DESIGN AND MANAGEMENT OF BIOMEDICAL APPLICATIONS SYSTEMS FOR NASA

QUARTERLY REPORT

FOR THE PERIOD

October 1, 1968 - December 31, 1968

DRF- 07302

DESIGN AND MANAGEMENT OF BIOMEDICAL APPLICATIONS SYSTEMS FOR NASA

NSR-09-010-035

Submitted to:

The Office of Technology Utilization (Code UT)
National Aeronautics and Space Administration
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I. INTRODUCTION

A. General Information - The purpose of this document is to report the work performed during the period October 1, 1968 and December 31, 1968 by GWU Biological Sciences Communication Project under NASA Contract No. NsR-09-010-035 in assisting in the design and management of the NASA sponsored BAT Program to relate aerospace technology to problems in biomedical research. Transfer of technology has been hampered traditionally by (1) the lack of continuous communications between biomedical and nonbiomedical researchers, and (2) the lag time between innovation in a prime mission area and its application in a cross disciplinary public sector area of interest such as biomedicine.

B. Summary -

(1) During the reporting period the focus of technical coordination of the program was shifted by TUD request from BSCP/GWU to Technology Utilization Division, NASA. Technical coordination of the teams is directed now from TU Division based on BSCP recommendations.

(2) The BSCP effort was, in part, concerned with correlation and analysis of data submitted by the teams to determine the depth of analysis possible, the quality and scope of the information submitted by the teams, its timeliness; and, therefore point out any improvements needed in reporting proceedures.

(3) Data thus far implies that the experimental aspect of the program has reached or shortly will reach a crucial point at which the program should be assessed in depth to determine if it should (a) continue, (b) continue in its present configuration or a modified version of it, or (c) be completely re-oriented.

(4) Indications are (a) that the methodology that the teams were asked to pursue is, in principle, sound, (b) that the biomedical sector is in dire need of technology to bring it abreast aerospace progress, (c) that the biomedical sector lacks the essential physical science and engineering staffing and other resources to apply much of aerospace technology to biomedical requirements, (d) that the value of a team to an institution tapers off rapidly once problem saturation level that appears likely at each institution is reached, and (e) that the program has a great deal of potential to offer in bringing technology (not just aerospace) to bear on the

problems of the public sector. However, to realize fulfillment of this potential, major evolution in the policies governing the implementation of the program is indicated. This entails a project development plan which will establish priority objectives in the public sector, initiate an enlightment and promotional campaign to obtain the cooperation and participation of other agencies with interests in technology utilization, provide continuity of policy, set concrete objectives and apply modern business techniques.

II. PROGRAM DESIGN

During the period of this report BSCP interacted with other government agencies to increase the visibility and acceptability of the program. Also discussions about the program were held with key individuals visiting the Biological Sciences Communication Project. The significant contacts are listed below:

A. Social and Rehabilitation Service (SRS) - There were two major areas of interaction with the Social and Rehabilitation Service. One initiated BATeam interaction with the N.Y. University Institute of Rehabilitation Medicine which is under the direction of Dr. Howard Rusk. In the spring of 1968 SRS representatives suggested that NYU-IRM participate in the program. The considerable delay in its participation was primarily due to NYU's efforts to organize itself to interact with the BATeam. This office exchanged correspondence with the Director of Research at the Rehabilitation Center, Dr. Windle, to work out arrangements.

The second interaction with SRS was associated with the SRS/NASA interagency conference to be held February 13, 1969. Organization of the conference was developed by BSCP through a series of meetings at SRS. BSCP developed the agenda and made all arrangements at the Goddard Space Flight Center for the conference with Dr. Albert Fleig. SRS responsibility was to invite members of their Rehabilitation Centers to attend.

B. Interagency Utilization Group, sponsored by the Department of Labor to exchange ideas on ways to improve utilization of research information, met twice during the reporting period. On October 24, 1968 Mr. Wilson attended a meeting of the group at which the CAP/Research and Demonstration Division, OEO, discussed its efforts to get research into use in urban communities. Another meeting held November 21, 1968 at the Office of Economic Opportunity was not attended by BSCP. A third meeting, December 6, 1968 sponsored by the Research Utilization Branch, Office of Education, presented the work being done under contract by Dr. Ronald Lippett, Program Director of the Center for Research on the Utilization of Scientific Knowledge, University of Michigan, for the OE. Dr. Lippitt explained the seminar type program he had developed and tested to improve the flow and acceptance by urban communities of new educational ideas growing out of research. Dr. Lippitt demonstrated the concept with his audience participating in role involvement to illustrate the concept and how the specific problem that confronts a community is agreed and the acceptance of new ideas may be enhanced. The scheme is additional justification of the validity of the multidisciplinary, person-to-person concept of the Biomedical Application Team program.

C. A National Academy of Engineering meeting was attended by Dr. Hartwig and Mr. L.S. Wilson October 30-31, 1968 at the State Department, Washington, D.C. The purpose of the meeting was to discuss ways in which engineering can help solve urgent problems in medicine and improve delivery of medical care to the public. Several panels of individuals prominent in medical and engineering disciplines presented their views on a variety of topics pertinent to the principle subject. The audience representing medical, engineering, industry, government, and other interested public sectors exchanged views on the issues presented by panels. However, only two really concrete points were made that touched on action to overcome the several well publicized and thread worn barriers between the disparate disciplines of medicine and engineering.

