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Argonne National Laboratory

APPLIED MATHEMATICS DIVISION SUMMARY REPORT

July 1, 1964 through June 30, 1965

RELEASED FOR ANNOUNCEMENT
IN NUCLEAR SCIENCE ABSTRACTS

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AEC Research and
Development Report

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois 60439

APPLIED MATHEMATICS DIVISION
SUMMARY REPORT

July 1, 1964 through June 30, 1965

Wallace Givens, Division Director

William F. Miller, Former Division Director
(Until December 8, 1964)

RELEASED FOR ANNOUNCEMENT
IN NUCLEAR SCIENCE ABSTRACTS

Preceding Summary Reports

ANL-6952 July 1, 1963 through June 30, 1964
ANL-6768 July 1, 1962 through June 30, 1963
ANL-6641 July 1, 1961 through June 30, 1962
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PREFACE

The objective of the Applied Mathematics Division is to provide mathematical support for the research and development programs of the Laboratory. This goal is achieved, in particular, by (1) conducting research in applied mathematics, numerical analysis, theory and practice of computation, and design of computers and information-processing equipment, (2) providing mathematical consultation, and (3) operating a computational service, using both digital and analog machines. The Division is prepared to provide mathematical assistance at any stage of the development of a problem from its initial formulation to its final solution.

The Consultation and Research Section is available to assist Laboratory personnel by mathematical consultation, in problem formulation, and in selection of appropriate mathematical and numerical techniques, and to carry out analyses of problems. The Applied Programming Section is specifically set up to program digital computing problems for members of other Divisions. The members of this Section generally work from a problem description provided either by the problem originator or jointly by the problem originator and a member of the Consultation and Research Section. In addition, this Section also provides production services.

It is the responsibility of the Programming Research and Development Section to conduct research in new programming techniques, to develop needed systems and subroutines, and to provide training courses and instruction in programming techniques for the benefit of members of the Division, as well as for other members of the Laboratory. The Digital Operations Section prepares machine-input data, schedules machine time, and operates the digital machines. The Analog Group is prepared to assist in the formulation, programming, and running of problems for the analog computer or to accept the problem and carry out these services entirely within the Group.

The functions of the Computer Engineering Section are (applied) computer engineering research, and the development and design of computers and information-processing systems having special application to the nuclear sciences.

APPLIED MATHEMATICS DIVISION

ORGANIZATION CHART

July 1, 1964 through June 30, 1965

ORGANIZATION CHART (Cont'd.)

TEMPORARY PROGRAM

Summer 1964

LONGER TERM

SUMMER 1965 (To June 30)

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APPLIED PROGRAMMING

Of major importance in reactor applications has been the development of one- and two-dimensional transport and diffusion theory codes. Using the Los Alamos DTK and LASL*-UNC/DTF programs as a guide, a one-dimensional S_n code, SNARG, has been written and the two-dimensional version, a joint effort with LASL, UNC, and ANL, is now being completed. The Argonne one-dimensional diffusion theory code, REX, is being rewritten; and CANDID, the ANL-CAI-CDC two-dimensional diffusion code, written to Argonne's specifications is now being tested and extended here. Standard data forms have been developed for input of problem specifications and cross section data applicable to both one- and two-dimensional transport and diffusion theory codes. The new standard cross section library, prepared by the XLIBIT code, is also being used by all programs which require or prepare cross section data. Several auxiliary programs have been written to assist in the conversion of existing cross section sets into the new XLIBIT format.

Three 704 kinetics codes have been combined and reprogrammed for the 3600 and a collocation method for the solution of the kinetics equations is being developed. Under way also is the reprogramming of ELMOE, an elastic scattering resonance code.

FORTTRAN programs received from other installations have been adapted to our system. We have incorporated parahydrogen properties into a version of the AGN heat transfer code HECTIC-II and prepared versions of the BNL thermalization transport theory code, THERMOS, and the GE general three-dimensional heat transfer program, THTB.

Turning to other fields of application, a calculation has been made of the relative error in a model surface temperature probe in liquid metal. This relative error was found to be given by a series and in a limiting case by an integral. The series was summed and the integral calculated for various values of the parameters involved.

A program has been developed to search for a special type of space curve in regions of seven-dimensional space. The curves are solutions of two equations each made up of two-by-two matrices of special type.

*
 LASL Los Alamos Scientific Laboratory
 UNC United Nuclear Corporation
 ANL Argonne National Laboratory
 CAI Computer Applications Incorporated
 CDC Control DATA Corporation
 AGN Aerojet General Corporation
 BNL Brookhaven National Laboratory
 GE General Electric Company

Several programs have been written to determine crystal lattice constants by least squares. A related program has been developed to construct a crystallographic scattering density from its Fourier transform when this is given. The input space group number (up to 74) selects the required symmetry and multiplicities.

Programs have been written to process data contained on 35 mm. film. Scanning and counting are done in one program, while other programs are concerned with a statistical analysis to determine the average length of time that independent particles remain in the field of view of the camera.

Another program simulates the last four stages of granulocyte development. Experimental information is used to set up mathematical models for the kinetics of metamyelocytes, band cells, mature polys in marrow, and mature polys in blood (so-called "four-compartment models").

Several equations describing the bending of circular plates under a symmetrical load have been checked and programmed. The program calculates the radial and tangential moment constants and the deflection constants resulting from the bending of thin flat circular plates subjected to a variable power term load.

A machine is being built by Central Shops to produce uniform rotations to simulate the growth of plants in an isotropic environment. Over a certain period of time the average orientation of the plants is zero. Their average angular velocities and accelerations are also required to be zero. A program has been written to produce a magnetic tape to control the machine and bring about such a motion.

The PHYLIS system for real-time computation as a Physics Division experimental aid has given valuable experience in the programming of applications for such systems. A further project is under way on the ASI 2100; it emphasizes graphic man-machine communication to ease and speed analysis of data on decomposition of gamma ray spectra.

In an effort to utilize and refine theoretical physics models, two joint efforts with the Physics Division are under way: One is an attempt to evaluate and use the nuclear shell model, most of the work being directed toward development of a shell model system. The other is an attempt to determine the agreement of various models for nuclear charge distribution with experimental results from mesic x-rays.

Determination of eigenvalues and eigenvectors of real and complex matrices dominate many of the programs prepared in the area of Chemistry Applications. Computations include fitting of eigenvalues to observed energy levels, generation and diagonalization of the spin Hamiltonian matrix, and investigation of statistical properties of energy matrices for the f^n configurations.

A program in the area of radiation chemistry has required the generation and integration of up to 30 differential equations relating the amounts of the various reactants and reaction products.

In the area of high energy physics, a system of bubble chamber data analysis programs has been developed in close collaboration with personnel of the High Energy Physics Division. The system is based on a "master list" which contains all the information which is currently available on the events in an experiment. Each program in the series updates the master list by adding the results which it obtains in processing each event to the information about that event on the master list. The original master list is prepared by the MASMER program, and the measurements of the events are then spatially reconstructed by the program HGEOM. The latter program, adapted from one written at Rutherford Laboratory, is a three-view program which performs its fits in the film plane. The data are then processed by a kinematic hypothesis testing and fitting program, GRIND. A data summary tape is then prepared by SUMTAPE. From this tape, histograms of physically significant quantities are then made by the program SUM-X adapted from a program written at Berkeley. The system also includes a program PRINTAPE which prepares various summaries about the state of the experiment from the master list.

A series of connected programs, integrating the CHLOE system with the CDC 3600, reduces data directly from film. One program scans the interesting areas of the film and writes the coordinates of everything which it sees in that area onto a magnetic tape. About 48 frames can be put on one magnetic tape at 200 bits per inch. Separate tapes are made for each of the two views and then merged onto one high-density tape. This magnetic tape is processed by the 3600 program, AROMA, which performs the microscopic pattern recognition of fiducials and individual sparks. It records the x-y coordinates of the fiducials and the widths and x-y coordinates of each spark. These data are then processed by the three programs of the AIRWICK system. The first of these, PAIR, associates the images of sparks in one stereo view with corresponding images in the other view and performs the spatial reconstruction of each spark. The second part, LINK, assembles the sparks into tracks. The last part of the program, FILTER, selects from the data those components which satisfy the requirements for being an event in the experiment being studied. Its points are then fitted to helices and the momenta and vertices are output in a format suitable for input to GRIND, which then performs kinematic hypothesis testing and fitting.

A number of Monte Carlo programs have been written to simulate various spark chamber experiments in order to determine their sensitivity, resolution, and biases. The systems so studied were a proposed experiment to study the Ke_2 decay, the neutrino facility at the Zero Gradient Synchrotron (ZGS), and the magnetic spark chamber facility now under construction at the ZGS.

