarm, it is apparent that the very circumstances that might call most urgently for activation of the alarm could be accompanied by a failure of the AC power; hence the need for the battery backup.

The standby pack is retrofittable into existing transmitters; that is, the pack fits entirely into the present transmitter cabinet. The battery, a set of nickel-cadium cells, is kept on trickle charge under normal conditions, so as to be always on call fully charged; a sensing relay responds to failure of the main power and within a second throws the battery onto the transmitter's internal DC bus to supply energy if a ring is called for. The battery will provide thirty minutes of ringing, enough, obviously, to warn of an emergency.

Long-playing battery

Something quite separate, and not to be confused with the above, is a small rechargable battery pack not much bigger than a Taccom receiver. It is typically kept in one pocket, and the receiver in another, with a tiny cable running between. Its function is to give the receiver a substantially longer ringing time than the 45 minutes it normally gets from a full charge on its own internal battery. Reason: Sometimes a receiver is to be used for many hours a day in situations involving much ringing, and if operated on its own battery alone, would run down long before the day ended. An example is in training deaf-blind clients to walk a straight line (correcting veering tendency); the trainer signals him when he veers via his Taccom by keying a hand sender (described below).

Hand sender

The hand sender (Figure 10) is a short range (about three feet) battery-operated transmitter. One of its uses is to demonstrate the Taccom system to visitors or to the handicapped clients. One hands such a person a receiver and then makes it ring by pressing the signal button on the hand-held sender several feet away. The advantage of the short range, of course, is that one does not ring all the receivers in the area, as would happen if he keyed the *main* transmitter. Thus a rehabilitation counsellor can work with a particular client in an institutional setting, make use of the short range Taccomm feature for some purpose or other, and not disturb other clients by making their instruments ring too.

End of line signal

Another specific use for the short range signal is to create a vibratory equivalent to the end-of-line bell on a typewriter. It works this way; the user of the typewriter wears his Taccom receiver in the usual way, and the hand sender is placed on the table alongside the typewriter with a small cable connecting the two. As he approaches the end of a line, the instant the warning bell rings, the hand sender is keyed for about one-half second, so the pocket receiver gives a brief burst. Thus, although the typist can neither hear the bell nor see the line he types, he gets his warning anyway, and he need not keep stopping to feel the carriage position to sense when he is near the end of his line. The complete system is shown in Figure 11.

To so aid him requires that the typewriter have installed on it a tiny switch at the bell hammer and also a small connector on the back of the machine so that the hand sender can be connected or disconnected according to whether the system is to be use. The typewriter is not encumbered in any way, then, when the new feature is not in use. So far as can be ascertained, most makes of machines can be equipped with the bell-switch, and, importantly, so can a Perkins Braillewriter. A latter instrument, so-equipped, was furnished to a deaf-blind braille user for a trial.

Selective ringing

The Taccom system at present is an "all-ring" system; receivers are identical and all respond in unison when the 25 khz. activation field is present. One can envision circumstances wherein it might be desirable to signal one receiver of another out of a group, paging one particular individual without disturbing any others. A brief study was made of ways to achieve such selective ringing. A straight-forward way would be to tune receivers in the area to different frequencies and modify the transmitter for multi-frequency operation. Subcarrier or tone modulation schemes would be another.

The selective ringing problem was studied briefly on a theoretical basis (conclusion: it would cause considerable complication of present equipment but nonetheless be quite feasible), but no hardware was built. No user or using agency to our knowledge felt a need for incorporating such a feature into his existing programs, while hardware for other Taccom ancilliaries (e.g., soundswitch) *was* needed—first hardware priority was given where need existed.

Sound switch

The sound switch Figure 12 is a microphonic device connected to the 115 volt transmitter to cause the keying of the transmitter in response to ambient sound.

One can demonstrate its function to a visitor holding a pocket receiver, for example, by giving a loud whistle; the receiver will vibrate for the duration of the whistle. (The sound will have been picked up, causing the transmitter to be keyed and thus activating receivers in the area.)

Useful sound switch applications are probably rather evident. The device can be placed near a telephone to signal its ringing to a deaf-blind person in the area. The same can be done with a doorbell. No electrical connections need be made, a fact that can be surprisingly advantageous. In the case of the Kew Gardens installation described earlier, for example, the usual city apartment situation was found: a street entrance with a row of intercom buttons to "beep" each unit, and the apartment in question some flights up. It would have been a costly task for an electrician to run secondary lines down to the street entry, install a special button, etc., to say nothing of getting the landlord's permission. As it was, however, a sound switch was strapped across the livingroom intercom speaker to pick up a visitor's "beep"—no connections whatsoever had to be made to the existing building wiring.

Further uses might be to pick up the buzz of a kitchen timer or the cry of an infant waking in the night (the sound switch could be suspended over the crib). The sensitivity can be varied over a wide range so as to make the switch respond only to loud nearby sounds or, if wanted, to much fainter sounds. In fact, the sensitivity can be increased to the point where it will key the transmitter intermittently from the sounds of a radio playing in the same room.

Light probe

A corresponding device, used to detect ambient light instead of sound, was designed and breadboarded. This unit ought to be thought of as a Taccom-like instrument for having a vibratory display, but beyond that, it has no direct connection either to the receiver or transmitter. It is, in fact, a totally self-contained unit resembling a small flashlight. Instead of casting light, though, it responds to light; aim it at a source of light and it vibrates like a Taccom receiver; aim it where there is no light and it is still. It embodies a lens, phototransistor, solid state amplyfying circuitry and a vibration motor.

The light probe could be used by a deaf-blind person to ascertain whether lights were on or off in a room, whether a pilot lamp glowed to show that an appliance was turned on and so forth. Also it might have application in travel, permitting one to home in on a front door light at night, etc.

Horizontal loop

When it became apparent that a simple antenna would be a worthwhile system improvement, a modified pocket receiver was designed whose loopstick was oriented vertically. Figure 13 shows this receiver; the loop-stick is held in a bulge or "blister" on the front.

With this kind of receiver in use, the transmitting antenna can be a single loop in the horizontal plane: it would run around the perimeter of the area to be covered (which could be quite large—some acres, in fact), going up-and-over to get by doors, and need not run across floorways in the interior, a bothersome point with the present system.

This new system would have been used at the outset, were it not for the thought that the receiver design would have been complicated and its shape slightly less advantagious for pocket carrying. Also it was thought that the original system would give the user somewhat more latitude in bending or stooping, where the receiver could depart many degrees from vertically, and still have little risk of missed calls.

These problems seem not to be troublesome as originally thought, and the new system now seems preferable—a step in a good direction. If and when more Taccom systems are installed, the one-horizontal-loop arrangement will probably be recommended for its simplicity.

Signalling codes

Just as a bell or buzzer can be used for simple messages ("go to the door"), it can also be used to convey information of much greater scope, for example by using Morse Code. A similar extension of the Taccom system has always seemed an exciting possibility: the receiver responds swiftly to keyed signals, and the transmission of Morse, albeit at a slow rate, should be possibly by simply connecting a telegrapher's key to the transmitter. Thus one could "talk" to a deaf-blind person at a distance, something not readily feasible at present so far as is known.* With a sound switch appropriately placed near a telephone receiver, Morse could be sent a deaf-blind person at his home via telephone.

At least the beginnings of coded signalling are now in view: Clients at the National Center distinguish the long slow ring for the hourly rest break from the rapid short rings of a fire drill. Also, visitors to the earlier-mentioned deaf-blind apartment dweller would identify themselves at the door by individual codes—two shorts, one long, etc. At the Sensory Aids Center an all-solid state code keyer has been breadboarded with which, by pressing a button, various ten-element sequences of dots and dashes can be initiated.

How useful such techniques might ultimately be is not known. To view the matter conservatively, a Morse signalling system might find little usefulness to most deaf-blind persons; indeed, on the basis of conversations with rehabilitation workers, there seem not to be many deaf-blind people who have learned Morse. On the other hand, the personal communication barrier is the dominant impact on this tragic double handicap, and anything that might help penetrate the barrier must have potential value.

PATHSOUNDERS

Approximately three years ago five Pathsounders[30] (ultrasonic mobility aids) were purchased under Contracts SAV 1057–67 et al., precedessors to the current SRS contracts at SAEDC. The Pathsounder is shown in Figure 14.

A follow-on effort has continued in the evaluation of these devices; this has involved a minimal expenditure, simply that needed for maintenance, responding to inquiries, and occasional acts of assistance to users and their instructors. The follow-on seems to have been highly worthwile; though it may have required only a tiny fraction of the SAEDC effort. The following is a brief summary of the status of each Pathsounder, with mention of the school or agency concerned.

The first unit is in use by a young woman blinded (totally) and deafened (partially) by a recent attack of meningitis. The rehabilitation counsellor, in overseeing cane-travel instruction for this client, requested a Pathsounder because of the difficulty she was having in bumping into above-the-waist objects and because of her inability to localize objects by sound. She reported the instrument most helpful and her lessons ended, she now retains it on long term loan. (Vision Center, Columbus, Ohio)

The second unit has been used in an effort to effect some limited travel independence for a fifteen-year-old boy blind from birth and confined to a wheelchair by cerebral palsy. The Pathsounder and appropriate training have got him "on his feet" to a modest extent, and his instructor reports encouragement. (Ohio State School for the Blind, Columbus, Ohio)

The third Pathsounder is in use by a blind Brooklyn resident, a cane-traveler who, according to the agency concerned, was trained with it, found it helpful in walking to work in a city environment, was allowed to retain it, and continues to use it. (The Jewish Guild for the Blind, New York, New York)

The fourth Pathsounder is in use by a twenty-one-year-old girl totally blind from birth, and confined to a wheelchair by cerebral palsy. She graduated from a residential school where she was given Pathsounder training; because of her travel progress the staff elected to have her retain an instrument, and she is now reported to be traveling independently and effectivelly in her new environment. (The Oak Hill School, Hartford, Conn.)

The fifth Pathsounder has been on loan to a college for use of teachers-in-training in its Orientation and Mobility Program. A rather thorough evaluation of the device's effectiveness was performed by several students, in particular, the effectiveness in easing a cane-traveler's course through fairly dense pedestrian traffic in downtown city areas. The results were favorable, and in fact, most encouraging; their publication by the investigators is anticipated. (University of Pittsburgh, Pittsburgh, Penna.)

Thus, all five SRS-owned Pathsounders continue to be beneficially employed, and the productive liaison between this Center and the schools and agencies involved should be evident.

Personnel

The Staff of the SAEDC during this grant included Vito A. Proscia, Research Associate and Director of the Center (to April 1972); George F. Dalrymple,

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*It is understood that experimental systems directed toward this end do exist, notably one proposed by Bell Telephone Company.

[Footnotes appear on p. 47]

DSR Staff Member and Acting Director; Nancy Brower, secretary (to August 1970); Evelyn Welch, secretary (August 1970—June 1972); Susan Sokalner, secretary (since July 1972); Norman L. J. Berube, Senior Technician. Additional work was done for the Center by Lindsay Russell, consulting Electrical Engineer, and Murry Burnstine, consulting Mechanical Engineer.

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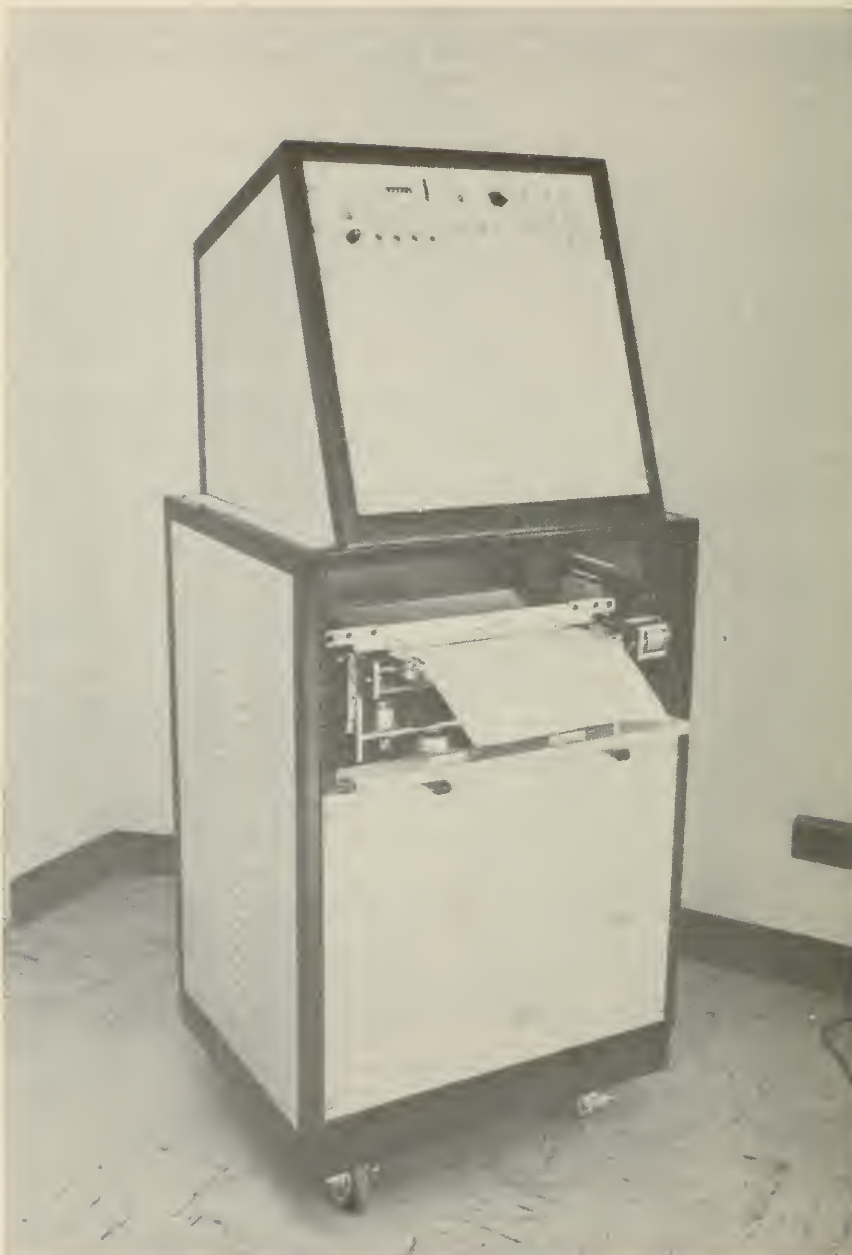

Figure 1

Model 3 BRAILLEMBOSS

Figure 2

Model 4 BRAILLEMBOSS

Figure 3

Dr. John Morrison at his
BRAILLEMBOSS Terminal.

Figure 4

Mr. Alan Downing at the
Prototype BRAILLEMBOSS Terminal.

Figure 5

Mr. Jack McSpadden of the IRS Little Rock District Office Showing the MIT BRAILLEMBOSS to Mr. Johnnie M. Walker, IRS Commissioner and Mr. Albert W. Brisbin, Regional Commissioner.

Figure 6

Mr. Paul Caputo Reading Braillembossed
UPI Newswire Copy.

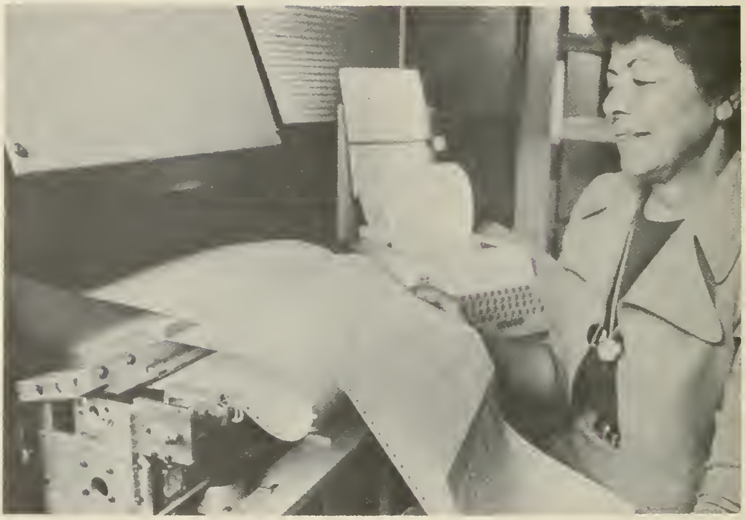

Figure 7

Mrs. Janet Fields Examining Braille
Produced on the BRAILLEMBOSS at
The National Braille Press, Boston, Mass.

Figure 8

TAC-COM Receivers

Front and Rear View.

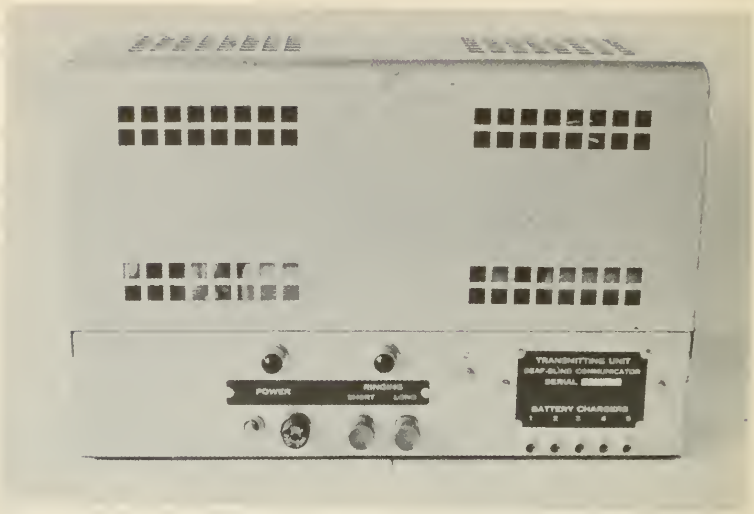

Figure 9

TAC-COM Transmitter

Figure 10

TAC-COM Hand Sender.

Figure 11

Mr. Vito A. Proscia Using the
TAC-COM End of Line Indicator on a
Perkins Braille Writer.

Figure 12

TAC-COM Sound Switch

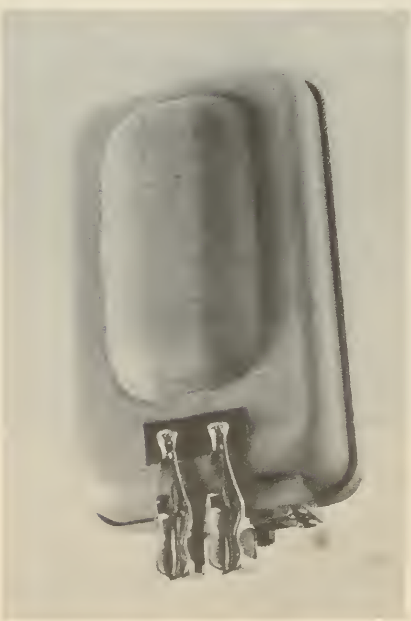

Figure 13

TAC-COM for Use
with Horizontal Loop.

Figure 14

PATHSOUNDER

Appendix I—Evaluation of the M.I.T. Automatic Brailler

The M.I.T. Brailler has been located in my office in N.A.S.A.'s Electronic Research Center in Cambridge, Mass. for three months. The Brailler is connected to a teletypewriter which is, in turn, connected by a telephone line, to a Digital Equipment Corp. PDP–10, a digital computer. I share this office with one other person.

I am blind; my office mate is not. Both of us are PH.D., Aerospace engineers, employed by N.A.S.A. to pursue research in the application of orbital mechanics to the determination of the motion of earth satellite. The teletypewriter has been used exclusively by us.

I have been involved in this type of work for ten years. By the nature of the work, it has been essential to program the results of my research on a computer for purposes of verification of the accuracy of the calculations, evaluation of the methods employed and investigation of possible applications. As is not unusual, I have called in programmers to carry out the actual programming and running of the results on a computer. I have had to rely on others to at least scan the numerical output in order to keep abreast of progress. The whole procedure has been quite unsatisfactory. The effort, time, cost, red tape, and the inefficiency of the procedures have led, in practice, to laying aside possible fruitful avenues for investigation.

With the advent of time-sharing capability, the situation has been completely altered. A scientist can now have direct access to the computer and almost zero turn-around time. However, for a blind scientist the time-sharing capability of computers is absolutely useless without a braille output device to reproduce the teletype output. It was my good fortune that, when the time-sharing facility became available to me, almost simultaneously, the M.I.T. Brailler was put at my disposal for evaluation purposes.

From a purely personal point of view, I cannot emphasize enough the almost unanticipated boost in morale the Brailler has afforded me. For the first time, I can access the computer directly and, for the first time, I can read the results of my labor. It is no exaggeration for me to say that, for the past three months, I have spent just about every waking moment either sitting at the Brailler and teletypewriter or preparing my next numerical experiment. Needless to say, I have not nearly exhausted the backlog, built up during the past ten years, of possible uses for the computer.

From the point of view of a productive worker, my contribution to the in-house effort has kept pace with my colleagues, which would not have been the case had I not had the Brailler at my disposal. I consider it an indispensable instrument for my work. Should I be deprived of its use, my value to my employer would suffer commensurately.

In my opinion, every possible effort should be made to ensure the development and further refinement of the M.I.T. Brailler and its availability to all blind persons who can demonstrate a legitimate use for it. The potential uses for the Brailler are by no means limited to my particular applications. The least that can be said is that whatever is available to a sighted person through a teletypewriter is available to a blind person through the addition of a Brailler. This capability alone is sufficient to justify the development of the Brailler.

The M.I.T. Brailler does have some shortcomings, but they do not nearly cancel its advantages. One difficulty with the present design, and one which will take some ingenuity to eliminate, is the dropping of a character at the end of a line. This defect has been more of an annoyance to me, rather than a hindrance, since properly formatting the output circumvents line-overlap. Noise is another annoyance which can probably only be ameliorated under the present design. Some aspects of the Brailler which can be improved are: size of the machine, manner of presentation of the brailled material as it issues from the machine, and reliability.

John Morrison.

Dr. Morrison wrote this report directly into the PDP–10 computer using a teletype and braillemboss. A text editor program, TECO (Text Editor and Correction) was used to correct, insert, delete, and modify report as necessary. Dr. Morrison then used an auxiliary program to format the report for the line length of the braillemboss. Following Dr. Morrison's directions a teletype at the SAEDC was attached via telephone to the computer and the report requested. The report was printed on the teletype directly from the computer's memory. This copy was retyped from the teletype copy without further editing.

George F. Dalrymple.

Appendix II—Semiannual Review

Date: 20 February 1971

To: Massachusetts Commission for the Blind

From: John Morrison, Department of Transportation, Transportation Systems Center

Subject: Operation and application of MIT–SAEDC's Embosser.

At this installation, the Braille Embosser is connected to a Teletypewriter (Mod. 33). This remote terminal can, at present, access by conventional (voice channel) telephone lines, either a PDP–10 computer (located in the building) or the Government Services Administration's computer center located in Atlanta, Ga. This latter facility is accessed by a local call to the Boston GSA office; then via leased lines through New York and Washington to Atlanta. The computer in Atlanta is a General Electric 440 Time-share system.

The remote terminal is in nowise limited in its use as a conventional Teletype by having the Braille Embosser attached to it. It is, as a matter of fact, not only used by myself, but by two or three other sighted persons. For the most part, I use the terminal to perform three functions.

The first of these—and by far the most important—is to input scientific programs into the computer and to output the results calculated by the computer. The Brailler is essential in both stages. The terminal produces a braille copy of my program, along with any errors in the program that the computer can find. This permits me to have a permanent copy of the program for future use and to make any necessary corrections. The output, of course, is most important since it contains the reason for doing the work in the first place.

The second use of the Brailler (and the Teletype) is to obtain copies (Braille and print) of manuals and shared library programs which are contained in storage in the computer systems. This facility has been especially helpful to me in learning how to use the GSA computer.

Finally, one of the computer programs (which happens to be available on both computers) is of particular interest to me for reasons other than mathematical or engineering. This program, called Runoff, was devised to assist in the preparation of reports. I write a report in braille; type it into the computer, including instructions or titling, centering, paragraphing, footnoting, etc. I get back a braille copy of just the report (without the instructions) and a typed copy in which my instructions for formating have been carried out. From the Braille copy, I can find my inevitable typing errors. Others can review the typed copy for modifications are then made, by Teletype input, in the computer. The computer then outputs the corrected report as a final copy or draft version. This report is being generated in this fashion. I may decide to make some alterations in the print punctuation as a concession to the braille reader to counterbalance the many concessions made to the print reader.