At the closing panel session Dr. George Bugliarello, Carnegie-Mellon University, remarked that throughout the two days of panels he had heard iterated to no end the difficulties in getting prime mission technology applied to medicine's needs but no one had suggested a means to get action. Dr. Don Flickinger, a panel member and a private consultant, cited his experience in the Air Force. Confronted with the problem of getting results and overcoming the tendency of engineers and medical professionals to procrastinate in decisions requiring cooperation of the two sectors, the Air Force gave a project officer authority to make decisions when an impasse was reached.

During the meeting, Dr. Marshall Lih, Department of Chemical Engineering, The Catholic University of America, Washington, D.C. discussed the Biomedical Application Program with Mr. Wilson. Mr. Wilson was invited to lecture in February 1969 to a workshop of students (principally Freshman) in engineering and other curriculum. The students are organized in groups to work on the problem of introducing the metric system in the U.S. Public Sector.

D. Other Activities

(1) Dr. Hartwig was called by Mrs. Mary Gray of the President's Committee on Mental Retardation for information regarding the potential application of aerospace technology to the requirement of the artificial uterus. The Committee had been contacted by producers of the 21st Century. He later received a call from Judy Powers of 21st Century for a further discussion on the subject. No further action has taken place.

(2) Dr. Halpern, Office of Policy, NASA, called and asked Dr. Hartwig to meet with Dr. Saul Roessein, Director of Dissemination, New Jersey Urban Schools Development Council, Trenton, New Jersey. A meeting date was setup but Dr. Roessein was unable to attend.

(3) Dr. Albert Fleig, Office of the Directorate, Goddard Space Flight Center, called and asked to visit BSCP to learn about the needs for instrumentation. He later visited and was given a large package of instrumentation needs based on the Biomedical Application Team interaction with the medical users.

(4) Dr. Robert Nunley, Department of Geography, University of Kansas, Lawrence, Kansas called and requested information on biotelemetry of migrating animals. He was told NASA developments and given some leads for further information.

(5) Mr. Paul R. Schwemler, North American Rockwell, called and discussed transducers that had been developed by NAR for the space program and that appear to have application in sitting prosthetic devices. NAR has made two available to investigators at Rancho Los Amigos Hospital. Apparently Rancho uses the transducers as a standard for transducers that are in the prosthetic socket.

(6) Dr. Hartwig was visited by Mr. John Vanden Brink of C.C. Searle Company who is interested in bioinstrumentation development. Dr. Hartwig gave him Tech Briefs and other information on the BAT Program.

(7) Information regarding the program was provided upon request to the Agency for International Development and to the State Technical Services Office, Washington, D.C.

III PROGRAM MANAGEMENT

A. General - This section reports the review of BATeam activities during the period October 1, 1968 to December 31, 1968. The major effort was review of the information submitted by the teams and a limited analysis of it.

B. Biomedical Identification Program

1. The Draft Compendium mentioned in the BSCP quarterly report for the third calendar quarter has been updated by sections as corrected information bacame available. Appendix A is the Table of Contents for the compendium and indicates not only those items indicated in the original draft but additional items considered desirable for inclusion. The teams indicated that the listing of problems and other information in the draft compendium were a useful compilation for their work. If the information in the compendium becomes reasonably stable a final draft will be submitted to TU Division for publication. Compilation of the problems and their status included in the draft compendium has been analyzed preliminarily along with data submitted by the teams in their quarterly and annual reports. From the activation of the first team (MRI) in 1966 to December 1, 1968, the data may be summed up as follows:

(1) Four hundred ten problems have been submitted to the three teams collectively.

(2) The teams have made 84 transfers. These range over eight criteria that might be classified as "soft" (e.g., conservation of a researcher's resources") to "hard" (resulted in a commercial product". Appendix B lists the criteria for a transfer. MRI contributed 22 transfers, RTI-29, and SwRI-33. Most of these are described briefly in Appendix C.

(3) Eighty-seven abstracts have been submitted by the teams. Thirty-six of these were closed without a solution, 18 abstracts are still considered active.

(4) Thirty-one institutions have participated in the program and eighteen of these are still active.

(5) Of the 410 problems, 102 problems other than those which resulted in transfers were closed out for one of the four reasons listed below:

(a) Researcher has no further interest in the problem - 20
(b) Researcher found his own solution - 21
(c) As a result of personnel transfer in the medical

institution the problem has either been closed or transferred to another institution along with the investigator and has been given a new number. - 39

(d) No present or foreseeable future NASA technology applicable - 22

TOTAL - 102

2. Observations

BATeam Reporting does not indicate any marked effort in data analysis probably because the number of problems acquired individually by the teams were not sufficient for a reasonable data base. At BSCP level however correlation of the data available from the three teams to date permits a preliminary analysis with some tentative observations. Tables prepared from the available data are included in Appendix D. Following are some tentative observations about the data:

(1) Table A, Problem Identification vs Transfer Completion Time gives an idea how long it takes to complete a transfer once the problem has been identified. The data suggests that as a team gains experience the time required to complete a transfer decreases. Information in team reports indicates that some of the solutions to the first problems referred to the team have application to later problems which are exposed. The added applications of exposed technology can be considered as a measure of its value. Improved reporting procedures and expansion of the acceptable conditions for a transfer may have facillitated the team effort to complete transfers in the past year of the program.

(2) Table B, Problem Identification vs Source of Information, strongly supports the thesis that the NASA data bank is the primary source of transfer information for the teams. This is expected because the NASA data bank contains most of the applicable technology and this is the source that the team must use. Their personal contacts are also important as sources of information.

