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Biomedical Computer Laboratory

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PROGRESS REPORT

No. 4

1 July 1967 - 30 June 1968

Biomedical Computer Laboratory
Washington University School of Medicine
St. Louis, Missouri

BIOMEDICAL COMPUTER LABORATORY

WASHINGTON UNIVERSITY SCHOOL OF MEDICINE

PROGRESS REPORT NO. 4

1 July 1967 - 30 June 1968

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I. INTRODUCTION

This progress report from the Biomedical Computer Laboratory (BCL) summarizes work done during the period from July 1, 1967 through June 30, 1968. The Biomedical Computer Laboratory collaborates with research investigators throughout the Washington University School of Medicine in the application of advanced computer techniques to research problems in biology and medicine.

One class of applications requires strong coupling of the computer to its environment. These applications often involve the use of a Laboratory Instrument Computer (LINC) or a Programmed Console (PC). We have pursued these applications by bringing signals from the laboratories to BCL by means of either analog tape recordings or telephone lines and, in some cases, by taking the computers to the laboratory.

A second class of applications requires a computer strongly coupled to its environment and also the advanced information processing capabilities available on large central machines. To meet the demands of this particularly difficult class of applications we have connected laboratory-style computers to our IBM 360/50 via telephone lines.

A final class of applications requires extensive use of large-scale computational services. Many investigators are assisted in their research through the use of generalized numerical, non-numerical, and statistical routines. This work is carried out in part by staff members of BCL in addition to those members of the Medical School, Division of Bio-Statistics, under the direction of Dr. Reimut Wette, and the University Computing Facilities Scientific Data Processing group, under the direction of Mr. George S. Whitlow, formerly Assistant Director of BCL.

On April 11, 1967, the formation of the Washington University Computer Laboratories (WUCL) was announced. This federation of computer research activities includes the Biomedical Computer Laboratory, the Computer Systems Laboratory, and the Computer Components Laboratory.

The Computer Systems Laboratory, which is under the direction of Professor W. A. Clark, is active in the design and development of a compatible set of "macromodules" from which arbitrarily large, complex, or specialized computer systems can be assembled.

The Computer Components Laboratory, under the direction of Professor W. N. Papian, is a part of the School of Engineering and Applied Science. The Laboratory performs applied research and development work in materials, devices, and circuits for advanced information processing systems.

A National Advisory Panel to advise WUCL on health-related activities was organized during the year and is composed of the following initial membership:

H. K. Beecher	Dorr Professor of Research in Anaesthesia	Harvard Medical School

R. W. Berliner	Director of Laboratories and Clinics, National Institutes of Health	Bethesda, Maryland
K. F. Killam	Professor of Pharmacology	Stanford University
F. M. Richards	Professor in Molecular Biophysics and Chemistry	Yale University
R. S. Snider	Professor of Anatomy and Director of Center for Brain Research	University of Rochester

The Panel held its first meeting on June 10-11, 1968. The agenda included a brief tutorial on computer technology, several demonstrations of biomedical computer applications, followed by initial discussions on developments leading to a national program of collaborative research. The Advisory Panel will meet periodically with the WUCL Coordinating Committee to review developing techniques and to advise upon desirable areas of application.

II. SOURCES OF SUPPORT

During the period covered by this report the primary source of support for the Biomedical Computer Laboratory was three grants from the National Institutes of Health:

FR 00161	Biomedical Computer Facility
FR 00215	Biomedical Information Processing Research
FR 00396	A Resource for Biomedical Computing

Collaboration with other investigators often involved work already supported by other grants. Most of this support was from the National Institutes of Health:

CA 05139	Training in Radiation Therapy, Physics and Biology
CA 10435	Clinical Cancer Radiation Therapy Center
FR 00218	Computer Technology Center for Biology and Medicine
GM 14889	Cyclotron Produced Isotopes in Biology and Medicine
HE 05673	Training in Cardiovascular Disease
HE 08594	Homotransplantation of the Heart
HE 09528	LINC Computer Study of Fetal Electrocardiograms
HE 11034	Circular Regulation and Myocardial Contraction
NB 03856	Auditory Communication and Its Disorders
NB 06947	Bioelectric Studies of Cerebral Cortex

An Advanced Research Projects Agency grant, an Atomic Energy Commission grant, and an IBM contract helped to support portions of several projects:

SD 302	Macromodular Computer Design
AT 01653	Parathyroid Scanning
IBM Contract	Study of Computer Requirements for the Biomedical Sciences

Finally, portions of many projects were supported by:

Washington University School of Applied Science and Engineering
Washington University School of Medicine

The sources of support for each of the research projects reported in Section V are listed there. All government support is listed by grant number only.

III. PERSONNEL

EMPLOYEES

Personnel employed by the Biomedical Computer Laboratory during the period covered by this report were:

Director

Jerome R. Cox, Jr., Sc.D.

Assistant Director

George S. Whitlow, Jr., B.S.

Assistant Director for Engineering

V. William Gerth, Jr., M.S.

Administrative Officer

Edward L. MacCordy, since August 8, 1967

Visiting Scientists

Roy E. Bentley, Ph.D., September 1, 1967 - September 1, 1968
John S. Clifton, Ph.D., July 1, 1967 - September 30, 1967
Ervin Y. Rodin - June 1, 1968 - June 30, 1968

Research Associates

William E. Ball, Sc.D.*
Richard A. Dammkoehler, M.S.*
William F. Holmes, Ph.D.
James M. Vanderplas, Ph.D.*

Research Assistants

G. James Blaine, M.S., since September 18, 1967
Andrew L. Bodicky, B.S.
A. Maynard Engebretson, M.S.
Ramasami Ganesan, M.S.
Donald H. Glaeser, M.S.
David Gurwitz, M.S.
Rexford L. Hill, III, M.S.
Monte D. Lien, B.S.
Walter E. Long, M.S., since August 14, 1967
Joanne Markham, B.A., since November 1, 1967

Donald J. Manson, Ph.D.*
Michael D. McDonald, B.S.
Floyd M. Nolle, M.S.
Elizabeth Van Patten, B.S.
David Velten, B.S.

Programmers

Madhukar Bhide, A.B.
Shirley J. Pummill, M.S.

Technical Assistants

J. Claude Bramwell, B.A., since May 28, 1968
Michael Hudson, B.A.

Engineering Assistant

Glenn M. Roa, since May 6, 1968

Programming Assistants

Lawrence K. Bolef, since June 3, 1968
Douglas W. Clark, since June 17, 1968
James E. Crawford, since June 17, 1968
Mark Drazen
I. Richard Hirsh
William V. Glenn, Jr., since September 18, 1967
Gerald C. Rossi, since June 3, 1968
Davis M. Swan, B.S.
Louis J. West, since June 6, 1968

Electronics Technicians

H. Dieter Ambos
Charles R. Buerke
Fred L. Francis
Kenneth L. Kunkelmann, since June 3, 1968
Stephen M. Rhode

Machinist

George C. W. Meyer

Office Clerk

Allen Sanders, Jr., since March 19, 1968

Keypunch Operator

Shirlene M. Spiva, since December 4, 1967

Secretaries

Merry M. Ambos
Virginia Bixon, since August 16, 1967
Wanda J. Meek
Sheryl L. Sharp

*Indicates at least 50% of the individual's effort is supported by another laboratory or department.

Changes in Personnel

During the period covered by this report the following personnel resigned or completed their work at the laboratory:

Mark Drazen, terminated August 31, 1967, rehired June 3, 1968
Fred L. Francis, terminated August 17, 1967
Ramasami Ganesan, terminated February 15, 1968
David Gurwitz, terminated February 7, 1968
I. Richard Hirsh, terminated August 31, 1967
Michael Hudson, terminated August 18, 1968
Walter E. Long, terminated December 8, 1967
Shirley J. Pummill, terminated June 30, 1968
Shirlene M. Spiva, terminated March 31, 1967
David Velten, terminated September 15, 1967

RESEARCH COLLABORATORS

During the period covered by this report the following investigators from other laboratories, departments, or institutions, collaborated with BCL staff members on problems of joint interest:

Washington University

L. J. Banaszak, Ph.D., Physiology and Biophysics
J. M. Barnes, B.A., Pediatrics
M. R. Behrer, M.D., Pediatrics
S. J. Birge, M.D., Metabolism
V. Bleisch, M.D., Pathology
D. A. Bridger, A.B., Information Processing Center
R. P. Eaton, M.D., Metabolism
J. E. Eichling, M.S., Radiology
J. M. Enoch, Ph.D., Ophthalmology
N. K. Flammang, M.S., Radiology
H. Fotenos, Radiology
T. L. Gallagher, Sc.D., Information Processing Center
S. Goldring, M.D., Neurosurgery
S. P. Londe, M.D., Surgery

G. C. Oliver, Jr., M.D., Medicine
E. J. Potchen, M.D., Nuclear Medicine
W. E. Powers, M.D., Radiology
A. Roos, M.D., Anesthesiology and Physiology
J. Satterfield, M.D., Psychiatry
J. H. Scandrett, Ph.D., Physics
P. E. Stohr, M.D., Neurosurgery
M. M. Ter-Pogossian, Ph.D., Radiology
L. J. Thomas, M.D., Anesthesiology
R. B. Woolf, M.D., Obstetrics and Gynecology
A. R. Zacher, Ph.D., CSL

Central Institute for the Deaf

D. H. Eldredge, M.D.
C. M. Donnelly
J. Broeckelmann, B.S.
I. J. Hirsh, Ph.D.
C. S. Watson, Ph.D.
N. R. McCanney

University of Chicago, Chicago, Illinois

H. A. Fozzard, M.D.

Yale University, New Haven, Connecticut

J. Lontz, Ph.D.

M. D. Anderson Hospital and Tumor Institute, Houston, Texas

Robert Shalek, Ph.D.
Joseph Castro, M.D.
Marilyn Stovall

University of Maryland, Baltimore, Maryland

F. G. Bloedorn, M.D.
Eugene Robinson, Ph.D.
Joe Rose

National Cancer Institute, Bethesda, Maryland

Ralph Johnson, M.D.
Dwight Glenn
Fred Faw

Ontario Cancer Institute, Toronto, Canada

J. R. Cunningham, Ph.D.
William Rider, M.D.
Joseph Milan

Temple University, Philadelphia, Pennsylvania

K. C. Tsien
John Wright, Ph.D.

McDonnell-Douglas Corporation

L. N. Medgyesi-Mitschang, Sc.D.

Methodist Hospital, Houston, Texas

Michael E. DeBakey, M.D.
David Brooks, M.D.