Regarding the performance of the Brailler in itself, there are four remarks:

1. Through some circuit change, the Brailler is now able to linefeed without dropping a character at the end of a line. This is a marked improvement.

2. I have requested that line-feed signals from the Teletype be interpreted by the Brailler as a space. This modification has not been made. A line-feed which does not occur at the end of a braille line always means a wasted line of braille paper. (This report is being typed in single space for that very reason.) Since a Teletype line is about double the length of the Braille line, about one-third of a braille page is empty. This is an extravagance which should be avoided.

3. The Brailler misses characters in what appears to be a random fashion. The cause has not as yet been precisely pinned down.

4. A convenience switch has not yet been provided for disabling the Brailler while non-essential material is being typed out on the Teletype.

Appendix III—Comments on M.I.T. Braille Embosser

The M.I.T. Braille Embosser has contributed significantly to my position in the computer field. I would say that other than my technical education at M.I.T., it has been the largest single reason that I have been able to get this far. I have been told by my employer in fact, that having an embosser was significant in my being hired.

I do feel however, that the Braille Embosser has some limitations. For example, the embosser is quite impractical for printing large quantities of material; whether it is a large core dump or just a large program. Also since the embosser prints with no special format, it does take some initiation to be proficient with it. This last problem is solved automatically when the user has had some experience with the machine. Also it is fairly trivial in most cases to supply the necessary software to produce correct format. Fortunately, for most of the applications required by a programmer, large dumps and large programs are fairly rare unless the user is a systems programmer, as in my case. I have found that in my case, I have been able to overcome this drawback by other means which are working out satisfactorily. There is no reason therefore, that a blind programmer can not make adequate use of the embosser to become worthwhile on the job.

In the future, I am hoping that a blind programmer could be equipped with both an embosser and an optacon. Between these two devices, there is practically nothing that blind person can not do within the same time span as his sighted colleagues.

The reliability has for the most part been satisfactory. I am however concerned that in the future more emphasis should be placed on the training of persons to become repairmen. When more units are placed, it will be obviously necessary to have a team of people that can go into the field and make necessary repairs to the units. This is especially crucial for those users who are not located near the Center as I am. I feel that if enough attention is payed to servicing the embosser, that a large number of machines will be made and placed in the field.

ALAN DOWNING.

APPENDIX IV

ROLLS-ROYCE LIMITED,
AMERICAN FOUNDATION FOR THE BLIND INC.,
New York, N.Y., August 1, 1972.

DEAR MR. GRAHAM: Very glad to hear you will be in this Country next month, though naturally sorry that your timetable will not permit you to visit us.

You will be very pleased to hear that the Braillemboss has been an unqualified success. Terry Hicks is delighted with it and by its help is a fully contributing, and very capable, member of our programming team.

We have no need to make any concessions as to the type of programming work we ask Terry to undertake, though in practice we avoid giving him jobs involving unusually large quantities of output, not because Terry would be unable to cope but because the difference in speed between the Braillemboss and a standard line printer would involve his taking rather longer than others.

It has been a great source of satisfaction to us to see such a successful outcome and we have many people to thank, not least yourself.

Terry Tate, whose enthusiastic and industrious guidance of Terry Hicks has been the most significant single factor in this enterprise, would like to see more blind people exposed to this type of environment. To this end we are considering the possibility of training others, though the form and extent of this will have to be carefully thought out and be ultimately approved by our Divisional Directors who, I should add, have gone out of their way to support us in this venture.

Perhaps Messrs Tate & Hicks could arrange to meet you in London for an hour? Please let me know if this is a possibility.

Yours sincerely,

DENNIS C. BOSTON.

FOLDING CANES

Since its inception, the Sensory Aids Evaluation and Development Center has been concerned with examining and developing devices to enhance the mobility of the blind. These devices have included the Pathsounder, straight line travel indicators, compasses, the folding cane, and other devices. Early investigations established the following criteria which must be met by a folding cane.

1. The weight of the cane cannot exceed one pound.
2. The folded cane cane must fit into a coat pocket (5x10x⅝ inches).
3. Aside from collision damage, the cane must survive 5,000 fold extend cycles, based on one year of use by an active blind traveler.

4. The assembled unit must provide a handle and tip with similar "feel" and sound generation capabilities as those experienced by current long cane users.

5. While the extended cane length cannot be changed by the user, the design must include provisions for supplying the cane assembly in two-inch increments of length over the range of 36 to 70 inches.

6. Opening and closing input forces cannot exceed the capabilities of women and children.

7. Opening, closing, locking, and storing procedures, must be compatible with "one-hand" operation.

8. The over-all design must be simple. Fabrication of component parts should not require specialized techniques, select fitting or assembly.

9. A realistic mass market price goal was estimated at under $10.00 each.[1]

Each of the then known available folding canes were examined and several tested. None met all of the requirements, especially that of feel and durability. Earlier work at MIT had produced a design concept, a central-steel-cable compressing conical joints, which showed promise of meeting most of the requirements. Work on canes using this concept produced the "aluminum-tube, swaged-joint, central-steel-cable folding cane."

During the conference for mobility trainers and technologists,[2] the Center was urged by several of the attendees to distribute the swaged-tube central-steel-cable crook handle folding cane in its present configuration for evaluation purposes to appropriate agencies and persons.

An evaluation involving approximately 100 canes was performed. The evaluation used qualified mobility instructors to interact between the Center and each subject. The mobility instructors recruited the subjects and determined the cane length and the tip desired by each subject. The cane and a data package was sent to an instructor for each subject. The data package included both instructions and the data collecting questionnaires. The instructor taught the subject how to assemble and disassemble the cane and at the appropriate times administered questionnaires. A pre-test questionnaire was used to determine the subjects' regular cane, travel skill, and travel habits, while the post-test questionnaire recorded his use, likes ,and dislikes of the cane.

The cane was well received and thought by most to have characteristics similar to their regular cane. Two problems reported were namely the large size of the crook and both the small diameter and surface of the grip.[3]

Continuing work on folding cane development during the evaluation produced a straight handle cane using the same principles as the crook handle cane.[4] Several usable but different prototypes for a straight handle cane were made. Each of the prototype canes overcame the difficulties discovered during the crook handle cane evaluation while retaining its desirable characteristics.

At this stage in the straight handled cane development, it was realized that this cane met the important above requirements, and that it should be made commercially available. A search was then conducted for both a manufacturer and an appropriate agency to assist by providing the tooling and initial production costs. The Northwest Foundation for the Blind through the Center provided a small subsidy to HYCOR,[5] a local aerospace company who agreed to make and offer for sale the straight handle cane for $12.00.

With the introduction of the cable cane by HYCOR, the Center's work in folding canes has been brought to a successful conclusion. The work on the folding cane has demonstrated the essential requirements of providing a new and useful appliance for the blind, from the realization of the need, to the development of a viable concept, to the practical design, to its test and evaluation, and to the appliance commercial marketing.

The support of the Center during the folding cane work was by the Vocational Rehabilitation Administration and the Social Rehabilitation Administration of the Department of Health, Education, and Welfare.

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[1] Final Report to the VRA from SAEDC, Oct. 31, 1965.

[2] Proceedings, Conference for Mobility Trainers and Technologists, SAEDC, MIT, Dec. 14, 15, 1967.

[3] Final Report to SRS from SAEDC, 1970.

[4] Annual Report to SRS from SAEDC, 1967.

[5] HYCOR, North Woburn Industrial Park, Woburn, Mass.

Braillemboss—A Braille Page Printer

The M.I.T. Braillemboss[1] is a braille page printer designed to emboss braille at similar or faster rates than teletypes. The Braillemboss accepts electrical braille-coded signals from a variety of sources and in turn produces braille pages. When operating continuously, it produces a page of braille every 1.6 to 2.0 minutes.

The Braillemboss lines are 38 cells long. Each page has 28 lines with 25 lines for braille and 3 blank lines for the top and bottom margin. The paper used by the Braillemboss is 100 pound-basis manila fan-folded sprocket-drive paper. When the sheets are separated and the sprocket drive strips are removed at the perforations, each sheet is a standard $11 \times 11\frac{1}{2}$ inches.

The heart of the Braillemboss is the embossing heads, each head contains 6 embossing pins in the braille cell configuration and an interposer pin beneath each embossing pin. These heads are fastened to a chain and so arranged such that one head is always supported under the platen, a steel female die containing 38 braille cells.

Each embossing pin is spring loaded upward. If an interposer pin is held in, then the corresponding embossing pin produces a dot when struck by the platen. If the interposer pin is out, the corresponding spring loaded embossing pin is merely forced down by the platen and no dot is made.

Each interposer pin is controlled by a selector bar. There are 6 selector bars, one for each dot, with 3 on each side of the head. Each selector bar is parallel to the head support track and is controlled by a solenoid (250 ma @ 40 volts). When a solenoid is energized, the corresponding interposer pin in the active head is held in.

The heads are positioned by both a support track and a tooth that engages the escapement rack. The tooth is held against the rack by a spring driven by a torque motor. This combination supplies a constant force to keep the tooth engaged.

The escapement rack is composed of two one-half pitch racks displaced by one pitch length. The rack shuttles back and forth at right angles to the head track and is driven by an eccentric. Each time the rack moves from one side to the other the head advances one cell. When the active head is in the last cell location, it closes an end-of-line switch used in the Carriage Return logic.

The platen is supported by two pivoted arms and driven by cranks at both ends of the cycle shaft. The rack is also driven by an eccentric geared at one-half speed to the cycle shaft. The cycle shaft is driven by a $\frac{1}{20}$ horsepower motor through a cycle clutch. Each time the cycle clutch solenoid is pulsed, the cycle shaft makes one revolution. The platen goes through one cycle, from top to emboss position, and back to top, while the rack moves from one side to the other side each time the cycle shaft revolves.

The fan-fold sprocket-drive paper is supported by two paper tractors mounted close to the head track and platen but on the output side. The paper tractors are driven by a Ledex Digimotor. Each time the Digimotor is pulsed (5 amps @ 40 volts), it advances the paper on braille line. A page register is also a part of the paper drive and provides one switch closure per page to enable a new page command to be accurately executed.

The emboss sequence is as follows. The electronics determine from the signals that a braille cell is to be embossed. The cycle clutch is pulsed and the appropriate selector bars are energized. The embossing is performed as the platen reaches the bottom of its excursion, the selector bars are released and the head is advanced as the platen reaches the halfway point on its upward travel. The space sequence is identical except that selector bars are not energized. When the active head is in the last (38th) cell, at the time the selector bars are released, an automatic line feed signal is generated. This provides an automatic carriage return at the end of the line. The paper is advanced and the next head becomes the active head in the first cell position.

The Carriage Return function is controlled by a flip-flop. When the Carriage Return flip-flop is set, a self-clocking series of cycle-clutch pulses are generated and the heads are stepped around. The automatic line feed signal when in the last cell resets the flip-flop and stops the heads such that the active head is in the first cell location. The Line Feed signal pulses the line feed Digimotor.

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[1] *MIT Braillemboss Specifications.* SAEDC August 1969 with latest revision.

The End-of-Page function is also controlled by a flip-flop. When the End-of-Page flip-flop is set, a self clocking series of line feed pulses are generated to step the paper. When the paper is stepped to the first line position on a page, the page register switch resets the End-of-Page flip-flop.

The electrical signals for the Brailleemboss are derived from three principal sources, manual (including a keyboard), a paper tape reader,[2] or a translator.[3] The manual modes are used primarily for test or limited addition to braille from other sources. The translator allows other devices such as model 28 or 35 teletypes, an IMB 2741, a card reader or similar devices to supply the electrical signals. A three connector adaptor has been made to permit paper tapes in other codes than brailler codes to drive the embosser through the appropriate translator.

DOTSYS—A Braille Translation Program

In 1964 the MIT SAEDC undertook the systems design of a programming complex adapted to a more ambitious and flexible braille utilization system, than had previously existed.[1] The system was dubbed DOTSYS (the DOT SYStem) and is described in some detail in the Proceedings of Braille Research conferences,[2] [3] and by Goldish.[4]

DOTSYS ability to translate teletypesetter (TTS) tapes into grade II braille was demonstrated twice during 1966. The first demonstration converted news service tapes into brailler code punched paper tapes. These tapes were then run on the MIT High Speed Braille Embosser, the predecessor of the Brailleemboss, to produce the braille. The second demonstration converted the TTS punched paper tapes used to print a textbook into stereograph punch cards. These cards were sent to the American Printing House for the Blind where interpointed zinc braille plates were made on their card driven stereograph. The braille was then embossed in the standard fashion.

DOTSYS consists of a number of program co-routines or "boxes" each which manipulates the information being processed in response to computer directed requests from successive elements in the computation chain.

This segmented approach to the programming of DOTSYS was predicated on certain projected advantages. Flexibility is achieved since new "boxes" can be introduced progressively into the system with but minor side effects on the rest of the system. Thus, new input media can be assimilated as it becomes available, the translation program can be upgraded, and new braille production techniques can be accommodated. Adaptation to computers of different sizes is facilitated since an overall processing operation can be segmented into blocks which fit the available computer, producing and storing intermediate results for batching operations. Finally, from a program writing and testing point-of-view, the "box" approach divides a very big overall job into digestible portions which individuals can program separately while maintaining effective communication with their co-workers, and the individual segments can be independently tested and debugged.

During the summer of 1967, the necessary parts of DOTSYS were written or modified to permit computer translated braille to be generated remotely from the computer. The necessary Input/Output (I/O) boxes were written for a time-shared computer (CTSS, an IBM 7094 at MIT).

The material to be brailled was typed into the computer by a typist using a model 35 KSR teletype. When the typist completed typing the material, (or when a maximum of 60 lines were typed), the typist, via a typed command, initiated the translation. The Grade II braille was sent to an MIT High Speed Braille Embosser through the teletype. (During the time the Embosser was printing braille, the Teletypewriter was printing meaningless hash.) The braille is correctly paged and of the standard format.

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[2] Friden Model SP–2 Paper Tape Reader.

[3] *One-cell Translators, Brailleemboss Interface Units.* SAEDC, TDS No. 8.

[1] Dupress, J. K., Buamann, D. M. B., Mann, R. W., "Towards Making Braille As Accessible As Print," EPL Report DSR 70249–1, MIT, June 1968.

[2] Proceedings—Braille Research and Development Conference, SAEDC, MIT, November 1966.

[3] Proceedings—Conference on New Processes for Braille Manufacture, SAEDC, MIT, May 1967.

[4] Goldish, L. H., "Braille In The United States: It's Production, Distribution and Use" Thesis (S.M.), Sloan School of Management, MIT, February 1967.

It was this system which was demonstrated at Perkins during the winter of 1968.[5] The operation of the remote braille production system was taught to approximately 48 members of the upper school faculty. Enthusiastic approval of the concept around which the system was designed—the production of braille material by an individual who is not familiar with Grade II braille—was unanimous. Many of the teachers were familiar with special forms of braille, such as the Nemeth mathematics code, yet understood only superficially the English encoding. Others could read it quickly, but were comparatively slow transcribers. Still others simply did not have time to make several braille copies themselves and were dissatisfied with the quality and necessary waiting period for volunteer supplied braille material. The most encouraging result of the demonstration was that well over half of those who used the equipment stated that were it available, they could continue to use it several times a month, even without any further modifications.

Development of DOTSYS was not continued further for several reasons. First, the program is in Fortran Assembly Language (FAP) for IBM 704 and 709 computers. These computers are now obsolete and have been superceded by the System/360. FAP is a machine language and cannot be readily transferred between similar computers and cannot be used on the 360 series without complete reprogramming or by emulation (now not readily available).

At the time of the Perkins demonstration the then current version of Embosser could operate at only one-half teletype transmission speeds and then only with frequent attention of the experimenter.

These limitations have been overcome. DOTSYS II has been written in a higher level computer language, COBOL, a nearly universal language. This language is available on most large computers regardless of manufacturer. Further, the Braillemboss has been developed to the point where it works reliably for long periods of time at MODEL 35 Teletype Speeds.

Pathsounder

The Pathsounder is an experimental mobility aid whose purpose is to "screen" the area ahead of a blind person and warn him of obstacles in his path, in particular when they come within a specified distance, usually set at six feet. It is a sonor device, making use of ultrasonic sound to probe the area under surveillance.

Used by a blind cane-traveler, it is typically worn at chest height by means of a cord around the neck. In such a manner it complements the cane in that it explores the above-the-waist region through which the user's head and shoulders will pass, thus warning of overhanging objects: mailbox, tailgate of truck, etc. With its six-foot range it gives earlier warning than the cane of things ahead and so can be helpful in crowded sidewalk travel for avoiding collisions with other pedestrians, cane pokes at their heels, etc. (The trainee is taught, upon onset of a signal, to stop or change direction slightly and seek an open path.)

The Pathsounder makes no audible sound under normal conditions (no obstruction ahead), but when an object comes within the six-foot range an intermittent buzzing sound is emitted by tiny signalers on the neckloop just under the user's ears. If the object comes to within two and one-half feet the sound changes to a high-pitched beeping to warn that the obstacle is now very close. The whole surveillance zone may be visualized as cone-shaped with the apex at the traveler's chest and an oval cross-section about 22 inches wide by 35 inches high at a point six feet in front. The device is about the size of a small camera and carries a rechargable internal battery.

Deployment of Pathsounders in the field has been effected through mobility instructors, who have functioned as intermediaries between the technical developers and the blind end-users. Many—or most—of the applications have involved clients with out-of-the-ordinary problems: blind wheelchair users, cane-travelers with faulty obstacle perception due to hearing loss or imbalance, those with injuries demanding extra upper-body protection, and so on. In several cases, normal cane-travelers (i.e. without other handicap than blindness) found Pathsounders helpful when their daily routes involved city travel on heavily crowded sidewalks.

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[5] Greiner, W. E., "Development of Braille For Classroom Use," Thesis (M.S.), Mechanical Engineering (MIT), February 1968.

Braillemboss Applications

The M.I.T. Braillemboss[1, 2, 3] is an automatic braille printer operated by electrical signals derived from one of many possible sources. It can operate at speeds compatible with many computer terminals. The Model 3 Braillemboss produces high quality braille of standard literary format. When operating continuously, it produces a page of braille every 1.6 to 2.0 minutes.

The most common Braillemboss application to date has been as a time-sharing computer terminal. As such it has made several blind professionals more productive and has helped them work more nearly at their potential. For this use the Braillemboss is connected in parallel with the page printer of an existing computer terminal. This arrangement permits the terminal to be used by either the blind user or his sighted colleagues.[4] It also reduces the complexity of the Braillemboss by not requiring an internal keyboard or data modems. The Braillemboss can be used with any computer that uses 110 Baud ASCII console typewriter or terminals.

The Braillemboss has been demonstrated as an output device for a computer data base system, the Internal Revenue Service (IRS) Integrated Data Retrieval System (IDRS). As such it provides a blind Taxpayer Service Representative (TSR) with access to the complete IDRS data base. Most of the TSR interaction with the taxpayer is done over the telephone. In most cases the blind TSR functions as well as his sighted co-workers and the taxpayer has no knowledge that his is dealing with a blind TSR. This demonstration has shown that the Braillemboss, operated as a computer terminal permits the blind to fill a variety of public service jobs requiring interaction with a computer data base. These jobs include reservations of all types, i.e. airlines, rental autos, hotels, motels, etc.; credit and account information; and inventory control.

The initial use of an earlier version of the Braillemboss was the production of single copy (or a few copies) of computer translated Grade II literary braille. In this application, a typist unfamiliar with braille can produce Grade II braille merely by typing plain English text, including a few easily learned format control characters, into the computer. Such a system has been demonstrated at Perkins School for the Blind in Watertown, Massachusetts by William Greiner.[5] This system consisted of the Braillemboss, Model 35 Teletype, braille translation program DOTSYS,[6] and an IBM 7094 timesharing computer at MIT known as CTSS. Applications for this mode of operation include public schools with blind students and agencies producing a limited number of braille copies. In both cases the computer translated braille increases the number of people capable of preparing braille to include those who are not expert Braillists.

A new and more versatile Grade II computer translation program, DOTSYS III[7] has been written. DOTSYS III is written in Cobol and as such can be made available on a large sumber of computers including but not limited to time-sharing systems. DOTSYS III and the Braillemboss has been used to produce a braille book, *In Darkness*, for the Library of Congress.[8]

Another application of the Braillemboss is the short run production of braille materials using punched paper tape as the storage medium. The Braillemboss has provision for a paper tape reader, Friden SP–2, as an input device. The punched paper tape for demonstrations has been prepared by several means. One demonstration project used tape punched on a modified Perkins Brailler by an expert Braillist.[9] Another method of preparing paper tape is by typing on a special Teletype converted by Mr. Ray Morrison. Grade I braille tapes can be prepared by any typist, but an expert Braillist must be used to produce Grade II

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[1] *Final Report to John A. Hartford Foundation,* "Development of a High-Speed Brailler System for More Rapid and Extensive Production of Informational Material for the Blind," SAEDC, Sept. 29, 1970.

[2] *M.I.T. Braillemboss Specifications.* SAEDC, August 1969 (with later revisions as applicable).

[3] *Braillemboss, A Braille Page Printer.* SAEDC. TDS No. 2.

[4] Lichstein, M. L., *Braille Computer Output.* (M.I.T.–SAEDC), August 1969.

[5] Greiner, W. E., "Development of a Braille System for Classroom Use." (S.M. Thesis, M.E. Department, M.I.T.), February 1968.

[6] *DOTSYS, A Braille Translation Program.* SAEDC, TDS No. 3.

[7] *Interactive Braille,* SAEDC, TDS No. 11.

[8] "Transcription of *In Darkness* via DOTSYS III and the Braillemboss," SAEDC, Nov. 7, 1972.

[9] *The American Revolution, A Short-Run Braille Pamphlet Demonstration.* SAEDC, TDS No. 7.

braille tapes. Still another method of generating tapes is by computer.[10] Each of these methods has been used and has been proven useful for particular applications.

Twenty (20) Braillemboss units have been produced at the Center with the support of the John A. Hartford Foundation. Earlier developmental work was supported and continuing demonstrations are supported by the Social Rehabilitation Administration of the Department of Health, Education, and Welfare.

DOTSYS and The East Indiaman

The Braille edition of The East Indiaman, by Ellis K. Meacham, (Little Brown and Co.), the first to be produced from teletypesetter input, was published in November 1968, only a few weeks after the ink-print edition. The Master Braille plates were produced with a minimum of human intervention, using a series of computer programs. The procedure can be described in three parts:

1. Conversion of the TTS codes into BCD codes and the insertion of the special format codes required for Braille.
2. Editing and correcting the BCD tape thus created.
3. Translation of the BCD tape into Grade II Braille.

The TTS input tape was translated to a formatted BCD tape by a modified DOTSYS[1] [2] system and programs. The following boxes were used: Inbox, Telcon, Unicon and Uniper. These programs, originally written to operate on the CTSS system at M.I.T. were modified for the 709 at the American Printing House for the Blind. This involved rewriting those parts of the programs which were CTSS-dependent.

The Unicon box was rewritten and expanded to perform some of the functions formerly handled by Telcon and Telcon was thereby considerably simplified. A major objective of DOTSYS is to minimize the reprogramming required to handle new forms of input and output. The Unicon box is independent of the medium which supplies its input. It is a permanent section of DOTSYS which performs the analysis and interpretation necessary to conform to the Braille rules. Telcon is just one of a possible set of conversion programs designed to translate compositors media into Universal code. There could be boxes written to convert Monotype, Linofilm, etc. Each of these boxes would be independent of the Braille conventions and would perform only that interpretation required because of the particular typesetting equipment and the conventions which govern its use.

The six channel paper tape which had been used to set the first galleys for The East Indiaman was copied onto magnetic tape. This step, performed in New York on an IBM 360/40 was necessary because the APH 709 has no paper tape reading facility. (Ironically, this operation which is technically the simplest, took an inordinate amount of time. Both the TTS tape and APH's 200 bit-per-inch magnetic tape are, in a sense, non-standard in terms of current technology and finding the appropriate machine configuration to accomplish the conversion proved quite difficult).