The following programs, listed by title only, chronicle accomplishments of the Applied Programming Section in the past year:

B100	BENDING OF CIRCULAR PLATES UNDER A PARTIAL UNIFORM LOAD
B101	DETERMINATION OF CRYSTAL LATTICE CONSTANTS, α -SPACINGS, AND χ AND ϕ ANGLES
B102	SURFACE TEMPERATURE PROBE ANALYSIS
B103	CALCULATION OF SOURCE TERMS FOR USE IN RE34 (REACTOR SHIELDING)
B104	COMPUTER SERVICES REPORT FOR LABORATORY ACCOUNTING
B105	COUNTING OF TAGGED PARTICLES IN FLUIDIZED BED
B106	DETERMINATION OF CRYSTAL LATTICE CONSTANTS
B107	CRYSTALLOGRAPHY INPUT-OUTPUT DATA MANIPULATION
B108	CALCULATION OF PRESSURE AND THICKNESS OF A VAPOR FILM DURING A TRANSIENT
B109	PURIFICATION OF ARGON FROM NITROGEN USING TITANIUM SPONGE
B110	LEAST SQUARES DETERMINATION OF COEFFICIENTS IN SUM OF EXPONENTIALS
B111	CALCULATION OF AUTO-CORRELATION OF COUNTS OF PARTICLES IN A FLUIDIZED BED
B112	STATISTICAL ANALYSIS OF TEST AND GRADE DATA
B113	GIG-BORER COORDINATES FOR 7.7M SPECTROMETER TOOLING
B114	TWO- AND THREE-DIMENSIONAL CRYSTALLOGRAPHIC FOURIER SUMMATION PROGRAM
B115	ANL FFE, A FORTRAN CRYSTALLOGRAPHIC FUNCTION AND ERROR PROGRAM
B116	CALCULATION OF MAGNETIZATION
B117	THERMODYNAMIC PROPERTIES AND ACTIVITY COEFFICIENTS IN MULTICOMPONENT SYSTEMS
B118	ATOMIC CENTER LOCATION
B119	STATISTICAL ANALYSIS OF HEMATOLOGY DATA
B120	VAPOR PRESSURE EVALUATION
B121	PATTERSON SUPERPOSITION PROGRAM
B122	STAFF SALARY ANALYSIS-SUPERVISORS SEPARATE
B123	STAFF SALARY ANALYSIS-SUPERVISORS INCLUDED

B124	TECHNICAL SUPPORT SALARY ANALYSIS
B125	LEAST SQUARES PLANE AND LINE FITTER
B126	TEMPERATURE CORRECTION FOR BOMB CALORIMETRIC DATA
B127	TEMPERATURE CORRECTION FOR BOMB CALORIMETRIC DATA
B128	TEMPERATURE CORRECTION FOR BOMB CALORIMETRIC DATA
B129	PACER-A DIGITAL COMPUTER EXECUTIVE PROGRAM FOR PROCESS SIMULATION AND DESIGN
B130	X-RAY DIFFRACTION DATA REDUCTION PROGRAM
B131	FORMATION AND CONCENTRATION OF HEAVY ELEMENTS IN FAST REACTOR FUELS
B132	PREPARATION OF TABLES FOR LIQUID-LIQUID EXTRACTION PROBLEMS
B133	THERMODYNAMIC PROPERTIES OF A BIMETALLIC SYSTEM
B134	ARGUS(2)-TRANSIENT HEAT TRANSFER PROGRAM
B135	EXPONENTIAL FIT USING ANLE208
B136	CALCULATION OF SOURCE TERMS FOR USE IN RE34 (REACTOR SHIELDING)
B137	A MODIFICATION OF ANL FLS (LEAST SQUARES CRYSTALLOGRAPHIC PROGRAM) TO ACCOUNT FOR OVERLAPPED DATA
B138	DETERMINATION OF POINTS AT CENTER OF CUTTING TOOL
B139	LEAST SQUARES FIT OF LIQUID AND VAPOR DENSITIES VS. TEMPERATURE
B140	MONTE CARLO SIMULATION, COVARIANCE CALCULATION AND FITTING OF COUNTS OF PARTICLES IN A FLUIDIZED BED
B141	DESIGN OF 750-KEV ACCELERATING COLUMN
B142	MONTE CARLO SOLUTION OF A STOCHASTIC DIFFERENTIAL EQUATION
B143	MULTIPLE FOCUSSING OF BEAM IN STRAIGHT SECTIONS OF ZERO GRADIENT SYNCHROTRON
B144	CALCULATION OF DEFINITE INTEGRALS
B145	GENERATION OF DATA FOR CRYSTALLOGRAPHIC PROGRAMS MET153 AND/OR B114
B146	CALCULATION OF VIBRATION CONTRIBUTION TO THREE THERMODYNAMIC PROPERTIES
B147	DETERMINATION OF REVERSIBILITY OF ELECTROCHEMICAL REACTIONS
B148	RADIUS-RATIO TABLES FOR AB COMPOUNDS

- B149 TWO- AND THREE-DIMENSIONAL CRYSTALLOGRAPHIC FOURIER SUMMATION PROGRAM
- B150 DETERMINATION OF CRYSTAL LATTICE CONSTANTS
- B151 LEAST SQUARES DETERMINATION OF PARAMETERS COMMON TO TWO FUNCTIONAL FORMS
- B152 LEAST SQUARES DETERMINATION OF PARAMETERS COMMON TO TWO FUNCTIONAL FORMS
- B153 SPECIAL POLYNOMIAL EVALUATION
- B154 TABULATION OF VAPOR PRESSURE OF PLUTONIUM HEXAFLUORIDE
- B155 THEORETICAL NEUTRON CAPTURE CROSS SECTIONS
- B156 DETERMINATION OF RADIOISOTOPES BY LEAST SQUARES RESOLUTION OF GAMMA SPECTRA
- B157 LINEAR REGRESSION OF VAPOR PRESSURE
- B158 AN ASYMPTOTIC REGRESSION
- B159 TEMPERATURE CORRECTION FOR BOMB CALORIMETRIC DATA
- B160 METAL-WATER REACTION STUDY
- B161 TEMPERATURE CORRECTION FOR BOMB CALORIMETRIC DATA
- B162 CRYSTALLOGRAPHIC D-SPACE PROGRAM
- B163 FIT TO RESISTIVITY VERSUS NEUTRON DOSE
- B164 TABULATION OF MAGNETIC SUSCEPTIBILITY VERSUS TEMPERATURE
- B165 VAPOR PRESSURE OF CADMIUM AND ZINC
- B166 LEAST SQUARES FITTING OF RADIOACTIVE DECAY DATA
- B167 ASSOCIATION OF Z_n^{++} AND VACANCIES IN NaCl
- B168 RESISTANCE CORRECTION FOR BOMB CALORIMETRIC DATA
- B169 CHRONOPOTENTIOMETRIC DATA ANALYSIS
- B170 COMPUTATION OF REACTION AND DECAY CHAINS
- B171 ERROR ANALYSIS OF QUADRUPOLE LENS SYSTEMS
- B172 DEVELOPMENT OF FORMULAS FOR THE INVERSE OF THE ERROR FUNCTION
- B173 THE CALCULATION OF FLOW SHEETS FOR ENRICHED ALLOY FUEL REPROCESSING
- B174 THE CALCULATION OF FLOW SHEETS FOR ENRICHED ALLOY FUEL REPROCESSING

B175	THE CALCULATION OF FLOW SHEETS FOR A FLUID-BED FLUORIDE VOLATILITY PROCESS
B176	FLUID-BED REACTOR DATA ANALYSIS
B177	UO ₂ -UF ₆ PILOT PLANT DATA ANALYSIS
B178	A COURSE IN NUMERICAL METHODS
B179	FISCAL YEAR JOB CARD REVIEW
B180	VAPOR PRESSURE CALCULATIONS
B181	GENERAL LEAST SQUARES PROGRAM
B182	NITRIDATION OF TITANIUM
C100	HYDROLYSIS OF THORIUM
C101	AUERBACH OPTICAL MODEL CODE
C102	REPULSIVE SQUARE WELL CALCULATIONS
C103	EVALUATION OF A FUNCTION FOR MOSSBAUER EXPERIMENTS
C104	CONSTANT DIFFERENCE OF SPECTRUM LINES
C105	SPACINGS OF ENERGY LEVELS
C106	LEAST SQUARES DETERMINATION OF SLATER PARAMETERS FROM OPTICAL SPECTRA
C107	LEAST SQUARES FITTING OF EIGENVALUES TO EXPERIMENTAL VALUES (LRL)
C108	TERM ARRAY OF ATOMIC SPECTRAL LINES
C109	A LEAST SQUARE RATIONAL FIT
C110	CUMULANT FUNCTION DETERMINATION FOR SPECIFIED FORCE FUNCTIONS
C111	DETERMINATION OF THE SPIN HAMILTONIAN MATRIX
C112	CONSTANT DIFFERENCE OF SPECTRUM LINES
C113	NMR LINESHAPE
C114	RIEMANN ZETA FUNCTION
C115	ZEEMAN AND HYPERFINE TENSOR PROJECTIONS FOR PARAMAGNETIC RESONANCE SPECTRA
C116	RADIATION CHEMISTRY KINETICS CALCULATIONS
C117	STATISTICAL PROPERTIES OF THE F SUPER N MATRICES