Problem Abstracts although successful in four cases were not a significant source of information. Unless the technique for encouraging the review of the problem abstract by NASA scientists and engineers is greatly improved this would not appear to be an economical means of identifying relevant aerospace technology to solve medical problems.

(3) Table C, Problem Identification vs Source of Technology tends to support the thesis that although BAT personal contacts

are the second most prominent source of information relevant to a transfer these contacts are highly associated with NASA centers, its grantees or contractors. This supports continued interaction of the BATeams with NASA scientific and engineering personnel.

(4) Table D, Source of Information vs Transfer Time gives an idea of the affect of the different sources of information on the length of time for a transfer. It appears that the length of time to accomplish a transfer is probably independent of the source of the information. However, it seems that if the NASA data bank is the source of information the transfer does occur in a little shorter length of time.

(5) Table E, Source of Technology vs Transfer Completion Time tends to substantiate the point that if a commercial source of the equipment is available that the transfer takes less time than if the investigator has to use his own finances to re-engineer the adaptation of the technology to his research.

(6) Table F, Problem Identification vs Hard/Soft Transfers indicates the effect on the total number of transfers caused by a extension of the concept of a transfer. Originally transfers were only cited when some benefit such as cost avoidance, instrumentation or technique could visibly be demonstrated. Under more recent criteria these would now be classified as hard transfers. As the concept of a transfer is expanded so that the team and the user agree that the applicability of the technology includes items other than the three i.e., soft transfers, the total number of transfers that are cited will increase.

(7) Table G, supports the assumption that a hard transfer takes more time to accomplish than a soft one - i.e. about 3 months difference on an average.

(8) Table H, indicates that the NASA bank of information contributed to more transfers but the team's personal contacts gave more hard transfers.

(9) Table I, shows that NASA centers and NASA contractor/grantees are the principal sources of information, are about equal in contribution and each source has contributed about twice as many soft transfer solutions as hard ones.

(10) Appendix E indicates the typical cycling of acquisition of problems experienced by the teams with their user institutions.

IV OTHER EFFORTS

A. Response to Inquiries - Visits from key individuals interested in the program.

(1) Dr. Don Flickinger (General, USAF-ret.) private consultant, met Mr. Wilson during a recent meeting at National Academy of Engineering and expressed interest in the BAT Program. He visited BSCP on two occasions to learn more of the program and its potential.

(2) Dr. Shane, School of Engineering, and GW University coordinator to the consortium expressed interest in the program which has led to several discussions.

B. Speeches, etc. - Mr. Wilson corresponded with Kepner-Tregoe and Associates, Inc., Princeton, N.J. and Synectics, Inc., Cambridge, Mass. to obtain information about their programs in problem solving. In addition leads to individuals who could contribute to development of Benefit/Cost criteria for the program have been sought. The ultimate objective is a training seminar which would serve two purposes: (1) indoctrinate members of the team in new ideas in problem solving, and (2) prepare a manual describing the program with particular emphasis on methodology and the techniques considered most valuable in defining problems confronting biomedical researchers.

It is evident that various organizations exist to attack a particular aspect of a problem but each depends on some established control to which the special technique is compared. A great deal of research and careful evaluation of techniques and authorities is necessary before a curriculum can be suggested for such a seminar.

V. INSIGHTS

A. Conclusions - Tentative conclusions implied by the data and information submitted by the teams to date are:

(1) The methodology as outlined in 8 steps, Appendix F, is basically sound. This is borne out not only by the experiences of the team but by both current and past literature on the subject of problem solving. Uniform application of the methodology by the teams is elusive. Teams report that strict adherence to the methodology is difficult because each institution and investigator within an institution presents a different profile. But one aspect of problem solving which is the locus of success is good problem definition.

(2) The personal approach through team interaction directly with the investigator is the most efficacious method of defining the problem. This is borne out also in testimony to and conclusions of congressional committees.

(3) In many instances the aerospace technology in the NASA computer bank is too advanced for the average investigator and direct or immediate use for him is precluded. He rarely has the engineering design and fabrication capability or funding resources with which he can readily adapt complex technology to his specific needs.

(4) The investigator usually does not consider his problem solved even though he acknowledges the applicability of the information the team has given him. Until the investigator has instrumentation demonstrated and has the empirical results which support or refute his hypothesis he does not consider his problem solved. Thus, technical information unsupported by instrumentation is associated with a considerable time lag before the researcher realizes the solution to his problem.

(5) The acceptability of aerospace technology to the investigator appears to be inversely proportional to the cost to him, i.e. the less resources or personal effort it costs him to try new technology the more attractive its adaptation to his project it is.

(6) The investigator professes awareness of the current developments in his special area of interest. He relies on his peers and contemporaries and a few journals to which he is able to give his attention for current information. However, there are an estimated 10^7 scientific and technical articles which have been published. Approximately 400,000 are recorded in the NASA computer bank that grows at the rate of about 75,000 additional items per year. It is not humanly possible for him, his peers or specialists to keep abreast this information generated in his own speciality let alone the cross-disciplinary research that bears on his own interest.

(7) Team activity is reflected in several things. It flucuates according to the timeliness of its funding by NASA. When contract renewal is overdue the teams slack off to the point of no work. This is due in no small part to the untentative position which the Research Institute places itself if it diverts other internal funding to cover the team expenditures on the NASA contract which may not be finalized as anticipated. In the case of a university contractor, there is even less flexibility in shifting funds than at a non-profit Research Institute.