The magnetic tape containing the TTS codes served as input to the modified DOTSYS which produced an intermediate BCD tape and a line-numbered listing suitable for editing. This first phase would remain essentially unchanged for producing any other book which had been set by paper tape controlled line-casting equipment. To publish a Braille edition from another composition medium would require that Telcon be replaced with another box. The initial conversion step might or might not be necessary.

Phase two, the editing phase, would remain unchanged no matter what sort of compositors tape is used. The number of iterations through the editing procedure vary depending on the completeness and correctness of the tape. In the case of East Indiaman the paper tape was used to set the first galley proofs.

From that point corrections to subsequent galleys and page proofs were made by hand in the metal and these corrections had to be detected and made on the intermediate BCD tape.

A new box, caller EDIT, was added to the system to facilitate error correction. This program reads correction cards, locates and changes the erroneous

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[10] *Conversion Table, Inches to Millimeters: A Braille Computer Generated Mathematical Table*. SAEDC, TDS No. 10.

[1] Proceedings—Braille Research and Development Conference, SAEDC, MIT, November 1966.

[2] *DOTSYS, A Braille Translation Program*. SAEDC, TDS No. 3.

information the intermediate BCD tape and writes a new tape incorporating the changes. Under console control the new tape may be printed completely or in part.

It is interesting and gratifying to note that the proof-reading and error-correction proceeded quite efficiently, despite the fact that the Printing House personnel involved had had no prior experience with this kind of work. Because there was some concern about how quickly they would learn the techniques required, it was decided that only two of the four Braille volumes would be edited in this fashion. The balance of the book was corrected by key-verifying the cards which were punched from the intermediate BCD tape. It is difficult and unfair to compare these two procedures. However, the general impression was that the new method worked quite well and could be expected to become even more efficient with practice, some modifications to the EDIT box, and, of course, cleaner input tapes.

The third phase was the translation of the corrected BCD tape to Braille using the Braille Translation program which has been operating at the American Printing House for several years. Because DOTSYS supplies the format code and special character codes usually added to the text by the key-punch operator, this BCD tape "looked" the same as it would had it been produced by keypunching. Thus, the translation phase, and the subsequent steps in the production of the book itself were those which have become conventional at the Printing House.

A Pamphlet, "The American Revolution," a Short Run Braille Production

One application of the MIT Braillemboss is the short run braille production where only a few copies of a specialized work are required. Brailling of the pamphlet, "The American Revolution" presented an opportunity to demonstrate this application.

The Braillemboss in the present state of development can routinely produce a page of braille every 1.0 to 2.0 minutes given the proper input signals. At the time of this demonstration only Machine No. 6, an experimental unit was available. This was a unit from the original Braille production. All of the specified changes in the Braillemboss required for improved accuracy, had been incorporated on this machine when the demonstration was performed. The only form of input available for this machine was punched paper tape.

The Howe Press of the Perkins School for the Blind has a paper tape punch controlled by a modified Perkins brailler. The pamphlet was brailled essentially the regular way on this Braille writer by a Stereograph Operator at the Howe Press while at the same time a punched paper tape containing the Braille codes was being generated. The paper tape was then hand edited and made into tape loops, each containing a single page.

The tape loops were individually run on the High Speed Braille Embosser (Braillemboss). The section of the pamphlet reproduced contained 32 pages of Braille, and 25 copies of each page were reproduced for a total of 800 pages. The total Braillemboss operating time was 20 hours spread over six working days.

Fifteen copies were given to Perkins Upper school students for their examination and use. The students were asked to record and report every error found. Several errors were spotted that existed in every copy. These errors which escaped detection in the taping editing process were later discoverd in the tape. Sometimes weak cells occurred in the last cell of a line. This was corrected in the redesign of the Braillemboss, but was not incorporated in the experimental machine. Eleven random errors were discovered; one random error per 43.6 pages, or 24 errors per million characters.

Other methods could be used for both input data preparation and storage. Relatively simple digital magnetic tape units are now available and could be used. A time-shared computer could be used to edit, translate into Grade II, determine the line and page division, and control the Braillemboss directly.

This program demonstrated the application of the Braillemboss for the production of a limited number of Braille copies. The usual process of Braille duplication requires the preparation and use of zinc or iron embossing plates to produce Braille. However, this demonstration showed that a single punched paper tape could be used to produce several copies of the material, thereby substituting one paper tape for many zinc embossing plates. The program also demonstrated one way the Braillemboss fills the gap between the large-run Braille printing system and the hand-transcribed Braille production.

One-Cell Braille Translators—Brailleemboss Interface Units

The M.I.T. Brailleemboss[1] requires electrical signals in the brailler code to drive the Brailleemboss. The various information transfer codes, while most are in a similar format to the brailler codes, cannot be used directly to drive the Brailleemboss as the resulting braille symbols would have meanings completely different than that commonly used. A translator unit is required to map the input codes into the brailler code.

The existing Grade I or Grade II literary braille codes are inadequate for computer programming for at least two reasons. First, several of the symbols required in computer programs, plus, equals, etc., are simply not defined in literary braille. They are written out when required. Secondly, format is very important in computer programing, therefore it is necessary that there be a one-cell braille-equivalent for each inkprint character used in the computer character set. The resulting code—developed in consultation with several people—uses the same characters for the alphabet as does literary braille, the lower four dots in the same combination as previously for the numbers, just like the Nemeth convention, but without the number sign and then the remaining characters in the 63 character ASCII character set are defined with the least ambiguous braille codes representing the more important inkprint characters.

There is an additional requirement on the translator, that of matching the electrical requirements of both the input device, a Teletype for example, and the Brailleemboss With a Teletype these inputs can be either switch closures on each code level or a serially coded current switching waveform. With other input devices still other inputs may be used which the translator must match.

Several different types of translators[2] have been designed, built, and operated. One of them is the "ASCII(63)/ASCII(67)—One-Cell Braille Translator." This translator is designed to connect either a Model 33, Model 35, or Model 37 Teletype to the Brailleemboss. It has the ability, by choice of cards in the input section of the translator, to receive either the current-switching waveform or switch closures on each code level from either a Model 35 "stunt box" or from an LRS 800 Receiving Selector. This translator also has the ability to map the lower case letters into the upper case letters such that a Model 37 Teletype can be used as an interface unit. Further, there is a remotely controlled on/off switch in the translator to permit the computer to control embossing. This can be employed if embossing of only computer output is desired and not computer input.

Another translator, the ASCII(63)—One-cell/DOTSYS translator, operates only with switch closures as inputs, but in two modes. The first translates the codes of the Model 33 or Model 35 Teletype into One-Cell braille while the second mode translates the special transmission codes used in DOTSYS[3] into brailler code.

A third operational translator is for the Teletypewriter code (TTY) used in the United Press International wire service 5 level code. This translator presently accepts only switch closures from a tape reader. Designed, but not yet tested, is the required input circuitry to operate on the serial current switching waveform. This translator has been used in a Braille News Demonstration.[4]

Translators have been designed but not yet built for 6-level Teletype Setter (TTS) codes and for Hollerith punched cards. It is planned to design translators for IBM EBCDIC and IBM MT/ST codes. These will be reduced to practice as both time and budget permit.

Taccom—A Communication System for the Deaf-Blind

Taccom (for "tactile communication") is a wireless remote paging system designed for the deaf-blind in particular, but with possible applications for the singly-handicapped deaf *or* blind.

The Taccom pocket receiver is the core of the system; it functions like the pocket pagers carried by physicians in a hospital, but with one important difference: instead of beeping to alert its user, it *vibrates*. (It feels like an electric

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[1] *Brailleemboss, A Braille Page Printer.* SAEDC TDS No. 2 and *Brailleemboss Applications,* SAEDC TDS No. 5.

[2] *M.I.T. Brailleemboss Specifications.* SAEDC, August 1969 (with later revisions as applicable).

[3] *DOTSYS, A Braille Translation Program.* SAEDC, TDS No. 3.

[4] *Braille News Demonstration.* SAEDC, TDS No. 12.

toothbrush running.) The receiver has the appearance of a tiny transistor radio and measures 2½″ x ⅞ x 5″. It weighs 6.3 ounces. It employs rechargable batteries and is normally plugged into a battery charger at night when not in use.

Two primary applications are: (1) To provide an effective "doorbell" for a deaf-blind person who may be alone in his house; and, (2) To effect an alarm system (e.g., for fire, etc.) in an institution or other setting where a number of deaf-blind persons may be spread about and must all be summoned at once.

The equipment involved includes the pocket receivers (one for each user), the centrally-located 115 volt transmitter, and a loop antenna which runs around the area to be covered by the radio signal. This service area can be fairly large—one hundred thousand square feet or more. The transmitter can be connected to push buttons at convenient locations, fire alarm boxes, time clocks—whatever suits the end purpose.

Ancillary attachments make possible other Tacoom applications:

1. End-of-line indicator for brailler or typewriter.
2. Auditory cue indicator (phone ringing, baby crying, etc.)
3. Ambient light indicator.
4. Message system (Morse code signalling, etc.)
5. Teaching/training aid.

Conversion Table, Inches to Millimeters—A Braille Computer Generated Mathematical Table

As an example of the use of the Braillemboss[1,2] as an output device of a time-sharing computer was the production of a braille inches to millimeters conversion table. Such a table was recently prepared for a rehabilitation client of the Massachusetts Commission for the Blind. The client has been trained to repair and rebuild foreign car automatic transmissions, but the only braille micrometers immediately available to him used inches. The transmissions are measured in metric units, i.e., millimeters.

The table was produced using the CTSS (an IBM 7094) time-sharing computer running a Fortran II program, a teletype, punched paper tape reader, Translator[3] and the Braillemboss. The table was embossed in "one-cell" braille, developed for computer programmer use. This braille system has a one-to-one correspondence between the braille and inkprint characters. The inkprint characters are those used in the 63 character ASC II, American Standard Code for information interchange) character set used in the model 33 and 35 teletype.

Approximately one-half day was used in writing the 33 statement Fortran-II program. During this time four minutes of computer time was used to input the program from the teletype, compile, test, debug, and recompile it.

Punched paper tape was used as a buffer between the computer terminal and the Braillemboss for several reasons. The first was to make a machine readable master such that multiple braille copies could be produced without incurring the costs of additional computer and terminal time. In addition, if facilitated the writing of the program, since Braillemboss timing considerations could be handled by an asynchronous punch paper tape system instead of special programming techniques not readily available in Fortran II. The Braillemboss carriage return (CR) time is in general much longer than the time for the teletype and computer CR time, such that data would be lost during the time the Braillemboss is executing a CR. All other functions of the Braillemboss, except the end of page function, are accomplished in less time than with the teletype.

The compiled program was loaded into the computer, and the initial and final page numbers were typed in, one page number per line. The Model 35 ASR teletype was set to the KT mode such that it produced both punched paper tape as well as printed copy. After the first page had been run on the computer, the end of the paper tape was loaded into the tape reader and the Braillemboss started. The normal tape reader input to the Braillemboss uses the Brailler code, not the ASCII used by the teletype; therefore, a cable adapter was used such that the tape reader was driven in its normal mode, but the output signals were fed into the teletype input jack of the Braillemboss. The Braillemboss running time was

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[1] *Braillemboss, A Braille Page Printer*, SAEDC TDS No. 2.
[2] *M.I.T. Braillemboss Specifications*, SAEDC, August 1969 with revisions.
[3] *One-Cell Braille Translators, Braillemboss Interface Units*, SAEDC TDS Nos. 5 and 8.

slightly longer than the terminal time (in spite of the fact that the Braillemboss is operated at a faster rate than the teletype) since each Braillemboss carriage return took longer than with the teletype. The terminal running time used for this table was 2.5 hours, but the computer time used was 1.9 minutes. It also took approximately three hours to run the program and to emboss the first copy.

The table as produced by the Braillemboss is embossed on one side only. If interpointed braille is desired, a suitable converter could be constructed such that the APH Automatic Sterograph at Howe Press could use the ASCII tapes to emboss the zinc plates for press use. Alternatively, the translator in the present embossing system could be used to drive a tape punch to produce paper tapes in the Brailler code used by the sterograph.

This demonstration has shown that the M.I.T. Braillemboss, when properly interfaced with a time sharing computer, can produce mathematical tables, in Braille, of any mathematical functions that can be programmed into a computer.

Interactive Braille—Remote Computer Translated Grade 2 Braille

A person with typing skills but with a minimum knowledge of Braille can produce a high quality Grade 2 Braille with ease and dispatch, using the Interactive Braille System. The necessary components of the system are:

(1) A time-sharing computer with DOTSYS3 stored in it.
(2) A teletype or other time-sharing computer terminal.
(3) A Braillemboss attached to the teletype.

It is not necessary for the computer to be located at the same place as the terminal and Braillemboss.

The Braillemboss is a Braille page printer[1,2] used to produce the output. DOTSYS3 is a version of DOTSYS III modified to use the Braillemoss[3] as output unit.

The material to be brailled is typed into the computer and stored in a data file. The material is typed in almost as it is written in normal inkprint. The teletype has only upper case so a control character is required to tell DOTSYS3 when to capitalize. A single equal sign (=) is typed preceding each word to be initial capitalized, two equal signs before each word to indicate that the word is solid capitals. Most punctuation is typed in directly.

Additional format control characters are required to tell the program when to start paragraphs, when the typist demands a new line to start not in the regular progression of text. Other format control symbols are used to indicate headings and titles. The most used symbols and format controls are listed on a single sheet (see over).

Some training is necessary for the typist to learn to create and manipulate the data files in the computer. This training can be accomplished in a few hours using manuals prepared by the time-sharing computer people.

After the input file is created, proofread and corrected if necessary, the computer is told by a single typed in command to produce the Braille. The computer translates the material and will either store the Braille to produce multiple copies or the computer can immediately output the Braille to produce only one copy.

This is essentially the system used at the National Braille Press and demonstrated there on January 31, 1972.

This Interactive Braille System is designed to be used in places where skilled Braille transcribers are not available, such as in a public school system with a few blind students enrolled. It can also be used in an agency environment to supplement the existing skilled transcribers or to free them from the relatively simple literary Grade 2 Braille to more specialized Braille which is more demanding of their skills.

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[1] *Braillemboss, A Braille Page Printer,* SAEDC TDS No. 2, Aug. 4, 1970.

[2] Final Report to John A. Hartford Foundation, "Development of a High-Speed Brailler System for More Rapid and Extensive Production of Informational Material for the Blind," SAEDC, Sept. 29, 1970.

[3] Gerhart, Millen, and Sullivan, "DOTSYS III, A Portable Program for Grade II Braille Translation," MITRE MTR 2119, May 14, 1971.

Braille Control and Format Codes DOTSYS III on IDC 360/67 with Teletype and Braillemboss Terminal

(029 Keypunch)

Capitalization:
= for initial capital of following word.
== for all capitals of following word.

Italics (Shift O TTY):
Underscore (___) before each word for one, two or three words.
Two underscores before four or more word italics, and
One underscore before last word.
Ordering Italics, Capitals, Accent, Delineator.

Force possible illegal contraction: /___ before and ___/ after letters.

Prevent contraction: $/ within the letters to be contracted.

Quotes:
"may be used for both left and right if no quotes within a quote is used.
$" for left double quote within a quote.
$"R for right double quote within a quote.
$' for inner opening quote.
$'R for inner closing quote.

Accent Mark:] (Shift M) TTY (12, 11, 0, 5, 8, Keypunch).*

Brackets:
< for a left bracket [.
> for a right bracket].

Short Syllable Sign: $SV.

Long Syllable Sign: $LV.

End of Poetry Foot Sign: $FT.

Caesura Sign: $CS.

Null Symbols: $/ Null replacement symbol generally used to prevent contraction.

Forced Blanks: $B.

Termination Symbol: $T.

Paragraph: $P.

New Line: $L.

Skip Multiple Line: $Slnnb (2 digits + blank) skip nn.

New Page: $PG.

Tabs:
One tab $TAnnb (start at position nn).
Multiple $STABmLnn (set tab m at position nn).
L for left justification, R for right justification.
D for decimal justification.
$#m before each item to be tabulated.

Titles:
$TLS before, and $TLE after each title produces centered title on each numbered page.

Heading:
$HDS, before and
$HDE, after for centered one line headings.

Poetry:
$PTYS, before and
$PTYE, after all poetry text.

Octal Braille:
$OCTaabbccdd for 4 codes.
Allows individual braille cells to be inputed.
Arrangement dot 1=10, dot 2=20, dot 3=40.
dot 4= 1, dot 5= 2, dot 6= 4.

Computer Braille: $CPBxxxx will print 4 codes each represented by graphic x in the computer braille code (ASCII to one-cell).

Letter Sign: +

Self Checking: The symbol $SCON$/$/$/$/$/ is used to turn self-checking on and $SCOFF is used to turn self-checking off. Delineator is ^ (circumflex, ShiftN) on TTY, or | (vertical bar) on keypunch.

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*To obtain accent control symbol on keypunch hold down Mult Punch key and strike, &, -, 0, 5, and 8 keys before releasing. The Mult Punch key automatically places keypunch to numbers mode. Do not release the Mult Punch key until all 5 keys are struck.

Braille News Demonstration

For several weeks the SAEDC translated into Braille, a portion of the news stories carried by the United Press International news wire. The resulting Braille copy was distributed to several blind people close to the Center. Through this service these blind professional people have been presented a new window to the world—a window very different from the one normally available to them. The news in depth was available to them when they desired it and in a form they could either skim or examine in detail at their convenience.

This has been done through the help and courtesy of Prof. J. F. Reintjes, R. S. Marcus, and R. B. Polanski of the Electronic Systems Laboratory of the Electrical Engineering Department of M.I.T. A UPI wire service 5 level page printer and reperforator was available for their use on a project (DSR 70149) sponsored by the American Newspaper Publishers Association.

The Braille was produced by the M.I.T. Braillemboss [1] equipped with a Teletype Translator [2] and driven by the paper tape which was punched on the UPI reperforator.

The page printer of the UPI wire service has a maximum line length of 72 characters while the line length of the Braillemboss is 38 cells. The Braillemboss has an automatic new line feature such that when the 38th cell is embossed, the paper is advanced and the carriage returned (advanced) ready to emboss the succeeding character at the beginning of the next line. With the difference in line length almost every inkprint line is embossed on two Braille lines, sometimes three. The word at the end of the first Braille line will be divided arbitrarily in almost every case. A simple modification was installed on the Braillemboss such that the next space after N cells have been embossed causes a carriage return command to be generated. The number N was set to 32 cells but can be changed over the total range of 1 to 38 cells.

The carriage return command is treated differently by the wire service page printer and the Braillemboss. The wire service page printer carriage return command does not advance the paper, only returns the carriage to the first printing location. It requires a separate command to advance the paper. The Braillemboss treats the carriage return command as a new line commnd; i.e., returns the carriage and advances the paper.

These two differences produce a Braille page with an unusual format. Each line of inkprint becomes a group of two or three Braille lines separated by a blank line. This blank line can be deleted by modifying the Braillemboss to require a line feed command after every external carriage return command. The Braille continues across the page lines also. A line feed counter modification similar to the cell counter could be added to start a new page after every 25 lines of Braille.

The reperforator was operated each day, from the time ESL personnel arrived for work until the roll of paper tape (2,000) feet was exhausted, generally about 5 hours. The tape was then run on the modified Braillemboss equipped with the TTY translator. The Braillemboss running time for a roll of paper tape was about 3 hours. A typical run produced approximately 200 pages of Braille.

Braille Production by DOTSYS III and the Braillemboss

The Braillemboss [3], [4] and DOTSYS III [5] combination has been used to produce several volumes of literary braille. Examples of this usage are "In Darkness", [6] IRS Publication 29, TDS #1, and TDS #2. This combination has also been used to produce in braille a poem "In Memoriam" by Frederick Silver.

The usefulness of this combination is not limited to literary or text materials only. A series of braille actuarial tables have been produced using the Braillemboss, DOTSYS III and computer-generated input material. The DOTSYS III poetry option was used to obtain the desired braille line format, i.e. each line of the inkprint table is started at the left hand margin of the braille and the braille continuation lines are indented 3 spaces.

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[1] *Braillemboss Applications, A Braille Page Printer.* (SAEDC TDS No. 5.)

[2] *One-Cell Braille Translators, Braillemboss Interface Units.* (SAEDC TDS No. 8.)

[3] *Final Report to John A. Hartford Foundation,* "Development of a High-Speed Brailler System for More Rapid and Extensive Production of Informational Material for the Blind," SAEDC, Sept. 29, 1970.

[4] *Braillemboss, A Braille Page Printer,* SAEDC, TDS No. 2.

[5] *Interactive Braille,* SAEDC, TDS No. 11.

[6] Dalrymple, G. F., "Transportation of *In Darkness* via DOTSYS III and the Braillemboss." SAEDC, Nov. 7, 1972.

A Fortran program was written to generate the input material. The necessary format control characters for the poetry line control were included as literals in the Fortran format statements. Text material for the title and headings could be generated by the use of literals in the format statements; however in this case the titles and headings were done separately using punched paper tape loops. The body of the tables were translated by DOTSYS III and stored in the computer disk files. The following steps were performed to braille out the table: Run the tape reader to place the heading and page number on the page, then the required number of lines of the table were read out from the computer, the heading placed on the next page, the required number of lines for the next page were read out from the computer, etc. until the entire table was read out. With some minor changes in the handling of titles the entire operation can be done automatically. A punched paper tape copy of the tables was also made for future reference and multiple copies if desired.

The computer generation of the tabular material relieved a typist of the task of inputting the material into the computer or a braillist manually producing each page.

One of the ground rules during the development of DOTSYS III was that it should be capable of producing any type of braille when suitable input material is provided. It was assumed that a suitable pre-processor program could be written to provide appropriate input material to DOTSYS III to produce mathematical braille. There exists a system of tabs and tab control for tabular material with each braille line less than the braille page width or poetry format for use with material containing longer lines. For example a suitable pre-processor can be written to take a simple suitable input file and convert the file into form that DOTSYS III will then translate into mathematical braille.

For tabular material there are two options presently available with DOTSYS III. If the table line-length is less than the braille line-length then the DOTSYS III system of tabs can be used. If the line is longer, then the poetry format should be used.

Braille copies of TDS #1, TDS, #2, and "In Memoriam" are available on request from the SAEDC.

Appendix VI—Braillembosses in Use

0.1 Sensory Aids Evaluation and Development Center (SAEDC): Serial No. 10 (prototype), June 69–May 70; Serial No. 27–4, May 70–present.

0.2 SAEDC: Serial No. 26–LP, Feb. 70–June 71; Serial No. 18, June 71–Sept. 71; Serial No. 26–LP, Sept. 71–present.

1. Mass Commission for the Blind (MCB), Dept. of Transportation, Dr. John Morrison: Serial No. 11 loan, Oct. 69–Nov. 70; Serial No. 13, Nov. 70–present.
2. Perkins School, Programming Course: Serial No. 12, Feb. 70–present.
3. MCB, WWLP, Springfield, Paul Caputo: Serial No. 22, newswire, May 71–Oct. 71; Worcester Polytechnical Institute, Philip Hall (Client, NH, DBS): Serial No. 22, ASCII, Sept. 72–present.
4. MCB, Honeywell, Alan Downing: Serial No. 26, loan, June 71–Sept. 71; Serial No. 24, Intermetrics, Sept. 71–Aug. 72; Honeywell, Aug. 72–present.

4.1 MIT, National Braille Press, Demonstration: Serial No. 20, loan, Sept. 71–June 72.

5. University of Manitoba, Don Keeping: Serial No. 28–4, Oct. 71–present.
6. Bristol Engine Division, Rolls Royce, T. Hicks: Serial No. 29–4, March 72–present.
7. MIT, Internal Revenue Service, Little Rock, Arkansas, Jack McSpadden: Serial No. 18, loan, April 72–present.
8. MIT, MITRE, Demonstration: Serial No. 19, loan, July 72–present.
9. MIT, Arkansas Enterprises for the Blind, Training: Serial No. 15, loan, Sept. 72–present.
10. Penn State University, Ronald Morford: Serial No. 23, Feb. 73—present.