IV. PHYSICAL RESOURCES

On April 15, 1964, the Biomedical Computer Laboratory was formed and the original staff moved into 5,515 square feet (gross) of laboratory space at 700 South Euclid Avenue just across the street from the main building of the Washington University School of Medicine. Equipment then available for laboratory applications of digital computers included the LINC (Laboratory INstrument Computer). This small stored-program computer has been designed specifically for use in biology and medical laboratories where there is a requirement for strong coupling between the computer, the investigator, and other experimental equipment. At that time there were six LINC's in the Washington University medical community. Nine more have been added since then for a total of fifteen including classic and commerical versions. Four belong to BCL, eight to our sister laboratory, the Computer Systems Laboratory, two to the Department of Neurology, and one to the Central Institute for the Deaf. In 1966 the Programmed Console was designed at BCL to function as a combined stored-program digital computer and remote display console for the IBM 360/50 installed during May, 1966, at the Washington University Information Processing Center. BCL's computational facilities now include three specialized Programmed Consoles built at the laboratory. In addition, six Programmed Consoles have been built by SPEAR, Inc., from plans and specifications developed at BCL and three more are being purchased at present. The six are now on loan for evaluation as an aid to radiation treatment planning at radiology centers in Baltimore, Maryland; Bethesda, Maryland; Houston, Texas; Philadelphia, Pennsylvania; St. Louis, Missouri; and Toronto, Canada. Other laboratory facilities include a data transmission distribution system, a well-stocked electronics shop, a large inventory of electronic and computer test equipment, a variety of digital system modules, and both analog and digital tape recorders.

During these past two years the laboratory space has been increased by 2762 square feet on the ground floor and 2532 square feet on the second floor of 700 South Euclid, and by 3463 square feet on the second floor of the building just south of the original space. Facilities for computational applications, laboratories, staff offices and a WUCL research library are provided in these acquired spaces. Direct communication with the IBM 360/50 at the Washington University Information Processing Center is provided via phone lines, Programmed Consoles and LINC's.

V. RESEARCH PROJECTS

The reports presented in the following sections are arranged according to the major research areas in which the Laboratory has been engaged during the past year. Each report lists the personnel who participated in the research and gives their affiliation. The academic degrees of all BCL personnel are omitted in these lists since this information can be found in Section III. Unless otherwise specified, all organizations and departments listed are part of Washington University. Also listed, by grant or contract number, is the support for each research project. The titles of applicable grants or contracts and the funding agency are provided in Section II.

References to other reports presented herein will be made by section number alone. References to any of the three previous BCL progress reports will be abbreviated thus: (see PR 3, A-1).

A. The Programmed Console

1) Autonomous mode - The PC functions as a small, independent computer that can solve certain problems requiring rapid interaction between the user and the program but that requires only modest computational ability.

2) Collaborative mode - The PC functions as a remote terminal with a phone line connection to a large central computer. The combination provides a powerful system for information processing, allowing the user to interact easily with his program and data.

The research reports presented herein describe improvements and additional features that have been incorporated in the PC, as well as the programs and routines that have been developed during the past year. Those unfamiliar with the computer may wish to consult BCL Progress Report No. 2 (see PR 2, A-1).

A-1. SPEAR PC Retrofit Program

Personnel: V. W. Gerth, Jr., BCL
J. R. Cox, Jr., BCL
H. D. Ambos, BCL

Support: FR 00161
FR 00396

As a result of engineering evaluation and field experience, certain improvements and additional features have been incorporated in the SPEAR PC's (S/N 101 through 105) that are involved in the Radiation Treatment Planning project and in the PC (S/N 106) at NIH. Improvements were made in the areas of memory and analog system operation, while added features include an incremental plotter and teletype interfaces.

Although all machines functioned extremely well, an intermittent problem with the memory in PC S/N 105 prompted a detailed evaluation of the memory system supplied to SPEAR by Fabri-Tek, Inc. Upon close examination, a number of inconsistencies between documentation and the actual memories were found, as were inconsistencies from unit to unit. In other instances, apparent engineering errors were found that were not drastic enough to cause consistent failure, but caused BCL to anticipate marginal operation. When informed of this situation, Fabri-Tek assigned a senior engineer to do a complete engineering review on a memory system returned to Fabri-Tek by BCL. The design review confirmed the BCL findings, and Fabri-Tek agreed to perform the necessary modifications to ensure reliable operation.

A redefinition of the analog-to-digital (A/D) conversion accuracy required in radiation treatment planning applications necessitated improvements in the PC Analog system. Although a 12-bit digital-to-analog (D/A) converter is used in the SPEAR PC, an alignment to 12-bit accuracy was not possible. In addition, system noise prevented stability and repeatability beyond 10 bits. The switching transistors in the D/A converter were changed to the inverted configuration and biased for minimum offset, and the weighting resistors in the lower order bits were modified. As a result, the D/A converter could be aligned to 12-bit accuracy. The noise problem was nearly solved by separate bussing of the DC power to the analog section directly from the power supplies and by careful local filtering. The remaining noise prevented 12-bit A/D accuracy, but somewhat more than the required 11-bit accuracy was achieved. Any further improvement appears to require extensive redesign of the circuit boards for a more compact layout and better shielding and the use of a laminar power bus.

A new implementation of the Calcomp incremental plotter interface (see PR 3, A-1) was designed by SPEAR and checked out by BCL. This implementation uses one special printed circuit card, as opposed to several standard cards used in the original implementation. Since the Calcomp plotter is playing an increasingly important role in the Radiation Treatment Planning project, BCL decided to install this interface in those PC's involved. A teletype interface also was designed at BCL for the SPEAR PC (see A-7) and is intended for use initially with the new PC autonomous assembler program, IMP (see A-9).

The modifications were performed on each machine in sequence. The memory was shipped to the Fabri-Tek plant, and the analog modules were shipped to BCL for modification and alignment. After this work was done, BCL staff members visited the site to install and check out all modifications. All work was completed by the end of May 1968, and reports from all participants indicate satisfactory performance.

A-2. Datamaster

Personnel:	A. M. Engebretson, BCL H. D. Ambos, BCL J. R. Cox, Jr., BCL G. C. W. Meyer, BCL N. Mayer, CSL A. L. Bodicky, BCL
Support:	FR 00161 FR 00396 SD 302

In an attempt to improve the speed characteristics of the Datamster, several different versions of belt-driven transports have been built and tested. The speed characteristics of these models were not significantly better than the present Datamaster (modified Language Master), which uses a friction drive between motor shaft and capstan flywheel. The principle source of speed variation could not be determined; the speed variation contained approximately equal amounts of random and periodic components. The periodic components had a periodicity similar to that of the capstan and drive belts. The unique problem of driving stiff Language Master cards past the head seems to be the primary reason for the poor performance of Datamaster transports as compared to inexpensive tape recorders.

BCL is still experiencing problems of incompatibility among Datamasters presently in use. The incompatability is caused by differences in head alignment and average card speed of each unit. The Bell and Howell Company, manufacturers of the Language Master, are developing a commercial version of the Datamaster in which capstan speed will be adjustable to compensate for speed differences that result from manufacturing tolerances. In addition, the heads will be precisely aligned at the factory. The variance in head alignment and average card speed of these Datamasters is expected to be considerably less than our present ones. The first Bell and Howell Datamasters are scheduled for delivery and testing in August.

BCL also has experimented with a "high-speed" Datamaster utilizing a four-track coding scheme. This experimentation was undertaken to determine if an inexpensive Datamaster, which was more reliable and more convenient to use than the present one, could be built.

Three of the Datamaster's tracks are used for data, and the fourth is used for timing information. The timing track reduces the speed tolerances necessary for reliable operation. With three data tracks, 1024 12-bit words are easily stored on a standard-size Language Master card. Three high-speed Datamasters have been built with standard four-track entertainment heads and a direct (with bias) recording scheme. The three units have proved to be compatible and reliable. We are now experimenting with a precision, four-track digital head and direct digital recording scheme.

We found that the quality of Language Master cards was marginal for use with the four-track heads. Approximately 10% of the cards would not work because of slightly misplaced magnetic tape or clumps of adhesive under the tape.

Language Master cards, which are made in large quantities, cost about 5¢ each. This cost should be compared to magnetic cards that are used with the Hewlett-Packard and Olivetti Underwood desk calculators and that cost from 50¢ to $2.00 each. If the high-speed Datamaster is eventually developed for the PC, it will probably be advisable to obtain higher quality cards. Since these cards hold four times as much data, an equitable price would be about 20¢ each.

A-3. Variable-Speed Datamaster Test Program (VSDM)

Personnel:	E. Van Patten, BCL A. M. Engebretson, BCL
Support:	FR 00161 FR 00396

The impossibility of adjusting the Datamaster motors of the various PC's all to the same speed has made the distribution of program cards difficult. This program was written to permit a card to be read at speeds different from that at which it was recorded. A diagram is displayed on the scope indicating in which direction to change the speed; a zero accumulator means that the checksum has been verified. The speed is controlled by the keyboard.

A-4. Rho-Theta Routines

Personnel:	J. R. Cox, Jr., BCL
Support:	FR 00161 FR 00396

A new, compact set of routines for the transformation of Rho-Theta transducer data from polar-to-rectangular coordinates have been written (see PR 3, A-5, and PR 2, A-12). These routines include an orientation procedure that is not limited to any particular placement of the transducer with respect to the coordinate axes. Slightly improved accuracy has been obtained as a result of careful attention to scaling and roundoff problems.

A-5. Field Calibration of the Rho-Theta Transducer

Personnel: A. L. Bodicky, BCL
W. V. Glenn, Jr., BCL
J. R. Cox, Jr., BCL

Support: FR 00161
FR 00396

The field calibrations of a Rho-Theta transducer can be carried out by the use of a new polar coordinate calibration fixture, the PC, and the transducer itself. The calibration fixture is a mechanical frame resembling one quarter of an octagon. The apex contains the pivot of a free swinging radial arm.

The cursor or stylus of the transducer is placed on a series of carefully inscribed radial or angular calibration marks on the fixture. Then a new program, CONSTANT, can be used to provide fast and accurate values of the constants for use in the Rho-Theta routines (see A-4). CONSTANT allows the visual determination of the straight line that best fits the series of points sampled.

A-6. A Teletype Interface for the Programmed Console

Personnel: V. W. Gerth, Jr., BCL
H. D. Ambos, BCL

Support: FR 00161
FR 00396

A teletype printer interface for the PC has been developed within the standard I/O structure using I/O Channel 2. The interface consists of Motorola MECL II integrated circuits and one discrete transistor switch mounted on a single printed circuit board. A 9.1-msec clock interrupts a delay loop in the control program. Then a flip-flop controlled by the information to be printed drives the teletype through the transistor switch. For the sake of simplicity, teletype codes are not rotated automatically, as in the Data Transmission system.

A-7. IMP - An Assembler for the PC

Personnel: M. D. McDonald, BCL

Support: FR 00161
FR 00396

The Instantaneous Manuscript Processor (IMP) is a PC program for typing, editing, assembling, running, and debugging PC programs.

IMP accepts assembly language as manuscript (MS) typed from the keyboard a line at a time. Each line is specially encoded and partially processed as it is typed. Room is available in memory for enough MS to produce a binary program 1000_8 words long. The MS can be converted and executed; then control can be returned to IMP so that the MS can be modified. The MS and resultant binary output can be written on Datamaster cards (MS so written can be read into IMP subsequently).