(8) (a) Another factor is the cycling of activity in an investigator's work and at his institution. The interests of clinical institutional and medical school investigators in the program, cycle according to the academic or clinical demands on the investigator's time and the funding cycle of health organizations and agencies supporting the institution. The team must adjust its interaction accordingly. As a result team continuity with an institution may suffer at a crucial time if its own renewal contract is delayed.

(b) The interaction between a team and an institution indicates several reasonably defined phases (see appendix E). The first phase which may take several months lays the ground work for the team to work with the institution. In the next phase the team develops its initial contact with the researchers and establishes a working arrangement. This is generally followed by a flurry of problems submitted to the team. Then a leveling off period follows that may stretch out or be very short. It is usually followed by phase of rapid decrease in the submission of new problems. This may be expected to tail off into a low level activity because the spate of new problems has been exhausted and continued problem submissions will rest solely on the few new problems a newly assigned member may bring to the team or the peripheral problems from on going work.

(c) A team's overall activities may be expected to exhibit phases a, b, & c, too. However, its overall load will likely level off for a longer period of time than that of the individual user, if they are not all one type, i.e., research or academic. The various types of institutions cycle differently according to their institutional mission. The team will experience a steady rate of submission for some time beyond that of an individual user. Still there comes a time when saturation is reached at all users and the overall team activity falters for lack of new investigators and their problems. If the team has not developed new sources of input its usefulness fades and its activity decreases. Consequently the team should look ahead and seek new participants to use the slack time or bolster its momentum. Meanwhile the old customer cannot be left without support - some transitional method to do this economically and effectively remains to be devised.

(d) In the aggregate acquisition of problems the SwRI and MRI teams plot as bell curve skewed right and RTI approaches a linear model. This may be due to the proximity of the user to the team. RTI's users are mostly close to it whereas the users of the other two teams are distant and more difficult to contact on a person-to-person basis.

(9) Institute management interaction with users has at best been spotty and it is not known what impact this could have on the generation of problems and support for researchers for whose problems technology is identified but without resources to adapt it. It is believed though that more interaction of research institute management above the team level would enhance the users' interest in the program and certainly improve program visibility.

(10) There are benefits accruing to the biomedical community and industry which can be equated roughly to dollars. The teams report that approximately$500,000 have been received by institutions or have been contributed from in house sources to support work to which Biomedical Applications Teams have contributed NASA information. Approximately $2,500,000 is pending in proposals submitted by researchers or institutes or which institutes estimate they still expect to apply from inhouse funds. This is described in more detail in Appendix G.

B. Recommendations

(1) Publish a project development plan for the program.

(2) Set up seminars at NASA Researcher Centers to increase the knowledge of the BATeams in the Center programs and results. This would tend to increase the number of NASA technology transfers into medicine and could by virtue of interaction with Center Personnel increase their interest in reviewing Problem Abstracts.

(3) Conduct surveys for potential innovative areas that offer promise in application to biomedicine.

(4) About one year hence hold a combined seminar panel to update teams in problem solving, techniques, priorities, benefits/cost approaches, etc. with objective of publishing a document.

VI. PLANS FOR NEXT QUARTER

A. To arrange and chair the 2nd SRS/NASA interagency conference at Goddard Space Flight Center and provide recommendations for future actions.

B. Continue the analysis of BATeam program data provided in the compendium, quarterly reports, etc.

C. Recommend agenda and other details for spring meeting with BATeam Directors.

D. Continue identification of life sciences innovations generated out of NASA Headquarters contracts.

E. Submit recommendations and provide follow-up on team program design and management.

A COMPENDIUM OF THE BIOMEDICAL APPLICATION TEAM PROGRAM OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

BY

THE DEPARTMENT OF MEDICAL AFFAIRS

GEORGE WASHINGTON UNIVERSITY SCHOOL OF MEDICINE

WASHINGTON, D.C. 20036

Contract No. NSR-09-010-035

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Criteria for Transfers

a. Conserves an investigator's resources by avoiding duplicatory re-research.

b. Is used by an investigator to develop a proposal.

c. Exposes technology which the investigator has re-engineered for his purposes.

d. Causes the investigator to redirect his effort to phase with other research which came to his attention as a result of the work with the Team.

e. Causes the investigator to cancel or defer his project because it may be premature or costs that are forecasted are too high.

f. Allows the investigator to complete his research project which might otherwise have been delayed or not finished.

g. Results in a new biomedical product, technique, or professional conclusion.

h. Accelerates the application of the state of the art in biomedical or medical research procedure.

TECHNOLOGY TRANSFERS GENERATED BY THE

BIOMEDICAL APPLICATION PROGRAM

KU-1: Spray-on electrodes developed by NASA for use by pilots and astronauts now commercially available and used extensively by cardiologists to study EKGs under exercise conditions.

KU-5: A respiratory helmet, based on a space helmet design, used to collect breath samples from children with heart defects.

KU-21: Technical data from the NASA data bank and other sources helpful to investigator wishing to photograph body cavities.

KU-24: A NASA contractor-developed electrical impedance system currently under evaluation as a method to measure amount of blood pumped through the heart.

KU-29: A commercially available air-abrasive device suggested by a NASA sponsored Biomedical Application Team member as a method of removing outer ear bone structure.

UM-1: Clean room techniques utilized for satellite construction now being used in design of ultrasterile operating rooms.

UM-4: Review of NASA literature assisted researcher studying methods of visually displaying speech patterns for speech therapy.

UM-8: A NASA-developed transducer designed to measure stress in propellant planned for use in studying elasticity of bones.