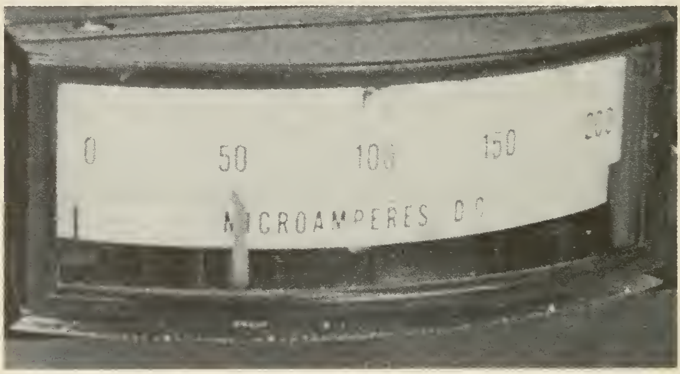
Electro-Tacter—A Tactile Panel Meter

An electrical panel meter has been devised for a blind user. The meter features a movable tactual indicator with a scale, an audible indication of coincidence between tactual and visual indicators, and complete isolation both electrically and tactually between the meter movement and the readout.

The meter uses an API model 371K Compack II controller whose basic movement is a contactless optical meter relay. A tactual scale is added to the meter below the set point adjustment lever. (For initial demonstration a 60° segment of a protractor was cemented to the set point lever guide. Each degree mark was filed to form an easily felt notch. Every 10th notch has an additional mark.) A tone is used to determine the agreement of the location of the visual indicator, and the location of the set point adjustment lever.

To read the meter, a momentary switch is held closed, activating the audible indicator. If no sound is heard, the set point lever is moved down scale until a tone indicates meter closure. The set point lever is then carefully adjusted for the exact point of the relay closing. The position of the set point lever is down scale when the reading cycle is initiated, the tone tells the reader to move up scale to the closure point.

A demonstration package has been assembled using a 200 microamp meter, a meter current source, and a Mallory Sonalert as the tone generator. Experiments with a blind subject has shown that accuracies of 2% can be obtained. The package is 5 x 8 x 12 inches and requires AC power to operate. Provision is included for an external current source to be measured by the meter.



METER FACE SHOWING TACTILE SCALE BELOW SET POINT LEVER

BRLCOM MULIMETER—A METER WITH A BRAILLE DISPLAY

A digital electrical panel meter has been devised for the blind user. It uses a commercially available digital panel meter and has a braille display in parallel with the numeric display of the meter. With this unit the numeric data is displayed both visually and in braille. It is the digital equivalent of the Electrotacter.[1]

The meter is an Analogic[2] Model AN–2532 Digital Panel Meter. This unit has both "Nixie" glow tube and BCD (Binary Coded Decimal) logic outputs. These logic outputs drive a four cell numeric braille display. Each cell of the display has four dots, the top four dots of the braille cell, those necessary to display the digits. (This model of braille output does not have the number sign, but a cell permanently indicating the number sign could be incorporated.)

The braille cell dimensions are those adopted by the NAC[3] and used in the Perkins Braillewriter[4] and the Braillemboss.[5] The resulting braille character has the braille characteristics with which a blind user is familiar except that the tactile surface is metal instead of paper.

The braille display is composed of modules each containing two cells. It is necessary to make dual cell modules as the smallest solenoids with adequate

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[1] *Electrotacter, A Tactile Panel Meter.* SAEDC, TDS No. 14, October 1970.
[2] Manual of Operating and Installation Procedures for Digital Panel Meter Model AN–2532. Analogic Corp., Wakefield, Mass. 1971.
[3] "Standards for Production of Reading Material for the Blind and Visually Handicapped," National Accreditation Council for Agencies Serving the Blind and Physically Handicapped, New York, 1970.
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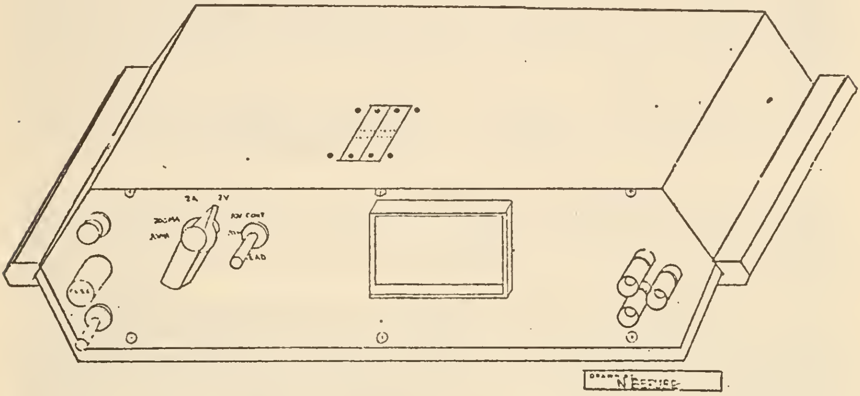
[4] Howe Press, Perkins School for the Blind, Watertown, Mass.
[5] *Braillemboss, A Braille Page Printer.* SAEDC, TDS No. 2, August 1970.

characteristics and sufficiently high reliability are 7/16 inch in diameter. This allows the solenoids to be mounted on ½ inch centers which is twice the pitch of standard braille cells. Smaller solenoids could be used but those available have not demonstrated sufficiently high reliability for this use. These modules can then be stacked to form a line of braille of any desired length.



The unit consists of a head or pin guide that positions the pins in the braille matrix. Each pin protrudes through the head such that it can be felt when its corresponding solenoid is energized. This head structure also contains springs that hold down the individual pins when the associated solenoid is not energized. The head is attached to a solenoid frame of main support. Each pin is connected to or controlled by a lever that serves as a connecting link with its appropriate solenoid. These levers are arranged in layers to prevent mechanical interference.

The head can also contain a latch arrangement for holding the braille pattern without expending power in the main solenoids. The latch can be controlled by either two solenoids, i.e. one solenoid for each cell, or a single solenoid for the two cells of the module.

The driver circuits for each cell consist of 4 Darlington transistors and 4 integrated circuits (IC's). The BCD code from the Analogic Meter is converted into the braille code by the IC's.[6] There is also included a strobe circuit that permits the cell to be turned on or off by an external switch such that the cell can be energized only when being read and can be off at other times.

Mr. Clawson?

Mr. Clawson. Thank you again, Mr. Chairman. It is a privilege to listen to this. My interest has been in the last several years directed to those subjected to seizures. Through Federal participation, we have now seen a breakthrough and the electronic triggering of a device that gives a warning that may be subject to seizures prior to the time one occurs. At that moment, they will be able to place themselves in a position whereby they will not do injury to themselves.

It is very elementary but still very important to the people afflicted with these physical and mental conditions.

So I am thrilled with the adventure you have engaged upon, because this is what it amounts to. We will probably never overcome these afflictions except through the combined efforts of technology and medicine.

My purpose here again is to introduce a constituent of mine, Dr. James Reswick. He is director of the Rehabilitation Engineering Center in Downey, Calif.

[6] Casamajor, A., Mackro, J., "The Design and Evaluation of a Braille Digital Voltmeter," Term Project 2 at MIT, December 1971.

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We have done a lot of things in Downey. That is also where the Apollo is built by NASA. He is a fellow student, I understand, of Dr. Mann whom you have just heard. They frequently cross paths in situations of this nature.

He became a professor of community medical health and medicine at USC, worked for the National Academy of Science Electrical Engineers. So it is a personal privilege for me as his Congressman to introduce to you, Mr. Chairman and this audience, Mr. James Reswick.

STATEMENT OF DR. JAMES B. RESWICK, DIRECTOR, REHABILITATION ENGINEERING CENTER, DOWNEY, CALIF.

Dr. RESWICK. Thank you very much.

Mr. Chairman and Mr. Clawson, we have two or three physicians sitting with two or three engineers, representing the collaboration of science and medicine in these hearings.

I have a couple of devices I would like to exhibit to you. But first, in my prepared statement I mentioned a project which impressed me very much at the George Washington University, being carried on by Thomas R. Shwarles. He took 27 high-level spinal injured patients who mostly, by and large, stay at home most of their lives. By the application of technology and training, he has made these people independent contributors to the gross national product of the country. He calculated a benefit-cost ratio, the benefits over a five-year period, divided by the cost actually spent in this training and for equipment. It ranged from 15.9 to 56. The country and the Government get back $56 for every dollar spent. These are real cases. They are in business now and are not only able to survive a competitive economy, but we can readily appreciate the difference it makes in their psychological well-being. Rather than being dependent on social services to sustain them, they are able to do this on their own.

The second point I want to make is that the successes at George Washington show it can be done for 27 handicapped people. But to be able to serve the millions of such persons throughout the Nation is a great challenge to government at all levels, particularly Federal, State and county. The problem is much complicated by the unique nature of the research-development-evaluation-training and distribution process in our free enterprise system. Devices which appear promising in a development laboratory such as one of the new rehabilitation engineering centers, almost universally represent great commercial risk when considered as new products for industry. The cost of design for production, the cost of special modifications for each patient, the cost of adequate training and education of physicians and allied health personnel in their application and the cost of marketing and subsequent maintenance is usually enough to discourage a potential manufacturer when faced with a market potential which is difficult to identify and quantify.

That is a problem. It has been overcome in some limited cases, but it has not resulted in solving the core of the problem for many people.

In my view, the most pressing present need is to begin the development of an effective federal-state effort, first to develop policy and then to administer a system to carry new devices to patients wherever they may be.

This will require first the building up within the rehabilitation service administration of a capability responsibility to develop policy and to administer the national rehabilitation engineering program, and, second, to develop mechanisms better to implement this policy through the state rehabilitation agencies. An immediate need is to appoint a permanent commissioner of RSA and then to implement the present law which specifies an appropriate staff group to assist in the development of policy and administration of programs. This step would be the basis for reaching out to state agencies, better to coordinate and encourage a higher level of service to the Nation's disabled population. The system used by the Veterans Administration, while having some deficiencies, could well be a model or source of suggestions for improving the RSA-State rehab agencies activities in rehabilitation engineering.

Let me illustrate two, I think, very exciting devices both of which come out of the rehabilitation center. I cannot emphasize the many failures which have occurred because of the lack of recognition of the need. But there is no reason, given the center of the enivronment, that a number of costs, government agencies cannot be brought effectively together.

The first example represents an attempt to do that. We are all aware of the amputee population of the world wearing prosthetics. These devices depend on a socket which connects to the artificial limb. It is a difficult and not very effective solution. It has been a dream for years to attach directly to the severed bone. Some initial devices have been actually used with patients. I have here the element which goes into the bone of a severed limb. The inter-medullary piece made of steel represents the kind of technology which surgeons are concerned with. But the problem of sealing the skin where it comes out against infection has thwarted research for years. This comes out of a research program conducted by the Atomic Energy Commission. They were attempting to develop plutonium covered beads to be used in reactors. That project never ended up with plutonium covered beads, but it did end up with a carbon which could be placed in the body, to which the tissue could grow and adhere. The skin grows and forms a natural barrier. This device was made at Kennedy Space Center with the cooperation of NASA.

The second problem which NASA has solved is to apply a special device which allows the prosthetics, the leg, to be pushed into position and locked in place. This is now part of the limb. The amputee, when he wants to take it off, merely pushes a button and takes it off. It was designed for use in space.

Here is a result arising out of the interaction of some space agencies. It will be placed in a patient at Rancho. We have worked as a team there to see what the problems were.

The second device was successful in private industry. There is the semiparalyzed individual who is unable to lift his toe when he walks. What I have here is a device which is surgically implanted in the leg of a stroke patient. On the outside, it is basically a radio transmitter which sends impulses to the device. On the shoe of the device is a transmitter also. So each time a step is taken, the little black box sends a signal to the nerve causing the person's foot to be lifted up through electrical impulses. This procedure shows extreme promise. Many patients report considerable improvement in their ability to walk and stand. We have applied this to the paralyzed hip muscles of stroke patients. So those formerly not able to walk are now able to do so. The ability to put a computer on this to program the movement is just around the corner.

I want to thank you very much, Mr. Chairman.

[The prepared statement of Dr. Reswick follows:]

STATEMENT BY JAMES B. RESWICK, SC.D., DIRECTOR, REHABILITATION ENGINEERING CENTER AT RANCHO LOS AMIGOS HOSPITAL

Mr. Chairman and Members of The Committee:

It is indeed an honor for me to have this opportunity briefly to bring to your attention certain critical needs of the Rehabilitation Engineering Program administered by the Rehabilitation Services Administration. Many others have convincingly shown this and other committees of the Congress the great potential of contemporary technology when effectively applied to improve the quality of life of the nation's severely disabled and, indeed, through modest expenditure to change these persons from lifetime recipients of federal-state support into working contributors to the gross national product.

I wish there were time for me to present in detail a number of specific examples of severely disabled persons who are now self-sufficient as a result of applied technology and training. Rather, for the record, let me include here as an appendix the summary of an excellent project carried on at George Washington University by Thomas R. Shwarles, M.A., entitled "Development of Modern Vocational Objectives for Severely Disabled Homebound Persons: Remote Computer Programming, Microfilm Equipment Operations and Data Entry Processes." Prof. Shwarles reports in this summary how some 27 spinal injured persons were equipped and trained to work in their homes. Based on a 5-year projection, he shows Benefit (Earnings to GNP) to Cost (Cost of equipment and training) ratios which range from 15.9 to 56. Many other examples are available to show that such true savings from tax monies do result from effective Rehabilitation Engineering Programs. The effect of such a change on the meaning-of-life to the individual is difficult to overestimate and impossible to value in dollars.

The successes at George Washington University show what can be done for 27 severely disabled. To serve the millions of such persons throughout the nation is a great challenge to government at all levels, particularly federal, state and county. The problem is much complicated by the unique nature of the Research-Development-Evaluation-Training and Distribution process in our free enterprise system. Devices which appear promising in a development laboratory, such as one of the new Rehabilitation Engineering Centers, almost universally represent great commercial risk when considered as new products for industry. The cost of design for production; the cost of special modifications for each patient; the cost of adequate training and education of physicians and allied health personnel in their application; and the cost of marketing and subsequent maintenance is usually enough to discourage a potential manufacturer when faced with a market potential which is difficult to identify and quantify.

But the difficulties can be overcome and some examples of new commercially available devices developed in the Rehabilitation Engineering Centers, including the Rancho-Medtronic Neuromuscular Assist Device and the High Density Flotation Bed of Gaymar Industries might be mentioned. If time permits, I would like to show you these new devices for the disabled as representative of technology in action.

In my view, the most pressing present need is to begin the development of an effective Federal-State effort, first to develop policy and then to administer a system to carry new devices to patients wherever they may be.

This will require, first, the building up within the Rehabilitation Service Administration of a capability responsibly to develop policy and to administer the National Rehabilitation Engineering Program, and second, to develop mechanisms better to implement this policy through the State Rehabilitation Agencies. An immediate need is to appoint a permanent Commissioner of RSA (Mr. James Burress is now Acting Commissioner), and then to implement the present law which specifies an appropriate staff group to assist in the development of policy and administration of programs. This step would be the basis for reaching out to State Agencies, better to coordinate and encourage a higher level of service to the nation's disabled population. The system used by the Veterans Administration, while having some deficiencies, could well be a model or source of suggestions for improving the RSA-State Rehab Agencies' activities in Rehabilitation Engineering.

Thank you, Mr. Chairman, and members of the committee, for attending my remarks.

Mr. BRADEMAS. Thank you very much, Mr. Reswick, for a most interesting statement.

Dr. Tichauer, I bring you the warm greeting of a constituent of mine, Mr. Smith.

STATEMENT OF DR. ERWIN R. TICHAUER, DIRECTOR, DIVISION OF BIOMECHANICS, INSTITUTE OF REHABILITATION MEDICINE

Dr. TICHAUER. Thank you. I am both a professional engineer and professional anatomist, specializing in biomechanics, the discipline which deals with the mechanics of the human body as a structure subject to both the laws of physics and the biological laws of life.

The term "disability," within the context of this testimony, does not carry the medical connotation of physical disability but refers to the inability to perform satisfactorily in an occupational or domestic environment as a result of a physical impairment. Man is exposed to equipment in industry and during activities of daily living. Interfacing the handicapped with equipment is a great American tradition. Perhaps the first publication dealing in depth with the problem of occupational rehabilitation after severe physical impairment was written by Frank Bunker Gilbreth, and was entitled "Motion Study for the Handicapped." This was published in 1917. His problems were the same as ours.

We have a vast source of technological data but we have a communications gap. Sometimes the barriers between the handicapped and his ability to earn a livelihood and have the satisfaction of independence are small, trivial, but they are vital in terms of economic needs. I hate to put a dollar yardstick on human suffering. Failure to interface man properly with the everyday tools of industry costs this Nation $20 billion a year. Sometimes solutions are ridculously simple. Many disabled have lost freedom of wrist movement. Using a pair of standard wire cutters, they may be occupationally disabled. But a specially designed bent tool enables them to perform satisfactorily. This makes the difference between complete ability and complete disability.

Sometimes the disabled have skills which other people do not have. They use wheelchairs providing great mobility. These help to carry tools from one place to another. However, there is a communication gap between the handicapped and the prospective employer in industry.

I submit respectfully that there is need for the development of a uniform American national standard for ability testing. This should be written so it could be readily understandable to the employer. There should be more research into the specific kinesiology, the motion patterns of the disabled.

Now I would like to have the chairman's permission to show a few slides.

[Slide]. Showing the effect of bent pliers on performance.

Measurements of range of motion on top of the slide are compared with the muscular effort necessary to produce movement shown at the bottom of the slide. The disabled person has to make four times the movements of an unimpaired individual to perform. He has to be four times better to keep his place, unless somebody puts a bend into the pliers and makes a tool suitable for his use.

Of 40 people placed in industry with bent pliers, 36 kept their jobs. Of 36 placed with straight pliers, only 15 kept their jobs. These are all wheelchair patients.

Sometimes people can sit and assemble things. But in order to get rid of the assembled merchandise, they have to toss it away. An individual may be disabled because he cannot put the stuff away after he has produced it.

[Slide.] Showing a device measuring the ability to perform tossing motion.

A biomechanical profile taken with these advanced devices displays the relationship between muscular effort and productive output and shows how, through simple relocation of a bin on the worktable, occupational ability can be restored. Using electrophysiology and kinesiology improvements to workplaces can be made without significant cost to the employer. As a byproduct, the employer receives handsome dividends arising from higher productivity of the work force in general.

[Slide.] A biomechanical profile is displayed which shows that a disabled produces slower than others and is noncompetitive. But, it also shows why. If you look at the slide which, says "eye muscles," you see the eyes control the movement of the wrist. By simple counseling, it is possible to tell him, look at the typist. She does not look at the keyboard. You do not have to look at it either. Look once and then move. A biomechanical profile based on electronic measurement of movements, shows why somebody cannot compete and by adequate instruction to industrial engineers who, after all, have the care of the victim of impairment under concern, to institute constructive corrective measures. The most effective remedy is to train the disabled himself to develop an effective motions pattern.

The Army has developed the lethal sniper scope, an infrared device displaying heat maps of entire areas. By this means it can be seen whether there is a man hiding in the bushes. A counterpart to this is the health preserving thermograph or infrared camera. Many people have sensory or vascular afflictions of the hand. The development of this paint scraper by tracing the blood flow through the hand by means of an infrared camera enabled a handicapped person to become competitive. It looks primitive but it is not. When we are in rehabilitation engineering, we must not lose sight that we fight the battle for the disabled. This can only be won if people are trained in the applications of newly devised tools. It is possible now with infrared photography together with X-ray to diagnose back pain. It is also possible to diagnose if back pain stems from an injury to the back or from the placement of the chair on the floor. The remedy is simple, put the wheelchair up on blocks while the individual is working and he can produce.

I respectfully submit to this committee that you consider exploring the possibilities of establishing research utilization centers where the shorest pathway can be developed for practical application of research results for the benefit of handicapped. I know it is dangerous to cut across Government agency lines. However, I submit, that the employer willing to hire the severely handicapped often feels he does not have the qualified personnel to evaluate the disabled. It is therefore necessary to establish standards. Standard evaluation procedures will give the disabled means to demonstrate to prospective employers what they can do. This, in terms which a foreman without sophistication, or higher education, will be readily able to relate to the needs of a manufacturing operation. It will show the employer that the disabled possesses skills and is able to utilize these just as well as the unimpaired.

Finally, I feel it is necessary to standardize these tests. Up to now, every rehabilitation center in the country pretty well works in a different way. There ought to ge a uniform standard for assessment throughout the country. The American National Standards Institute should be consulted in this respect.

To come back to the fears of the employer as to reliability in exposing the disabled to a risk for which he may be prosecuted, it is necessary to realize that care for the handicapped or disabled individual comes within the scope of a safety engineer or industrial engineer. I have satisfied myself to the best of my knowledge and belief that funds have not been even requested by the National Institute for Occupational Safety and Health for any future fiscal year, for tarining in these matters. I feel it is necessary to bring together with NASA and all other industrial organizations, the National Institute for Occupational Safety and Health as a training resource for engineers into play, and bring the disabled to the attention of these organizations, so that they can be rehabilitated and employed with benefit to the national ecoomy, but even more important, with benefit to themselves.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Tichauer follows:]

TESTIMONY OF ERWIN R. TICHAUER, PROFESSOR OF BIOMECHANICS, THE CENTER FOR SAFETY AND DIRECTOR, DIVISION OF BIOMECHANICS, INSTITUTE OF REHABILITATION MEDICINE, NEW YORK UNIVERSITY

Mr. Chairman, Distinguished Committee: I am both a professional engineer and professional anatomist, specializing in biomechanics, the discipline which deals with the mechanics of the human body as a structure subject to both the laws of physics and the biological laws of life.

My direct sub-specialty, which I have helped to pioneer, is occupational biomechanics, the mechanics of the human body, healthy as well as diseased, in work situations and activities of daily living. I am active as a teacher, researcher, consultant to industry and advisor to several other medical institutions and engineering colleges as well as to government agencies.

The term "disability", within the context of this testimony, does not carry the medical connotation of "physical disability", but refers to the inability to perform satisfactorily in an occupational or domestic environment as a result of a physical impairment. There are two basic thrusts to be considered in the development of technologies for the rehabilitation of the physically handicapped.

Firstly, the development or further development of technologies which aim at the improvement of physical function. By way of illustrative example, electronically operated artificial limbs, reading devices for quadriplegics, and the field of hyperbaric medicine and other medical disciplines are mentioned.

Secondly, there is need to develop and apply research methods and technologies designed to facilitate the reintegration of the impaired into a productive, competitive employment process or, if this is not possible, to provide methods of interfacing with domestic equipment so that they can lead at least a relatively independent life at home.

The latter aspect is a time-honored American tradition. Perhaps the first publication dealing in depth with the problem of occupational rehabilitation after severe physical impairment was written by that great American, Frank Bunker Gilbreth, and was entitled *Motion Study for the Handicapped*, as early as 1917. His problems did not differ from ours. The problems in 1917 and the ones in 1974 are alike. Sophisticated technologies developed in many fields were then, just as today, available. The problem was, and is still, how to apply this vast national heritage of superior American research and technology to the practical benefit of the handicapped. To achieve this, a three-pronged approach is necessary: one, research geared to assess the potential and utility of the vast storehouse of technological and medical basic knowledge amassed at the expense of taxpayers' money, and an equally significant expenditure of the emotional and intellectual resources of devoted researchers.

To mention one example: NASA has amassed a vast inventory of basic research results, technological applications, know-how and project management. Nevertheless, because NASA was not conceived as a rehabilitation agency, we are not fully appraised of the nature and magnitude of the benefits, which are undoubtedly major, and which may accrue to the disabled from the space effort. This is not the fault of the space agency; it is ascribable to a communications gap which simply exists between NASA, the rehabilitation community, the rehabilitee and the potential employers of rehabilitees.

Once these technologies have been assayed it is necessary to conduct mission-oriented research towards a direct application to the rehabilitative process.

Finally, and this must be said here, to conduct research without concurrent training at least in the field of rehabilitation and disability prevention is, I beg respectfully the Committee's forgiveness for my harsh language, utterly useless. Once a new technology is developed, people, professionals and technicians, are required to apply the technologies and deliver the necessary care. Without a supply of trained radiologists and X-ray technicians, the X-ray tube would still be a fascinating curio displayed only in museums to scholars of physics.