Larger programs also can be entered and debugged in small sections; the MS written on cards; and the entire set of MS assembled by means of IMPASSE, a program overlay for IMP.

A-8. DUMP

Personnel:	M. D. McDonald, BCL
Support:	FR 00161 FR 00396

DUMP is a PC program that allows the user to obtain a teletype copy of the contents of specified locations in memory in either signed (-3777 through +3777) or unsigned (0000 through 7777) octal form. Output can also be obtained in decimal form.

The program is relocatable; i.e., the binary can be loaded anywhere in memory and run where loaded.

A-9. DMUTIL - a PC Utility Program

Personnel:	E. Van Patten. BCL
Support:	FR 00161 FR 00396

An abbreviated version of the PC Utility program (see PR 3, A-9) was written for use in the autonomous mode. The program handles the copying of Datamaster cards and provides location-by-location checking of the copy for greater reliability. The card header is displayed upon reading so that the program can be used simply for identifying cards. Provision also was made for copying 14-inch cards.

B. Computer Applications in Radiation Treatment Planning

Activity in support of the Radiation Treatment Planning project has continued at a high level during the period of this report. The five participating institutions have provided constructive criticism and helpful suggestions that have contributed to further refinement of the initial developments. As in the last report (see PR 3, B), no attempt will be made to show the indirect support provided by these institutions, and only BCL personnel will be listed under each separate project.

The major efforts have been to provide added convenience and increased accuracy in the Superimpose Beams program, to furnish flexible alternatives in the generation of beam data, and to assess the overall accuracy of the Radiation Treatment Planning system.

A meeting of the participants in the Radiation Treatment Planning project was held at Pere Marquette State Park, Grafton, Illinois, on November 10, 1967. The following radiotherapists and physicists attended:

Mr. K. C. Tsien Dr. John Wright Dr. Frankl Nichini	Temple University Hospital Philadelphia, Pennsylvania
Dr. Eugene Robinson Mr. Joe Rose	University of Maryland Baltimore, Maryland
Dr. J. R. Cunningham Dr. William Rider Mr. Joseph Milan	Ontario Cancer Institute Toronto, Canada
Dr. Joseph Castro Mr. C. J. Karzmarc	M. D. Anderson Hospital Houston, Texas
Dr. Ralph Johnson Mr. Dwight Glenn	National Cancer Institute Bethesda, Maryland
Dr. William E. Powers	Washington University St. Louis, Missouri

The participants related their experiences in using the PC and presented comments and suggestions for improvement. The primary concern of the participants was the apparent distortion of isodose curves when using a large viewing window, although the original intent of the large viewing window was to provide approximate results. More detailed and accurate curves could be obtained by focussing down on areas of interest with a smaller window. In response to this concern over the need for good accuracy even with large window sizes, the Superimpose Beams program was modified as described herein. This is an example of the fruitful interactions that has enhanced the acceptance and clinical use of the Radiation Treatment Planning system.

B-1. Superimpose Beams Program

Personnel: W. F. Holmes, BCL
A. M. Engebretson, BCL

Support: FR 00161
FR 00396

Several revisions have been made to the programs described last year (see PR 3, B-1 and B-3). First, the accuracy and convenience of plotting permanent copies of treatment plans has been greatly improved. The original program produced a rather inaccurate result whenever a large area of the patient was selected for calculation of the dose distribution. This problem was known, and it was intended that accurate detailed views of small critical areas would be used to supplement a large picture. Although this procedure was practical using oscilloscope displays, it took too long to plot the results. The revised program can quickly calculate a rough display of the isodoses over a large area, just as before; and a program option will recalculate the doses at four times the original accuracy, taking sixteen times as long. These displays can be photographed for a permanent record. Life-size plots of the results are always calculated at the higher accuracy and have proved to be quite satisfactory in actual use. Since a plot takes 5 to 10 minutes to prepare, the data needed to re-create a treatment plan can be stored on a Datamaster card for future use. In this way the radiotherapist can devise a number of treatment plans at one session, leaving the actual plotting to a technician. The plans can also be stored for instructional purposes or can be used to test whether increased experience can produce improvements in plans used in past treatments. This program was released in February and is now in active use.

Several revisions to Superimpose Beams have been made since February, although they have not yet been released for use. The program can accept beam cards digitized with unequal fan line intervals (see B-3). This capability provides increased accuracy at the edge of the beams, particularly when wedge fields are desired. The source-skin distance (SSD) of the beams can now be changed, thereby allowing the beams to be set at a constant distance from a given point. This point is usually chosen to be near the center of the tumor. Certain treatment centers use this method because with their therapy machines it provides for more accurate positioning of beams around the patient.

B-2. Assessment of the Accuracy of X-Ray Beam Data

Personnel: R. E. Bentley, BCL
H. Fotenos, Radiology
J. Lontz, Yale University

Support: FR 00161
FR 00396
CA 05139
CA 10435

X-ray beam data for PC radiation treatment planning programs have been obtained by interpolating between the contours of isodose charts. Three procedures, based on similar algorithms, have been used. The first was a hand method, carried out with the aid of a ruler and a desk calculating machine. The others, known respectively as "Reduce Isodose" and "DIGIT", the former used in conjunction with "Draw", are described elsewhere (see B-3, 4, and 5). The procedures are applicable to Cobalt-60, linear accelerator, betatron and electron beams, and to both straight and wedged fields.

Extensive tests are being carried out to determine the accuracy of these procedures. The result is deemed acceptable if either of two criteria is satisfied at all points on the chart. These criteria are that the calculated dose be within ±1% of the value given by the original chart or that the position of an isodose line be reproduced within ±2 mm of its original position. In most instances, satisfactory results have been obtained.

B-3. Draw Program

Personnel: W. F. Holmes, BCL

Support: FR 00161
FR 00396

The Draw program allows the user to enter line drawings into the PC by means of the Rho-Theta transducer (see A-4). After line drawings are digitized, they can be plotted, revised, and stored. The program works as follows:

(1) Orientation - Oscilloscope displays ask the user to touch two points along a horizontal line and then an origin point. These displays may be changed to fit each application.

(2) Description - An optional descriptive questionnaire requests verbal and numerical information to be stored along with the graphical data.

(3) Spacing - The user requests any interval from 1 to 10 mm as the spacing between stored points. The spacing can be changed at any time, permitting a flexible choice between accuracy and data storage.

(4) Drawing - The data are sampled and stored as a set of curved line segments containing one or more points. These segments are grouped into files, which the user creates by typing in a name. Each file of drawings may be displayed on the oscilloscope at any time. The drawings can be revised by deleting or adding segments.

(5) Plotting - The files of drawings can be plotted (life-size) on a Calcomp digital plotter (see PR 3, B-3). The drawings may be compared with the originals for accuracy.

(6) Storage - The data can be stored on Datamaster cards for later processing or revision.

The Draw program has been used to digitize radiation beam isodose charts. These data were sent via telephone line to the IBM 360/50 computer for further processing (see E-1 and B-4).

B-4. Reduce Isodose Program

Personnel:	J. Markham, BCL R. E. Bentley, BCL
Support:	FR 00161 FR 00396

Beams, in order to be used in PC radiation treatment programs, must be described by a table of dose values at grid intersections (see PR 3, B-4). The grid referred to is composed of a series of lines at equally spaced depths in the patient, intersecting a series of rays emanating from the source of radiation. One method of determining this table of dose values consists of finding the intersections of isodose lines with the rays (fan lines) and depth lines; then by using interpolation or extrapolation, as needed, the dose values of the grid points are inferred. The program, Reduce Isodose, written in FORTRAN for the IBM 360/50, uses this method to calculate dose values. The isodose lines are represented by a table of x and y coordinates produced by the Draw program (see B-3). These coordinates are transmitted from the PC via phone line to the IBM 360/50. The grid is variable, and different grid configurations can be tried with one beam. The required input information for the grid consists of the number of depth lines, the number of isodose lines, the interval between the depth lines, and the distance (along the base line) between the two outermost fan lines. The program assumes a straight line between each two consecutive points along the isodose lines. Interpolation or extrapolation along the fan lines is logarithmic and is linear along the depth lines. For grid points at which interpolation or extrapolation is possible in both directions, the distance between the two points along the fan line which may be used for interpolation or extrapolation is compared to the distance between the two depth points which could be used. The fan line direction is utilized unless the distance between the fan line points is greater than some variable multiple (3 is being used currently) of the distance between the depth points.

B-5. DIGIT

Personnel:	W. V. Glenn, Jr., BCL
Support:	FR 00161 FR 00396

DIGIT is a program that is used in a semiautomatic procedure for accurately generating beam dose tables from isodose charts of cobalt beams (regular or wedge), electron beams, and betatron beams. DIGIT also records these beam tables on Datamaster cards.

Sampling routines (using the Rho-Theta transducer) and answers to various interrogative oscilloscope displays provide the PC with the necessary data for plotting a grid on a Calcomp plotter and for determining the dose values at selected points on the plotted grid.

The program consists of the following steps:

(1) The user orients the Rho-Theta with respect to the base line of an isodose chart.

(2) He types in the following beam and grid information: SSD, field width, field length, grid system desired, depth line spacing, and number of isodose lines to be sampled on the isodose chart.

(3) Next, he specifies boundary fan lines in the central portion of the grid and, using Rho-Theta sampling, positions the fan lines on the base line of the isodose chart.

(4) The grid is plotted on the Calcomp plotter; additional program DM cards are entered; and final plotting and labeling is accomplished.

(5) The user types in the values of the isodose lines to be sampled, writes a DM card containing grid point coordinates, and enters more program cards.

(6) The user then overlays the plotted grid on the isodose chart and samples isodose intersections with grid fan lines in the central region and with grid depth lines in the penumbra region.

(7) Finally, he writes a standard or a mirror-image beam card.

Beam cards produced by DIGIT can duplicate the original isodose lines on the isodose chart (via Superimpose Beams, Plot Isodose, Plot Plan) with a maximum error of 1.6 mm.

B-6. GRIDTUB

Personnel: W. V. Glenn, Jr., BCL
N. K. Flammang, Radiology

Support: FR 00161
FR 00396
CA 10435

This program was written to calculate grid point doses in a water phantom. Measurements are taken from one stationary and one moving anthracene crystal, as the latter moves through a radiation beam in planes perpendicular to the central axis of the beam and progressively further from the source.

Grid information (SSD, FW, FL, depth interval, fan line positions, and title) are entered into the PC as in DIGIT (see B-5). Grid point coordinates are calculated for a 12 by 19 grid system having equal fan line intervals (consistent with the limits of an earlier version of Superimpose Beams); a sampling loop is then entered whereby the moving crystal (with the pointer of the position transducer directly above and out of the water) is moved in and out of the beam in the abovementioned planes (this corresponds to scanning left, right, left, etc., across the beam on Depth Lines 0, 1, 2, etc., of the radial grid system). As the position transducer intersects each fan line on a particular depth line, the voltages from the two crystals are sampled and the dose at that grid point is calculated. Having calculated all grid point doses, the program exits from the sampling loop and writes a completed beam card.