UM-10: Review of NASA literature revealed helpful data on methods of measuring and analyzing microcirculation.

UM-11: Search of NASA data bank failed to reveal satisfactory techniques for measuring muscle-produced heat, resulting in decision to change scope of research.

UW-1: A NASA sponsored Biomedical Application Team designed and developed system for delivery of water and medication to the respiratory tract, utilizing a respiratory mask.

UW-5: Search of NASA literature failed to reveal apparatus for studying visual learning, memory and other performance characteristics of mentally retarded children, resulting in submission of a proposal to develop such an apparatus.

Appendix C

Corrected to Nov. 1, 196

UW-10,11: A small temperature telemetry system developed by NASA and now commercially available has been forwarded to a researcher interested in temperature of internal organs and body cavities.

UW-12: A search of NASA literature revealed data useful to a researcher developing apparatus for infusing various fluids into blood vessels of experimental animals.

UW-20: NASA literature reveals telemetry systems to be used with an enzyme electrode to measure tissue oxygen and glucose concentration.

MU-1: A search of NASA literature revealed a report of value in measuring changes in metabolic activity of single cell organisms under influence of electromagnetic field and currents.

MU-2: A Search of NASA literature revealed data of interest to a researcher studying heart sound recording.

MU-5: Information on design of catheter pressure measuring systems gathered from commercial source by Biomedical Application Team member and forwarded to investigator.

MU-7: NASA literature search revealed references of use to researcher studying methods of measuring blood flow.

MU-8: Photoenhancement techniques developed by NASA now being applied to enhance radiographs at medical school.

MU-12: Information on a NASA contractor-developed impedance cardiograph made available to researcher interested in patient monitoring

CI-1: Data obtained from NASA documents to be used in developing miniature rechargeable energy systems for use with implanted prosthetic devices.

SLU-7: A NASA-developed micrometeroid sensor has been modified to measure muscle tremor.

DU-1: Use of NASA-developed image enhancement techniques has aided researchers in calculating ventricular blood volumes.

DU-6: Suggestion of NASA engineer helps eliminate problem of blurring television picture of muscle fiber contraction.

DU-20: Personal contacts of a NASA sponsored Biomedical Application Team resulted in design and fabrication of a multi-electrode needle to be used to monitor electrical signals from the heart.

DU-23: Image enhancement techniques developed by NASA now being applied to clearing up electron micrographs.

DU-24: A NASA sponsored Biomedical Application Team currently designing system for monitoring EKG signals from multiple sites on patient's body.

DU-28: Personal contacts of a NASA sponsored Biomedical Application Team provided techniques for fabricating fluid amplifiers.

DU-29: NASA contractor reports provide data for the re-design of a sucrose gap chamber.

HSS-1: NASA researchers suggest telemetry and pressure system for studying force and strain applied to braced broken bones.

NCSU-2: NASA data bank search revealed information on life support system for opossum embryo used by investigator to support choice of animal in sleep studies.

UNCD-2: A NASA sponsored Biomedical Application Team designed and fabricated system for electrical stimulation of bone growth now being evaluated.

UNCD-11: A search of the NASA data bank revealed technical data being used as supportive data in a grant application for funds to study microorganism assay.

UNC-12: An entry in a NASA publication has allowed an investigator to operate a microtome in sub-zero temperatures.

UNCD-13: Extensive data search by NASA sponsored Biomedical Application Team resulted in choice of sterilization method to be used in dental clinic.

UNCD-14: Search of the NASA data bank revealed information on design of laminar flow clean rooms for use in new dental school laboratory building.

UNC-9: An on-site NASA sponsored Biomedical Application Team suggestion led to the reduction of analysis time of electrophoretic scans by an order of magnitude.

UNC-13: A NASA sponsored Biomedical Application Team suggestion improved the durability of hand braces.

WF-3: Paraplegic patients may be able to control urinary function because of a prosthetic valve system developed by a NASA engineer in response to a Biomedical Problem Abstract.

WF-6: Search of commercial literature by a NASA sponsored Biomedical Application Team revealed best available battery operated biomedical tape recorder.

WF-7,10: NASA-generated techniques in digital image processing advances medical program in holography.

WF-13: A NASA-designed miniature radiation dosimetry probe made available to a radiologist for evaluation in a cancer therapy program.

WF-30: A NASA sponsored Biomedical Application Team literature search revealed a commercially available blood vessel constrictor operating on a pneumatic/hydraulic principle for use in surgery.

WF-39: A NASA data bank search revealed a report useful to an investigator studying the physiological effect of short-lived radioisotopes.

WF-45: Information gained by a NASA data bank search being used in application for a grant to study effects of radiation on animal cells.

WF-50: An onsite suggestion provided transfer of information on application of time-series analysis to computer processing of biomedical data.

WF-54: An on-site NASA sponsored Biomedical Application Team interface resulted in the design of, and agreement to fabricate, a device to measure concentration of an indicator dye in a model vascular system to permit gathering of data on blood flow.

WF-58: NASA data bank provides usful information to researcher studying the application of ultrasonics to diagnostic medicine.

HUV-1: Physically handicapped patients more readily adapt to their environment by use of a redesigned NASA lunar gravity simulator.
HUV-2, -3, -5, -7, -8, -13, -14

SRS-6: Documents from the NASA data bank on generation of cutaneous stimuli were major elements in initiating two research projects.
SRS-1, -2, -3, -4, -5, -7

BLM-3: A NASA-generated EKG R-wave triggering device was constructed to actuate a ventricular assist device.