C118	PROGRAM PROCESSOR
C119	LEAST SQUARES FIT TO A TRIGONOMETRIC FUNCTION
C120	NEUTRON SCATTERING AMPLITUDE OF FISSIONABLE ISOTOPES
C121	STATISTICAL CORRELATION OF F SUPER N EIGENVALUES
C122	MEASUREMENTS OF FAST REACTIONS IN RADIATION CHEMISTRY
C123	SPECIAL THERMOMETER CALIBRATION DOWN TO 0.3 DEGREE K
C124	EIGENSYSTEMS OF HERMITIAN MATRICES
C125	FERMI-DIRAC FUNCTION
C126	NUCLEAR MAGNETIC RESONANCE LINE SHAPE
C127	CALCULATION OF FAILURE RATES FOR STATISTICAL DISTRIBUTIONS
C128	RELATIVE X-SECTIONS OF NUCLEAR REACTION ISOMERS
C129	FITTING PARAMAGNETIC RESONANCE ABSORPTION SPECTRA
C130	CALCULATION OF CONFIDENCE INTERVALS
C131	ANALYSIS OF ELECTRON PARAMAGNETIC RESONANCE SPECTRA FOR ONE OR TWO NUCLEII
C132	DETERMINATION OF CRYSTAL LATTICE CONSTANTS
C133	CRYSTALLOGRAPHIC D-SPACE PROGRAM
C134	DOUBLE INTEGRATION OF MAGNETIC RESONANCE CURVES
C135	ELECTRIC-FIELD GRADIENT MATRIX CALCULATION
C136	ZONE MELTING COMPUTATIONS
C137	THERMAL ELECTRIC POWER OF QUENCHED METALS
C138	TRANSPORT INTEGRALS FOR PHONON DRAG RESISTIVITY
C139	CALCULATION OF $\sin^2\theta$ FROM POWDER PHOTOGRAPHS
C140	DIFFUSION TO FIXED SINKS
C141	CRYSTALLOGRAPHIC D-SPACE PROGRAM FOR THE CDC3600
H100	OPTICAL DESIGN FOR PROPOSED 12-FOOT BUBBLE CHAMBER
H101	MUSICIAN
H102	MASMER
H103	BUBBLE CHAMBER MAGNETIC FIELD CALCULATION (PURDUE)

H104	MASCOT
H105	MONTE CARLO GENERATION OF NEUTRAL DECAYS
H106	HYPERON PRODUCTION CROSS SECTIONS (STANFORD)
H107	NEUTRINO SPECTRUM IN THE ZERO GRADIENT SYNCHROTRON NEUTRINO FACILITY
H108	EVENT DRAWING FROM H105 OUTPUT DATA
H109	POWER SERIES AND LEGENDRE SERIES LEAST SQUARES FIT
H110	LOGLK
H111	SUM-X(UCRL)
H112	PRINTAPE
H113	TRANSLATE (CERN)
H114	VIEW
H115	REDUCTION OF LANDAU FLUCTUATION DATA
H116	LENS
H117	CAMERA FINDING
H118	ANALYTIC FIT TO REFLECTION FUNCTION
H119	PION PRODUCTION DISTRIBUTION FUNCTION
H120	DD80 OUTPUT FOR POLARIZED PROTON ANALYSIS
H121	SUMTAPE
H122	MAP
I100	DATA ACQUISITION AND/OR TIME-SHARING VIA REMOTE CONSOLE
I101	MONTE CARLO MODEL FOR 3600 OPERATIONS
P100	RESONANCE SCATTERING BY CAPTURE GAMMA RAYS
P101	SPECTRUM CORRECTION
P102	AUERBACH OPTICAL MODEL CODE
P103	CONVERSION AND REDUCTION OF RIDL CHANNEL ANALYZER DATA
P104	LEGENDRE POLYNOMIAL COEFFICIENTS FOR GEOMETRIES
P105	COMPUTATION OF MASS SPECTRAL FUNCTIONS
P106	CHARGED PARTICLE DATA REDUCTION PROGRAM FOR THE MULTICHANNEL ANALYZER

P107 LEAST SQUARES ANALYSIS OF GAMMA-SPECTRA

P108 PROCESSING OF RESONANCE SCATTERING DATA

P109 FLOOR OF HILBERT DOMAINS

P110 CALCULATION OF PROBABILITY DISTRIBUTION FROM BESSEL FUNCTIONS

P111 RADIUM RETENTION IN THE HUMAN BODY

P112 LINEAR COMBINATION OF SPECTRA

P113 ZEEMAN SPECTRAL FIT

P114 GRAPHICAL DATA REDUCTION ON THE ASI 2100

P115 ANALYSIS OF MULTIPLE EXPOSURE SMOKE PLUME NEGATIVES

P116 HYPERFINE STRUCTURE IN MESIC X-RAYS

P117 ATOMIC BEAM RESEARCH ON RADIOACTIVE ATOMS HYPERFINE F-9 (LRL-B)

P119 PARSING OF ARITHMETIC STATEMENTS

P120 ANALYSIS OF MAGNETIC SPECTROGRAPH DATA

P121 DISTRIBUTION OF ISOTOPIC ABUNDANCES FOR POLYATOMIC SYSTEMS

P122 LEAST SQUARES FIT OF EXPONENTIAL DECAY DATA

P123 FORSTER DECAY TIME INTEGRAL

P124 AUTO-CORRELATION AND POWER SPECTRUM COMPUTATION

P125 MEASUREMENT OF SMOKE PLUMES

P126 ATOMIC RESEARCH ON RADIOACTIVE ATOMS HYPERFINE 4-94 (LRL-B)

P127 TRANSFER MECHANISMS OF ELECTRONIC EXCITATION ENERGY

P128 LEAST SQUARES FIT OF SUM OF EXPONENTIALS

P129 8-DETECTOR DATA REDUCTION FOR THE VAN DE GRAAFF

P130 MATCHING OF SECTIONS OF FLOOR OF HILBERT DOMAINS

P131 AUTO-CORRELATION OF GAMMA RAY FREQUENCIES

P132 MEASUREMENT OF BONE SECTION RADIOGRAPHS

P133 AUTOMATIC SCANNING OF TRACKS IN NUCLEAR EMULSIONS

P134 MULTIPLE SCATTERING CORRECTIONS FOR NEUTRON SCATTERING IN THIN PLATES

P135 CALIBRATION OF AN ABSORPTION RECORDER

P136 POLYNOMIAL ROOT EVALUATION BY RESULTANT PROCEDURE NUMBER 2

P137 DATA CONVERSION FOR ABSORPTION RECORDER
The program request has been withdrawn.

P138 INVERSION OF OVERLAP MATRICES IN CRYSTALS

R100 05R (ORNL)

R101 RE129 (REACTOR KINETICS) FOR THE 3600

R102 RE138 AND RE171 FOR THE 3600 (INVERSE KINETICS)

R103 USE OF LASL ROUTINE H2P

R104 GAM-1 (GA)

R105 NEARREX

R106 THERMOS (BNL)

R107 PRESSURE CALCULATION IN Na LOOPS OF TREAT

R108 FREQUENCY RESPONSE CALCULATIONS

R109 PROCESSING AND PLOTTING REX FLUX OUTPUT

R110 COUPLED KINETICS HYDRODYNAMICS FOR FARET

R111 ACORN, AUTO-CORRELATION, CROSS-CORRELATION, NOISE REJECTION

R112 THE UNFOLDING PROBLEM OF DETECTION SYSTEM OUTPUT

R113 FREE CONVECTION HEAT TRANSFER OF ELECTRICALLY CONDUCTING FLUIDS

R114 MAGNETIC EFFECTS IN COMBINED FORCED AND FREE CONVECTION IN A
BOUNDARY LAYER FLOW

R115 NON-NORMAL MODE INPUT FOR THE ELMOE CODE

R116 PUNCHING OF DSN FLUX CARDS FOR 160A USE

R117 STABLE-3 HYDRAULIC FLOW STABILITY ANALYSIS (KAPL)

R118 WIGLE (WAPD)

R119 KINEMATICS OF TWO-BODY REACTIONS

R120 LEGENDREVILLE

R121 MUSCATONE

R122 REX

R123 KAGANOVE'S KINETICS

R124	RESONANCE INTEGRAL CALCULATION
R125	CALCULATION OF REDUCED VIRIAL COEFFICIENTS
R126	BRW-HYDRAULIC FLOW STABILITY IN BOILING WATER REACTORS
R127	REACTOR MELTDOWN STUDY
R128	GENERAL HEAT TRANSFER ANALYSIS
R129	DECAY HEAT LOAD VERSUS ENGINE SHUTDOWN
R130	HEAT TRANSFER AND FRICTION FACTOR SUBROUTINE
R131	AX-3600
R132	RECAP-2
R133	RECAP-3 (WAPD)
R134	LIQUID FILM GENERATOR ANALYSIS
R135	ADAP-ANALOG DATA PROCESSOR
R136	ELMOE FOR THE 3600
R137	SNARG
R138	NUMERICAL SOLUTION OF CERTAIN INTEGRAL EQUATIONS OF THE FIRST KIND
R139	DRIBIT
R140	XLIBIT
R141	EXTERMINATOR (ORNL)
R142	GAMMA SPECTRUM COMPUTATIONS
R143	CONVECTIVELY COOLED NOZZLE DESIGN
R144	STDY-36
R145	ORCO-ORTHONORMAL CONSTRUCTION
R146	TEMPERATURES IN AN ENERGY-GENERATING TUBE

PROGRAMMING RESEARCH AND DEVELOPMENT

Systems Programming

Programming support has been given in connection with the CONTROL DATA 3600 digital computer as Argonne's principal computation system and the CONTROL DATA 160-A and IBM 1401 as peripheral computers. Work carried out for these computer systems includes the following:

1. Maintenance and Modification of 3600 Programming Systems Supplied by Control Data Corporation (CDC).

Programming systems written by CDC and in full use include: SCOPE, an operating system; the 3600 FORTRAN compiler; an ALGOL compiler; and COMPASS, an assembly program. Each system is constantly being improved and corrected by the manufacturer through recommendations from the users as well as on its own accord. Argonne has made numerous contributions to help increase the efficiency and usefulness of these systems (see below).