A second version of GRIDTUB is in preparation; it is similar to DIGIT in the variety of grid systems available and flexibility in positioning the fan lines. There are options to plot the grid and write out DM cards containing grid point coordinates, thereby enabling multiple grids for the same beam to be prepared in advance so that when therapy machines are free, several beam cards can be generated from the different grids in order to more quickly determine the optimum grid system for a particular beam and, thus, the best beam card.

In addition, there is a preliminary "Probe Plot" subroutine that produces an x, y Calcomp plot of the beam's intensity as the crystal moves back and forth on succeeding depth lines (0, 1, 2, etc.) across the beam. The abscissa is the perpendicular distance from the beam's central axis; the ordinate is the intensity of the beam as taken from the moving crystal. This subroutine helps determine where to place the fan lines in a grid system by showing where the intensities are either stable or rapidly changing across different depth lines.

C. Cardiac Research

This section contains several reports concerned with the application of computers to cardiology. Much of this work has been aided substantially by scientific collaboration and financial support from other departments in the University. Our colleagues and the sources of support are noted at the beginning of each report.

C-1. Electrocardiogram Rhythm Monitoring

Personnel:	G. C. Oliver, Jr., M.D., Medicine F. M. Nolle, BCL J. R. Cox, Jr., BCL H. A. Fozzard, M.D., University of Chicago
Support:	FR 00161 FR 00396 HE 11034 HE 05673

Work has continued on the development, evaluation, and description of successive ECG transformations in the Rhythm Monitoring program (see PR 2, A-6, and PR 3, D-1). Present plans call for two ECG inputs to the PC from leads chosen for optimal representation of the QRS complex and P wave, respectively.

A description of recent work on each of the transformation levels follow in the paragraphs below.

(1) Sample - The QRS channel is sampled every 2 msec and stored in a small circular buffer. The P channel is sampled every 4 msec, and the average of the last four samples is stored in a circular buffer.

(2) AZTEC - The AZTEC transformation is now written as a subroutine. Two separate AZTEC strings are currently produced for the QRS and P channels using parameters K and T (see PR 3, D-2), which are specially chosen for each channel. Since 14 arguments must be transferred, the subroutine is called twice every 20 msec to process the last 10 QRS channel samples and the last 5 P channel samples.

(3) Primitive - The P channel AZTEC is searched in a manner similar to the QRS channel AZTEC search. Segments of P AZTEC, 200 msec in duration, are categorized as quiet or high noise. The P recognition algorithm, which operates only on quiet data, searches for slopes that form an upright or inverted V-shaped signal whose height and width are within prescribed limits. The P character is coded in a manner identical to the QRS coding. Separate Primitive strings for QRS and P channels are mixed in a common circular storage buffer.

(4) Cycle - The QRS and P Primitive strings are scanned to determine the order of occurrence of events, where an event is defined as either a QRS complex or a P wave. For each event, two intervals are computed. One interval is the time between the start of the event and the start of the most recent event that was of the same type (e.g., QQ interval).

For a QRS event, the second interval (QP) is the time between the start of the QRS and the start of the most recent event if that event is a P wave. If the most recent event is not a P wave, then the QP interval is specially coded.

For a P event, the second interval (PQ) is the time between the start of the P and the start of the following event if that event is a QRS. If the following event is not a QRS, the PQ interval is specially coded.

Considerable data reduction is achieved by grouping together all consecutive measurements or events of the same type in a manner similar to the line-forming section of AZTEC. For example, all consecutive QQ's that have the same noise classification form a QQ line if the difference between the maximum and minimum intervals does not exceed an aperture, K. In this case, K is not constant but is dependent on the previous value of the line. The outputs of Cycle are the four interval measurements, QQ, QP, PQ, PP, and coded descriptions of the events, QRS and P.

(5) Sequence - This final transformation is in its early stages, with work being done on the LINC-8 (see C-4). Cycle data are sent continuously from the PC to the LINC-8 and stored on LINC tape. In this manner, different Sequence level algorithms may be tested on long runs of the same data.

Evaluation of the distortions introduced by various transformations has been accomplished mainly by using the criterion that an electrocardiographer can make the correct rhythm diagnosis from a pseudo ECG that was reconstructed from the given transformation. The AZTEC and Primitive transformations have been evaluated in this manner using a PC program that plots long sections of these two transformations (see C-3). The Cycle transformation has been evaluated in this manner using LINC-8 printouts and displays of data sent from the PC.

Considerable effort has been devoted to developing a mathematical language for describing the successive transformations. A language that is similar in some respects to Backus Normal Form has been successfully used to provide a compact description of both the AZTEC and the Primitive transformations.

Publication:

J. R. Cox et al, "AZTEC, a Preprocessing Program for Real-Time ECG Rhythm Analysis," IEEE Transactions on Bio-Medical Engineering, Vol. BME-15, No. 2, April 1968, pp. 128-129.

C-2. A Hardware Sample Instruction for the PC

Personnel: F. M. Nolle, BCL

Support: FR 00161
FR 00396

The PC used for ECG rhythm monitoring has been modified by the addition of hardware to interpret the code, SMX 4 + v ($0 \leq v \leq 3$), as SAMv. The voltage on Channel v is converted to an unsigned 12-bit number with zero volts converted to 0000 and -10 volts converted 7776. The code 7777 is not allowed in order to facilitate conversion to a signed 11-bit number. The hardware shares the analog system used by the ANG instruction. Execution time is 16 memory cycles.

C-3. PA2PLT

Personnel:	W. V. Glenn, Jr., BCL F. M. Nolle, BCL
Support:	FR 00161 FR 00396

This program was written for the PC to enable the Calcomp plotter to plot parallel columns of QRS channel Primitive and AZTEC data as generated by the ECG rhythm monitoring programs. The Primitive string consists of QRS and non-QRS data, which are labeled regarding noise level, duration, and, if QRS, slope code. The corresponding AZTEC data appear in the second column. In addition to plotting the lines and slopes, PA2PLT enables the plotter to label them with duration and value.

C-4. LINC-8 Installation

Personnel:	F. M. Nolle, BCL H. D. Ambos, BCL
Support:	FR 00161 FR 00396

A Digital Equipment Corporation, LINC-8 computer was installed to be used primarily as a data collection station for the ECG Rhythm Monitoring program. Initially, communication with the PC is by serial transfer via the LINC-8 relay register and external level lines. The combined PC/LINC-8 system is proving to be a powerful tool for evaluating and further developing the ECG rhythm program. A variety of LINC-8 programs already have been written to manipulate the Cycle level output for display, printout, and storage.

C-5. Cardiac Output by the Dye-Dilution Technique

Personnel:	G. C. Oliver, Jr., M.D., Medicine F. M. Nolle, BCL
Support:	FR 00161 FR 00396 HE 11034

A program, which was initially written for the LINC computer (see PR 2, D-10) to provide the rapid calculation of cardiac output and mean circulation time from indicator dilution curves, has been rewritten for the LINC-8. The new version includes a number of modifications that facilitate ease of operation. By use of an option scope display, the program can be operated by an individual with little or no programming experience. Current options allow the user to read into the memory a dye curve or a calibration curve, file either of them away, read into the memory a previously filed curve from digital tape, delete a filed curve, or compute cardiac output and mean transit time. The current program is designed for use with dynamic calibration curves rather than step-function calibration curves; the ability of the user to select by cursors that portion of the curve for exponential curve fitting has been retained.

C-6. A Model for the Generation of the Human Electrocardiogram

Personnel:	W. E. Long, BCL H. D. Ambos, BCL J. R. Cox, Jr., BCL
Support:	FR 00161 FR 00396 Washington University

A system for simulating the depolarization wave of the heart has been designed and constructed. The LINC with interface electronics produces the simulated depolarization wave on a plastic model of the heart. This model has separate conducting surfaces, and by placing this simulated heart in a plastic torso filled with water, simulated electrocardiograms (ECG's) and vectorcardiograms (VCG's) can be recorded.

Final test results have shown the septum to be electrically silent in the heart model. This was determined to be a result of the low output impedance of the voltage sources used to simulate heart dipoles. While the septum is inactive, the field generated by the ventricles is not significantly altered from what is thought to be physiologically correct.

Electrocardiograms and vectorcardiograms have been recorded from simulations of "normal" depolarization activity as well as from a simulation of a myocardial infarct and ventricular hypertrophy. Allowing for a silent septum, the ECG's and VCG's recorded on the present model are consistent with the conventional theory for their production. Also, the study of the effects of changes of the heart's position (both rotational and translational) on the recorded VCG were made.

C-7. On-Line Computer Monitoring of Thoracic Impedance for Estimation of Cardiac Output

Personnel: S. P. Londe, M.D., Surgery
G. C. Oliver, Jr., M.D., Medicine
F. M. Nolle, BCL

Support: FR 00161
FR 00396
HE 11034
HE 08594

Study of the cardiac-related portion of the thoracic impedance signal in canines has continued (see PR 3, D-9). Cardiac output was altered by intravenous infusion of epinephrine (0.1 mg) or sodium ethalenediamine tetracetic acid (N_a-EDTA 30 mg/Kg) with methoramine hydrochloride (Vasoxyl 0.2-0.4 mg/Kg).

The height and slope of the cardiac-related impedance waveform increased directly with cardiac stroke volume increase after the administration of epinephrine. EDTA administered over a 1-minute period was followed by a rapid decline in height and slope of the impedance waveform. The cardiac output decline to zero during this period was so rapid that the dye dilution technique gave no intermediate measurements for comparison.

Publication:

S. P. Londe et al, "On-Line Computer Estimation of Cardiac Stroke Volume," Accepted for Publication in Surgical Forum.

D. Diagnostic Isotope Studies

The reports presented herein describe the progress BCL has made in applying computer techniques to the field of isotopic data collection and analysis. Personnel involved in this research and financial support are listed at the beginning of each report.

D-1. Gamma Camera Interface for the Programmed Console

Personnel:	V. W. Gerth, Jr., BCL R. E. Bentley, BCL J. R. Cox, Jr., BCL S. M. Rhode, BCL
Support:	FR 00161 FR 00396

An interface for the PC has been developed that allows on-line, real-time processing of signals from the Nuclear-Chicago Pho/Gamma III camera, a commercial version of the Anger camera. This combination is used for cerebral blood flow dynamic studies reported elsewhere (see D-3).

The Gamma camera produces X and Y pulses whose amplitudes are proportional to the X and Y coordinates of a nuclear event as viewed by the camera face. A Z pulse is also produced and is used to trigger the processing of the X and Y pulses. The X and Y pulse amplitudes undergo A/D conversion, and their merged digital values specify a unique address in the PC memory. Thus, the context of the appropriate address is increased by one for each nuclear event.