BLM-4: A NASA designed control system has been found valuable for incorporation into an artificial heart control system.

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Corrected to Nov. 1, 196

BLM-6: A new series of films developed by a NASA contractor being studied as materials to waterproof and bacteria proof cardiovascular prosthetic devices.

GLM-1: NASA data bank documents in the analysis of convection/diffusion processes of fluids indicated to the investigator that the area had been sufficiently covered.

GLM-3,9: NASA-sponsored translation of Russian papers on gold-iron electrodes and polarographic methods for oxygen tension determination are providing information on instrumentation for studies on local tissue oxygen consumption.

GLM-11: Lack of available NASA data bank information on antielectrostatic spray technology has led an investigator to redesign apparatus.

WSM-4: Space wearing apparel designed for astronauts used to study effects of heat stress on cardiovascular system.

NWR-3: A NASA-developed but commercially available telemetry system now being applied to patient monitoring.

RNV-5A: NASA pressure measurement technology to be used to measure pressure areas of seated patient to assist in design of custom seat pad for prevention of decubitis ulcers.

	YEAR OF PROBLEM IDENTIFICATION	TRANSFER COMPLETION TIME	SOURCE OF INFORMATION	SOURCE OF TECHNOLOGY	HARD OR SOFT TRANSFER
YEAR OF PROBLEM IDENTIFICATION	X	A ✓			F ✓
TRANSFER COMPLETION TIME		X			
SOURCE OF INFORMATION	B ✓	D ✓	X		H ✓
SOURCE OF TECHNOLOGY	C ✓	E ✓		X	I ✓
HARD OR SOFT TRANSFER		G ✓			X

Appendix D

TABLE A

PROBLEM IDENTIFICATION PERIOD VS. TRANSFER COMPLETION TIME

YEAR OF PROBLEM IDENTIFICATION	AVERAGE TRANSFER COMPLETION TIME FOR			
	MRI (months)	RTI (months)	SwRI (months)	OVERALL (months)
1966	9.4(8)*	12.0(9)	6.9(7)	9.7(24)
1967	6.5(15)	9.2(9)	4.3(23)	5.9(47)
1968(to date)	**	3.2(9)	3.5(10)	3.4(19)

* Numbers in parentheses are the numbers of transfers
** Insufficient data

COMMENTS: On the basis of the above data, the following observations can be made:

1. As the teams gain experience, the time required to complete a transfer decreases.

TABLE B

YEAR OF PROBLEM IDENTIFICATION VS SOURCE OF INFORMATION

SOURCE OF INFORMATION	NUMBER OF TIMES INFORMATION SOURCE CITED AS RELEVANT BY									
	MRI			RTI			SwRI			
	1966	1967	1968	1966	1967	1968	1966	1967	1968	TOTAL
BAT PERSONAL CONTACT	4	6	**	5	5	2	4	4	10	40
NASA DATA BANK	5	11	**	5	4	6	3	18	14	66
OTHER DATA BANK(S)	2	1	**	2	2	1	1	0	1	10
P. A. RESPONSE	0	0	**	0	1	0	0	3	0	4
TOTAL	11	18	**	12	12	9	8	25	25	120

* Years are years of problem identification

** Insufficient data

COMMENTS: On the basis of the above data, the following observations may be made:

1. The NASA data bank is the most effective source of information on transferable technology.

TABLE C

YEAR OF PROBLEM IDENTIFICATION VS SOURCE OF TECHNOLOGY

NUMBER OF TIMES TECHNOLOGY SOURCE CITED AS RELEVANT BY

SOURCE OF TECHNOLOGY	MRI			RTI			SwRI			TOTAL
	1966*	1967	1968	1966	1967	1968	1966	1967	1968	
NASA CENTER	3	3	**	4	4	1	4	6	8	33
NASA CONT/GRANTEE	5	7	**	4	5	2	1	3	3	30
OTHER GOV'T AGENCY	0	0	**	2	0	1	0	1	1	5
OTHER COMMERCIAL	1	2	**	1	2	1	1	1	0	9
OTHER NON PROFIT	1	0	**	0	0	0	0	0	0	1
FOREIGN SOURCE	0	0	**	0	0	1	0	2	0	3
TOTAL	10	12	**	11	11	6	6	13	12	81

*Years are years of problem identification

**Insufficient data

COMMENTS: On the basis of the above data, the following observations may be made:

1. The NASA sources of technology (centers, contractors, and grantees) are by far the most effective sources of transferable technology.

TABLE D

SOURCE OF INFORMATION VS. TRANSFER COMPLETION TIME

(For Period May 1966 - December 1, 1968)

SOURCE OF INFORMATION	AVERAGE TRANSFER COMPLETION TIME FOR MRI (months)	RTI (months)	SwRI (months)	OVERALL (months)
BAT PERSONAL CONTACTS	8.4(10)*	10.7(12)	4.7(18)	7.4(40)
NASA DATA BANK	8.3(16)	6.0(15)	4.3(25)	5.9(56)
OTHER DATA BANK	6.0(3)	10.6(5)	8.0(2)	8.7(10)
PROBLEM ABSTRACT RESPONSE	0	17.0(1)	3.7(3)	7.0(4)

*Numbers in parentheses are the number of times the source of information was cited as relevant.

COMMENTS: On the basis of the above data, the following observations may be made:

1. It appears that transfers in which a source of solution was the NASA data bank, took less time to complete, but the difference between information sources is slight.