A commitment to provide rehabilitation services entails an obligation towards the professional preparation of the necessary personnel. A decision to conduct rehabilitation research implies a moral obligation to train personnel which can transport the results of research into the realm of practical usefulness. Research and the training of practioners and the practical process of rehabilitation are inextricably interwoven and a decision to engage in any one of the three carries the moral and fiscal responsibility to engage in all three.

The following figures about the nation's largest epidemic have been compiled from a variety of sources. In the last year alone, there were 2¼ million accidents which led to disability and hospitalization. This does not even include motor vehicle accidents. The total estimate of disability stemming from breakdowns of occupational safety and health alone amounted to more than 5 million incidents at an estimated cost of more than $20 billion. Total time lost was 200 million man days. Vocational disability affects 17 per cent of the civilian population of working age in the United States. It is projected that almost 22 million persons will be vocationally disabled by 1980. Occupational disability resulting from physical impairment is indeed the nation's major epidemic. However, technologies developed over recent years show that it is possible to do something about it.

Professional people have few probelms only in compensating for even the most severe disabilities.

Quadriplegic lawyers and engineers are commonplace. It is the individual with limited skills or skills which have become obsolete due to his physical impairment who has to wage a long, drawn out battle, not only for physical but also for economic survival, within the framework of a competitive working environment. This battle can be won if the technologies necessary to achieve successful interfacing of the disabled with the workplace are disseminated and their application taught to those engaged in ability assessment, placement, employment and supervision of the productive act itself.

How this can be done will now be demonstrated with four examples:

EXAMPLE 1

Numerous individuals who suffer from inflammation of peripheral nerves, or damage to the peripheral nervous system due to motor car accidents or, perhaps, are arthritic, have lost to some extent, freedom of movement of the wrist joint. They may be confined to wheelchairs but nevertheless have been adjudged perfectly capable of wiring electronic devices. Already, on the first working day, it may be found that they are completely disabled because they cannot loop thin wires around stout pegs when using the pliers commonly employed for such purposes. If the victims of such physical disorders are lucky enough to have been treated in a rehabilitation center where the level of training of the physicians and allied health professionals goes beyond the purely medical aspects to include knowledge of the technologies involved, and if they are equally lucky to find employment in an enterprise where the industrial engineer and the employment officer have received training in the anatomy and physiology of work, then it will be immediately recognized that the afflicted has lost the ability to bend the wrist and instead, recourse is being taken to a simple technological remedy—leave the wrist straight but bend the pliers.

A kink in the handle of appropriate magnitude and at the right spot does indeed make the difference between complete disability and complete ability.

The potential employer of a disabled individual has every right to ask if this person will be able to perform economically without major modifications to the workplace and has a chance to become a stable employee, if minor modifications of his physical environment are made.

This assurance can be given by means of The Biomechanical Profile, which displays clearly the relationship between physiological effort and productive output under a variety of circumstances. In the particular example at hand, the job is simulated in the laboratory and the resultant Biomechanical Profile shows clearly that with the wrist straight and the tool bent there is little muscular effort and a great range of movement. However, when the tool is straight and the wrist bent, the worker has to work twice as hard to have half the output. He starts with an immediate economic handicap compared with the unafflicted.

Just as we are looking for potential and useful spin-offs from NASA technology, so does each industrial employer routinely expect a useful "by-product" from rehabilitation engineering. He is more likely to employ the handicapped if it can be demonstrated that employment of the handicapped, because of the necessary improvement to the production method, will automatically increase the level of productivity and quality of the enterprise in general. It can be shown from simple industrial statistics that disability of the wrist when the disabled and the healthy are compared is not a difference in kind, but a difference in degree, and that more than twice the number of healthy individuals get through the training period when instructed in the use of bent pliers. It can, furthermore, be shown that the use of an anatomically correct tool by the impaired and healthy alike reduces production costs and enhances the quality level of the product manufactured.

EXAMPLE 2

The next example will deal with what is commonly known in industry as a "tossing motion." Wrist drop is one of the more frequent and unfortunate aftereffects of both injury to the spinal cord due to trauma as well as numerous other central and peripheral nervous system disabilities. The inability to extend the wrist makes it impossible for the afflicted to toss the finished product away after it has been successfully processed.

It is, therefore, necessary to evaluate the ability of wrist extension prior to placement. This again can be done in a technologically oriented rehabilitation center where the people are trained, if not in practice, then at least in the principles of industrial engineering and occupational safety and health so that the question may be answered to the satisfaction of the employment officer before it has even been asked.

With a suitably constructed device, the Biomechanical Profile of wrist extension is taken and if it shows that the prospective employee fatigues extensively under such conditions, then he is simply counselled to move the tote bin, where the finished articles are deposited, to a different position so that at the termination of the work cycle he may scoop the component into a bin rather than toss it away. Again, the position of a box makes a difference between ability and disability.

EXAMPLE 3

The next example will address itself to difficulties of hand movement, defective visual fields and difficulties with eye-hand coordination. These are experienced frequently as a consequence of all kinds of physical disability as well as of treatment with medications. It is now possible to simulate, in the laboratory, the entire motion cycle involved in a work situation by means of relatively simple devices. During a simulated work cycle, hand movement, eye movement, and wrist movement are measured electronically. The resulting Biomechanical Profile shows not only that something is wrong but also what is wrong and what can be done about it.

In this particular case, it can be seen that the impediment to successful employment is defective eye-hand coordination or continuous control of wrist movement by a pair of anxious eyes of the patient.

It is possible to instruct the patient in the proper use of the eyes, if necessary to explain to him that a typist does not necessarily look at the keyboard, but to advise him merely to look briefly at the target and then to forget looking and move purposefully towards it. The length of paper consumed to produce the Biomechanical Profile is indicative of the time needed to perform the operation. The reduced duration of the production cycle subsequent to such instruction helps to minimize head movement and thus produces better eye-hand coordination. This makes the individual competitive again.

Apparatus employed in the foreshown examples of ability testing is bulky, crude, expensive and requires a laboratory setting. However, it is reliable. The same degree of reliability could be achieved much more economically by not constructing "one of a kind" ad hoc devices but by employing the technologies of miniaturization and mission-oriented manufacturing developed by NASA and other agencies. This would provide a battery of uniform and standardized tests which can be administered in a rehabilitation setting and industry as well, by trained technicians, with repeatable and meaningful occupational results. There is still a certain communications gap between the medical rehabilitation center, the vocational evaluator in an institution, and the employer. They do not speak the same language and do not have the same sense of values.

This is what the employer is looking for in a prospective employee, be he disabled or unimpaired:

(1) Can the employee produce economically, with a minimum of supervision, while enjoying, at the same time, a high standard of physiological and emotional well-being.

(2) The Occupational Safety and Health Act makes it incumbent upon the employer to protect the working population from all hazards, including biomechanical ones, and the question may arise whether a pre-existing disability increases a minimal contingency of occupational disease or accident, due to a pre-existing disability, to a real hazard. Under such circumstances, the employer will be liable and is, therefore unlikely to hire.

(3) Can an employee be transferred sideways within the enterprise to a different task should economic or technological considerations make this necessary.

(4) Most important of all, which motion elements in common use in workplace design throughout a given enterprise, according to its own system of motions study currently in fashion, can the applicant for employment perform. This is perhaps the most important consideration.

(5) A communications gap may arise. The employer is not always sure that the disabled individual's evaluation is based on a battery of tests adequately duplicating the standard elements of motion used in the production process. There is often suspicion that pre-employment tests, carried out in a rehabilitation setting, are contrived, out of date, and do not attest to the existence of abilities and skills ncessary to perform effectively in "real" work situations. Many industries are quite eager to hire the disabled, even those with severe impairments. However, they have to satisfy needs of insurance carriers not to increase the

general level of occupational hazard within the enterprise, which could be raised by the exposure of individuals with pre-existing disabilities to occupational disease and accident.

I respectfully submit that the battery of tests administered to disabled seekers of employment shall be identical with the battery of tests given to the unimpaired, and shall be identical in a rehabilitation setting, in the corporation's employment office and also, if so desired, in an insurance carrier's evaluation unit. Such tests, if realtistically designed, will not only show the abilities and limitations of the disabled seeking employment, but will also demonstrate clearly that disability may well be a cause of superior skill and increased safety of performance. In many settings, the fixed work surface height and the relative mobility of wheelchair bound individuals is a distinct advantage, particularly under circumstances where small quantities of inventory or tools have to be carried from workplace to workplace, such as is the case in light assembly work and quality control.

The individual who lost one arm, in spite of the disaster which befell him, if properly trained and evaluated, will be highly competitive, productive and safe in the assembly of electric appliances, or in small press work where one unused hand can get into the way of machine or tools. Even prosthetic devices, be they the old fashioned hook or the more sophisticated electronically governed artificial arm, have, to be best of my knowledge, not been evaluated in terms of standard industrial motion study. Therefore, it is not known whether their users do not possess skills not available from the unimpaired.

There are numerous consensus standards in use throughout industry in this country. I respectfully submit the need for the development of a uniform American National Standard for ability testing. This is not a small enterprise. The development of a Standard may require several years to complete. Nevertheless, it will pay handsome dividends when we think of the projected number of disabled, based on current statistics.

There is a need to develop mass screening techniques and to recall that the X-ray tube would have been useless without the development of trained and qualified personnel. Another device will now be demonstrated, and advanced technology which is available but which cannot be utilized because application methods and qualified personnel have not been trained as yet. I refer to infrared photography, or thermography, which was developed by NASA and other enterprises to a high level of perfection. (*Example 4*)

By way of over-simplification, it may be considered a "soft tissue" X-ray procedure. It is a health preserving variant of the lethal "sniperscope" of the Armed Forces. It can be used to demonstrate if a tool or chair cuts off blood circulation to a limb unless modified, or to confirm the existence of back pain not diagnosable by other means. It can even be used to show if such back pain is suffered by an individual only if performing in an environment involving exposure to vibration. However, the apparatus today costs $40,000, a price comparable with an X-ray machine, but it is only in common use for the detection of breast cancer.

Other applications, highly dramatic and illustrative, dealing with clotting in important blood vessels, injuries to joints and other conditions are still in the research stage because not only of the cost of the instrument, which, if developed properly can become an important tool for mass screening of employee ability, but also due to the complete unavailability of trained personnel. The thermograph could even be developed into a rapid mass screening device to predict the danger of decubital ulcers so common in people with central nervous system and spinal cord injuries. Because of its potential predictive value, it could well make it possible to institute preventive measures before the affliction occurs. This would be particularly important to the wheelchair bound severely disabled.

The X-ray tube was mentioned earlier. With respect to infrared photography as applied to rehabilitation and occupational safety and health alike, a comparison can be drawn to the cardiogram. The cardiograph was developed in 1920 and was potentially a most useful instrument, but condemned to uselessness during the first ten years of its existence which were spent in standardizing the procedure and training personnel. We should learn from past experience and conduct application training concurrent with the development of new technologies. Today we have effective thermographs but relatively few people who can use them and even fewer who can interpret the significance of the pictures adequately and meaningfully.

Another urgent need which could be fulfilled by application of existing research results is the development of "spray on" electrodes. Respiratory monitoring, necessary to combat disability resulting from pulmonary afflictions such as emphysema or the black lung of miners, as well as the interfacing with the human body of the numerous varieties of electronically governed assist devices, including electronic prostheses already available, is currently impeded by the suffering of the disabled from a lack of electrodes which can be sprayed on in an aerosol fashion and be left in place on the human skin for days or perhaps weeks, without causing damage and/or irritation.

Finally, adequate telemetric care of the victims of heart disease while at work would be made feasible through such development.

Care for the disabled at the workplace by needs must be largely in the hands of the industrial engineers, safety professionals and industrial hygienists. Rare is the industrial enterprise which employs sufficiently large numbers of disabled to warrant the hiring of qualified rehabilitation professionals. Therefore, in a realistic setting, one occupational safety and health specialist will normally be concerned with the care for the disabled and unimpaired alike. The Occupational Safety and Health Act mandates that the National Institute for Occupational Safety and Health train personnel qualified to put industry into compliance with the Act. The William Steiger Act has been designed to ensure occupational safety and health for all workers, be they disabled or not.

To the best of my knowledge, the National Institute for Occupational Safety and Health has not requested, for the forthcoming fiscal years, funds for training programs. It will be a national disaster if training programs in occupational safety and health are phased out. A serious technology gap may result. This is an age of changing workforce and changing technology. Our industrial workforce gets older and, therefore, becomes more and more exposed to disability, which makes the prevention of vocational disability stemming from physical impairment an item high on the list of national priorities. The workforce is this country's only meaningful resource. Quite apart from the human suffering, which is very real to anybody connected with actual industrial work situations, we cannot afford attrition of the workforce by premature retirement caused by disability. We are already in danger of becoming a less developed country with respect to health care for the working population. A technology gap with respect to the effective utilization of our human resources is rapidly developing between this and other countries.

I, therefore, submit respectfully to this Committee, two proposals:

(1) An intensified program of training of practitioners in the fields of occupational safety and health, focusing on both the needs of the healthy and the disabled under the auspices of the current framework of the National Institute for Occupational Safety and Health in cooperation with other agencies such as the Social Rehabilitation Administration and the Social Security Administration. A task force should be empanelled to determine not how much we save by the phasing out of training programs, but by how much we stand to lose in terms both monetary and in human suffering.

(2) Research utilization centers should be established. They should have a specific mandate: to search for basic scientific and technological developments, to explore their potential relevance to rehabilitation, to develop procedures of practical utility for vocational assessment meaningful to the rehabilitation community and the industrial employer alike.

And, finally, they should be charged with the onus of training adequate numbers of personnel skilled in the practical application of the technologies available so that meaningful results can be obtained and a maximum number of disabled—those with sub-clinical impairments, those with medium disability and those who are severely disabled—can be reintegrated into the employment process.

A report of the Space Research Coordination Center of the University of Pittsburgh shows that the greatest need of this country in the field of biomechanical and human factors engineering is qualified instructional personnel. Poverty caused by disability, be it in terms financial and material, or by way of job satisfaction, is very real. It is also one of the causes, on a major national scale, of the inability of many industries to compete successfully in international markets. It bears on our deficit of payments and most importantly, it diminishes the level of human happiness in this country. I, for one, feel that something can be done about it through appropriate legislation, which makes feasible the two proposals above. This, of course, must be followed by faithful and effective implementation, in accordance with the intent of our legislators, of any such laws passed.

New York University Medical Center,
Institute of Rehabilitation Medicine,
New York, N.Y., December 27, 1973.

Memorandum:

Re: Dissemination of NASA Technology.
To: Howard A. Rusk, M.D., Chairman, Department of Rehabilitation Medicine.
From: James M. Dwyer, Erwin R. Tichauer.

This memorandum is written in response to your recent request:

SUMMARY

1. Much NASA technology is well documented and, with modification, could be useful in the biomedical area.
2. The hardware for many systems was produced in limited quantities and can be duplicated inexpensively only through quantity production.
3. Joint ventures among laboratories could result in few-of-a-kind costs being shared. They would necessitate multi-party contracts that NASA is skilled in supervising.
4. The potential payoff in exploiting such technology is enormous. Biomedical telemetry alone could halve hospitalization costs for many conditions.
5. The research benefits would be great. There would be dramatic benefits in aids for the disabled.
6. New legislation and funding mechanisms are needed to make the benefits of NASA research available to the community at large.

INTRODUCTION AND GENERAL RECOMMENDATIONS

The NASA program of the 1960's will long stand as one of mankind's great achievements. A by-product is a huge inventory of accumulated knowledge and technique stored in progress reports, on computer tape, embodied in existing hardware, and, in some cases, carried as personal experience by the men who did the work. Since the focal point of the NASA work was telemetered control over living man, all of this expertise holds enormous promise for the medical community. This memorandum suggests how some of this can be transferred to the American medical community.

The physician working in a busy hospital has but little time available to sift through the data that NASA has produced. Furthermore, results are often couched in sophisticated engineering language with which physicians may be unfamiliar. Access to individual reports will benefit few doctors, and fewer patients. The amount of data must be reduced to manageable size. For example, the design of units to handle human excretion in zero gravity involved some considerations also met in the nursing care of the paraplegic. An astronaut confined to a capsule for a week has many similarities to a patient in a wheelchair. The design work of a light-weight, odorless disposal system may contain information useful to *any* hospital. The main point is that *some* hospitals should obtain a few of these systems for study and evaluation.

Immediately, a second consideration presents itself. Neither the hardware, nor its documentation, are particularly useful in and of themselves. They must be evaluated in a medical setting and they must be modified for clinical use. The present system of NASA Regional Information Centers is basically useless. What is needed is not a system of documentation depositories, but technical assistance centers with a three-fold mission:

(1) To locate not individual reports, but sets of reports related to a particular question. Further, assistance should be available to render these documents in terms understandable to a physician. The centers should sponsor courses, symposia, lectures, etc. for and by the medical community.

(2) The regional centers should be able to deliver components and/or assembled hardware to qualified investigators. They should be able to help in carrying out modifications.

(3) The centers need to have funding available to qualified groups to utilize any new opportunities developed. The economics of this area are discussed later.

Here it is sufficient to note that neither documentation nor hardware will be exploited unless competent personnel are available. Basically, this means the centers should be sponsoring research and development projects within the biomedical community.

The utilization of NASA technology will require a close, continuing cooperation between the engineering and medical communities for which there is, at present, no mechanism. The concept of expanded NASA Regional Information Centers would provide such a mechanism. Bioengineers, located at the NASA Centers, should act as the counselors and advocates for the medical community in a dialog with manufacturing groups. The bio-engineering groups should be able to fund promising projects initiated by the medical and biomedical sectors. Only when all these elements are interacting will the enormous potential of NASA technology be truly "available" in the sense that patients in a hospital will receive services.

GENERAL CONSIDERATIONS

(1) NASA has made a real and ongoing effort to see that its knowledge and skill are widely disseminated. Outstanding in this regard are: Biomedical Applications Team, Southwest Institute, 8500 Culebra Road, San Antonic, Texas 78284; Technology Applications Group, George Washington U. Medical Center, Biologic Sciences Communications Project, Washington, D.C.; Stanford U. School of Medicine, Biomedical Applications Team, Palo Alto, Calif.

(2) A major problem facing a medical researcher attempting to exploit this technology is its highly specialized nature. For instance, the use of solid-state electronics usually involves the use of custom designed "chip" circuits absolutely essential to the operation of the whole system. Such chips were produced in small quantity on the basis of cost-plus contracts and are no longer commercially available. It is of paramount significance to develop a funding mechanism to make this circuitry cheaply available to clinicians so that it can be incorporated in a number of devices used in the diagnosis and treatment of stroke and cancer patients.

(3) The current policy of widely disseminating written reports on NASA technology, but denying funding for hardware construction and/or modification, makes sure that everyone knows of opportunities available but denies any possibility of utilizing them. With few exceptions, NASA developed devices which cannot be reproduced commercially using low budget funding.

The original equipment was built to custom design in small production runs. This consideration extends to precision motors, electronic components, electro-optical transducers, exotic metal alloys, and other extraordinary items.

Either NASA or some other agency should develop a funding mechanism to make these developments not only visible but also financially accessible.

(4) It should not be supposed that extraordinary sums of money are needed. The per item cost of producing a device capable of telemetering blood pressure, heart rate, respiration, and EEG data from a subject in a high velocity centrifuge was conservatively estimated at 2.5 million dollars. Such a figure becomes understandable when it is realized that one solid-state chip circuit costs approximately $80,00. The next one hundred would cost about one hundred dollars each, totalling ten thousand dollars. But the next ten thousand circuits would cost one dollar each, for another ten thousand dollars.

These are the economics: "one-of-a-kind" production is astronomically expensive: "few-of-a-kind" batches are cheap. Much of NASA technology was in the one-of-a-kind capability, so that devices can be produced for wider use that are relatively cheap. (The dramatic drop in the cost of desk top calculators is an example of the leverage this type of economics can exert.)

SUGGESTIONS FOR THE FUTURE

(1) It is necessary to disseminate hardware *AND* information to a multiplicity of researchers in hospitals, medical centers, academic laboratories, and industrial laboratories. NASA is the logical agency to oversee this process. It has had the experience of working with specific contractors for production of limited, highly specialized items and also has built-up an efficient information transfer capability.

(2) NASA should formulate guidelines that would require joint ventures among several institutions for items in the few-of-a-kind class. Two purposes would be served. It would provide a strong incentive for discussions among many

laboratories seeking to become eligible for such joint ventures. Also, it would be a mechanism to keep project costs down because the same fund would be doing double duty. For example, it would be wasteful for one institution to try to build an exo-skeletal system; but for four laboratories to jointly build seven or eight, aimed at locomotion, arm movement, lifting, etc. could achieve significant savings and at the same time expedite the transmission of technological know-how.

(3) It would be necessary for legislative changes to implement such concepts. Not only NASA, because most government agencies are oriented towards projects conceived and executed by individual contractors.

A variety of techniques are possible for maintaining accountability. The most obvious would be that an individual laboratory would sub-contract parts of a project to other laboratories for the production of a particular system.

EXAMPLES OF SPECIFIC TECHNOLOGY CURRENTLY DEVELOPED BUT NOT COMMERCIALLY AVAILABLE

1. Spray-on Electrodes

These incorporate a silver powder in a fluid matrix and can be applied to large or small areas over selected muscles. They are superior to conventional conducting paste cup electrodes because they can be left on a subject for longer periods and have little motion induced voltage.

At present these electrodes are fabricated in each laboratory from a variety of industrial sources of silver powder. Some care must be taken to ensure that the particular batch of silver powder is not admixed with irritating additives.

Our own institute is currently developing "in house" expertise within the Divlsion of Biomechanics in developing spray-on electrodes for:

A. Respiratory monitoring (prevention of crib death).

B. Myographic electrodes for long-term adhesion time (Myoelectric prosthesis; Intensive Care cardiac monitoring).

2. Sub-miniature Biotelemetry Unit

NASA has developed the technique of transmitting physiological signals by radio to a high degree. The circuits are well-defined and several generations of prototypes have been employed in NASA laboratories, orbital flights, and in medical laboratories outside NASA. The applications range from EMG, EKG to remote respiration monitoring, all while a subject is free to move about and exercise.

However, each laboratory much delve into the NASA literature to find the relevant data and individually try to locate suitable components from standard industrial sources.

3. Composite Epoxy Cloth for Orthotic Devices

Standard steel frames are difficult for weakened patients to manipulate in such devices as leg and arm braces. Epoxy cloth is highly flexible until "cured," and rigidly holds its shape under heavy loads. It permits the custom fabrication of orthotic devices which are light in weight and form-fitting in a matter of hours. Most important the components are easily replaced.

These cloths are produced in limited lots under NASA contract. The graphite-glass formulations that are currently available commercially are not easily cured at room temperature.

4. Prosthesis DC Motors

NASA has developed a wide variety of small, light-weight motors that are easily controlled with high precision for unfurling solar panels and positioning antennas.

Such motors, combined with suitable hardware, are useful in artificial limbs, mechanical page turners, etc., and other prosthetic devices. The Biomechanics Laboratory would be interested in using such motors to develop precision loads for use in measuring biomechanical profiles.

The motors available from industry incorporate some of this NASA development but are necessarily produced for a limited range of applications and often require excessive currents or do not meet the precision control specifications of the original NASA contracts.

5. Exo-skeletal Suit for Locomotion Analysis

The Langley Research Center has developed an exo-skeletal framework that permits the measurement of one limb's motion relative to a second limb to a precision of 1%. A second generation prototype incorporating a telemetering capability is under test at Emory University and the V.A. hospital in Miami.

The Biomechanics Laboratory has, with some difficulty, built a lordisimeter using similar principles but producing information of a different nature. Our laboratory would be most interested in exploiting the inherent capability of such a device in measuring the response of the body to a variety of lifting tabs.

This system has considerable clinical interest because it would allow the dynamic characterization of neuropathically injured patients recovery progress during a treatment program. It would permit quantitative gait analysis free of encumbering wires. It also measures the ability of a patient to trace out a three dimensional pattern.

6. Oculometer

The Biomechanics Laboratory of this institute has great interest and expertise in eye-hand coordination studies. In evaluating pilot visual coordination NASA has developed a system that allows free head motion but can measure eye direction, pupil position, pupil diameter, direction and velocity of scan and radio of horizontal to vertical scan excursion. Such a system would inevitably produce information of great significance to clinical biomechanics as well as in the treatment of brain damage.