Since dynamic studies are of interest, a real-time clock has been developed to provide time reference information. The major components of the Gamma camera interface are individual analog signal conditioners for the X and Y pulses, a digital signal conditioner for the Z pulse, individual A/D converters for the X and Y pulses, a system control panel, a patch panel, a real-time clock, a real-time clock display panel, and two new instructions for the PC.

The analog signal conditioners provide amplitude and level modification of the X and Y pulses to bring them into the range required by the A/D converters. Two gain and two bias settings are switch-selectable and are provided with precision trim adjustment. A DC test signal also is available; a precision dial allows overall alignment. The digital signal conditioner provides a translation from the logic system of the camera to the logic system of the system control panel.

Model AD128 A/D converters built by EG&G, Inc., are used for X and Y pulse conversion. These units provide up to 8 bits of precision with a maximum conversion time of about 13 μsec.

The system control panel provides selection of control functions by the operator and includes a number of test features and possibilities for different configurations of the system. Any part of the system can be exercised independently for test and calibration. The processing rate can be controlled (utilizing a delayed reset feature) from the maximum rate possible to single-pulse processing commanded by pushbutton. Status lamps provide information regarding interaction of the system with the PC Interrupt and I/O structure.

The patch panel allows complete flexibility in partitioning the address of the PC memory register that is to be indexed, with regard to X and Y. A facility is also provided to indicate out-of-range conditions to the control panel. Logic "1" and "0" jacks are provided so that a base address can be specified for the data collection buffer.

The real-time clock is a 25-bit counter driven by an 8-kHz crystal clock for a time resolution of 125 μsec. The most significant bit of the counter is considered an overflow indicator. A 24-bit buffer register allows the clock value to be dumped and then read into the PC in 12-bit words while the clock continues to run. The real-time clock is interfaced to the PC through the IOT instruction using IO Channel 4 and IO Modes 0 through 6.

As an adjunct to the real-time clock, a new branch class instruction called Sense Clock (mnemonic is SCL) has been added to the PC. The branch condition is the state of the overflow bit of the real-time clock. With the addition of the SCL instruction, the real-time clock can also function as an interval timer. Both the clock and interval timer modes are useful in the Gamma camera system. Another new instruction called External Index Memory (mnemonic is XIM) has been developed. When the XIM instruction is executed, the memory register corresponding to the state of the new external address bus is indexed, and, in general, the P-register goes to p+1. If the contents of the memory register, after indexing, equal 7777_8, the P-register goes to p+2. In this manner, overflow can be detected. Upon transfer of the data on the external address bus to the S-register, a pulse is delivered to the interface, which releases the A/D converters for the next camera pulse.

D-2. Processing of Gamma Camera Data

Personnel:	R. E. Bentley, BCL V. W. Gerth, Jr., BCL R. L. Hill, BCL E. J. Potchen, M.D., Nuclear Medicine
Support:	FR 00161 FR 00396 AT 01653

The interface between the Nuclear-Chicago Pho-III Gamma camera and the PC (see D-1) has been used in the study of cerebral blood flow. The radioisotope, Xenon-133, is injected into a subject's blood stream and allowed to diffuse throughout the brain. The Gamma camera serves as an imaging device to determine the amount of radioactivity trapped in different regions.

When a photon from the radioactive material strikes the camera face, two pulses, which are proportional in voltage to the X and Y coordinates, respectively, are produced. These voltages are converted to digital signals, 8 bits for each coordinate. In this particular application, only 3 bits of information per axis are used. The combined 6-bit number is then used to select one of 64 addresses in the memory of the PC, and the content of this location is incremented by one. Thus, the surface of the camera is divided into an 8 by 8 matrix, and each cell is approximately 1 cm square.

Data are collected for a series of successive frames; the starting time and duration of each frame are preset and controlled by the real-time clock (see D-1). After allowing space for program, the core of the PC accommodates about 40 separate frames.

The program consists of two phases: The first, the data gathering phase, is concerned with the collection of data. The second phase is the processing program, in which corrections can be made for background, dead time, and uneven response over the crystal face. Each frame can be displayed in different modes, including dot patterns and isocount contours. The program also provides both the facility to view a graph of counting rate versus time on either a linear or a logarithmic scale for each of the 64 cells and the facility to calculate the best-fit line to a selected portion of each curve.

The ultimate goal is to determine the rate of blood clearance for each region of the brain. When this rate has been computed for each of 64 camera cells, contours having equal clearance rates are displayed. From these contours, it is possible to infer the existence of abnormal paths of blood flow.

Paper Presented:

R. E. Bentley, E. J. Potchen, and V. W. Gerth, Jr., "Immediate Assessment of Gamma-Camera Dynamic Studies Using a Small Digital Computer," presented at the 15th Annual Meeting of the Society of Nuclear Medicine, St. Louis, Missouri, June 1968.

D-3. Regional Cerebral Blood Flow Studies

Personnel: E. J. Potchen, M.D., Nuclear Medicine
J. S. Clifton, BCL
R. L. Hill, BCL

Support: FR 00161
FR 00396
AT 01653

Using the magnetic tape data acquisition equipment discussed last year (see PR 3, F-5), studies of regional cerebral blood flow (rCBF) have been performed using Xe-133 dissolved in saline, which is injected into the subject's internal carotid artery. Four cylindrical probes are placed in a diamond-shaped cross-section with parallel axes, and data from each probe represent approximately one quadrant of the brain. For each injection of isotope, counts from the four probes are accumulated in 2/5-second time increments continuously over a period of 10 minutes. These data are written on magnetic tape as four 5-digit BCD words.

A FORTRAN computer program has been written to process the magnetic tape on an IBM 360/50 computer. Data are grouped in the following manner: each 0.4-second increment is considered for the first 20 seconds; then data points are grouped and averaged in 10-second increments from 20 seconds to 10 minutes. Corrections can be made to the data for background counts and for isotope decay.

A measure of the regional cerebral blood flow is calculated by the method of Zierler[1]:

$$\mathrm{rCBF} = \frac{H_{max} - H_{10}}{\mathrm{Area}} \lambda \qquad (\mathrm{ml/100g/min})$$

where

H_{max} = maximum count rate

H_{10} = count rate at 10 min

Area = area under curve to 10 min

λ = partition coefficient, a patient parameter.

The data are printed and plotted versus time for each probe, and values for rCBF for each probe are given.

1. K. L. Zierler, "Dynamic Clinical Studies with Radioisotopes," Proc. of a Symposium at Oak Ridge, Tennessee, October 1963, U.S. Atomic Energy Commission.

Papers Presented:

J. S. Clifton et al, "A Digital Data Acquisition System for Nuclear Medicine," Int. Journal of Applied Radiology and Isotopes, 1968, Vol. 19, pp. 505-509.

R. L. Hill et al, "rCBF: Data Acquisition and Analysis" (to be published).

E. J. Potchen et al, "Regional Cerebral Blood Flow - Studies on the Early Portion of the Curve," Clinical Research, 16 (1968), p. 244.

D-4. Radioactive Oxygen Dispersion Program (COUNTS)

Personnel:	E. Van Patten, BCL V. W. Gerth, Jr., BCL M. M. Ter-Pogossian, M.D., Radiology J. E. Eichling, Radiology
Support:	FR 00161 FR 00396 GM 14889

A study is being made of the efficiency with which oxygen is dispersed throughout the human body. In this study, radioactive oxygen is inhaled by the patient, and a record is made of the isotopes passing specified points on the body. The record is obtained by means of detectors planted at these points. The output from the detectors is recorded on magnetic tape using a Picker Nuclear Instrumentation tape recorder.

The LINC program, COUNTS, reads the tapes that have been recorded and counts the number of pulses that have been induced by the isotopes in specified intervals over a period of about 10 minutes. Then these raw counts are adjusted exponentially to compensate for the half-life of the oxygen. The resulting points are then plotted on the Calcomp plotter for subsequent analysis.

An interface for the LINC to process the Picker tapes has been designed. This interface utilizes the OPR 6 instruction in conjunction with the TN gates into the accumulator. The occurrence of a pulse sets a flip-flop synchronizer that enables the TN_0 line. The next execution of an OPR 6 instruction enables TNEL and sets A_0 to the "one" state. All other bits are set to the "zero" state. If an OPR 6 is executed and no pulse has occurred, A_0 will be set to the "zero" state. During execution of the OPR 6, the flip-flop chain is cleared to be ready for the next pulse. The LINC control lines used are BCPL, BPRESET, BOPR 2.2, OPR 6, TNEL, and TN. A threshold detector and pulse generator provide standard pulses from the tape recorder. An input pulse more negative than -0.5 volts produces an output pulse for processing.

E. Collaborative Data Processing

The reports presented in this section describe the work accomplished in implementing the collaborative modes of operation of the Programmed Console and LINC computers. In addition, other developmental work in establishing computer-to-computer operations is described. Of special interest is the switchover from Remote Access Computing System (RACS) to Operating Systems/360 (OS) made this spring. Again, as in the preceding sections, personnel involved and financial support are listed at the beginning of each report.

E-1. Collaborative Data Processing Under OS

Personnel:	E. Van Patten, BCL D. A. Bridger, Information Processing Center G. J. Blaine, BCL M. Drazen, BCL
Support:	FR 00161 FR 00396 Washington University

The switchover has been made from Remote Access Computing System (RACS) to the Multiprogramming with a Fixed Number of Tasks (MFT) configuration of Operating System/360 (OS). In addition, Houston Automatic Spooling Priority (HASP) provides disk queueing for input/output. Additions and modifications have been made to OS and to HASP to accomodate PC's and LINC's.

The IBM 360 utilizes an IBM 2701 data adapter unit that contains two parallel data adapters and one Type III data adapter and, in the future, will have just two Type III's. The Type III provides full-duplex, 1200-bps, point-to-point operation.

Characters transmitted have 10 bits each; a START bit, a 7-bit American Standard Code for Information Interchange (ASCII) character, a parity bit, and a STOP bit. The ASCII character set is readily converted to PC or LINC keyboard codes peripherally or to Extended Binary Coded Decimal Interchange Code (EBCDIC) for the IBM 360/50 centrally.

A protocol to guide the exchange of messages was worked out using a minimum of control characters. Each message is preceded by STX and followed by ETX and by a longitudinal redundancy check (LRC). To ensure that a message can always be presumed to have been received, the message must be at least three characters long and, after a delay to permit resynchronization, be followed by a negative response (NAK). Should a noise burst alter any of the other control characters, the NAK is an indication that a message has been sent. A single response is returned, a positive (ACK) or negative (NAK) acknowledgement. The NAK requests retransmission because of a parity or LRC failure or because NAK was received in lieu of a complete message. The IBM 360 will time out after a 2-second void and resend either its last response or an ENQ requesting a repeat of the PC's last response. The message, EOT, signals the termination of the job and, when sent from the time-out state, signals the readiness of the 360 for another job. The message, CAN, is sent by the 360 to inform of a crippling I/O error. Programs utilizing this protocol are being written for the IBM 360, the PC, and the LINC.