TABLE E

SOURCE OF TECHNOLOGY VS. TRANSFER COMPLETION TIME

(For Period May 1966 - December 1, 1968)

SOURCE OF TECHNOLOGY	AVERAGE TRANSFER COMPLETION TIME FOR			
	MRI (months)	RTI (months)	SwRI (months)	OVERALL (months)
NASA CENTER	8.5(6)*	10.8(9)	4.9(18)	7.2(33)
NASA CONTRACTOR/GRANTEE	9.3(12)	10.7(11)	3.4(7)	8.4(30)
OTHER GOV'T AGENCY	0	12.3(3)	2.0(2)	8.2(5)
OTHER COMMERCIAL FIRM	4.3(3)	7.0(4)	4.5(2)	5.5(9)
OTHER NONPROFIT INST.	7(1)	0	0	7.0(1)
FOREIGN SOURCE	0	1.0(1)	2.5(2)	2.0(3)

*Numbers in parentheses are the numbers of times the source of technology was cited as relevant.

COMMENTS: On the basis of the above data the following observations may be made:

1. Transfers are completed faster when the NASA center is a source of technology than when such is the case with NASA contractors and grantees, but the difference is slight.

2. The few times transfers were accomplished with commercial technology (9/81), the completion time was less than that of NASA technology, which is to be expected.

TABLE F

PROBLEM IDENTIFICATION PERIOD VS. HARD/SOFT TRANSFERS

	HARD TRANSFERS/TOTAL TRANSFERS FROM			
YEAR OF PROBLEM IDENTIFICATION	MRI	RTI	SwRI	TOTAL
1966	4/8	5/9	3/7	12/24
1967	5/15	4/9	1/17	10/41
1968	*	1/9	3/10	4/19

*Insufficient data

COMMENTS: On the basis of the above data, the following observations may be made:

1. There is an increase in the number of soft transfers, relative to the total, in 1967 and 1968 owing to the revision of definition of transfer.

TABLE G

HARD OR SOFT TRANSFER VS TRANSFER COMPLETION TIME

(For Period May 1966 - December 1, 1968)

HARD OR SOFT TRANSFER	AVERAGE TIME TO COMPLETE A TRANSFER FOR			
	MRI (months)	RTI (months)	SwRI (months)	OVERALL (months)
HARD	8.4(9)*	11.7(10)	4.6(7)	8.5(26)
SOFT	6.9(14)	6.1(17)	4.6(27)	5.6(58)

*Numbers in parentheses indicate numbers of transfers classified as either hard or soft

COMMENTS: On the basis of the above data, the following observations may be made:

1. As expected, the hard transfers take longer to complete than the soft.

TABLE H

SOURCE OF INFORMATION VS. HARD/SOFT TRANSFERS

(For Period May 1966 - December 1, 1968)

	HARD TRANSFERS/TOTAL TRANSFERS FROM			
SOURCE OF INFORMATION	MRI	RTI	SwRI	TOTAL
BAT PERSONAL CONTACT	6/10*	7/12	6/16	19/38
NASA DATA BANK	5/16	2/15	2/22	9/53
OTHER DATA BANK	0/3	1/5	0/2	1/10
PROB. ABSTRACT RESPONSE	0/0	1/1	0/1	1/2

*Numbers refer to the number of times the particular source of information was cited as relevant to the transfer.

COMMENTS: On the basis of the above data, the following observations may be made:

1. Although the NASA data bank was a source of information for more transfers, fewer of the transfers were considered hard.

2. BAT personal contact was cited as relevant to more hard transfers than all other information sources combined.

TABLE I

SOURCE OF TECHNOLOGY VS. HARD/SOFT TRANSFERS

(For Period May 1966 - December 1, 1968)

SOURCE OF TECHNOLOGY	HARD TRANSFERS/TOTAL TRANSFERS FROM			
	MRI	RTI	SwRI	TOTAL
NASA CENTER	5/6*	5/9	5/17	15/32
NASA CONT/GRANTEE	3/12	6/11	2/7	11/30
OTHER GOV'T AGENCY	0/0	1/3	0/1	1/4
OTHER COMMERCIAL FIRM	1/3	1/4	1/2	3/9
OTHER NONPROFIT INST.	0/1	0/0	0/0	0/1
FOREIGN SOURCE	0/0	0/0	0/2	0/2

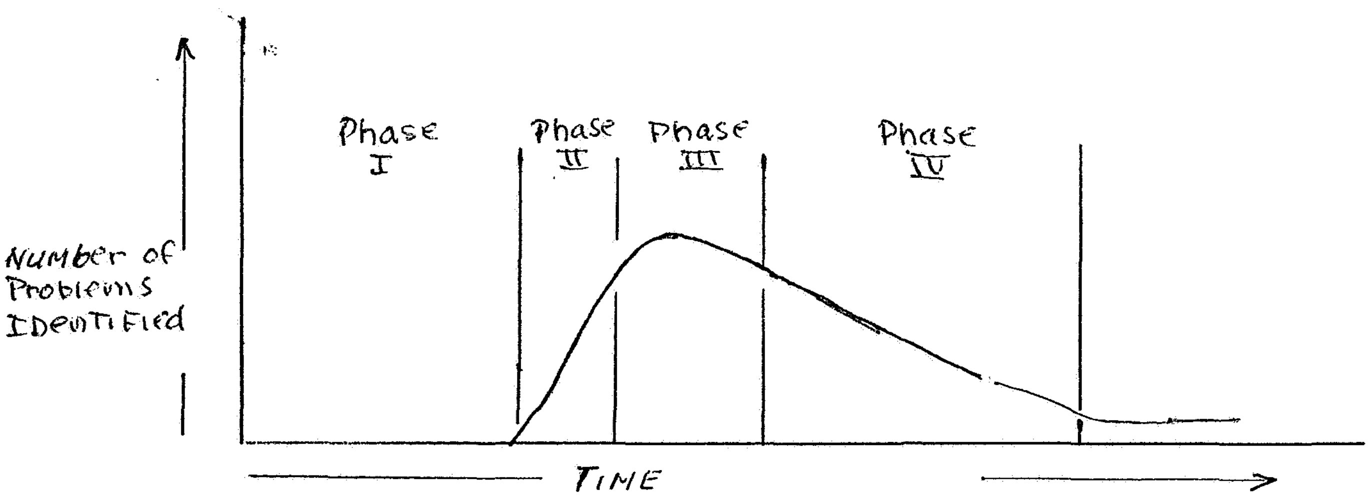
*Numbers refer to the number of times the particular source of technology was cited as being relevant to the transfer.