As each new version of a system is released, various modifications for fitting it to local needs have been prepared, edited, and included. Extensive reliability testing is performed on every system before it is made available for production use.

To promote an organized approach in making local modifications, a programming systems (software) status committee has been formed. It has been the purpose of this committee to review the many submitted requests for software modifications (RSM) and to provide for the orderly disposal of each. In the past year 60 RSM's were reviewed: 18 were considered of general appeal and submitted to CDC, which has implemented 14 of them; 23 others have been implemented locally; 10 were rejected; and 9 have been deferred for later consideration. Effort in this direction is continuing except that the rate of changeover to newer versions is rapidly declining.

2. Disk File Acceptance Tests.

In November, 1964 a disk file unit (#828) and a disk file controller (#3632) were delivered for use with the CDC 3600/160-A satellited system. Because the acceptance of the disk file was to be based on its high reliability and performance it was necessary to subject it to an extensive set of programmed tests. The majority of diagnostic tests were written by Control Data and supplemented by four test programs prepared and programmed by Argonne. All tests were scheduled and run in late February, 1965 with moderate success.

3. Disk File Software.

Argonne is doing almost all its own systems programming for use of the disk file. Work has begun and is nearing completion for locally modifying the SCOPE operating system to utilize the disk in scheduling and handling the standard input/output functions of the 3600 system. The project of placing the entire systems library on the disk is also in its final stages. Programming systems for allowing general customer use of the disk file are under way and will be provided.

4. Cathode Ray Tube (CRT) Display System

Programs have been developed for use of the CRT display unit (DD80A) and camera recorder associated with the 3600 system. This configuration gives users a conveniently flexible and rapid procedure for recording graphical and tabular data.

5. Remote Station Typewriter

A program-controlled input/output typewriter (3692) has been attached to the 3600 system via a data channel (3606). This device may be used to perform basic read and write operations on alphanumeric data. Appropriate programming to handle these functions has been inserted into the SCOPE operating system. The momentary interrupt switch gives the user a convenient means of interrupting his running program and communicating with it. He might divert processing from its normal flow and experiment with other algorithms programmed into his system, or perhaps make external adjustments to parameters while computation is in progress.

6. Microwave Data Link to the High Energy Physics Building

The microwave link for high-speed transmission of data between the High Energy Physics (HEP) and Applied Mathematics (AMD) Buildings is currently operated five days a week. Each station consists of: a) a CDC 160-A with access to magnetic tape drives, b) a CDC 8528 Digital Communications Terminal, and c) a Motorola MR20 Frequency-modulated Transceiver.

Programming to facilitate use of the link in conjunction with other input/output devices has been incorporated into the Standard Peripheral Processor, a comprehensive 160-A software package. The Processor allows tape-to-tape transmission in either direction and also tape (in AMD) to printer (in HEP) transmission.

Each 160-A data word transmitted is sent twice for error checking. If errors occur during transmission, the Processor calls for re-transmission of the current block of data, but no record is kept of this event.

7. PHYLIS (Physics On-line Information Station)

A data link from an ASI-2100 computer in the Physics Building to the CDC 3600 provides access on a real-time interrupt basis to users of the 4.5 MEV Van de Graaff and 12 MEV Tandem Van de Graaff accelerators.

Programming for handling these real-time interrupts represents the largest single modification made to the SCOPE monitor. The system has had thorough check-out and been declared fully operational. Actual implementation awaits the delivery of SCOPE version 6.1.

Numerical Methods

The project to certify the systems library of function subroutines for the CONTROL DATA 3600 is nearing completion. All of the single-precision real and complex variable, and most of the double-precision function routines provided by Control Data Corporation have been tested. As a result of these tests four CDC routines (TANF, ATANF, SIN, and EXPF) were modified and an additional six (RANF, LOGF, CLQG, POWRF, CSIN, CUBERTF) were replaced by routines written at Argonne.

One of the major additions to the 3600 subroutine library was a package to do triple-precision (~ 40 decimal places) floating point arithmetic in a manner completely compatible with the TYPE OTHER feature of the FORTRAN compiler. Use of the package requires only appropriate declaration of variables in a FORTRAN program. Work on a companion input/output package has also been started.

Additional contributions to the subroutine library include routines for the complete elliptic integrals K and E, for the error and complementary error functions, and for Romberg and Havie quadrature. Work has started on routines for the Coulomb wave functions, the log of the gamma function, and the solution of systems of ordinary differential equations.

Research efforts have been directed at finding new function approximations and new methods for computing functions. Most of the subroutines mentioned above are based on rational Chebyshev approximations generated by Argonne codes for the second Remes algorithm. A continuing project has already produced many new approximations for the Fermi-Dirac integrals. The work on the Coulomb wave functions includes the derivation of some new generating functions of confluent hypergeometric functions.

Automatic Theorem Proving

A study has been conducted of the efficiency of the set of support strategy, a strategy developed at Argonne and described in the last Summary Report. As a result of attempts to find proofs of various mathematical theorems automatically, it was determined that this strategy vastly improved the efficiency of automatic theorem proving. It was established that there are theorems which appear to be beyond a 65,000-word memory without the strategy but which are easily provable with it.

Since one of the long-term goals of a theorem-proving program is its use by the mathematician, it is desirable to obtain proofs by use of the computer in the language corresponding to the mathematical problem under consideration. The program PGI works in the language of first-order predicate calculus. A proof, if obtained, is given in that language. A program was developed and implemented for the CONTROL DATA 3600 to take the proof from PGI and translate it into the appropriate mathematical language.

An important and promising additional strategy has been partially formulated. This strategy is imposed on the already existing structure, with the goal of significantly improving the power and efficiency of the

SEARCH procedure. A portion of this strategy has been implemented on the 3600, and a preliminary study of its effect is under way. Preliminary evidence indicates a sharp reduction in memory requirement because of the strategy.

New Library Routines

CONTROL DATA 3600

ANL A150	FAIRY	D. Jordan	Prime factor arithmetic
ANL A151		W. Cody	Triple precision arithmetic package subroutine
ANL B050	DABSF	W. Cody	Function subroutine to find the absolute value of a double-precision number
ANL B151	TANF,COTF	W. Cody	Evaluates the tangent or cotangent of a floating point argument X
ANL B152	ATANF	K. Hillstrom	3600 FORTRAN routine for the arctangent
ANL B153	SINF,COSF	K. Hillstrom	3600 FORTRAN systems routine for the sine and cosine
ANL B154	ATØX	K. Hillstrom	3600 FORTRAN routine for the (arctangent of x) over x
ANL B250	ATHØX	K. Hillstrom	3600 FORTRAN routine for the (hyperbolic arctangent of x) over x
ANL B350	LØGF	N. Clark	3600 FORTRAN systems routine for the natural logarithm
ANL B351	EXPF	N. Clark	3600 FORTRAN systems routine for the exponential function
ANL B352	CLØG	N. Clark	3600 systems complex logarithm routine
ANL B454	CUBERØØT	W. Cody	3600 FORTRAN systems routine for the cube root
ANL B455	PØWRF	N. Clark	3600 FORTRAN systems power function routine
ANL C351	BESSEL	L. Shalla	3600 FORTRAN routine for Bessel functions $J, Y, e^{-X}I, e^{X}K$
ANL C352	GAMIN	E. Thieleker	Single precision incomplete gamma function

ANL C353	CLEBSH	D. Jordan	3600 package for computation of angular momentum coefficients. The labels of the routines included are CLEBSH, RACAH, TRIANG, XPIF, ZBAR, and WIG9J
ANL C354	ELLIPK	K. Hillstrom	Complete elliptic integral K floating point routine
ANL C355	ELLIPE	K. Hillstrom	Complete elliptic integral E floating point routine
ANL C356	GAM LONG	E. Thieleker	Single precision gamma function
ANL C357	ERF	W. Cody	3600 FORTRAN compatible routine for the error function
ANL D150	HAVIE	K. Hillstrom	3600 FORTRAN library routine for Havie integration
ANL D151	ROMBERG	K. Hillstrom	3600 FORTRAN library routine for Romberg integration
ANL F150		D. Mueller	Package of routines to perform the Householder reduction on complex matrices and to calculate eigen-systems for hermitian matrices
ANL F151	AIP	S. Crick	Accumulative inner product for use by ALGOL programs
ANL F450	LINEARSYSTEM	S. Crick	Crout with equilibration and iteration
ANL G550	RANF	N. Clark	To produce a uniformly distributed sequence of random numbers
ANL J950	LØGAX	C. Cohn	Logarithmic axis plotter
ANL J951	LINAX	C. Cohn	Linear axis plotter
ANL N250	TROUBLE	D. Brooks	A snapshot dump routine
ANL Ø050	SYMGR	R. Krupp	PHYLIS link simulator
ANL Q050	TIMEF	J. Ohde	Time and date subroutine

Abstracts of 3600 Newsletters

The 3600 NEWSLETTER, published at irregular intervals, contains current information and news of interest to users of the CDC 3600 and its related equipment.

3600 NEWSLETTER No. 14

7/2/64

Correction to CDC publication (Pub. No. 60081600), ALGOL for the 3600, June, 1964.

3600 NEWSLETTER No. 15

7/2/64

Revisions and modifications to the 3600 FORTRAN compiler and library routines announced.

3600 NEWSLETTER No. 16

7/16/64

New format for SCOPE JOB control card announced and described.

3600 NEWSLETTER No. 17

7/24/64

The supervising, maintaining, cataloging, and distributing of AMD Program Library materials described.