The programs that implement the PC/LINC communications will reside in one partition of the IBM 360/50 memory. They will provide access to disk files in response to function requests to GET, PUT, PUTR (replace), DEL (delete), or GETD (get directory). The programs will also, when the request is to RUN, put programs and data from the disk files into the input stream of OS for batch processing (such jobs are given top priority by OS), and will make the output available to a remote terminal.

E-2. IBM 360/50-PC Communications Under RACS

Personnel: E. Van Patten, BCL
D. A. Bridger, Information Processing Center

Support: FR 00161
FR 00396
Washington University

The use of RACS in the IBM 360/50 was discontinued, as anticipated, in June of this year (see E-1); nevertheless, work on the communications programs was carried on throughout the year in order to gain as much understanding of the problems of such communications as possible. Hopefully, the project of implementing a collaborative mode of operation with OS will proceed more efficiently and faster for the experience gained.

Programs that were reworked and refined were the basic communications routine, the cold start procedure for the PC, a program that handled the accessing of the PC program library stored on a 360 disk, and a program that would copy the PC library from the disk to LINC tape and rewrite the disk from LINC tape.

E-3. IBM 360/50-LINC Communications Program

Personnel: M. Drazen, BCL
W. F. Holmes, BCL

Support: FR 00161
FR 00396

Using the LINC tapes for storage, a program enabling the LINC to communicate with the IBM 360/50 (operating under the RACS time-sharing system) makes possible the transmission of large amounts of program and data. Taped information is used in a manner completely compatible with LINC Assembly Program No. 6

(LAP6). In this way, LAP6 can be used to write, edit, list, and store FORTRAN programs for later transmission. After execution of a FORTRAN program by the IBM 360/50, LAP6 can be used to print out the results.

Only 8-bit ASCII characters are transmitted. Internally, the IBM 360/50 converts to and from EBCDIC, and the LINC converts to and from its keyboard code. Control is handled by a subset of the ASCII control characters. Provision is also made for sending pairs of octal digits as if they were ASCII characters to speed the transmission of large blocks of data.

E-4. Automatic Data Switching System

Personnel: D. Gurwitz, BCL

Support: FR 00161
FR 00396

A program was initiated to develop a switching network that would allow dial-up interconnection for computer-to-computer communications. The dial-up interconnection was to include both voice and full-duplex data connections for any of the computer stations located at the Washington University Computer Laboratories, the hospital complex, or the Information Processing Center. The program, which had been carried through the design and breadboard development phase, was terminated after a critical review of the present computer communication requirements.

In view of the development and progress with the IBM 360/50 time-sharing system at the Information Processing Center, it has been decided that primary emphasis should be placed on computer-to-computer communication for any of the laboratory and hospital stations to the IBM 360/50 system at the Information Processing Center. This change should result in a simplification of the design constraints placed on the switching network. Planning now underway will take advantage of this simplification.

E-5. Time Sharing Computer Service

Personnel: W. F. Holmes, BCL

Support: FR 00161
FR 00396

A teletype unit, installed in the Biochemistry Department of the Medical School in late May, communicates by telephone line with a General Electric 265 time-sharing computer. Service is available to qualified users in the basic medical science departments on an experimental basis, as an aid in the continuing development of communication systems between the University's IBM 360/50 and the PC and other small computers.

There are three objectives: First, the teletype is being compared with small computers as an input/output device. Of special interest are data transmission rates, programmable displays of text and figures, and analog input. Second, the need for quick response is being tested. The General Electric system provides response times of a few seconds to commands for editing and running programs. The IBM system will provide quick access to its disk files for program editing and data storage, but will normally require delays of several minutes to execute programs. Finally, a number of users who have rarely or never used computers are running programs. The difficulties they encounter in writing and running simple BASIC or FORTRAN programs are being observed in order to take advantage of the flexibility offered by small computers using programmed displays for input/output.

F. Other Applications of Computers

Computer applications that are not described in the previous sections are reported in this section. A few supporting activities are also described. As in many of the preceding sections, much of the work depends upon collaboration with our colleagues. Their names and any associated financial support are listed at the beginning of each report.

F-1. Routine Processing of Clinical Fetal Electrocardiograms

Personnel:	D. H. Glaeser, BCL M. R. Behrer, M.D., Pediatrics J. R. Cox, Jr., BCL R. B. Woolf, M.D., Obstetrics/Gynecology J. Barnes, Pediatrics C. R. Buerke, BCL
Support:	FR 00161 FR 00396 HE 09528

Acquisition and processing of the fetal electrocardiogram (FECG) using techniques previously described (see PR 2, 7; PR 3, D-4) has continued throughout the past year. This routine will remain unchanged pending completion of work on optimum processing of the FECG (see F-2). A total of 202 patients have visited the laboratory for 716 recording sessions. Of these, 464 recordings were made on 133 normal patients and 229 recordings were made on 51 patients with complicated pregnancies. The remaining records (23) were requested by attending physicians in attempts to refute diagnosis of fetal death. The complications group is divided as follows:

	Patients	Recordings
(1) Rh Negative	27	127
(2) Diabetes	5	37
(3) Habitual Aborters	4	30
(4) Confirmed Twin Pregnancies	9	24
(5) Other	6	11
Total	51	229

Among the total population of patients, 18 visited our laboratory eight or more times during a single pregnancy.

Processing of 294 records from 92 patients has been completed to this date. Of these, 127 records from 50 patients have resulted in satisfactory averaged FECG's. Some results of analysis of these data have been published(1).

(1) M. R. Behrer, D. H. Glaeser, J. R. Cox, and R. B. Woolf, "Quantification of the Fetal Electrocardiogram Through LINC Computer Processing," American Journal of Obstetrics and Gynecology, October, 1968.

F-2. Optimum Processing of the Fetal Electrocardiogram

Personnel:	D. H. Glaeser, BCL J. R. Cox, Jr., BCL
Support:	FR 00161 FR 00396

The adaptation of the techniques of signal detection and estimation to the problem of providing a clear and reliable fetal electrocardiogram (FECG) has been reported (see PR 3, D-5). A continuation of this work has led to the definition of the structure of an optimum detector for a single FECG in additive white, Gaussian noise.

Detection of the FECG is complicated by two major difficulties: First, the shape of the signal can be specified only statistically; and second, the time of occurrence is not completely known since the signal is only quasi-periodic. The model of the experimental situation used to develop the optimum detector assumes that each interval in which an FECG exists is dealt with separately. This "observation interval" is assumed to consist of a signal (the FECG), which is a sample function from a zero-mean Gaussian process, added to a "white" Gaussian noise. The location of the signal within the interval is assumed to be a random variable that has a known first-order probability density function. The analysis was performed using discrete time approximations for easy implementation of the detector on a digital computer. Under these conditions, the signal is an L-dimensional Gaussian vector, $\underline{s}$; the noise is an M-dimensional Gaussian vector, $\underline{n}$, with uncorrelated components. An observation, $\underline{r}$, is an M-dimensional vector that has components consisting of either noise (at those instants where no signal is present) or the sum of signal and noise samples.

$$\underline{r} = (n_1, n_2 \cdots n_{v-1}, s_1+n_v, s_2+n_{v+1}, \cdots s_L+n_{v+L-1}, n_{v+L}, \cdots n_M) \qquad (1)$$

For the observation vector in Equation (1), the signal is located at time v. To define the signal process, only the covariance matrix need be specified, and the noise is completely specified by its rms value.

Computer simulations on the LINC and on the 360/50 were performed to quantitatively compare the performance of this optimum detector, using as a basis the above problem definition, with the routinely used threshold-crossing detector. A covariance matrix for the FECG was generated using 125 sample waveforms of the fetal QRS taken from the data collected in the past. Using computer-generated observations with some of these fetal QRS complexes as signals and using also a pseudo-random number sequence to represent noise samples (see PR 3, F-2), simulation of the optimum detector has shown that performance is sufficiently improved to successfully produce averages of the fetal QRS at a signal-to-noise ratio of 0.25, while the threshold-crossing detector will not produce a readable average for a signal-to-noise ratio below 2.

Further work will determine precisely what improvements in clinical data processing can be effected through the routine use of this detector. The greatest obstacle to its incorporation in the clinical situation is its speed of operation. Approximately 2 minutes of computer time are necessary (with a classic LINC) to process 1 second of data in the simulations. This processing time can be improved to some degree by using a computer having faster memory or by using special hardware designed to implement the detector algorithms, but real-time operation at present does not seem feasible.

F-3. Optimum Estimation Techniques for the Fetal Electrocardiogram

Personnel:	L. Medgyesi-Mitschang, Graduate Student, Electrical Engineering J. R. Cox, Jr., BCL
Support:	FR 00161 FR 00396 Washington University

Algorithms for the estimation of signals in noise that were developed last year (see PR 3, D-5) have been reworked to simplify their exposition. In addition, specific a priori densities that fit the requirements of the algorithm have been listed. An article describing this work has been completed and will soon be submitted for publication(1).

(1) J. R. Cox, Jr., and L. N. Medgyesi-Mitschang, "An Algorithmic Approach to Signal Estimation Useful in Fetal Electrocardiography," to be published.

F-4. Automatic Scanning and Pattern Recognition

Personnel:	J. H. Scandrett, Physics A. R. Zacher, CSL V. Bleisch, M.D., Pathology
Support:	FR 00161 FR 00396 FR 00218 Washington University

A random-programmable, flying-spot CRT film scanner with 13-bit by 13-bit addressing and 6-bit measurement of film density is now in operation. Augmenting the scanner are a storage oscilloscope, a keyboard, sense switches, two digital angle encoders and an IBM 2260 alphanumeric display. The entire scanner system is connected to the IBM 360/50 through an interface simulating an IBM 2361 large core storage device.

Commands are sent and data retrieved by executing normal IBM 360/50 load instructions. An absolute address sent to the interface causes a word to be returned via the interface which appears as if it were fetched from memory. The structure of a command, transmitted on the address lines, is composed of a 13-bit address plus two 3-bit command fields. For example, a new 13-bit address can replace either the old x or y address for both the scanner and the display scope. An encoder command provides a real-pulse to the appropriate encoder. The scanning CRT can be set in either of two states of focus - small spot or adjustable defocussed spot for area scanning. A display command intensifies the scanning spot, starts the 6-bit A/D converter measuring the light pulse, and 12 μsec later makes available the new film density value. A double photomultiplier system is used, one monitoring the CRT face and one measuring transmitted light. The outputs are logarithmically differenced, giving a density measurement independent of CRT light source variation. Every command returns the contents of a 32-bit data register to the IBM 360/50. The format is: 6-bit film density register, 7-bit keyboard register, 10-bit encoder register, 6-bit sense-switch register, and lines signaling completion of a density measurement.