Given the prospect of securing an oculometer, the Biomechanics Laboratory would be willing to produce or secure the components for several more in conjunction with other laboratories. The incentive would become even stronger if discussions made it likely that several laboratories would use similar systems in different ways so as not to duplicate experiments unnecessarily.

SPACE RESEARCH COORDINATION CENTER—TWO SURVEYS OF THE NEEDS OF ENGINEERING SCHOOLS IN THE FIELD OF BIOMECHANICAL AND HUMAN FACTORS ENGINEERING EDUCATION

(By Erwin R. Tichauer, Professor and Director, Division of Biomechanics, Institute of Rehabilitation Medicine and the Center for Safety, New York University and Alan A. Glaser, Assistant Professor, Mechanical Engineering Department, University of Pittsburgh)

The Space Research Coordination Center, established in May, 1963, has the following functions: (1) it administers predoctoral and postdoctoral fellowships in space-related science and engineering programs; (2) it makes available, on application and after review, allocations to assist new faculty members in the Division of the Natural Sciences and the School of Engineering to initiate research programs or to permit established faculty members to do preliminary; work on research ideas of a novel character; (3) in the Division of the Natural Sciences it makes an annual allocation of funds to the interdisciplinary Laboratory for Atmospheric and Space Sciences; (4) in the School of Engineering it makes a similar allocation of funds to the Department of Metallurgical and Materials Engineering and to the program in Engineering Systems Management of the Department of Industrial Engineering; and (5) in concert with the University's Knowledge Availability Systems Center, it seeks to assist in the orderly transfer of new space-generated knowledge in industrial application. The Center also issues periodic reports of space-oriented research and a comprehensive annual report.

The Center is supported by an Institutional Grant (NsG–416) from the National Aeronautics and Space Administration, strongly supplemented by grants from the A. W. Mellon Educational and Charitable Trust, the Maurice Falk Medical Fund, the Richard King Mellon Foundation and the Sarah Mellon Scaife Foundation. Much of the work described in SRCC reports is financed by other grants, made to individual faculty members.

PREFACE

The two surveys of the Needs of Engineering Schools in the Field of Biomechanical and Human Factors Engineering Education were conducted for the Biomechanical and Human Factors Division of the American Society of Mechanical Engineers during 1966 and 1967 by Erwin R. Tichauer, Executive

Committee, Biomechanical and Human Factors Division, American Society of Mechanical Engineers and by Alan A. Glaser, Education Committee, Biomechanical and Human Factors Division, American Society of Mechanical Engineers.

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OBJECTIVE

Several excellent surveys about the state of the art of bioengineering, biomechanics, and biomechanical and human factors engineering at American universities and colleges do already exist (*1–13*).[1] Likewise, already under way are studies designed to determine the best syllabus structure for the training of engineers in those branches of the profession which are life-sciences oriented (*14–16*). This report endeavors to complement and supplement the aforementioned two strands of inquiries with the opinion of engineering educators about the needs to train, in sufficient numbers, badly-needed professionals for the practice of our fast-developing discipline. While the purpose of the Two Surveys was to obtain information on biomechanical and human factors engineering education in particular, the results are of interest and apply to most areas of biotechnology.

THE SAMPLE

One hundred seventy-six engineering schools (*17*) enjoying full professional accreditation were canvassed by two different surveys.

The first survey, completed in 1966, indicated the need for additional information, so a second survey was conducted in 1967. Responses were good for both surveys, with 161 respondents for the first and 111 for the second. Both surveys were directed at the needs basic to the training of engineers, life-science orientated in their professional outlook, expected to practice as specialist engineers in their own right and not merely as, for example, instrumentation engineers, supporting programs of other disciplines. Instructions for the questionnaires emphasized that the term "course" should be deemed to include each and every scheduled activity (e.g. formal classes, laboratories, seminars, organized work by graduate students on a thesis or dissertation for a degree, supervised undergraduate projects with substantial instructional content, etc.). It was emphasized that the existence or absence of a formal curriculum in the field at the institution canvassed was not a criterion for participation and that the survey would not be concerned with questions as to whether these activities would be concentrated in one department, be interdisciplinary, multidisciplinary, be administered by individual, committee, or faculty, or even a committee of representatives from various faculties.

APPROACH

Preliminary conversations with a number of academic and administrative officers of various institutions provided convincing arguments that the surveys under consideration can be best conducted at the level of interests of academic deans. The one argument, advanced most frequently, stated that most deans were well informed not only about happenings within their own faculty, but, due to service on committees and frequent formal and informal contract with officers of administration at a higher level and their own colleagues (i.e. other deans) in other faculties, they had normally a good overview about most programs, current as well as planned, throughout the entire institution. Furthermore, there seemed to be some consensus of opinion that an academic dean, even if he himself were not interested, would be in a good position to know who would

[1] Numbers in parentheses refer to the bibliography.

be interested and forward the questionnaire to that interested and competent party to be filled in. During conversations with many academic officers, it was also concluded that a very simple, one or two-page questionnaire would well be the most likely to insure speedy, and comprehensive replies. This format was used for both surveys.

NATURE AND PROCESSING OF THE DATA RECEIVED

For the 1966 Survey, the questionnaires were divided into two groups: those returned by schools which maintained bioengineering, biomechanics, biomedical or human factors courses, and those returned by institutions which were not active as yet in the field.

The former returned 28 questionnaires; the latter, 133, which indicates that by 1966 roughly 1 in 6 schools had organized activities of some sort in the field. Careful perusal of the raw data received lead to the conclusion that the results of the survey could best be discussed by a relatively unsophisticated, nonmathematical, and qualitative treatment of the raw data on the basis of percentage response tabulation.

For the 1967 Survey, the situation changed considerably. Institutions having a degree program or at least formal course work in bioengineering/human factors engineering and which returned completed questionnaires now numbered 58. Out of these 58 institutions, 30 reported themselves as having formal course work or programs, and the remaining 28 institutions are known to have such activities from the results of other surveys. (*1*, *2*, 7) In addition, 44 out of these 58 have funded research projects in the field. (7) Another 37 institutions returned their questionnaires filled out in detail and evidently have definite interest in the field; approximately half of these already have funded research projects in bioengineering or human factors engineering. (7)

The remaining 16 respondents indicated that they had no interest at present. Thus, the 1967 Survey shows that at least 1 in 3 institutions out of the 176 canvassed has formal organized bioengineering/human factors engineering activities of some type. This indicates a doubling of the activity shown by the previous year's Survey. Assuming the other 37 institutions which have interest continue to have it, it is possible the ratio could be increased considerably in the next few years.

Since 95 institutions out of 111 responding have at least a definite interest in bioengineering/human factors engineering, it was decided to simply report the gross percentages rather than divide the data into two groups as was done for the 1966 Survey. The 1967 Survey form allowed space for the respondent to add comments if desired, and the most pertinent and interesting of these are included in the results presented below.

CORRELATION WITH RESULTS FROM OTHER SURVEYS

The doubling of activity in bioengineering/human factors engineering, which was indicated by the 1966 and 1967 Surveys, represented such a large increase that it was decided to validate this result by a closer study of the surveys listed in the bibliography.

Institutions which did not respond to the 1967 Survey but are known (1, 2, 7) to have bioengineering/human factors activities number approximately 39. Thus out of the 176 institutions canvassed about (39 + 58 =) 97 have organized bioengineering/human factors activities of some type and the corrected ratio of activity should probably be closer to 1 in 2 institutions being active with a definite tendency to increase even more.

The number of institutions having graduate degree programs in bioengineering/human factors engineering is approximately 35, according to the ASEE Annual Directory of Engineering College Research and Graduate Study (7) and this figure has remained static according to their 1966 and 1967 results. Considering the variability of reporting survey results, this figure compares reasonably with those presented here.

On the basis of research projects and research expenditures, the increase in interest is more definitely indicated. Again drawing from the ASEE Annual Directory (7) the number of institutions having research projects in bioengineering/human factors engineering was 73 for 1966 with a total research expenditure of $9,102,069. For 1967, 95 institutions reported research projects with a total research expenditure of $14,025,421, and this represents a 1.5 times increase in funding from the previous year.

On the basis of research projects in the particular areas of biomechanics and bioengineering, 40 institutions reported projects in these areas totalling $2,374,991 for 1966. For 1967, 66 institutions now had bioengineering or biomechanics projects with expenditures of $4,948,155. This represents roughly a doubling of research funding from 1966 to 1967 but is due primarily to large grants (over $200,000) which were received by a few institutions. For 1966, the smaller projects in biomechanics and bioengineering averaged about $42,000 over about 38 schools, while for 1967, the smaller projects averaged about $33,000 over about 60 schools. These results correlate with those of the present Surveys by showing a large increase in interest in the field with more institutions providing starting funds (as indicated by the decrease in the average project size). The fact that many institutions are doing research with minimum funding indicates the desire to do research in this area does exist, and that students and faculty are available to start larger programs when funds become available.

From the above considerations, it appears that the 1966 and 1967 Surveys did obtain a reasonably accurate cross-section of the interest, opinions, and potential in the field of bioengineering/human factors engineering education. Evidently a sizeable increase in activity in the field has occurred during 1966–1967. This increase in activity measured in terms of new research projects, funding, or new institutions entering the field is on the order of 1.5 to 2 times the previous 1966 level. Considering the responses from the 1967 Survey plus the evidence from other Surveys, it is probably also reasonably accurate to say that now 1 in 2 institutions, or better, have activity of some type in the area of bioengineering/human factors engineering.

RESULTS FROM THE 1966 SURVEY

A. Returns from institutions with bioengineering, biomechanics, biomechanical, or human factors engineering courses (*total returns: 28*)

Question 1: For the purposes of maintenance and development of existing Biomechanics, Bioengineering, and Human Factors Engineering courses we have found the availability of:

[In percent]

	No response	Adequate	Inadequate	Very adequate
Instructors		7.1	71.4	21.4
Research workers	3.6	17.8	71.4	7.1
Teaching films	21.4		35.7	42.8
Specialized textbooks	21.4	3.6	14.3	60.7

This table shows that there appears consensus among experienced institutions that the availability of instructors and research workers generally is inadequate but not, in the majority of cases, very inadequate. It should be noticed, however, that many of these institutions can supply their own demand for junior instructional and research staff from within their own student body. It is worth noting that the level of response with respect to Teaching Films and Specialized Textbooks was much lower than in the case of Instructors and Research Workers. However, among those who responded, there was substantial agreement that the need for teaching films was either inadequately or very inadequately met and that in the case of specialized textbooks, in the overwhelming majority of cases, the need for such literature was strongly felt.

Question 2: In the planning of new courses to be approved in the future in Biomechanics, Bioengineering, and Human Factors Engineering we have found the availability of:

[In percent]

	No response	Adequate	Inadequate	Very inadequate
Instructors		3.6	89.2	7.1
Research workers	3.6	14.3	75.0	7.1
Teaching films	7.1		50.0	42.8
Specialized textbooks	3.6	3.6	32.1	60.7

It is considered that the replies to this set of questions do not vary substantially from those given to Set 1 and have probably been conditioned by them.

Question 3: The need for specialized workshop-seminars to train instructors in the Biomechanics, Bioengineering, and Human Factors field.

	Percent
Does not exist	----
May exist at some institutions	25.0
Exists at many institutions	60.7
Is general and urgent	14.3

There seems to be a three-to-one consensus of opinion among experienced institutions that there exists a real need for instructor training.

Question 4: The level of training of Biomechanics, Bioengineering, and Human Factors engineers in Human Anatomy and Physiology as distinct from Psychology is at present.

	Percent
Adequate	----
Inadequate	25.0
Very inadequate	75.0

It should be noted that all institutions with courses did reply to this set of questions, and there appears to be substantial agreement that it is necessary for engineers to adopt an engineering approach to life sciences and to learn to explain behavior and function of the live organism on the basis of its structure and Newtonian mechanics. Hence, the need for the development of a specialized engineering anatomy and physiology is very real indeed.

Questions 5 and 6 did not apply to this group of returns, and no answers to them were received.

B. Returns from institutions without instructional activity in the field of bioengineering, biomechanics, biomechanical, or human factors engineering (total returns: 133)

It was this group which returned most of the incomplete questionnaires, and it may perhaps be concluded that these institutions replied only to those questions falling within their scope of either experience or direct interest.

Question 2: In the planning of new courses to be approved in the future in Biomechanics, Bioengineering, and Human Factors Engineering we have found the availability of:

[In percent]

	No response	Adequate	Inadequate	Very inadequate
Instructors	63.9		13.5	22.5
Research workers	70.6	26.3		3.0
Teaching films	86.4		10.5	3.0
Specialized textbooks	63.9		6.7	29.3

The high level of "No Response" to this question deserves attention. Likewise, it should be noted that about 90% of those responding to the question of Availability of Research Workers found these "Adequate." Personal conversations have confirmed that a good number of institutions without organized instructional programs do have individual or organized research activity in our field, often because one or more qualified researchers accidentally "drifted" onto campus or were recruited in connection with a defense- or space-orientated project. It should also be noted that a great majority of responsive answers found the availability of Instructors and Specialized Textbooks "Very Inadequate" rather than "Inadequate" while the situation with Teaching Films was considered to be slightly better.

Question 3: The need for specialized workshop-seminars to train instructors in the Biomechanics, Bioengineering, and Human Factors field.

	Percent
No response	6.7
Does not exist	0.9
May exist at some institutions	55.7
Exists at many institutions	9.7
Is general and urgent	27.0

Apparently, the need for specialized seminars was considered to be either slight or very great, according to preferences by a majority of respondents. Follow-up conversations revealed that the degree of feeling was not affected in any way by the desire of the institution to consider a program at a future date if instructors were available and was distributed fairly evenly between institutions interested in a program and those who were not.

Question 4: The level of training of Biomechanics, Bioengineering and Human Factors Engineers in Human Anatomy and Physiology as distinct from Psychology is at present:

	Percent
No response	31.5
Adequate	5.2
Inadequate	46.5
Very inadequate	16 7

Again, as can be expected with this group, there was a fairly high level of "No Response" to this question, perhaps because of lack of personal experience. The frequency distribution of responsive returns, however, indicates a clear consensus of opinion expressing a need for training in Human Anatomy and Physiology. Follow-up conversations revealed that the feeling of "Very Inadequate" was practically unanimous among those institutions who had operative research programs in progress. Almost all of these, at one time or other, had needed to complement or supplement behavioral data by basic structural and functional considerations (anatomy and physiology).

Question 5: We do not have organized Biomechanics, Bioengineering, and Human Factors activities as yet because:

	Percent
This is not intended to form part of our program as yet	59.4
No interest among the student body	4.5
Lack of instructors	36.8
Lack of texts	33.8
Lack of teaching films	7.5

The wording of the question as well as the fact that the returns amount to 142% would, at first glance, suggest that the individual sub-questions were treated by the respondents as interdependent. Careful analysis of the rough data revealed that, invariably, those who indicated "Lack of Texts" as principal cause laboring against organized programs simultaneously marked "Lack of Instructors", so that there are two well-defined groups giving rational cause for lack of a program. The larger of them replied: "not intended to form part of (their) program . . . yet;" and the second group, slightly smaller than the first, practically infers that it is the combined lack of instructors and texts which has prevented the institution of a program. It should be noted that all respondents answered this question.

Question 6: We (would, would not) consider a Biomechanics, Bioengineering and Human Factors Program if trained instructors were available:

	Percent
No response	6.9
Would	36.0
Would not	57.1

This question also shows a high level of response; however, the high level of "No Response" replies to Question 2 was deemed to be indicative, in many cases, lack of interest in the availability of instructors and teaching aids. Therefore, the reliability of replies was tested by direct follow-up conversations with a representative sample. As a result of these conversations the opinion was formed that only about 20 or slightly more than 15% of the respondents would indeed, without hesitation and qualification, embark on a program if instructional personnel were available; whereas, of the 76 negative replies, 30 qualified their answers in later conversations by stating that in addition to instructors they needed laboratories, hardware, and, of course, funds. Hence, the answers to Question 6 must be treated as the least-well-considered question of the entire questionnaire.

RESULTS FROM THE 1967 SURVEY (TOTAL RETURNS: 111)

Question 1: What do you think of the idea of broadening engineering's base from the physical sciences to include some study in the biological sciences for all students?

	Percent
Like the idea	37
Like the idea as an option for some students	62
Dislike the idea	1

Most comments were enthusiastic about this proposal, since the general concensus among respondents was that there is a great future for bioengineering. Biological courses should be included in the engineering curriculum just as the humanities and social sciences are now. The main problem will be to fit these courses into an already crowded engineering curriculum without replacing the humanities or social sciences. Evidently a major change in the usual engineering curriculum will be required to implement this. One step in this direction that was recommended is for ECPD to accept biology in their evaluation of sciences.

Question 2: What is the best method of developing young faculty equipped to offer courses in bioengineering or biomedical engineering?

	Percent
By the natural process of utilizing the graduates of current programs	51.4
By summer courses	25.2
By workshops during the academic year	5.4
Combination of above choices	14.4
No opinion	3.6

Evidently it is the opinion of most institutions that faculty be developed from the graduates of current programs, however, the percentages were sufficient for having summer courses and workshops as alternatives. It was suggested that the workshops could be held as part of technical or educational conferences.

Question 3: Is an associated medical school, dental school, or school of veterinary medicine essential, desirable, or not required, in connection with a biomedical engineering program?

	Percent
Essential	41.5
Desirable	50.4
Not required	8.1

The majority of respondents emphasized the need for an association with a medical facility.

Question 4: Are the biology courses developed specifically for medical students, satisfactory for students in a biomedical engineering program or for engineering students who desire to elect such courses?

	Percent
Yes	41.5
No	42.3
Depends	2.7
No opinion or don't know	13.5

There is enough of a bias in these results to say that biology courses for medical students are not always satisfactory for engineers. Reasons given for this include too much emphasis on memorization, not enough mathematical rigor, and this recommended by many respondents is to have special courses in biology de-
the requirement for having many prerequisite medical courses. The solution to
signed just for engineers. Respondents who answered yes indicated, on the other hand, that their method enables engineers to learn how medical scientists think and therefore has more of a broadening effect on the engineer's outlook. Since most bioengineers work as a team member with medical people where it is important to have cooperation, this point of view cannot be neglected.

Question 5: Are the engineering and science courses developed for an engineering program, satisfactory for medical students, physicians, dental students, and dentists who wish to acquire some background in biomedical engineering?

	Percent
Yes	19.8
No	70.3
Depends	4.5
No opinion or don't know	5.4

Evidently sufficient experience is available to make the definite conclusion that engineering courses are not suitable for medically-trained people. The major reason for this is that medical/dental students do not have enough background in mathematics, physics, and basic engineering concepts. The solution suggested for this is to provide the engineering background by means of well-designed short courses. Developing such courses would be a challenge since experience shows that engineers apparently have less difficulty when taking medical courses than medical/dental students who are taking engineering courses. Evidently it is difficult to replace years of engineering training and experience by a short review of basic engineering, since medical/dental students generally have the same high school and early college background as engineering students and ought to be able to do as well given sufficient time.

Question 6: Can students who have a B.S. in engineering hope to satisfy the requirements for an M.S. or Ph. D. in biomedical engineering as rapidly as they might in more conventional fields? If not, how much more time would be required for the biomedical engineering programs?

	Percent
Yes	47.8
No	45.9
Depends	2.7
No opinion or don't know	3.6

Additional time required is: ½ to 3 years.

At a good percentage of institutions completion of graduate work in bioengineering does take longer. To insure the growth of this field, we are obligated to reduce this additional time.

Question 7: What do you think of the idea of adding functional antomy and kinesiology to the existing instruction in physiology and psychology or as a replacement for one of the courses in the social sciences or hunmanities?

	Percent
Like the idea	44.2
Dislike the idea	35.1
Depends	1.8
No opinion	18.9

Those opposing this idea indicated that the engineering curriculum is already crowded, and if anything, it is the physical sciences that should be replaced instead of the liberal arts courses. Such a combination course would have to be carefully planned and integrated to meet engineering requirements. Present courses in these areas are generally taught descriptively without the mathematical rigor demanded by engineers.

Question 8: Should the U.S. National Committee on Engineering in Medicine and Biology, which is already operative under the auspices of the National Academy of Engineering, act as a committee of liaison between the physical sciences and the life sciences?

	Percent
Yes	67.6
No	13.5
No opinion	18.9

This question provided space for the respondents answering negatively to state the reason for their position. The most notable comments included such things as:

"It is not broadly enough concerned with physical science."

"There are liaison groups in environmental engineering which can be expanded to do this."

"This work is better done locally."

"I have no faith in this group."

"Let's not get bureaucratic."

"The present committee needs some modern active bioengineers on it."

Question 9 asked the respondent to give his own definitions of the terms biomechanical engineering, human factors engineering, and biomedical engineering. The definitions listed below are a summary of the responses received. Of the three terms, the most widely recognized was biomedical engineering.

Question 9: How do you define Biomechanical Engineering?

Responses:

"The application of mechanical engineering to problems of biology and medicine."

"We don't."

"I don't like this term."

"Never heard of it before."

"The N.I.H. is studying definitions."

"Fragmented disciplines are hard to define."

"Good luck on this!"

How do you define Human Factors Engineering?

Responses:

"The study and application of human physical factors in engineering."

"The engineering of man-machine systems."

"The study of the response of man to engineering environments."

"The application of engineering in support of psychology."

"We don't."

"I can't."

"I wish I could."

How do you define Biomedical Engineering?

Responses:

"The application of engineering to biological and medical problems."

"The instrumentation measurement and analysis of physiological systems and the design of artificial organs."

"The application of engineering in the solution of clinical problems."

"It is already defined in the scope of the IEEE Biomedical Committee."

"The definition for this includes the other two."

"There are ten different ways to define it."

"I don't!"

"I wouldn't use the word."

The interested reader is referred to Martin (*2*) and Sauer and Nevins (*6*) for more concise definitions of terms used to name the various areas of biotechnology.

Question 10: If you desire to make additional comments concerning bioengineering/human factors engineering, place them in the space below. If applicable, state your research and training objectives in bioengineering/human factors engineering.

Of the 111 respondents, 33 gave responses to Question 10, and these are summarized as follows:

"This is a rapidly growing field."

"All departments are interested."

"We are establishing a bioengineering department."

"To make a contribution in these areas, one needs to be an exceptional engineer."

"We want to train M.S. and Ph. D. engineers who can serve on interdisciplinary teams."

"We need engineers in this field."

"I favor undergraduate bioengineering courses as the best means to develop good bioengineers; these graduate programs don't do a thorough enough job."

"Once you get the research, then bioengineering training programs can be developed."

"We don't consider designing equipment as bioengineering."

"Your questionnaire is loaded!"

"Your survey is most interesting; we would be interested in seeing the results."

"We are eager to hear more about this work."

"Keep up this work; it is needed."

"This is one of the frontiers of the 20th century."

The following areas of research were mentioned in the responses to question 10: sanitary engineering, environmental engineering, instrumentation, clinical problems, biomechanics, prostheses for humans, and animals, safety research.

SUMMARY

The important results of both surveys can be summarized as follows:

1. The basic physical science courses taken by every under graduate engineer should include the fundamentals of biology, anatomy, and physiology.

2. In order to develop any biomedical engineering program, it is the opinion of most schools that an associated medical school, dental school, or school of veterinary medicine is essential or at least desirable.

3. For the purpose of planning, developing and maintaining courses in biomechanics, bioengineering, and human factors engineering, the availability of instructors, research workers, teaching films, and specialized textbooks is inadequate.

4. The best method of developing young faculty equipped to offer courses in bioengineering is, in the opinion of most schools, by the natural process of utilizing the graduates of current programs. Acceptable alternatives are summer courses for faculty and specialized workshop serminars which could be held as part of technical or educational conferences.

5. Biology courses developed specifically for medical students are not always satisfactory for engineers since they lack mathematical rigor and place too much emphasis on memorization. Special biology courses designed for engineers are favored as a solution to this problem. On the other hand, engineering and science courses developed for an engineering program are, in the opinion of most schools, not suitable for medical and dental students who want to learn some bioengineering. The primary reason for this is that medical and dental students lack the basic mathematics, physics, and engineering principles which are regularly applied in bioengineering courses.