Appendix I: the procedure for submitting programs to the AMD Program Library.

Appendix II: the suggested format for program writeups.

Appendix III: outline of the classification scheme used for cataloging programs.

3600 NEWSLETTER No. 18

9/17/64

Description given for modifications and corrections made to programming systems designated SCOPE 5.1, ALGOL 1.0, FORTRAN 4.1, and SORT 1.0.

The systems tape which contains these systems was assigned No. PRD 10-12.

3600 NEWSLETTER No. 19

10/16/64

Certain restrictions regarding TYPE OTHER Q1Q subroutines explained.

Availability of a new random number generator routine, RANF, announced.

Current status of the manuals stock and program library materials listed.

3600 NEWSLETTER No. 20

10/17/64

Description given for hardware modification to the 3600 which changes the I/O Illegal Instruction Flip-Flop into the Monitor Protection Flip-Flop.

3600 NEWSLETTER No. 21

11/3/64

Description given for modifications and corrections included in the release of Systems Tape PRD 10-13, and in particular those systems designated SCOPE 5.1, ALGOL 1.0, FORTRAN 4.2, and SORT 1.0.

3600 NEWSLETTER No. 22

2/9/65

Further clarification given concerning the engineering changes to the CDC 3600 announced in NEWSLETTER No. 20.

3600 NEWSLETTER No. 23

3/5/65

Release of Systems Tape PRD 10-14 announced; modifications and corrections contained in system versions SCOPE 5.4, FORTRAN 4.3, COMPASS 4.1, ALGOL 1.1, and SORT 2.0 given.

3600 NEWSLETTER No. 24

4/29/65

Description given for equipment configuration and communication programs available for using the CDC 3600 on-line to the PHYLIS system.

3600 NEWSLETTER No. 25

5/20/65

Changes for implementing the new system versions SCOPE 6.0, FORTRAN 5.0, COMPASS 5.0, ALGOL 1.2, and SORT 2.0 described.

COMPUTER ENGINEERING AND COMPUTER SYSTEMS

PAULETTE

Subsequent to feasibility studies on a high-resolution image dissector tube, PAULETTE has entered the development stage. PAULETTE is a computer-controlled device designed to count tracks made by sub-atomic particles in a fine grain photo-emulsion. Tracks, whose position and density indicate the energy distribution, average approximately 1 to 2 microns in width. They are present in large quantities in the emulsion, which is on the surface of a 2-inch by 10-inch plate of glass. An area of the emulsion is enlarged onto the image dissector tube, which then performs a digitally synchronized scan. Since the tracks are much longer than they are wide, multiple scans must be performed to determine the length. Each time the scan detects information of the approximate width of a track, the digital coordinate is transferred into the computer, where a list of coordinates is made for each scan. The computer correlates successive lists and keeps a running count of the number of occurrences of the information. If the information meets the length requirements, it is designated a track, and is added to the total for that particular segment of the 10-inch dimension. A typical segment of lineal distance would be $1/4$ millimeter, and might contain several thousand tracks.

The digital computer used to control PAULETTE will be a PDP-7; it will initiate the scans and correlate the lists. It will also be used to control the precision plate transport to be constructed. It is expected that PAULETTE will accurately "count" a plate in about one hour, whereas present human counting may take a whole week.

Hybrid Computing System

The essential components of a hybrid computing system put into operation this year are two Pace analog computer consoles, a Digital Equipment Corporation PDP-7 digital computer, and an interconnecting link. Two Reeves high-speed analog consoles are soon to be added to the configuration.

The hybrid link provides:

- a) Ten simultaneous sample and hold circuits with a multiplexer and an analog-to-digital converter.
- b) Ten digital-to-analog converters.
- c) Ability to slave analog to reset, hold, and operate functions.
- d) Special control functions (interrupts, control toggles, clock controls, etc.).

Such an interconnected system provides logical program control by the digital computer of the analog computer, and digital simulation of dynamic variables. It adds the capability of precise numerical integration to the analog computer, and otherwise lends itself well to the study of dynamic systems where both discrete and continuous data are involved.

LAURA

Development continues on LAURA (Laser Activated Ultra-Precision Ranging Apparatus), a manual-type measuring table for high energy physics bubble chamber photographs. This table replaces the conventional-type wires connecting cross-hair indicator and shaft encoder, with a beam of coherent light from a HeNe gas laser. The beam of light is emitted from the laser, which is firmly fixed with respect to the table. The light is reflected out onto the measuring surface by a mirror on a movable shaft. The light is then incident upon a cylindrical mirror which surrounds the indicator cross-hairs. This mirror spreads the beam and returns it along the same emission path to a beam splitter. Two photomultipliers are used beyond the beam splitter to obtain a voltage which is proportional to the difference of the split beam intensities. This voltage is used as the error signal to control a servo-system applying torque to the movable shaft so that the split beams are in constant balance. The shaft angle (as read by a high-precision brushless encoder) together with a second angle will provide the position of the cross-hairs to within the desired measuring accuracy. It is expected that LAURA will provide precision measurement capabilities over measurement areas substantially increased from that of conventional tables. LAURA is being interfaced to an ASI-210 computer, which in turn will solve the optical triangle.

Integrated Circuit System Design

A continuing study program in the area of integrated circuitry has been initiated. It involves (1) evaluation of single units, including determination of the reliability of integrated circuit sockets and welded nickel wire interconnections, and (2) design and fabrication of test units to ascertain operational times for various logical functions. Potential applications are in data transmission terminals, in the control logic between experimenter and computer, and as an integral part of a small, special-purpose computer system.

Variable Time Modulation for Data Transmission

It is desirable to use that form of modulation or coding for data transmission which will allow maximum transmission without exceeding the bandwidth of the medium used. In the figure are examples of three types of modulation and the period of time required for transmission in each of a six-bit word. Example A is phase modulation, which carries its own timing and does not require a clock at the receiving end. The other two examples do require a clock at the receiving end to be synchronized with a sending clock. All three examples have their maximum frequency component set at the bandwidth.

Example A requires twice the transmission time of B because it carries its own timing along with the data; if data rate were no problem, A would probably be the best choice of the three.

Examples B and C both require synchronized transmission but the proposed Example C requires less time on the average for a word to be transmitted. Coding for Example C is as follows. Since the first bit in the word is a "one," a positive voltage is applied for 1/2 cycle. Since the second bit is a zero, a negative voltage is applied; and since the third bit is also a zero requiring no change in polarity, we will allow only 1/3 the full cycle time for this bit. The same time is allotted to all bits that follow if there is no polarity change. Transmission time is less (by 1/3, on the average) because the time allotted to the second and all following bits, until the polarity changes, is only 1/3 the normal bit time. It is planned to build equipment to test this idea.

COMPUTER UTILIZATION IN DIVISIONAL RESEARCH

Applications of the CHLOE System

The automatic film scanning system CHLOE has now been used for several different applications. Most of these have used the ASI-210 CHLOE Liberator or BIM 117 programs to produce data on magnetic tape in a convenient form for use in subsequent processing. The CHLOE hardware digitizes points on the boundaries of exposed areas of the film. The Liberator collates the data on specific objects and provides macroscopic parameters. For example, in a spark chamber photograph, it provides the co-ordinates of fiducials and the centroid and width of each spark.

Approximately one thousand pictures have been measured in an experiment to determine the helicity of electrons in μ -decay. A total of some 125,000 pictures must finally be measured. The measured data have been satisfactorily processed by a reconstruction program, where they were fitted to straight lines. The fit made to CHLOE measurements was found to be five times as good as the fit to manually produced measurements. The measurements of each picture on the CHLOE system takes about six seconds.

Two hundred and fifty pictures have been measured in an experiment on K-decays which altogether involves 100,000 pictures. Subsequent analysis will utilize many of the techniques used in a system known as AROMA-AIRWICK.

A few complex spark chamber events involving associated production in a magnetic field have also been measured. These events have been processed by the AROMA-AIRWICK system on a CONTROL DATA 3600, which processes the raw digitizations from the film, identifies fiducials and sparks, reconstructs the sparks in space, associates them into tracks, and yields the momenta and direction of the particles. The AIRWICK output has been processed by the kinematics program, GRIND.

Bubble density measurements have been made from enlargements of bubble chamber film and reliable results have now been obtained for 300 tracks.

CHLOE has also been used to measure photographs of oscilloscope traces made in experiments on reaction kinematics. About 100 photographs a week are now being measured by the Liberator and analyzed satisfactorily.

Exploratory work is also going on in such diverse areas as fingerprint identification, bone radiological photographs, optic nerve signals, galactic shapes, and microscopic particle counting.

The BIM 117 program was developed in this latter connection for use in the automatic classification of chromosomes. Analysis is accomplished by programs on the IBM-704 and GUS machines to "recognize" and reconstruct chromosomes from fragments, and to classify them formally by preparing a machine "karyotype."

Another scanning and measuring system, POLLY, is now being planned. It will utilize a PDP-7 as its control computer and will feature a scanning stability at least four times better than CHLOE, and a high-speed minor scanning system superimposed on a coarse but precise center-positioning system. It is being designed with the facility of a human operator to assist the computer with the pattern recognition problems on the film being scanned and/or measured.