SCOPEMON is a new interrupt-actuated monitoring program, residing in a private 45,000-byte memory partition in an OS/360-HASP environment. To execute a program the user types the program name on the IBM 2260. SCOPEMON then checks for the existence of a data set member with the indicated name on the IBM 2314 disk. It then checks for executability of the program and if successful initiates execution. Any job running in a lower partition is interrupted. Incorporated in SCOPEMON is a "common area" containing three packed 128- by 128-point binary images and appropriate image-describing parameters. These images can be passed through a series of image-processing programs. The system has resulted in an impressive increase in efficiency of the IBM 360/50 for pattern recognition and graphics programming particularly since the flexible file capabilities of OS/360 and a full array of compilers are available to the user of the scanner system.

Several utility programs have been developed for scanning and displaying images. One program magnifies a subregion of an image already scanned and displayed on the storage scope. Another displays density as a function of horizontal position for a single sweep across a previously scanned picture. A display of density gradient can also be obtained. Random scans over a selected portion of an image can produce a density histogram useful in developing automatic background-estimating algorithms. A variety of conventional graphical output programs suitable for photographic recording also are available for data plotting. Other programs produce printed density maps and contours. There is a sequence of programs for image processing of binary stored images, including complementing, differentiating, filtering, and contour following.

A system of programs for identifying stained leukocytes is under development. The basic method, built on the work of Ingram and Preston(1), uses image-shrinking to count and classify objects (nuclear segments) within a cell. The method uses a subroutine, PHAGE, which follows and deletes boundary points of an object. The difficulties in the process of counting objects by consuming them have to do with preserving connectivity. PHAGE creates for each object a tree whose branch points represent the points on a partially consumed object at which connectivity is broken. The ends of the tree are the ultimate convex fragments of the original object. The data accumulated for each branch are: total area, number of sub-branches, perimeter, and number of image-shrinking passes until branching occurred.

The tree of data gives general, though incomplete, information about the size and shape of the represented object. Using only a small portion of this information, the program can, at present, separate leukocytes into three classes: segmented granulocytes, band granulocytes, and all other types.

The cell images are recorded on 35-mm film through a green filter. A magnification is used such that typically four or five leukocytes (and many erythrocytes) appear in one frame. The computer program proceeds without human intervention to choose suitable density thresholds for viewing the nucleus and cytoplasm of the leukocytes; then, from a rough binary image of the entire picture, the leukocyte images are located. Each leukocyte image, in turn, is raster-scanned with appropriate thresholds to form two detailed binary images of the cell - one showing the nucleus alone, the other showing the cytoplasm and nucleus. The program, using the cytoplasm image as a mask to limit its search, locates and consumes each nuclear segment, forming the tree structure. A band granulocyte is then recognized as a cell with one nuclear object having a suitable ratio of $(\text{circumference})^2/\text{area}$. A segmented granulocyte has more than one nuclear mass with relatively narrow communicating necks.

(1) M. Ingram and K. Preston, Jr., "Importance of Automatic Pattern Recognition Techniques in the Early Detection of Altered Blood Cell Production," Ann. N. Y. Acad. Sci., 113, p. 1066 (1964).

F-5. Nonlinear Cochlear Microphonics

Personnel:	A. M. Engebretson, BCL D. H. Eldredge, CID
Support:	FR 00161 FR 00396 NB 03856

During the past year, the study of nonlinear aspects of cochlear microphonics (CM) in the guinea pig has continued. At high enough sound pressures, the middle ear is certainly nonlinear and introduces overtones, combination tones, and interference. Interference is a nonlinear phenomenon in which the presence of one tone decreases the amplitude of the response to a second tone. At levels below the level at which the middle ear is significantly nonlinear, interference between two tones in the cochlear microphonics has been found to be a localized phenomenon and not distributed uniformly throughout the cochlea. These experiments support the argument that cochlear nonlinearities occur in the hair cells, or somewhere else in the organ of Corti, rather than in the hydromechanical traveling wave.

Three pairs of electrodes were used in the experiments so that the nonlinear effects could be measured simultaneously at three places along the cochlea. The stimulus consisted of a 500-Hz tone and a second higher frequency tone. The change in the 500-Hz component in the CM was measured as a function of frequency and intensity of the second tone.

Because of the low-pass nature of the cochlea, the traveling wave for the 500-Hz tone propagates from Turn I to Turn III with increasing amplitude. The higher frequency tone propagates with increasing amplitude up to some position along the cochlea and rapidly decays beyond this point. At 2000 Hz, the maximum occurs near the position of the Turn II electrode. The results of a typical run are shown in the following table. The intensity of the 500-Hz tone was 50 dB SPL at the eardrum.

Intensity of 2000-Hz Tone at the Eardrum (dB SPL)	Change in the 500-Hz Component		
	ΔCM_{I} (dB)	ΔCM_{II} (dB)	ΔCM_{III} (dB)
OFF	0	0	0
30	+¼	-¼	-¼
40	+½	-¼	-¼
50	+½	-½	0
60	+¼	-1¾	-½
70	-¼	-5¾	-1¾
80	-2¼	-12½	-3¼
90	-9	-20¼	-5

The characteristics of interference in the CM that are evident from this experiment are as follows: (a) The magnitude of the 500-Hz component decreases as the intensity of the interfering tone is increased; (b) the change is different in each turn of the cochlea; (c) interference is most pronounced in the vicinity of the maximum of the traveling wave for the interfering tone.

For a test tone of 500 Hz and for an interfering tone of 2000 Hz, interference is greatest in Turn II, next greatest in Turn I, and least in Turn III (see above table). When the frequency of the interfering tone is increased to 6000 Hz, interference is greatest in Turn I and is practically nonexistant in Turns II and III. When the frequency of the interfering tone is decreased to 1000 Hz, interference is about the same in Turns II and III and is greater than in Turn I.

Since the amount of interference in Turn I at 6000 Hz is greater than that in Turn II or Turn III, the interference observed at sound pressures up to 90 dB SPL does not occur in the middle ear. Furthermore, hydromechanical nonlinearities are not likely to account for these observations. Fluid eddies have been observed in the cochlea but these eddies are always on the apical side of the maximum of the traveling wave. For an interfering tone of 2000 Hz, interference is observed in the CM of Turn I, which is basal by approximately 7 mm from the position of the fluid eddies. In the guinea pig, 7 mm is nearly half the length of the cochlea.

Another observation restricts the place of interference to either the hair cell or local, as distinguished from overall, mechanical phenomena. If interference occurs throughout the full height of the column of fluid in scala vestibuli, the reduction in amplitude of the 500-Hz tone would be expected to be greater for positions farther along the cochlea. As shown in the foregoing table, this is not true since the reduction of the 500-Hz component is 12 dB in Turn II and only 3 dB in Turn III at a sound pressure of 80 dB.

F-6. Mathematical Models of the Mechanics of the Cochlea

Personnel:	J. R. Cox, Jr., BCL
Support:	FR 00161 FR 00396

A description of the combined fluid and membrane motion in the cochlea has been developed. This description is an improvement of the lumped-constant approximation described last year (see PR 3, E-4). The integro-differential equation, which describes the motion, reduces for long wavelengths to the fourth order partial differential equation developed last year. Approximate solutions of this integro-differential equation seem to have the desired properties, but no firm conclusions can be drawn until a method of solution that leads to more accurate results is found.

F-7. Evoked Response Display System

Personnel:	S. Goldring, M.D., Neurosurgery P. E. Stohr, M.D., Neurosurgery R. L. Hill, BCL H. Agress, Jr., Neurosurgery
Support:	FR 00161 FR 00396 NB 06947

The program begun last year (see PR 3, F-3) has been completed and used successfully for the simultaneous transmission from the operating room to a remote LINC of eight evoked responses from independent probes placed on the surface of the brain. Along with a multiplexer, a LINC interface has been built to send control pulses over the 1000 feet of coaxial cable necessary to connect the two sites.

Using closed circuit television the surgeon can view the computed results of any one, two, or all eight responses during surgery. Later he can compare any one response to any other from the same or previous sessions.

F-8. Investigation of Methods of Treating Hyperactive Children

Personnel:	E. Van Patten, BCL J. Satterfield, M.D., Psychiatry
Support:	FR 00161 FR 00396

A study was begun of the effects of various drugs on the brain wave patterns of hyperactive children. As an aid to this research, a LINC program was written to analyze samples of such brain waves recorded under controlled conditions. A varying number of samples was included in each run. Each was first displayed on the LINC scope and thereafter could be excluded from the cumulative data by keyboard option. Provision was also made for obtaining a hard copy of the waveform on the Calcomp plotter if desired. When a sample was selected for inclusion in the calculations, the mean positive and negative peak amplitudes and the average interval between peaks were determined, as well as the overall average of all the data points. At the end of a run, histograms were plotted of the averages of the individual samples.

F-9. A Digitally Controlled Audio Stimulus Generator

Personnel:	F. M. Nolle, BCL J. R. Cox, Jr., BCL
Support:	FR 00161 FR 00396

A description of the design and operation of a device that modulates an audio frequency carrier with a digital trapezoidal envelope has been completed (see PR 1, A-23 and A-24). The effects of fast-switching transients were examined in detail. Two extrapolation methods (a zero order hold and first order hold) were analyzed as means of improving the performance during transitions.

Publication:

F. M. Nolle, A Digitally Controlled Audio Stimulus Generator, Washington University, St. Louis, Missouri, 1968 (M.Sc. Thesis).

F-10. A Large, Stimulus-Control Interface for LINC

Personnel:	A. M. Engebretson, BCL D. H. Eldredge, CID N. R. McCanney, CID R. T. Kimack, CID C. M. Donnelly, CID
Support:	FR 00161 FR 00396 NB 03856

New stimulus-control logic has been installed in the Physiology Laboratory at the Central Institute for the Deaf (CID). This equipment makes possible the control of more complicated experimental situations with the LINC computer. The logic provides 56 buffered output lines that are capable of driving 100-mA relay coils or supplying 15-volt control pulses. The unit contains two 12-bit buffered D/A ladders that can be used to operate voltage control oscillators, analog plotters, or oscilloscope displays. The logic provides sixteen 4-bit input channels that can be connected to the BCD output of a counter, a shaft encoder, or special parameter switches.

The system was designed so that small portions of the logic will operate independently of other portions. In this way, the relatively large system was designed, constructed, and checked out without a complete complement of logic cards. Half the logic cards have now been purchased to fulfill the immediate needs of the laboratory.

Presently under construction, for use with the new control logic, are three 6-bit signal attenuators, a 4-bit power attenuator, and the necessary mixer and switching circuitry so that a stimulus consisting of three independent signals can be controlled from the LINC.

F-11. New CID Equipment for Signal Detection Experiments

Personnel:	A. M. Engebretson, BCL C. S. Watson, CID J. Broeckelmann, CID I. J. Hirsh, CID R. T. Kimack, CID
Support:	FR 00161 FR 00396 NB 03856

A PDP-8S computer has been purchased by Central Institute for the Deaf to control the stimulus presentation and to monitor and record the responses from four human subjects. Construction of four subject consoles, an operator console, interface logic, and signal attenuators is now nearly finished.