6. Completion of graduate work in bioengineering can take longer than in the more conventional engineering fields. For the Ph.D. in bioengineering, the student may require one-half to three years beyond that required to complete the usual Ph.D. in engineering.

7. The U.S. National Committee on Engineering in Medicine and Biology should continue to act as the committee of liaison between engineering and the life sciences.

Approximately 133 institutions which responded to the Surveys have no bioengineering, biomechanics, biomechanical or human factors engineering department with a formal degree program; however, over half of these are interested in establishing programs when funds, instructors, and textbooks become available. Of the 176 institutions surveyed, it appears that at least 1 out of 2 are active in some way with graduate and faculty research, special courses, undergraduate projects, and/or faculty bioengineering committees. With 1 in 2 institutions now having activity in the area, there will undoubtedly be more efforts made to incorporate bioengineering/human factors principles into the engineering curriculum.

The impetus for the establishment of new curricula and programs comes from the many students and faculty (7, 10–13) who now recognize bioengineering in its many facets as one of the frontiers of our century.

ACKNOWLEDGEMENT

We are greatly indebted to the deans of all engineering schools participating in this inquiry for their extremely speedy and prompt attention to the questionnaires. Very special thanks are due to many deans or their deputies who took great pains in expressing valuable opinions, be it as professional engineers or as educators, about the future and the needs of the bioengineering programs in this country.

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Mr. Brademas. Thank you very much.
Dr. Reich?

STATEMENT OF DR. THEOBALD REICH, PROFESSOR OF SURGICAL RESEARCH, INSTITUTE OF REHABILITATION MEDICINE, NEW YORK UNIVERSITY MEDICAL CENTER, ACCOMPANIED BY MYRON YOUDIN, DIRECTOR OF BIOENGINEERING

Dr. Reich. I thank you very much.

I am accompanied this morning by Myron Youdin. He is director of the bioengineering section at the Institute of Rehabilitation Medicine and is the liaison between the institute and NASA's Research Triangle Institute. Mr. Youdin has 30 years' experience in technologic development in bioengineering.

The overriding importance of the subject which is being considered today is illustrated by the awesome burden estimated to approach $4 billion a year that only one malady—stroke—of the many that cause chronic disability poses on our Nation. What does technologic research and development have to do with this problem?

The answer is that in the life sciences and the health care field, discoveries, new and better ways of doing things, and ability to predict and avert catastrophe—the path of all of these—is often paved by technologic advances which make possible the gathering of new, more precise, and more accurate information to clarify the unknown, unmask the mysterious, and accomplish the heretofore impossible.

The past decade has given birth to technology unmatched in our history. Our Government has been deeply involved in sponsoring technologic research. A substantial, perhaps even a major part, of which as related to the life sciences, has been carried out by NASA. It is for this reason that I would like to address the problem of how to translocate this technology and apply it to the health care field most effectively.

A good bit of our own work and the work of many of our colleagues utilizes methods, techniques, and instruments the development of which was stimulated by NASA's needs. A good bit of NASA technology has already filtered down to practical use by life scientists and physicians in the clinical field. Some of this technology was developed "in-house" or on contract; some was developed privately, inspired or based on NASA methods or techniques; and some was developed by private industry when NASA no longer required its particular service.

For example, biotelemetry which is used widely in our studies of the cardiovascular system, and which has been used by other life scientists to study biologic phenomena ranging from behavior to circulatory adjustment under natural conditions, and which today is a standard method for monitoring human patients in cardiac care units, illustrate how a development that has been perfected basically because of NASA's needs has found application in biologic research and in health care.

A fortuitous circumstance which has benefited our own research greatly involves the space technology products section of the General Electric Co. Upon completion of its NASA work, this section of GE under its manager, Mr. Jack Guy, was left with a great deal of know-how and was thus able to devote not an inconsiderable technologic effort to support our own work at New York University Medical Center's Institute of Rehabilitation Medicine in the development of a method to detect the evolution of circulatory insufficiency in the brain before on-set of a paralytic stroke. I need not dwell on the potential significance of this research which has been funded by the Goldman Foundation.

NASA itself appreciates the potential value of its developments and of its know-how in this regard. It publishes bulletins and briefs, and it sponsors regional centers in three sections of the country to whom inquiries concerning NASA technology may be directed. However, this is where the problems arise.

First, the experience of our colleagues at our medical center is that NASA publications do not reach most of them. Second, the ideas and answers proposed by NASA have often been incomplete, unsophisticated, not reduced to practice, and with which there has been no experience—we suspect—even in the NASA house. They have the earmarks of having been formulated by people who do not appreciate the problems of health care.

Such ideas are far from operational, and they usually require a research project within a research project as a first step in their development and utilization. It is therefore clear that there is need for closer liaison between NASA, the sector responsible for health care, and life scientists. NASA's regional centers also have not fulfilled the requirements for better communication, basically for the reasons that we have just enumerated. In spite of a best effort, the approach has been rather superficial.

To overcome these problems, we recommend the establishment of study groups of informed potential users with an interest in a particular domain of NASA's technologic development and know-how. The purpose of these study groups would be to explore NASA's inventory of developments and cull out those that may be applied to a segment of the health care field represented by a particular user study group.

Such user study groups ought to contain life scientists with knowledge of needs that exist in a particular biomedical domain and who would therefore be in a good position to identify products and ideas which they can utilize from the NASA inventory, biomedical engineers and technologists who would be in a position to evaluate the feasibility of transforming NASA products and ideas for applicability to the biomedical domain, and NASA scientists and administrators who would be able to guide the user study groups through NASA archives, inventories, laboratories, centers, et cetera.

The user study groups would reciprocate by introducing NASA scientists to the health care environment and the users' needs. Engineers and technologists who have not worked in a biomedical or clinical setting often do not comprehend the clinical shortcomings of their developments and therefore their uselessness. We feel very strongly that such exposure of technologists would accelerate and catalyze the transformation of NASA technology to biomedical operational methodology.

The user study groups would categorize NASA's technology first, as purely conceptual and therefore, requiring further study and development; second, as ideas, methods, and appatratus that have been tried and tested in the laboratory, about which there is information concerning performance and results only under restrictive laboratory conditions, for which there are construction blueprints for a potential user, models of which may exist for the user's personal inspection and better yet, which may be made available to the potential user for trial and evaluation; third, the user study group would identify that NASA technology with which there is experience in the field and which has been manufactured commercially.

The user study group might advise regarding the estimated costs of development or acquisition of a particular product or idea and the level of scientific training and the number of personnel required to use it.

Finally, the user study group would help in designing more effective techniques for dissemination of information, utilizing such avenues as scientific and technical journals of interest to a particular user group, oral presentations at such conventions, catalogs concerning products and ideas applicable in a particular sector of health care and biomedical field, seminars and workshops, and similar information dissemination methods.

The successful application of biomedical technology to better health care can be documented from the experience of other governmental agencies. The National Science Foundation today and the Atomic Energy Commission in the past are two organizations whose sponsorship of technologic and methodologic research has led to products and techniques that find wide application today. It is therefore unfortunate that the National Science Foundation, for example, has been instructed to rearrange its priorities and shift its support of technologic research in the health care field to solar energy even when such research involves a disease which causes a $4 billion drain annually and therefore falls clearly under NSF's classification of Research Applied to National Needs (RANN).

We want to emphasize, Mr. Chairman, that we do not wish our remarks to be interpreted as a castigation of NASA, its officials, or another agency. It is our desire to make constructive suggestions about how to utilize an important and expensive by-product of a governmental research organization's efforts for our citizens' welfare and best interests.

Once again, Mr. Youdin and I want to thank you for the privilege of speaking to your committee this morning. We will be glad to respond to any questions that you may have.

Before concluding, Mr. Chairman, we would like to permit Mr. Youdin to present the committee with two cogent examples to demonstrate the deficiencies of which we speak.

Mr. Brademas. Thank you, sir.

Mr. Youdin. Drs. Mann and Reswick are difficult people for an engineer to follow, but I would like to cite a few practical examples of incapacitated, or people who will be incapacitated and will require rehabilitation, examples which have not been cited.

For example, of our present population, there are 20 million people now over the age of 60. In other words, one out of every 10 is over the age of 60. Based on existing statistics, approximately 40 percent, 8 million people, will become mentally disabled as a result of aging.

Now at the Institute of Rehabilitation, we have organized and are pursuing a program for the rehabilitation of the intellect of these persons. One of the problems we ran into is in gathering encephalographic data. We ran out of space as to where to put all this data and reduce it. We know NASA has this kind of know-how because this is the kind of technology that was developed for monitoring the activities and well-being of our astronauts.

So as the clinical engineer and liaison to NASA, I proceeded to go after this information. I did get the information but the information that I got, and this is not criticism, but I want to give you a practical example of how the inefficiency of transmitting information becomes a very costly and time-consuming process. The information that came back was a computer read-out of short five- or six-sentence summaries of every bit of information that corresponded to the key words, encephalography, which had ever been perpetrated or pursued at NASA.

That kind of information is of no great value because what it means is that a clinical engineer, a biomedical engineer, and medical people must now take that and sift through it and proceed from that point to search throughout the entire country as to where this technology exists. Frankly, we do not have the money to send the people east, west, up and back to look at prototypes and determine what technology is available. If we could not get technology, even a form which we could put to use immediately, it would be of no great value.

I think it is a practical example of an inefficient situation to transfer information definitely there. It results in added expenses, duplication of effort, and waste of time. In other words, it puts a project back by months and months until this can be cleared up.

One other example of a population of persons who need rehabilitation are amputees. Now, for example, the Department of the Army has stated that there are 4,000 jobs available for the maintenance of underwater lockers. We know from programs we are conducting at the institute that amputees are suitable, are able to be trained to undertake this type of work. We also know, as you stated, Mr. Chairman, the phenomena of weightlessness in an astronaut is very similar to the phenomena of buoyancy in an amputee immersed in water. We feel that is directly applicable to this research.

Again, the inability to get the needed information in a concise and useful way is going to impede this type of rehabilitation program.

Thank you.

Mr. Brademas. Thank you very much.

Dr. Cooper?

STATEMENT OF DR. IRVING S. COOPER, DIRECTOR, INSTITUTE OF NEUROSCIENCE, ST. BARNABAS HOSPITAL, NEW YORK, N.Y.

Dr. Cooper. I am grateful for the opportunity to appear before this subcommittee in order to demonstrate the manner in which contribution of applied technology can be innovatively utilized to cure and rehabilitate countless individuals who are incapacitated due to various diseases of the central nervous system.

My testimony shall consist of a motion picture film illustrating five patients, totally incapacitated by neurologic diseases, previously thought to be irreversible. The first three patients were alleviated by a technique which we developed which is called cryogenic brain surgery. This technique employs basic knowledge and technology of the science of cryogenics or extreme cold. It is a science extensively applied by NASA.

The second two patients have been relieved by a device which we conceived and developed and which is referred to as a brain pacemaker. This consists of a system which selectively stimulates certain portions of the human brain. It could be markedly advanced by existing electronic technology employed by NASA.

The five cases on the film each represent the first case of its particular disease ever to be reversed, or in some instances cured totally. The diseases are:

1. Heredofamilial intention. (This also applies to the tremor of parkinsonism and multiple sclerosis.)
2. Dystonia musculorum deformans.
3. Spastic paralysis of stroke.
4. Spastic athetosis of cerebral palsy.
5. Incapacitating generalized myoclonus.

The brain pacemaker has also been employed to arrest uncontrollable convulsions of epilepsy.

These patients are part of a series of 8,000 cases operated by my colleagues and myself in our institution. The research and development of the techniques referred to have thus far received no economic support from either NIH or NASA.

[Film.]

Now I would like to show some actual incidents recorded on film.

This man has had this particular type of trauma for 30 years. It is inherited, it is a very common trauma. It does not always get this serious. We placed a cryogenic probe in the left side of his brain, which controls the right side of his body and destroyed a small part of the brain called the thalamus. This relieved the trauma from the right side of his body. He is the first patient who has ever been relieved of this type of trauma and has remained cured.

This is dystonia. The surgery in this type of case gave us the lead in cerebral palsy. She also was the first. She was operated on by the cryosurgical technique and she is shown here with her own child 15 years later. What this method does is it freezes a small portion of the brain and renders it functionless.

This lady had a stroke in the part of the brain called the midbrain. Three years before, she was totally paralyzed on the left side of her body and spastic. What I am demonstrating there is the severe spasticity which is one of the incapacitating features of the stroke. In this case, it was called by all the neurologists who had seen her previously and by ourselves as a spastic paralysis.

I want to demonstrate the fact of relative safety. We performed three operations on this very helpless person. The first, in the back of the brain where we destroyed a nucleus in the cerebellum. It made her a little bit better. Most patients can tolerate this type of surgery well. Therefore, when all her symptoms came back in 2 years, demonstrating that other parts of the brain had picked up this sympton, we performed precisely the operation as performed on the first man and we did stop the trauma and we were surprised that quite a bit of her spasticity disappeared. What appeared to be an irreversible spastic paralysis was beginning to reverse itself. After not having moved in many years, within moments of the operation she was able to do that.

In that same year, we started to operate on a third part of the brain which we found out affected motion. At that time she was rendered free of spasticity and I am sure she represents the first case of reversible paralysis following stroke. That has lasted this length of time without remission. One of the things particularly striking was the ability of her to move her foot which, as you recall before the operation could not be moved even by the examiner.

Following this, there is a very brief segment of an operative scene. It is not very gory if anyone is frightened of it, close your eyes.

This plate carries the electrodes of the brain pacemaker which we developed. It is an operation in which we placed these electrodes on the surface of a part of the brain called the cerebellum, which acts as a rheostat to other parts of the brain. One of the favorable features of this operation is that brain tissue is not destroyed. The electrodes are merely placed on the surface of the brain so they can subsequently stimulate that part of the brain. That is one set of electrodes being placed.

The second set of electrodes is being placed on the anterior surface of the cerebellum and this is merely a sequence showing placement of the second set of electrodes. It is near a venus channel.

These wires coming from the electrodes are brought out of the skull but remain under the skin and come down under the skin in the neck to a receiver placed under the skin of the patient's chest. A radio frequency wave placed over that receiver stimulates those electrodes and makes that part of the brain function.

When it functions, it functions to inhibit or shut down an undesirable activity.

This is a 29-year-old man with cerebral palsy. He is primarily a spastic atrophied. He has never walked in his life, never risen from a chair, although he is intelligent and actually holds a master's degree in psychology.

Now, the stimulator, unlike the other operations, has a gradual effect over several months. This shows the patient after just 5 days of stimulation at the age of 29, for the first time in his life rising from his chair and ambulating.

We have since had him back at the hospital for recheck. He was operated on 5 months ago and he has continued to improve, has his hands at his side and has quite a different life. You will see on his right side a little valice which carries the power pack. The tape represents the antenna placed over the receiver, under the skin in his chest. This is automatically timed and continues to charge this part of the brain on and off throughout the 24-hour cycle of the day.

This is one which would have interested the gentleman from California, since he mentioned his interest in epilepsy. She twitches this way any time she attempts to make a movement. She was totally bedridden, 46 years old, and in addition to these uncontrollable movements, had periodic uncontrollable convulsions of epilepsy. She had been treated. Her husband was a naval officer and she had been treated in Government hospitals for the past 3 years. She received excellent medical treatment without any response.

This demonstrates the same patient after use of the pacemaker on only one side of the cerebellum. She has total use of her arms, there is aberration of her legs and trunk, partial aberration in her legs and complete relief from seizures.

The goal with this particular pacemaker is to improve it with technology already in the hands of NASA, to minimize powerpacks so they can be totally implanted in the body and also so it would telemeter information out to the brain which would be valuable in caring for the patient and making certain the equipment was working.

I just would like to conclude by urging, as my fellow colleagues have, that Congress realize the great human needs that exist in the health field, particularly among the incapacitated. I urge you to place this human need certainly, if not the first, among the first priorities.

Thank you.

Mr. Brademas. Thank you very much for an exciting presentation.

Because my colleague on the subcommittee, the gentleman from Idaho, Mr. Hansen, must move to another meeting, I will yield to him to ask any questions he might have at this time.

Mr. Hansen. I would express my appreciation to all of you for some very exciting testimony.

While the problems in applying what we have learned are implicit in much of what we have heard, it is still a very hopeful and encouraging development. I might note that I agree fully with the implications of some of the testimony that I have heard with respect to the priorities of these research efforts.

I have been concerned, as was voiced here, that our preoccupation with producing energy, especially kilowatts, must not permit our attention to be diverted from some of these very promising but much less known problems. I have expressed this concern in the meetings I have attended as a member on the Joint Committee on Atomic Energy. This includes, as you know, many important programs in medicine, biology, and other areas.

Often in the urge to produce electricity, sometimes we overlook some of the basic research programs so essential to the future progress. Today's basic research becomes tomorrow's applied research. Even with an increased effort in many of the research programs we can see a falling off of support for some of the very important medical applications.

I visited in the last few months most of our national laboratories where there are some exciting things going on and where I have seen heart warming dedication and enthusiasm to put what we are learning to use in relieving suffering as we have seen in presentations this morning.

First, for example, a medical research program has at Brookhaven produced results similar to those we have seen here. Medical uses of radioisotopes and heart pacemaker are applications of research sponsored by the Atomic Energy Commission.

It strikes me, however, as I listened to the testimony this morning that a major stumbling block is that of developing the mechanism that will initially create greater awareness throughout the country of what is going on in some of the laboratories and universities with these programs.

Second, this will make it possible to more effectively coordinate those efforts and tap and apply those results in the way we have seen can be done from the testimony here this morning.

A question that I would propound to the panel and solicit any suggestions which you may care to offer is, how much awareness is there and what is the best way to increase that awareness through RSA, through other Federal agencies, or through congressional initiatives? What is the best way to develop better communication and a mechanism to more effectively apply the total resources we have to some of these obvious problems?

Mr. Brademas. Dr. Reswick?

Dr. Reswick. Mr. Hansen and Mr. Brademas, you earlier raised the question of how much money was being spent at the engineering rehabilitation centers and what is needed.

First, I would like to say what is needed is a total system. But maybe more important and much more difficult to handle is the system which gets the developed things from the laboratory into the hands of the people who can apply them throughout the country. It seems the State agencies and a wide variety of national agencies are the proper governmental units to carry this forward.

Right now, around $4 million is spent in the RSA for rehabilitation engineering centers. People here can correct me if I am wrong. From RSA, the Veterans' Adiminstration spent about another million or so and perhaps NSF and NIH, in the area of rehabilitation would add a few million more.

The five existing centers could easily spend up to a million dollars each. I think that is kind of a critical amount.

There are throughout the country potential centers which are ready to blossom out, at least a half dozen that I know of. So if we take five and add six more at a $1 million level, that comes out to $10 or $11 million just in the RSA administrative activity. I also made a point in my other remarks that I feel personally that the RSA, as an organization, needs considerable enhancement of staff and budget allocation to effectively manage this program. They have been doing, I think, an extremely good job, given the personnel that have been focused in this area. But it desperately needs to be expanded.

When you add now the ability to deliver this through the agencies, through the private enterprises, you get into increases in funds. But it is even many, many millions of dollars more that need to be made available to the State and other agencies for actual vocational rehabilitation for the millions of disabled people throughout the Nation.

Mr. Brademas. Yes, Dr. Tichauer?

Dr. Tichauer. Mr. Hansen, I still would like to return for a moment to the communications gap. To make research useful, it is necessary to apply the results. Since it is a major effort to do so, it is necessary to present the results in such a form as to immediately create an awareness how this can be utilized by the future employer of the handicapped, and designers of furniture for the handicapped.

We have not even evaluated the oldest forms of prostheses with respect to the potential usefulness in the common industrial environment, without modifying the environment nor have we communicated the available motions inventory of the disabled to the supervisor.

I agree with Dr. Reswick that a program should be directed at the point of actual usage. I do think this is where our major shortcoming is, dissemination of knowledge in a form which can be understood by the nonsophisticated, by the designers of products, of prostheses. The most sophisticated prostheses have no use unless they can perform within the constraints of industry. To get the producers into the same language, into the same sense of values as the producers of advantaged technologies, a high priority should be assigned to the establishment of research utilization programs which should be conducted concurrent with research programs proper.

Mr. Brademas. Dr. Mann?

Dr. Mann. To reinforce and perhaps expand a bit on the remarks of my friend and colleague, Jim Reswick, a central issue is in a sense using the parlance of the Federal agencies, the designation of a lead agency.

I have the highest regard and respect for a number of the other agencies which have been identified today. However, each of them in its own way does not see this area of rehabilitation as their prime focus. I think they need to be encouraged, mandated, as the term used earlier, to collaborate. But I think there needs to be a designation of a lead agency.

One of the internal problems is the understandable confusion sometimes evident on the part of well-meaning people who wonder how it is NIH does not make a more substantial contribution in this area. Their contribution is very modest. The same can be said for all the other agencies that have been mentioned in the context of this problem.

However, let us assess Jim Reswick's statement of 10 or 11 centers operating at about $11 million a year. That is a reasonable level in terms of what it does. It identifies these problems, brings technologies and technicians to bear on well-defined patient goal-oriented problems. What it does is demonstrate feasibility. It gets to the point where the dropfoot stimulator looks like a feasible concept, or the cane for the blind looks like a feasible project. But there is a very large gap between the demonstrations of feasibility and its general availability to the public that needs it. The problems here, of course, become the whole question of the way the free enterprise system is applied. In most of the things we are talking about here, the prospect of profit is modest, indeed. So the Federal Government is going to have to address a more forceful and direct way. Of how these concepts shown to be feasible are in fact encouraged by public support and private investment into the marketing of these techniques, I need not bring to your attention the recent experience of venal dialysis and the impact that has on the course of health care to be delivered to the American people.

The existence of a technology which is superb in the main test has nevertheless a cost associated with it. We must address ourselves as to the ways we enforce that process.

As we move, the Congress moves and the administration moves to some form of national health policy, it is obvious that we have illustrated on a disability basis the public will religiously clamor for that when they or their loved ones are afflicted by these problems.

So, in my view, an appropriate lead agency is needed to bring together the technology of clinicians both medical and engineering and paramedical, bring these services where the patients are. But please don't overlook the carry-on problem by which we make any kind of technology available to the American public.

Mr. BRADEMAS. Dr. Reich?

Dr. REICH. The National Science Foundation under its RANN program has a phrase which I think is adequate here. It is "user interest and user applicability." I think we have to remember that ideas have to be culled out as to what is available. The only people who can do this effectively are the people who are going to use it. One really has to organize user study groups, I cannot find a better term than that, to find out what exists in technology, in NASA, NIH, anywhere. We want to look into this in order to identify those areas and that work which can be developed and brought to full fruition.

I think in the judgment of feasibility also, I certainly endorse Dr. Mann's ideas. As these front runner organizations, research centers in technology, engineering technology, their prime responsibility should be to identify feasibility. There are simple gadgets which, for example, can be used quite easily, and there are those that require assistance. To use this, these have to be identified, and this information has to be made available on a very common basis to everybody who is going to try it, whether it be in New York, Chicago, anywhere in the United States.

Mr. BRADEMAS. Mr. Goldenson?

Mr. GOLDENSON. I would like to raise the question of whether the time has not come, just as when Sputnik first was launched, this country did not have the thrust to get a man on the Moon. I wonder whether the time has not come for a conference such as was held during the Sputnik incident, where all the scientists got together and it was then determined that NASA, based on all the science put into that plan, would launch a satellite and launch a man on the Moon by a certain time. If such a conference were to be called, you bring in NASA, your Department of Defense, every agency of the Government involved, your top scientific schools and medical schools for such conference.

Out of this you set forth a plan and perhaps we could call it the Medical and Technological Institute. Who it should be under is something you gentlemen would have to determine, but that institution would concern itself with medicine and technology, and would carry out the plans of the conference. So, in effect, you are taking a 1-year, 5-year plan to bring into being some of the fantastic things we all know are right on the frontier of being available to the public. Yet, we are all fumbling around for an answer.

I only raise that as a possibility.

Mr. BRADEMAS. Thank you. That is something that will give us further food for thought as we consider what you have told us here today.

I have several questions which I would like to put to you and at the outset, I would like to say how enormously illuminating and inspiring has been this discussion of where we may be able to go if we put our minds and wills to it.