Solution of Polynomial Equations

In 1957 the concept of "Resultant Procedures" was conceived. The corresponding code for the IBM-704 proved very successful and has not necessitated any changes in the past seven years. With the acquisition by the Applied Mathematics Division of a CONTROL DATA 3600, however, it was felt the code should be rewritten and possibly improved. Based on the performance of the "1957 Resultant Procedure," it was felt that a less conservative approach could be tolerated, and therefore an even faster code designed. This was indeed accomplished by the RSSR routine (Root-Squaring and Subresultant Routine). The idea was to make the code very fast for frequently encountered distributions of the zeros of polynomials as they occurred in the past, and not to worry too much over other types (such as multiple complex zeros) as long as the routine ultimately was able to obtain them all. With the 3600 Fortran Code RSSR, the total time requirement for the solution and the reconstruction from its linear factors of a polynomial of degree 10 is usually less than one second. The code for the CDC 3600 is to be issued as ANL-6987.

COGENT Compiler

The COGENT (Compiler and GENeralized Translator) programming system is a compiler whose input language is designed for the description of symbol manipulation and translation algorithms. The system has been tested and can now be used on the CONTROL DATA 3600, i.e., it is a program which runs on the 3600 and compiles its input language into 3600 assembly language.

The class of symbol-manipulating programs which may be described concisely in the COGENT language includes compilers, so that the COGENT system may be used to compile other compilers. This capability was used in producing the system itself: an initial version of the system was written in the COGENT input language and then hand-translated into assembly language. This hand-translated version was then used to produce a machine-translated version. When applied to a variety of test programs, the hand-translated and machine-translated versions compiled identical object programs.

An improved version of the compiler was then written in the COGENT language and compiled using the initial version. This improved version operates three times as fast as the original version and produces more efficient object code; when it was used to compile itself, the improved version required 35 minutes to compile 1,500 card images of COGENT input language into 28,000 card images of assembly language. Further improvements are expected to increase this speed by at least a factor of two.

In addition to the compilation of compilers, the COGENT system is applicable to such fields as algebraic manipulation, mechanical theorem-proving, and heuristic programming. At present, however, only test programs in these areas, such as a symbolic differentiation program have actually been completed and run.

Conceptually, COGENT is an attempt to unify the concepts of syntax-directed compilation and recursive list processing. This unification is achieved by using a description of the syntax of the input and output languages processed by a COGENT program to determine a natural mapping of phrases of these languages into list structures, which are used to represent these phrases internally. Thus the COGENT language is actually a list-processing language which retains the generality of such languages as LISP or IPL-V, but provides greater conciseness for the case where the lists being processed represent linguistic phrases.

Error Control in Solving Differential Equations

In the numerical solution of ordinary differential equations, choice of integration increment, or stepsize, is a most important consideration. Too big a step, and the truncation error of the numerical approximation will exceed the desired accuracy. Too small, and computing time will be wasted; in addition, roundoff error may build up in the calculations to unwanted proportions. Furthermore a fixed stepsize is often inappropriate because truncation error for a given approximation scheme varies with the solution function and its derivatives. The question of how to vary the stepsize over the integration interval so as to give a prescribed overall accuracy in the fewest steps has recently been studied, with the following results:

One determination of stepsize consists in adjusting increments so that each step contributes the same amount to the accumulated truncation error. With this possibly optimal choice have been compared stepsizes which are constant, which attempt to preserve significant digits by yielding constant relative error, and which are "natural" in that new errors at successive steps are approximately the same.

Conditions under which several of these stepsizes are equal have been investigated. Also, in an example, the effect of arbitrarily assigning initial stepsize is illustrated.

The ultimate goal of such work is the creation of computer integration programs which can automatically monitor their own accuracy.

Machine Learning

A checker playing program in the list-processing language IPL-V has been written for the purpose of studying programming methods used in constructing decision-making programs and as a benchmark for testing the IPL-VC computer system, a system for processing IPL-V statements directly or by the use of basic subroutines. The complexity of the decisions involved precludes use of ordinary digital machine and programming languages.

In the checker play, a strategy consists in constructing future game positions, evaluating these according to some set of checker principles and deciding on a course of play as a result of this evaluation. List processing organization is natural for constructing future positions as well as for modifying the strategy by altering the principles applied and the manner of application.

Experience gained in play between the program and human opponents has enabled the development of a program which has played as well as an average checker club player, as rated by a checker master. It is of interest that promising evaluation of alternate moves has evolved, even though checker experts have difficulty explaining their skill except in qualitative terms or from experience with known sequences of moves.

Construction and use of the program have provided valuable experience in the IPL-V language.

Design of Ducts for Steady Supersonic Gas Flow

The designers of supersonic jet engines and of rocket nozzles have a common problem — the shaping of ducts to carry gas travelling steadily at a speed greater than that of the sound waves in it. If the walls of a duct carrying such a flow (supersonic flow) contain sudden bends then the gas may exhibit aerodynamic shocks. Across a shock the gas changes direction, velocity, pressure, and density within a very short distance. A quite general computer program to solve the equations representing the flow patterns is evolving at Argonne.

Knowledge of these flow patterns within projected ducts enables the designer to optimize his design. Such information can be obtained in the case of ducts of rectangular cross section from wind tunnel experiments and, when the number of shocks present is small, from fairly straightforward calculations. When a duct has circular or annular cross section, however, wind tunnel techniques are less valuable and calculations are very much more complex.

The current project involves the development of a computer program which will yield flow patterns containing a large number of shocks in and issuing from ducts with rectangular, circular, or annular cross section. The computer program under development will deal with ducts in which shocks may be adequately considered as instantaneous changes in direction, velocity, pressure, and density of a gas which is not viscous and does not conduct heat.

To aid the designer, the program will accept definition of the duct not only as a specification of the position of the walls but as the specification of a desirable velocity, pressure or density distribution on these walls. In this case the program will, in the course of obtaining the flow pattern, give the shape of the duct which has the requested distributions on its walls.

Simultaneous Classification Problems

A statistical theory for selecting a procedure when one is confronted with a number of identical classification problems has been developed; it takes advantage of estimating the global picture based on "past experience" if the problems arise sequentially and of "concurrent experience" if the problems arise simultaneously. Such problems occur in certain classification problems connected with pattern recognition and also in signal detection over noisy channels. The work in this line is based on approximating certain procedures which are optimal if the "full global picture" is known completely and exactly.

One of the main drawbacks to the above theory is that one must have exact knowledge of the statistical behavior in the various classes, and this may be hard to arrive at in practice. However, current work indicates that this drawback can be eliminated if the "past history" is known completely. It is believed that this last approach is a quite realizable method of attacking the mechanical pattern recognition problem.

Reactor Diffusion Equation Analysis

Mathematical tools capable of analyzing fast reactor physics systems are now being developed. A fundamental tool used in this work is multi-group, diffusion theory approximation for describing the neutron density in a reactor. Successful and rapid solution of the resulting equations enables engineers and physicists to design better nuclear reactors at lower cost. These diffusion equations form a system of coupled partial differential equations which, in order to effect a solution, are approximated by means of finite-difference equations and then solved by means of iterative methods on which various acceleration techniques are imposed. The work consists of the study, development, and implementation of such acceleration techniques. In addition the numerical codes developed to achieve the solution are to be versatile enough to handle various geometries, adjoint and perturbation calculations, as well as various boundary conditions.

Stochastic Problems in the Theory of Multiple Scattering

In many of the problems of radiative transfer and transport theory the change of state of a scattered particle depends on the angle through which it is scattered as a result of a collision. It is therefore of interest to know, for a particle transmitted through a slab of scattering material, the distribution of the number of collisions in which the angle of deflection of the particle belongs to some specified subset of the space $[0, \pi]$ of possible angular deflections.

In order to study this distribution a discrete model, developed by P. J. Brockwell, has been used. In it the set of directions of motion $\{a_1, a_2, \dots, a_m\}$ of the particle and the set of possible angular deflections $\{\theta_1, \theta_2, \dots, \theta_n\}$ each constitute a finite set. The backward Kolmogorov equations for this discrete process give rise to systems of ordinary linear differential equations for the moments of the joint distribution of the number of deflections through angles $\theta_1, \dots, \theta_n$ for given incident and emergent directions of motion.

Computer programs using sets of 30 and 120 directions are being developed to determine, for any given constant differential cross-section, the emergent angular distribution of particles for each possible incident direction of motion. If N_j denotes the (random) number of deflections through angle θ_j experienced by a particle which is scattered by the slab, then the mean and variance of an arbitrary real linear combination of the numbers N_j is also determined for any given incident and emergent directions.

The programs have been used in particular to investigate the spectral distribution of low energy gamma radiation transmitted through slabs of finite thickness.

Decomposition of Stationary Isotropic Transport Operator

A recent step toward better handling of the general linearized problem for the transport equation was the successful decomposition of the stationary isotropic transport operator in three space dimensions. The method of separation of variables led to continuous sets of regular and generalized eigenfunctions. Since the operator is not self-adjoint, an intuitive generalization of the known situation of plane geometry would have been inadequate. In order to find the generalized eigenfunctions it was necessary to evaluate and analyze a particularly bothersome improper integral. Results may indicate a new approach to spectral theory.