F-12. Flip-Chip Module Tester

Personnel: H. D. Ambos, BCL
V. W. Gerth, Jr., BCL

Support: FR 00161
FR 00396

A tester for flip-chip modules has been built consisting of central timing and pulsing circuits, a regulated power supply, a patch panel, and a mounting panel. Most commonly used modules, such as gates, inverters, flip-flops and light drivers may be tested without patching by means of prewired connectors.

F-13. SINCOS

Personnel: M. D. McDonald, BCL

Support: FR 00161
FR 00396

SINCOS is a LINC program for generating tables of fixed-point sines and cosines in LAP6 manuscript format. The user may specify, as input in decimal form, the upper and lower limits of the range over which the functions will be tabulated and, also, either a step size or the number of points desired. Angles can be specified in radians, pi-radians, degrees, minutes or seconds, or any combination thereof. Output is written in LAP6 MS format in Blocks 350 and following on Unit 1.

F-14. Q&A

Personnel: M. D. McDonald, BCL

Support: FR 00161
FR 00396

The Questions and Answers (Q&A) program for the LINC is a subroutine that allows the user to display textual information on the scope, ask questions of the viewer, and receive responses thereto. The subroutine has been completely revised so that character codes are compatible with LAP6 text. In addition the text string and the answer buffer are now separate from each other and from the calling sequence and can, therefore, be located in upper memory. This Q&A program is incompatible with the previous (LAP4/GUIDE) version.

F-15. GRAPHX Plotting System

Personnel: D. J. Manson, BCL

Support: FR 00161
FR 00396

GRAPHX is based on a control language for an incremental plotter that uses the editing facilities of LAP6. A manuscript consisting of control statements, arguments, and text is produced and interpreted by GRAPHX to operate the plotter. Although the control language can be mastered in an hour, it is sophisticated enough to allow (a) nested do loops, (b) total memory overlay, by user-created binary programs, e.g., data generating programs, (c) type font changes, (d) open subroutines, and (e) flexible plotting of data, including a limited capacity to suppress hidden lines.

The system has been used to plot finished figures for publication, isometric drawings, and a short summary of its own operation and control language. The system utilizes a slightly modified version of the Calcomp subroutine package described previously (see PR 3, B-3).

F-16. Information Processing Research

Personnel: R. A. Dammkoehler, BCL
M. Bhide, BCL

Support: FR 00161
FR 00396

A requirement for convenient user access is reflected in many current computer systems designs. Most of these efforts are directed toward implementing interactive systems in which multiple users have a direct time-shared access to a large scale computer.

Recent studies cast considerable doubt on the efficiency of time-sharing as a computer-aided problem solving mechanism. One important observation(1) is that while problem solving in a time-shared environment requires fewer man hours, more computer time is consumed, suggesting that additional exploratory computer runs are undertaken with data and programs that are not properly preprocessed or edited. Unfortunately, with the exception of extremely simple tasks, most jobs need extensive preparation. This is true for jobs of both the experienced and the inexperienced user and particularly important in medical data processing. We observe that a

(1) Sackman, H. "Time-Sharing Versus Batch Processing: The Experimental Evidence," SP-2975, System Development Corporation, Santa Monica, California, October 10, 1967.

typical user seldom has access to data preparation devices and when he does, uses them inefficiently. Long turn around time, duplicated or wasted efforts, device queues and frequency of errors, very often attributed to lack of interaction between computer and user; could in fact be avoided through better preprocessing and editing of data and programs. That the user can, and in fact, in a time-sharing environment often receives valuable assistance from the computer in preparing a program, cannot be denied. However, whether a great part of the power of a large-scale computer need be devoted to such relatively simple tasks is debatable.

The primary objective of this research project is to develop an economically feasible, console-oriented program and data preparation facility; an objective which we feel can be best achieved by physically and logically separating preprocessing functions from computing needs. Thus, our initial efforts have been directed toward design and development of a separate system for preprocessing, data acquisition and program preparation.

The design of any system for construction, manipulation and maintenance of files of data and programs should be subject to the following general constraints: a) The system should be functionally capable of servicing multiple consoles and multiple files; b) the physical file set may contain many files, each with its own content and logical organization; c) the system should undertake manipulation of the input stream and structure the file according to format specifications stated by the user, and d) the system should be simple to learn and economical to use.

A model of such a system has been developed for our IBM 360/50 with IBM 2260 display terminals. Various control, management and function processors requisite for such a system were identified and programmed by the BCL staff. The principal features of the system are that it permits a high degree of variability in file structure and format. The files are variable in length and the amount of information to be stored is restricted only by the available file storage capacity. Although operational in a multiprogrammed environment, the model needs to be thoroughly tested to discover its vulnerability to potentially catastrophic errors and be made fail-safe to these, for the success of the system ultimately depends on this.

In using the system, one does not have to refer to a manual or code list. Most of the user's communications take place in response to questions displayed by the computer. Once the user specifies the number of records and specifies the file format by means of a stylized representation, the input can be entered as a continous stream in blocks of any length up to 480 characters. The stream is accepted, edited, checked, formatted and stored as records. These records are displayed back to the user following each console entry.

The user can make changes in the file both while creating it and later. Any part of a current file, on display or otherwise, is immediately modifiable. Users can communicate with the system any time during operation by keying in commands on the bottom three lines of the 2260 scope. Every communication evokes a response. The commands are the following simple keywords shown on the chart below. Of these 14 commands, ENTER and DISPLAY are default conditions. All other requests evoke a single response. The command DISPLAY is assumed to be the next command if there is no further request from the user.

Keyword(s)	Action
ENTER	Enter data
DISPLAY	Display records
RECORD XXX	Display record XXX
INSERT XXX	Insert the record keyed in above, after record XXX in the file
DELETE XXX (YYY)	Delete records XXX through YYY
REPLACE XXX	Replace record XXX with the one keyed in above
FORWARD XXX	Display records XXX beyond that last displayed
BACKWARD XXX	Display records XXX before the one displayed last
COPY "file A" XXX YYY "file B" (ZZZ)	Copy records XXX through YYY of "file A" on to "file B" after record ZZZ
PUT "file A" XXX YYY "file B" (ZZZ)	Copies records as above and removes them from "file A".
OPEN	Open a file
CLOSE	Close a file
GIVE	Copy the file on a tape to be physically carried away by the user

Work on the prototype has also demonstrated that further commands are necessary. A search and retrieval processor would apparently be of great value. Experiments have shown that the user should be able to initiate a search by specifying with his request, the field, the reference value and the conditions such as, "equal to", "less than" and "greater than" within a field and "or", "and", "not", etc. within a record.

Once it is felt that all functional requirements for such a system have been met, an attempt will be made to synthesize the instruction sequences (structure) of the model, preparatory to the design and realization of the program and data preparation facility in macromodular form.

VI. TRAINING ACTIVITIES

During the year BCL engaged in the following training activities:

Course in LINC and PC Programming, October 1967

The course was taught by Michael D. McDonald and included binary arithmetic and coding in both machine language and assembly language. Attending the course were:

Umit Aker, M.D.	Cardiology
Norma Alkjaersig, M.D.	Medicine
Frances Bannowsky	Physiology
James Blaine, M.S.	BCL
Henry Casson, M.D.	Anesthesiology
George Chan, M.D.	Medicine
Ashley Coppland, M.D.	Medicine
Anthony Fletcher, M.D.	Medicine
Helen Fotenos	Radiology
Stanley Lang, M.D.	Physiology
Walter Long, M.S.	BCL
Pat Lucas, Ph.D.	CID
Nedra Mugavero	Radiology
Larry Sherman, M.D.	Medicine
Joseph Vermylan, M.D.	Medicine

Course in LINC and PC Programming, June 1968

The course was taught by Michael D. McDonald and was held primarily for the personnel of BCL. The subject matter included binary arithmetic and coding for the two computers in both machine language and assembly language. Attending the course were:

Brad Binnington	Barnes Hospital
Lawrence Bolef	BCL
Abbie Braxton	St. Louis University
D. L. Camenga, M.D.	Neurology, City Hospital
Robert Eldredge	Student
N. K. Flammang, M.S.	Radiology
H. Fotenos	Radiology
Robert Metzger, Ph.D.	Dental School
John Meyer, M.D.	Veterans Hospital

V. Ramakrishna, M.S.	CSL
Glenn Roa	BCL
Phyllis Roberts	St. Louis University
Gerald Rossi	BCL
Howard Rothman, Ph.D.	CID
Jay Selman, B.S.	CID
Carl Sherrick, Ph.D.	Princeton University
Carl Smith, M.D.	Pathology
Barbara Stadtmiller, B.S.	Physiology
Louis West	BCL

PC Programming, July 1968

A course was taught by Michael D. McDonald at the request of the Department of Nuclear Medicine. The course included binary arithmetic and programming in machine language for the Programmed Console.

Al Van Amberg	Nuclear Medicine
N. K. Flammang, M.S.	Radiology
H. Fotenos	Radiology
Jane McWilliams, B.S.	Nuclear Medicine
Pat Pernoske	Nuclear Medicine
E. J. Potchen, M.D.	Nuclear Medicine
Barrie Siegel	Nuclear Medicine
Becky Studer, M.S.	Nuclear Medicine
Tom Wharton	Nuclear Medicine

VII. PUBLICATIONS

Publications and papers presented during the period covered by this report are listed below. In addition, a few papers now published, but not listed in previous reports are included.

W. E. Ball and R. I. Berns, "Automast-Automatic Mathematical Analysis and Symbolic Translation," Comm. of ACM, Vol. 9, No. 8, p. 626, August 1966.

M. R. Behrer, D. H. Glaeser, J. R. Cox, and R. B. Woolf, "Quantification of the Fetal Electrocardiogram Through LINC Computer Processing," American Journal of Obstetrics and Gynecology, October 1968.

R. E. Bentley, E. J. Potchen, and V. W. Gerth, Jr., "Immediate Assessment of Gamma-Camera Dynamic Studies Using a Small Digital Computer," Presented at the 15th Annual Meeting of the Society of Nuclear Medicine, St. Louis, Missouri, June 1968.

R. Burstein, G. S. Whitlow, and H. C. Wasserman, "The Use of Norethindrone - Mestranol in the Immediate Post-Partum Period: A Preliminary Report," Digest of Obstetrics and Gynecology, pp. 31-41, February 1968.

S. L. Clark, Jr., "The Synthesis and Storage of Protein by Isolated Lymphoid Cells, Examined by Autoradiography with the Electron Microscope," American Journal of Anatomy, Vol. 119, pp. 375-404, 1966.

J. S. Clifton, E. J. Potchen, and R. L. Hill, "A Digital Data Acquisition System for Nuclear Medicine," International Journal of Applied Radiology and Isotopes, Vol. 99, pp. 505-509, 1968.

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