I am very glad to see you here today, Mr. Goldenson, and you are obviously not a culprit in the indictment I am about to deliver. But, I must say that we, in the House of Representatives, have a terribly difficult time in getting the attention of the news media on matters of some consequence. This hearing today may well be an example that there are some constructive things going on in the Congress of the United States. But, we have a hard time getting the attention of the public, and I have unburdened myself at lengthy sermons on this matter to my friends on the staff of the New York Times, the Washington Post, and other publications.

Mr. Goldenson, would you like to respond?

Mr. GOLDENSON. Yes. I think that is definitely so. In that connection, we are having Dr. Fletcher invited to our city by our broadcast division, both radio and television, to attend a luncheon. I think more of that has to be done. We have to enlist the aid of other networks to concern themselves with the problem and an important hearing such as this, I think it should be covered by all three networks, to take the implementation of what you and your committee are trying to do. This should get out to the public.

Mr. BRADEMAS. We have communications problems, too. But I appreciate the leadership you and ABC are giving in this field.

Let me turn quickl yto some questions, and perhaps if you will not take it ill, I would remind you that we are in the House and not the Senate, and perhaps we can impose the 1-minute rule because we still want to give a few minutes to our friends from RSA.

One of the questions I would ask is, is it necessary to develop interdisciplinary resources in universities in the United States, if we are going to make headway in alining the developments in engineering and medicine?

Dr. MANN. Mr. Brademas, you are aware of the interuniversity program in Boston. I would agree with you completely. There needs to be an intensified and enlightened educational program in disciplinary boundaries between science technology and medicine.

Our approach is several fold. One, the generation of a new breed, if you will, of medical doctors to pursue a major part of their program at the Harvard Medical School but who are preselected from applicants with mathematical and engineering backgrounds. They have special courses taught by MIT and Harvard, where the thrust is scientific.

In the field of biomedical engineering, which includes both research in physiology as well as what has been referred to as clinical engineering, the direct involvement as students and engineers in a clinical environment has produced a very vigorous program because of the student interest. This whole area of health, sometimes I think the university administrators would say is appalling. So the interest is there and the programs are developing.

Mr. BRADEMAS. Dr. Reswick?

Dr. RESWICK. I agree. The interest in a number of activities are under way. The problem is these men who graduated recently cannot find jobs. The potential is ready to burst.

Mr. BRADEMAS. Dr. Berenberg?

Dr. BERENBERG. I have been at the Harvard Medical School seeing the great excitement of people coming over from MIT. I would suggest to the Chair, when programs are developed they not forget the advanced training needed, fellowship support and the special expertise in this field.

Mr. BRADEMAS. I might say that as the chairman of this subcommittee I have been very critical of this administration for cutting back not only research funds in the rehabilitation field, but also for cutting back training funds. Obviously, it is not possible to mount effective programs if you do not have the educated and trained people to support them, as well as the money.

Dr. Tichauer?

Dr. TICHAUER. We have 60 graduate students in physical and health sciences, who are all being brought together in the same classroom.

I would like permission of the chairman to submit this report by the Space Research Coordination Center, Pittsburgh, Pa. This enumerates desirable courses in the life and medical sciences for physical scientists and engineers. [See p. 92, SRCC Report No. 124 appended.] It also shows something else: There is no shortage of students but there is a shortage of instructors.

I found on a recent trip to England and Poland where I was conducting seminars, that the bottleneck is the lack of qualified instructors willing to devote their time to the training of graduates in marketable skills relating to rehabilitation, occupational safety and health, and human productivity.

Mr. BRADEMAS. I have one other question. One of the policy decisions that I had derived from what most of you have said today gives support to the judgment that perhaps as we consider extending the Rehabilitation Act, we ought to mandate the Rehabilitation Services Administration to enter into cooperative relationships with NASA and those other departments of the Federal Government that support research and development that may produce technologies susceptible of application to the rehabilitation of the handicapped.

Rather than pursuing another alternative which would simply be to admonish and urge, is there disagreement—and if there is, do not hesitate to voice it—is there disagreement among you in respect to that particular proposal?

Dr. RESWICK. Perhaps the issue should be stated in stark terms, but let me just say, in my mind, the RSA and a number of other agencies have done a lot of interacting. Under grants from NIH and the VA, they have attempted to bring together a number of people throughout the agencies and throughout the world today in developing a lot of pressure as to these problems.

Mr. BRADEMAS. And having put that hypothetical question to you, I do not mean to judge one way or another what RSA is doing. Let them defend themselves here in a moment.

Mr. YOUDIN. I would say the mandate is almost necessary because all other methods have failed up to now. One of the important things is to salvage information which is available now. This is in contrast to other plans for the future which, of course, have to be carried out. But there is still a wealth of information available immediately and I think that is one way to get it out.

Mr. BRADEMAS. Well, I am not hearing any dissent for my proposition.

Professor Mann?

Dr. MANN. The only caveat I would offer is that it would be terribly important that there be somebody in charge, lest the essential attractiveness of this results in a competition of the effort. I think mandate is in order.

Mr. BRADEMAS. Do you think there ought to be a special office within RSA, in charge of this particular responsibility?

Dr. MANN. I may extend my remarks. That is the need within RSA's advisory functions, people who provide advisory support for a broadening and strengthening of their functions staffwise, to deal with the broadening program. The program I believe thus far has been admirably pursued but if the boundaries are to be extended to take in all these other agencies, NASA and all the others, if RSA were to be designated the lead agency, there should be a mandate to them to compete with the other agencies. You would have to mandate.

Mr. BRADEMAS. I have been around here long enough to know that an admonition or a budget without a mandate is not terribly effective.

Do you find in respect to the present functions of RSA, there is a pattern of a peer review of their policies and programs? That is to say, to put it in another way, do they consult in RSA? Do they consult with people like you, your association, people across the country, your peers?

Dr. RESWICK. In my experience, I would say emphatically, yes. But also there is a tremendous room for enlargement and improvement and bringing in people of great status.

Mr. BRADEMAS. Gentlemen, again I want to thank you. I can assure you I think that although we have not had an army of members of the committee here today—this being a Friday morning in an extremely busy institution—what you have had to say will be widely studied and I am hopeful we can have more hearings on this subject. So I am very grateful to all of you.

I think we shall now hear from Mr. James Burress, Acting Commissioner of RSA, accompanied by Dr. James Garrett and Mrs. Joan H. Miller.

Mr. Burress, Dr. Garrett, and Mrs. Miller, we are very happy to see you.

STATEMENT OF JAMES BURRESS, ACTING COMMISSIONER, REHABILITATION SERVICES ADMINISTRATION, SOCIAL AND REHABILITATION SERVICE, DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE; ACCOMPANIED BY DR. JAMES GARRETT, ACTING COMMISSIONER FOR RESEARCH AND DEMONSTRATION, REHABILITATION SERVICES ADMINISTRATION; AND JOAN H. MILLER, DEPUTY ASSISTANT SECRETARY FOR WELFARE LEGISLATION, DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Mr. BURRESS. I feel quite humble making a statement following such an exciting presentation and I don't intend to have as my defense of what we have done in terms of supporting the program of engineering research. I am here simply to put before you the position in which we are today and hope that what I say might serve as a foundation for planning our further activity in the course of present and future events that have been well illustrated for us through the preceding testimony.

I have with me Dr. James Garrett, who, as you know, has been associated with the rehabilitation research program for its entire history, about 20 years. He is, I think, more than any other person in the country, leading the way toward the implementation of applied technology to the needs of the handicapped and the dissemination of information through our public programs.

We also have Mrs. Joan Miller, the Deputy Assistant Secretary for Welfare Legislation for the Department.

I won't try to read this through, Mr. Chairman, because time is of the essence. I know this document can be included in your record.

We have been concerned with finding ways of serving the far more seriously disabled through the development of devices not only in mobility, but also in the use of the human anatomy. To do so has been the concern of our program through its long history. In 1954, the Office of Vocational Rehabilitation (OVR), through authority granted under the Vocational Rehabilitation Act enacted that year, began the support of research and training activities in the fields of prosthetics, orthotics, and sensory aids. In this respect, the OVR in those days joined with the Veterans' Administration, the Army and Navy, the National Institutes of Health, the Childrens Bureau and the Office of Education in closely coordinated programs of research and training. The program was designed at that time to focus major emphasis on the problem of the amputee.

The program has been closely coordinated over many years through the consultation and advice provided all agencies by the National Academy of Sciences Committee on Prosthetics Research and Development. As progress was made in certain areas and manpower was developed to undertake other problem areas, the program was expanded to include orthopedic bracing, mobility devices such as wheelchairs and sensory aids such as hearing aids, reading machines for the blind, and many other similar devices.

I should like to shorten this statement quite a bit, but still leave you with as strong assurances as I can at this point that the $4 million we have invested in the program at this time represents a small amount in terms of the good it has brought us to this date. This is a most cost effective effort.

Hopefully, our investment will be increased to $5 million in the coming year. It too, perhaps, coud be doubled depending on research priorities with the ample justification reflected here today.

We also have a statement included here which I think will support the question you put forth as to the assurance of excellence in the kinds of activities going on and of applicability of research findings. We are trying to take advantage through use of foreign currencies, of developments in Poland, Yugoslavia and other countries, which Dr. Garrett could cite to you. But I want to deal for a moment with a matter not referred to in my paper but certainly referred to in the testimony. That is the very important subject of application and utilization.

Timely and full utilization of what we know has been, in my estimation, one of the major stumbling blocks to the extension and improvement of our services to the more severely handicapped.

During this week, I had a very exciting experience at a cybernetics institute right here in Washington, D.C. I saw demonstrated a young woman who was a high-quad, quadriplegic. She could only move her tongue. They had developed a device attached to a typewriter and through a multiple system of electronic devices, this woman has been able to type at the rate of 22 to 25 words per minute with her tongue. This opens up the opportunity for her to do many things at home.

I asked her about getting outside the home for a job. This came up in a discussion with a group of people from the Department of Transportation who are giving some real serious consideration to devices that will improve the mobility of people limited in terms of being able to walk and who use wheelchairs to get back and forth to places of employment.

In terms of the application of most of this technology, our administrators naturally would have to have a greater knowledge of the research. Too few program administrators know of the new devices and their potential. I saw an illustration of a deaf-blind person on television using one of the sensory devices, signaling him to pick up a phone. When the voice was transmitted, it was transmitted in Braille. That certainly opened up a new horizon for that young man.

We need to take more time in training rehabilitation staff and in acquainting the public with these new developments. The other part of the problem is the capacity of the industry to find ways of producing these kinds of equipment at a cost that can be reasonable to the purchaser or user.

This, in summary, is where we are. I hope we can look forward, Mr. Chairman, to greatly increased emphasis in this area. As I suggested earlier, if we are to serve the most severely disabled, we must have these kinds of tools with which to do it. Thank you.

[The prepared statement of Mr. Burress follows:]

STATEMENT OF JAMES BURRESS, ACTING COMMISSIONER, REHABILITATION SERVICES ADMINISTRATION, DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Mr. Chairman and Members of the Committee: We are pleased to have the opportunity to appear before this Subcommittee to discuss the application of technology to the needs of handicapped persons. We would like to present a description of the Rehabilitation Services Administration program of research for improved rehabilitation service systems for the handicapped using and developing appropriate technologies.

BACKGROUND

Our concern in this area has a long history. In 1954, the Office of Vocational Rehabilitation (OVR), through authority granted under the Rehabilitation Act enacted that year, began the support of research and training activities in the fields of prosthetics, orthotics, and sensory aids. In this respect, the OVR in those days joined with the Veterans Administration, the Army and Navy, the National Institutes of Health, the Childrens Bureau and the Office of Education in closely coordinated programs of research and training. The program was designed at that time to focus major emphasis on the problem of the amputee.

The program has been closely coordinated over many years through the consultation and advice provided all agencies by the National Academy of Sciences Committee on Prosthetics Research and Development. As progress was made in certain areas—that is artificial limbs—and manpower was developed to undertake other problem areas, the program was expanded to include orthopaedic bracing, mobility devices such as wheel chairs and sensory aids such as hearing aids and reading machines for the blind and many other similar devices.

During the middle 1960's, a concentrated effort was mounted by the Rehabilitation Services Administration (RSA) to utilize wherever possible the technologies developed in the United States space and defense programs. A joint program was developed with NASA whereby unclassified technology would be made available to rehabilitation specialists for use in resolving complex rehabilitation problems.

After eight years experience, the program was gradually changed toward a more realistic approach of placing engineers, physicians and related scientists together physically in a clinical setting to work on patient problems. Under this approach, the necessary teamwork was established at a level of expenditure that would produce cost effective results and improve communications between the disciplines. This program was set up as the core area for an expanded program called Rehabilitation Engineering.

In the past year, arrangements similar to those we now have with NIH have been worked out with the National Science Foundation and its Research Applied to National Needs (RANN) program, as well as with the Department of Transportation and the Department of Housing and Urban Development.

SPECIAL FOREIGN CURRENCY PROGRAM

A major effort of research and demonstrations under the Special Foreign Currency Program was mounted and continues in the field of Prosthetics and Orthotics.

In countries where both technology and medical practice compare favorably with that of the U.S., such as Poland, Yugoslavia and Israel. more sophisticated research prosthetics and orthotics is supported by the SRS with Special Foreign Currency. In Poland, SRS-sponsored research has developed the widely acclaimed treatment of amputees immediately following amputation through the fitting of a prosthesis and then early (within 24 hours) ambulation. Widely accepted throughout the U.S. and the world, this technique reduces hospitalization costs and time and allows the patient to return to normal vocational activities within 30–45 days following the amputation. Compared to so-called conventional management, this results in a rehabilitation time saving of from six months to one year.

NATIONAL SYSTEM OF REHABILITATION ENGINEERING CENTERS OF EXCELLENCE

In July 1971, the SRS/RSA, following the advice of the National Academy of Sciences, began the expanded program called Rehabilitation Engineering. The plan developed by the NAS calls for continuation of the very successful project research grant program of the previous 15 years. In addition, it recognizes that certain institutions of higher education with existing schools of medicine and engineering which have very active rehabilitation service, research and training programs have demonstrated their capability in the area of Rehabilitation Engineering over the years. The first Rehabilitation Engineering Centers were funded in FY 1972. The centers funded to date with their core research areas are:

(1) Rancho Los Amigos Hospital-University of Southern California—"Functional Electrical Stimulation of Paralyzed Nerves and Muscles."

(2) Moss Rehabilitation Hospital-Temple and Drexel Universities—"Neuromuscular Control Systems."

(3) Texas Institute for Rehabilitation and Research, Baylor University College of Medicine and Texas A & M University—"Effects of Pressure on Tissue."

(4) Harvard University and Massachusetts Institute of Technology—"Sensory Feedback Mechanisms."

(5) Northwestern University and the Rehabilitation Institute of Chicago—"Internal Total Joint Replacement."

Recent significant results with program impact include the following: functional electrical stimulation for muscles in hemiplegia, flotation (mud) bed for spinal cord injured and burn patients to prevent pressure ulceration of the skin, light weight cosmetic and functional drop-foot braces, modular prostheses, control of externally powered upper extremity devices through pattern recognition techniques and EMG, bio-feedback devices for physical training of disabled and early mobilization of patients with severe fractures of lower extremity with fracture bracing techniques.

With this past history, the SRS/RSA welcomed the provision in Sec. 202(b)(2) of the Rehabilitation Act of 1973 for a rehabilitation engineering priority. In carrying out the provisions of that Act, RSA in Fiscal Year 1974 will be committing something in excess of $4 million—$2 million in rehabilitation engineering centers of excellence, $1.2 million in rehabilitation engineering activities within the research and training center program, and the remainder in eleven rehabilitation engineering projects. For Fiscal Year 1975 we expect to increase our investment to the $5 million earmarked in the new Act.

We would be happy to respond to any questions you may have.

Mr. BRADEMAS. Thank you very much, Mr. Burress.

By the way, let me say we are aware of your outstanding record in your regional responsibility.

Dr. Garrett, it is very good to have you before us. Have you a statement you would like to make?

Dr. GARRETT. I do not think so.

Mr. BURRESS. We are very pleased within RSA to have Dr. Garrett back within RSA, because it will make it possible for him to relate research more directly to the issues.

Mr. BRADEMAS. I appreciate that. I am impressed by what I take, Mr. Burress, to be your indication of the need to give more attention to support and linkages to the application of technology to the rehabilitation of the handicapped. I would hope that the expression of concern on your part will find some listeners down at HEW, at other levels—even in the celestial realms of the Office of Management and Budget—when they look at both the training and research components of RSA.

It would seem to me, on the basis of what we have heard today, that not to provide for training are research in this field is fiscally irresponsible.

What about the linkage problem? I have heard the criticism voiced today here by Mr. Goldenson and Mr. Gorman at the outset, then by other gentlemen, about the lack of communication between NASA and RSA, for one example. Could you comment on that?

Dr. GARRETT. I would be glad to comment on that, Mr. Chairman. First of all, we had in the beginning a written agreement with NASA to set up an experimental program with the technological utilization group in NASA on an experimental basis. They were to work with some of our research and training centers and some of our program grantees to determine whether or not, within this vast store of technology, there were methods or techniques which could be helpful in problems of rehabilitation.

After about 8 years of this cooperative effort, and Dr. Reswick here was one of those involved in that effort, as was New York University, we found that merely the sharing of information was just not enough to bring technology to bear in the solution of human problems.

The reason for that is because we have, as was pointed out, a dichotomy between fundamentally the engineers on the one hand and the health scientists on the other. Therefore, we determined, based on this experience, that the only way technology could be brought to bear on the problem was to start where the problem was, which was in the clinical setting.

Therefore, this national system of rehabilitation engineering centers, of which you have had two representatives today, is an effort to have engineering, medicine, and health-related personnel brought together at the clinical level in order to solve the problems.

In other words, merely mandating the sharing of information is not enough. The only way in which we will have any solution is to apply what we know where the problems exist and where the demand is for the solution. That is the reason for the rehabilitation engineering centers.

Mr. BRADEMAS. Don't you think in view of the testimony we have have here today we need to put substantially more money into the rehabilitation engineering centers than we are presently doing?

Dr. GARRETT. You have a problem I suppose of balance of the research program. If you look at our particular budget, which for 1974 is $20 million and for 1975 is $20 million. You will see that we have built-in continuation costs of the research and training centers which roughly take up half of that appropriation request. So when one talks in terms of 20 or 25 percent, this means devoting a very considerable part of those resources in terms of available funds to rehabilitation engineering research. The resources that we are bringing to bear are in the regular R. & D. program as well as in the research and training center program.

Mr. BRADEMAS. I was about to say, Dr. Garrett, I appreciate the sensitivity of your situation, so I will not press you further.

Mr. GORMAN. I would like to make one comment. Dr. Garrett is perfectly right. Mandate is one thing, but we will have to go before the Appropriations Committees to get the money.

Now, the administration has not set up the full authorization amount for research. They sent up $20 million this year for fiscal 1975. RSA says they expect to increase their budget to $5 million. Big deal.

There is $25 million in authorized money and 25 percent of that amount equals more than $6 million.

In other words, they are not even requesting the authorization in H.R. 8070. It seems to me totally inadequate in terms of what they are doing now. I am just taking the small figures that are in the law and I say why isn't the President sending up the full amount in the total vocational rehabilitation budget? I want the record to be very clear on this. This great leap forward to $5 million earmarked in the new act leaves me flatter than a pancake.

Mr. BRADEMAS. Dr. Garrett, do either of you, Mr. Burress or Mrs. Miller, wish to respond?

Mrs. MILLER. Perhaps I can respond. In evaluating the budget, the decision was made to put more in services. While the budget only increased slightly, the purchase of services through the Social Security Act and the title II act is increasing.

There is $137 million outside RSA programed services. We feel, as Dr. Garrett said and also as Mr. Burress said, that we need to take the research and apply it to the operating vocational rehabilitation service programs. I think through the State programs we have put money in services. I would like to put that on the record.

Mr. BRADEMAS. I appreciate that, but I must say in all candor that that reminds me of Mr. Nixon saying how much more we are doing in the human resources field this year than last year. But he also fails to point out that a good chunk of that increase, to which he was vigorously opposed, was shoved down Mr. Nixon's throat by the Congress of the United States.

So I would like to express my own hope that when another look is taken at the budget for rehabilitation, that there be consideration of the impact of these hearings. It is also my view that the people testifying today are among some of the most knowledgeable in this area. I feel it would be fiscally irresponsible for this administration not to seek adequate funding both for research and training.

I met a few days ago with other physicians concerned with rehabilitation research and training and they brought to me the same kind of message I heard today. So I think it becomes in large part a question of what the administration believes to be important. Some of us on this committee, both Democrats and Republicans, have tried to get across the point that we think greater investment in rehabilitation is much more important than some of the programs which the administration apparently feels are important.

Mr. BURRESS. Mr. Chairman, I cannot disagree with you. I have been in rehabilitation 30 years of my life and it is my life. I believe this is the avenue where we can make a significant difference in our Nation today. I take the liberty of making that statement.

We have a lot more ground to cover and as was illustrated today, we can do it. I also feel very strongly that the whole rehabilitation program should be so structured that it has good meaning and purpose, that it has public acceptance, and that, to the people who receive services, it means a restoration of dignity and self respect.

I believe this should be the goal of all the efforts we are making today.

Mr. BRADEMAS. I appreciate that response very much, Mr. Burress. I will ask you one more question before we adjourn. It is the same question, in effect, I put to your predecessors; namely, your reaction to a proposal that we should make it mandatory that the RSA engage in cooperative relationships with other Federal departments in respect to the application of technology to problems of the handicapped.

Mr. BURRESS. I would welcome that. I think you have already mandated several activities which we are carrying out this year. I believe we are underway with some of the cooperative efforts with some of the other agencies that are concerned, and the only hesitation I have is being able to financially support this kind of a mandate.

It is embarrassing, I believe, to be asked to dig a ditch with a shovel which has no handle on it, if I make myself clear.

Mr. BRADEMAS. I appreciate that response and I should have thought it might not be wise to ask you to give a judgment with respect to that mandate without giving you some appropriate resources to be able to carry it out. That is the reason many of us are working on the act concerning education for handicapped children. For the courts are insisting on the constitutional right of handicapped children to an education—yet the money is not available.

I hope you will allow us, Mrs. Miller, Dr. Garrett, and Mr. Burress, to invite you back again.

The Chair wants to thank all of those who testified today. We are grateful to all of you. The subcommittee is adjourned.

Thank you.

[Whereupon, at 12:58 p.m., the subcommittee was adjourned, to reconvene subject to the call of the Chair.]

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sons are among the most poignant, unable to communicate with other humans via speech or sight, or to receive cues from bells, lights or other signaling apparatus. For the workshops and residences of the National Center for the Deaf-Blind on Long Island, New York, the M.I.T. Sensory Aids Evaluation and Development Center developed the TAC-COM communication system. Smaller than a pack of cigarettes, the device is carried in a shirt pocket or apron of a deaf-blind person. This personal, portable receiver is coupled electromagnetically to a localized radio transmitter arranged to transmit coded information in the workshops for coffee breaks, shift bells, and the paging of individuals and in the residences for door bells, oven timers, etc. When the radio link is activated the personal receiver vibrates very vigorously, thereby communicating to the deaf-blind person through the tactile or cutaneous sense, one of the few remaining sensory channels available to the deaf-blind individual.

In this very brief testimony I have attempted to set out several specific examples where a combination of knowledgeable and committed technologists and clinicians, conscious of the real needs of physically handicapped persons, and equipped with appropriate resources and support, have demonstrated that technology can create new horizons of promise and competence for humans deprived of normal human capability.

I earnestly hope that the modest federal research, development and evaluation funds which have already proven so productive can be significantly increased. The Rehabilitation Engineering Center program of the Social and Rehabilitation Service provides one good way to concentrate engineering and clinical attention on certain important classes of disability.

I hope you will consider substantially expanded support of the existing R.E.C.s and the inauguration of several more. I also believe that the Vocational Rehabilitation Act should provide that research, development and evaluation budget which will permit the SRS to support research grants in addition to the Rehabilitation Engineering Center program.

It is very clear that the fruits of these efforts make good sense, both in human terms, as well as in educational and employment enhancement.

Thank you very much."

Continue with T.D.S. #16