PUBLICATIONS AND PAPERS

Publications

- 1) D. V. Gopinath(1), C. E. Dickerman(1), and L. Bryant, Calculations on Coherence of Failure in Hypothetical Meltdown Accidents in an EBR-II-Like Reactor, Trans. Amer. Nucl. Soc., Vol. 7, No. 1 (June 1964).
- 2) Louis C. Just and Nye F. Morehouse, Jr., The Simulation of Large Transients in Neutron Reactors, SIMULATION 3, No. 1, 11-14 (July 1964).
- 3) W. F. Miller, M. A. Fisherkeller, and K. E. Hillstrom, The PHYLIS Executive Program, Proc. European-American Nuclear Data Committee Conference on the Automatic Acquisition and Reduction of Nuclear Data, Karlsruhe, Germany, July 13-16, 1964. Ed. K. H. Beckurts, W. Glaser, and G. Kruger. Gesellschaft für Kernforschung, Karlsruhe, 1964, pp. 475-482.
- 4) R. Vonderohe and D. Gemmell(2), A Description of the PHYLIS On-Line Computing System, Proc. European-American Nuclear Data Committee Conference on the Automatic Acquisition and Reduction of Nuclear Data, Karlsruhe, Germany, July 13-16, 1964. Ed. K. H. Beckurts, W. Glaser, and G. Kruger. Gesellschaft für Kernforschung, Karlsruhe, 1964, pp. 156-163.
- 5) W. F. Miller, J. W. Meadows(1), J. F. Whalen(1), and A. B. Smith(1), On-Line Data Acquisition and Feedback to Accelerator Control: A Status Report, Proc. European-American Nuclear Data Committee Conf. on the Automatic Acquisition and Reduction of Nuclear Data, Karlsruhe, Germany, July 13-16, 1964. Ed. K. H. Beckurts, W. Glaser, and G. Kruger. Gesellschaft für Kernforschung, Karlsruhe, 1964, pp. 222-232.
- 6) W. F. Miller, General Survey: Status and Immediate Future of Computer Development for Nuclear Physics Applications, Proc. European-American Nuclear Data Committee Conf. on the Automatic Acquisition and Reduction of Nuclear Data, Karlsruhe, Germany, July 13-16, 1964. Ed. K. H. Beckurts, W. Glaser, and G. Kruger. Gesellschaft für Kernforschung, Karlsruhe, 1964, p. 41.
- 7) J. Span(3) and M. Ribaric, On the Self-Diffusion of Ions in Ion Exchange Resins, J. Chem. Phys. 41, 2347-2350 (October 1964).
- 8) W. J. Cody, Double-Precision Square Root for the CDC-3600, Comm. of the ACM, Vol. 7, No. 12, 715-718 (December 1964).
- 9) David Jacobsohn, Comments on "A Suggestion for a Fast Multiplier," IEEE Trans. (Letter to the Editor) EC-13 (6) 754 (December 1964).
- 10) J. R. Van Ryzin, Asymptotic Solution of the Compound Decision Problem with $m \times n$ Finite Loss Matrix, Ann. Math. Stat. 35 (4) 1847 (Abstract) (December 1964).
- 11) Harold Greenspan, Representative Digital Computer Codes for Space-Independent Reactor Kinetics, Appendix I to "General Reactor Dynamics." Vol. 1: Reactor Physics and Control. The Technology of Nuclear Reactor Safety. The MIT Press, pp. 201-204 (1964).

- 12) M. Ribarić, The Relation Between the Reflection Properties of the Body and the Reflection Properties of Its Parts II, Arch. Rat. Mech. Anal. 16 (3), pp. 190-213 (1964).
- 13) George J. Mitsis, On the Transport Equation in Plane Geometry, Nucl. Sci. & Eng. (Letter to the Editor) 19, 461-474 (1964).
- 14) John R. Van Ryzin and J. F. Hannan(4), On the Compound Testing Problem for Two Specified Distributions, Ann. Math. Stat. 35(4) 1836 (Abstract) (1964).
- 15) J. W. Butler, Agnes Stroud(5), and Margaret K. Butler, Automatic Classification of Chromosomes, Proc. Conf. on Data Acquisition and Processing in Biology and Medicine, Rochester, New York, 1963. Pergamon Press, Oxford, Vol. 3, pp. 261-275 (1964).
- 16) Richard J. Royston, The Resolution Function of a Two-Rotor Neutron Velocity Selector, Nucl. Instr. & Methods, 30, pp. 184-202 (1964).
- 17) J. E. Moyal, Multiplicative Population Processes, Jour. Appl. Probability, 1, pp. 267-283 (1964).
- 18) Lawrence Wos, Daniel Carson, and George Robinson, The Unit Preference Strategy in Theorem Proving, AFIPS Conference Proceedings Vol. 26, 1964 Fall Joint Computer Conference, pp. 615-621.
- 19) W. J. Cody, Chebyshev Approximations for the Complete Elliptic Integrals K and E, Mathematics of Computation, Vol. 19 (89), pp. 105-112 (January 1965).
- 20) J. H. Doede(6), R. H. Vonderohe, N. Holongak(7), C. J. Nuese(7), and C. M. Wolfes(7), Fast Neutron Irradiation Effects on GaAs_{1-x}P_x Diode Laser Threshold Currents, Z. Angew. Math. Phys 16(1), 99-100 (January 1965).
- 21) M. Donald MacLaren, Nearly Modular Orthocomplemented Lattices, Trans. Am. Math. Soc., pp. 401-416 (January 1965).
- 22) Walter Gautschi, Certification of Algorithm 236 [Bessel Functions of the First Kind], Comm. ACM, Vol. 8, No. 2, pp. 105-106 (February 1965).
- 23) J. Van Ryzin, The Sequential Compound Decision Problem with m x n Loss Matrix, Ann. Math. Stat. 36 (1), pp. 362-363 (Abstract) (February 1965).
- 24) Y. Ikebe, A Note on Triple-Precision Floating-Point Arithmetic with 132-Bit Numbers, Comm. ACM, Vol. 8, No. 3, pp. 175-177 (March 1965).
- 25) D. Woodward, Continuous Transformations and Stochastic Differential Equations, Trans. Am. Math. Soc., Vol. 115 (3), pp. 76-82 (March 1965).
- 26) P. J. Brockwell, Generalized One-Dimensional Scattering Processes with Applications in Three Dimensions, Nuovo Cimento, Vol. 36, No. 2, pp. 370-384 (March 1965).
- 27) J. W. Butler, Automation of Experimental Science, Journal of Data Management, 3, No. 3, pp. 32-39 (March 1965).

- 28) W. J. Cody, Chebyshev Polynomial Expansions of Complete Elliptic Integrals, Mathematics of Computation, Vol. 19 (90) pp. 249-259 (April 1965).
- 29) J. Van Ryzin, Repetitive Play in Finite Statistical Games with Unknown Distributions, Ann. Math. Stat. 36 (3) pp. 729-730 (Abstract) (April 1965).
- 30) Richard King, A Faster Double-Precision Square Root for the Control Data 3600, Comm. ACM., Vol. 8, No. 4, p. 202 (Letter to the Editor) (April 1965).
- 31) L. Fosdick, Approximation of a Class of Wiener Integrals, Mathematics of Computation, Vol. 19, No. 90, pp. 225-233 (April 1965).
- 32) Robert Hermann, Compactification of Minkowski Space, J. Math. Phys. 6, pp. 817-819 (May 1965).
- 33) L. Bryant and R. M. J. Cotterill(8), Vacancy Clustering During the Quenching of a "Typical" Noble Metal, Bull. Am. Phys. Soc. 10, p. 581 (Abstract) (June 1965).
- 34) Calvin H. Wilcox, Uniform Asymptotic Estimates for Wave Packets in the Quantum Theory of Scattering, J. Math. Phys. 6, p. 611 (1965).
- 35) Robert K. Clark, List Processing Techniques in the Automatic Analysis of Spark Chamber Data, Proc. Conf. on Programming for Flying Spot Devices, Bologna, Italy, 1964. CERN Report 65-11, Geneva, pp. 15-24 (1965).
- 36) R. J. Royston, J. Butler and P. Pennock, A Program for Calibrating the Flying Spot Cathode Ray Tube for CHLOE, Proc. Conf. on Programming for Flying Spot Devices, Bologna, Italy, 1964. CERN Report 65-11, Geneva, pp. 43-54 (1965).
- 37) J. W. Butler, M. K. Butler, and A. Stroud(5), Automatic Classification of Chromosomes II, Proc. Conf. on Data Acquisition and Processing in Biology and Medicine, Rochester, N.Y., 1964. Pergamon Press, Oxford (1965) (in press).
- 38) G. K. Leaf, An Approximation Theorem for a Class of Operators, Proc. of AMS (in press).
- 39) J. E. Moyal, Incomplete Discontinuous Markov Processes, Jour. Appl. Probability (1965) (in press).
- 40) H. Greenspan, W. Hafner, and M. Ribarić, On Varying Stepsize in Numerical Integration of First Order Differential Equations, Numerische Math. (in press).
- 41) Erwin H. Bareiss, A Spectral Theory for the Stationary Transport Operator in Slab Geometry, Jour. Math. Anal. & Appl. (in press).

- 42) Robert Clark and W. F. Miller, Computer Based Data Analysis Systems, Methods in Computational Physics, Vol. 5, Academic Press, New York (in press).
- 43) P. J. Brockwell, The Multiple Compton Scattering of Low Energy Gamma Radiation, Phil. Mag (in press).