COMMENTS: On the basis of the above data, the following observations may be made:

1. The NASA centers were the source of technology for half of all hard transfers.

With the teams at Midwest Research Institute and Southwest Research Institute, a definite pattern of team/user interaction is emerging. This pattern is in evidence when plotting number of new problems identified vs time as shown in Figure I.

Figure 1



PHASE I: GROUND WORK; ESTABLISHING CONTACTS W/INVESTIGATORS

PHASE II: LARGE NO. PROBLEMS IDENTIFIED IN SHORT PERIOD OF TIME

PHASE III: LEVELING OFF OF PROBLEM IDENTIFICATIONS

PHASE IV: DECLINE OF PROBLEM IDENTIFICATIONS

Not surprisingly, this curve corresponds favorably to the standard product life cycle curve used in marketing research. The Research Triangle Institute team/user interaction pattern is slightly different in that the curve is much flatter, i.e., Phase II is very small and Phase III is very large.

Active Problem Phases of Completion

1. RECORDING
2. DEFINITION
    a. Intelligent Laymen's Language
    b. Biomedical Sciences Language
    c. Physical Sciences Language
3. SEARCHING
    a. INTRA-Team and Institute
    b. INTER-NASA Agencies
    c. EXTRA-Government Sources
4. ABSTRACTING
5. EVALUATING
    a. Team
    b. Researcher
6. TRANSFERING
7. FOLLOWING-UP
8. DOCUMENTING

Active Problem Phases of Completion

Appendix F

Funding (Actual and Estimated) Outgrowth

of

Biomedical Application Team Program Contribution
(For Period May 1966 - December 1, 1968)

	Actual Thousands	Estimated Thousands
I. Midwest Research Institute		
A. To investigators of User Institutions	26	55
(1) Regional Federal Med. Program to University of Mo. (X-Ray enhancement)	(12)[3,4]	(25)
(2) HEW to University of Wisconsin		
(a) Temp Telem.	(10)	(20)
(b) Enzyme	(2)	(5)
(c) Breath Spray	(2)	(5)
B. Internal to Research Institute (MRI)	48	145
(1) University of Kansas KU-24, KU-29	(10)[5]	(10)[5]
(2) University of Wisconsin Learning Machine SRS to U. of Wis.	(38)	(65)
(3) University of Kansas Mental Retardation Center		(20)
(4) University of Minnisota		
(a) Sterile Room UM-1		(10)
(b) Bone Deterioration UM-8	(15)	(30)
(c) Pressure Meas. between teath		(10)
Sub Total	74	200

Appendix G

	Actual Thousands	Estimated Thousands
II. Research Triangle Institute	35	260
A. To Investigators of User Institutions	(35)[3,4]	(260)
B. Internal to Research Institute (RTI)	113	2286
(1) Received from users to make them instrumentation	(63)[5]	(63)[5]
(2) USAF to RTI optical scann	(50)	(243)
(3) Duke/RTI to NIH image processing (submitted)		(1800)
(4) Duke/RTI to NIH to be submitted		(180)
Sub Total	148.	2546

	Actual Thousands	Estimated Thousands
III. Southwest Research Institute	101	
A. To Investigators		
(1) To Investigators (West Coast)	(95)[3,4]	
(2) To Investigators (Southwest)		
(a) HEW to Univ of Texas Med.	(3)	(3)
(b) VA (Internal) SRS-8A	(3)	(14)
B. Internal Research Institute (SwRI)	1818	
(1) TIRR funded to SwRI (Probes)	(1.8)[5]	(1.8)[5]
(2) State of Texas to SwRI Health Information Systems	(30)	(30)
(3) Post Office to SwRI opns Research study - mngmt Dept. for predicting equipment utility	(150)	(150)
(4) Proposal to OTU/NASA Reliability and Quality assurance for non-district testing survey		(70)
Sub Total	282.8	386.8

Sub Totals:	Actual	Estimated
(1) Midwest Research Institute	74	200
(2) Research Triangle Institute	148	2546
(3) Southwest Research Institute	282.8	386.8
	504.8	3132.8
		-504.8
Unfunded Balance		2528.0

NOTES:

1. Actual funds are those for which researcher has rec ved a grant to cover cost of work or which his institute has applied from its own funding resources.

2. Estimated funds are the total funding needed including actual funds which grant allows to complete or institution estimates it must supply to cover cost of the instrumentation for the researcher.

3. Figures in parentheses included in figure above with parentheses.

4. Amount spent or funded out of total estimated cost.

5. Total cost of project (funded or expended) by researcher or institution.