- (1) Reactor Physics Division
- (2) Physics Division
- (3) Nuclear Institute "Jozef Stefan" Ljubljana, Yugoslavia.
- (4) Michigan State University
- (5) Biological and Medical Research Division
- (6) High Energy Physics Division
- (7) University of Illinois
- (8) Metallurgy Division

ANL Reports

- 1) ANL-6590, Spectral Representation and Criticality Problem of a Two-Region Cell Transport Operator, by I. Pollack* and E. Bareiss.
- 2) ANL-6888, IPL-VC, A Computer System Having the IPL-V Instruction Set, by Donald Hodges.
- 3) ANL-6908, The Analysis of Complex Gamma-Ray Spectra, by William J. Snow.
- 4) ANL-6914, Decomposition of the Stationary Isotropic Transport Operator in Three Independent Space Variables, by Erwin H. Bareiss.
- 5) ANL-6940, Spectral Theory for the Stationary Transport Operator in Plane Geometry, by Erwin H. Bareiss.
- 6) ANL-6952, Applied Mathematics Division Summary Report, July 1, 1963 through June 30, 1964, R. F. King, Editor.
- 7) ANL-6970, The Generalized Riemann Zeta Functions and Their Applications in the Calculations of Neutron Cross Sections, by M. Atoji** and F. L. Clark.
- 8) ANL-6978, NEARREX, A Computer Code for Nuclear Reaction Calculations, by P. A. Moldauer***, C. A. Engelbrecht***, and G. J. Duffy.
- 9) ANL-6988, Singular Integrals and Singular Integral Equations with a Cauchy Kernel and the Method of Symmetric Pairing, by Erwin H. Bareiss and Charles P. Neuman†.
- 10) ANL-7010, pages 246-250 of Reactor Physics Annual Report, An Importance-Weighting Procedure for Averaging Group Parameters in Multigroup Diffusion Theory, by D. H. Shaftman** and Harold Greenspan.
- 11) ANL-7016, Program Catalog with Permuted Description Index for Control Data Co-op Computers, by N. J. Purcell.
- 12) ANL-7022, COGENT Programming Manual, by John C. Reynolds
- 13) ANL-7050, Proceedings of the Conference on the Application of Computing Methods to Reactor Problems, May 17-19, 1965, by Margaret Butler.
- 14) ANL-7061, A General Theory of First-Passage Distributions in Transport and Multiplicative Processes, by J. E. Moyal.

*Central Shops Department

**Chemistry Division

***Reactor Physics Division

†Harvard University

AMD Technical Memoranda

- 1) No. 54, The Sequential Compound Decision Problem for $m \times n$ Loss Matrix, by J. Van Ryzin.
- 2) No. 55, Double-Precision Square Root for the CDC-3600, by W. J. Cody.
- 3) No. 71, Tables of the Complete Elliptic Integrals K , K' , E , and E' , by M. A. Fisherkeller and W. J. Cody.
- 4) No. 72, Some Theorem-Proving Strategies and Their Implementation, by L. Wos, G. Robinson, and D. Carson.
- 5) No. 73, CHLOE-GPP1, A General Purpose for the CHLOE System, by Donald Hodges.
- 6) No. 74, GYRO I Macro-Programmed List Processing System, by George Robinson.
- 7) No. 75, The Cathode Ray Tube Scanning Stations of the CHLOE System, by Richard Wehman.
- 8) No. 76, Three Applications of Subroutine ANF105 - Generalized Solution of Matrix Equations, by D. L. Phillips.
- 9) No. 77, Householder's Method for Complex Matrices and Eigensystems of Hermitian Matrices, by Dennis J. Mueller.
- 10) No. 78, The Givens-Householder Method for Symmetric Matrices, by James Ortega.
- 11) No. 79, The Structure of Yet Another Algol Compiler, by H. Kanner, P. Kosinski, and C. L. Robinson.
- 12) No. 80, H5-1, A Hybrid Programming Language, by Donald Hodges.
- 13) No. 81, A Note on Some Characteristics of the Control Data 3600 Computer, by Yasuhiko Ikebe.
- 14) No. 82, The Real Time Communicator Maintenance Manual, by J. A. Byram, R. A. Aschenbrenner, K. Bish.
- 15) No. 83, DAPHNIS Technical Manual, by Vernon Tantillo.
- 16) No. 84, Operating Procedures at the ASI-2100 for the PHYLIS SYSTEM, by Kenneth Hillstrom.
- 17) No. 85, Automatic Classification of Chromosomes II, by J. Butler, M. Butler, and A. Stroud*.
- 18) No. 86, A Proposal for a Disk File Control System for the Control Data 3600, by George Robinson.
- 19) No. 87, A Finite Difference Technique for Scattering Problems, by Milton E. Rose.

- 20) No. 88, Description of the Applied Mathematics Building 221, ANL,
by D. A. Davis and R. E. King.
- 21) No. 91, POLLY, A High Precision Film Scanning and Measuring Device,
by D. Hodges, R. Wehman, and G. Wittmus.
- 22) No. 92, ANL-CDC Reprogramming Series I, Cross Section Nomenclature
for ANL Reactor Codes, by R. Avery**, M. Butler, and H. Greenspan.
- 23) No. 93, ANL-CDC Reprogramming Series II, Input Specifications for ANL
Reactor Codes, by M. Butler, H. Greenspan, and S. Sparck.
- 24) No. 94, ANL-CDC Reprogramming Series III, XLIBIT - ANL Cross Section
Library Code, by S. Sparck and E. Mueller***.
- 25) No. 97, BASIC - An Engineering Research Programming Language for GUS,
by George A. Robinson.
- 26) No. 99, C909: A Simple Wire Length Calculating Program, by Donald Hodges.
- 27) No. 100, The CHLOE Liberator, by Donald Hodges.
- 28) No. 101, GUS Computer Cathode Ray Tube Output, by Jerry Becker.
- 29) No. 103, Repetitive Play in Finite Statistical Games with Unknown
Distributions, by J. Van Ryzin.
- 30) No. 104, Paper Tape-to-Card Converter, by Richard King.
- 31) No. 105, A Stochastic Population Process and Its Application to Bubble
Chamber Measurements, by P. J. Brockwell and J. E. Moyal.

*Biological & Medical Research Division.

**Reactor Physics Division.

***Control Data Corporation.

Papers Presented at Meetings

- 1) The PHYLIS Executive Program, by W. F. Miller, M. A. Fisherkeller, and K. Hillstrom, EANDC Conference on the Automatic Acquisition and Reduction of Nuclear Data, Kernforschungszentrum, Karlsruhe, Germany, July 13-16, 1964.
- 2) A Description of the PHYLIS On-Line Computing System, by R. H. Vonderohe and D. S. Gemmell*, EANDC Conference on the Automatic Acquisition and Reduction of Nuclear Data, Kernforschungszentrum, Karlsruhe, Germany, July 13-16, 1964.
- 3) On-Line Data Acquisition and Feedback to Accelerator Control: A Status Report, by W. F. Miller, J. W. Meadows**, J. F. Whalen**, and A. B. Smith**, European-American Nuclear Data Committee Conf. on the Automatic Acquisition and Reduction of Nuclear Data, Karlsruhe, Germany, July 13-16, 1964.
- 4) General Survey: Status and Immediate Future of Computer Development for Nuclear Physics Applications, by W. F. Miller, European-American Nuclear Data Committee Conf. on the Automatic Acquisition and Reduction of Nuclear Data, Karlsruhe, Germany, July 13-16, 1964.
- 5) Automatic Classification of Chromosomes, II, by J. Butler, M. Butler, and A. Stroud***, Conference on Data Acquisition and Processing in Biology and Medicine, Rochester, New York, July 15, 1964.
- 6) On the Compound Testing Problem for Two Specified Distributions, by John R. Van Ryzin, Annual Meeting of the Institute of Mathematical Statistics, Amherst, Massachusetts, August 26-29, 1964.
- 7) List Processing Techniques in the Automatic Analysis of Spark Chamber Data, by Robert K. Clark, Meeting on Programming for Flying-Spot Devices, Bologna, Italy, October 7-9, 1964, presented by Richard Royston.
- 8) A Program for Calibrating the Flying Spot Cathode Ray Tube for CHLOE, by R. J. Royston, J. Butler, and P. Pennock, Meeting on Programming for Flying Spot Devices, Bologna, Italy, October 7-9, 1964, presented by Richard Royston.
- 9) Computer Analysis of Photographic Data in Biology, by J. W. Butler, Margaret Butler, and Agnes Stroud***, Meeting on Programming for Flying Spot Devices, Bologna, Italy, October 7-9, 1964.
- 10) Progress Report on Testing of CDC 3600 Systems Subroutines for Elementary Functions, by N. Clark, W. Cody, K. Hillstrom, and L. Shalla, The 14th Co-op Conference, Michigan State University, East Lansing, Michigan, October 7-9, 1964.
- 11) A Note on Some Characteristics of the Control Data 3600 Computer, by Yasuhiko Ikebe, The 14th Co-op Conference, Michigan State University, East Lansing, Michigan, October 7-9, 1964, distributed by W. J. Cody.

- 12) Fast Neutron Irradiation Effects on Ga As_{1-x}P_x Diode Laser Threshold Currents, by J. H. Doede****, R. H. Vonderohe, N. Holongak[†], C. J. Nueset[†], and C. M. Wolfes[†], presented by J. H. Doede at the International Symposium on Laser-Physics and Applications, Berne, Switzerland, October 13, 1964.
- 13) The Unit Preference Strategy in Theorem Proving, by Lawrence Wos, Daniel Carson, and George Robinson, 1964 Fall Joint Computer Conference (American Federation of Information Processing Societies), October 27-29, 1964, San Francisco, California.
- 14) Computer Analysis of Chromosome Data, by J. W. Butler, Margaret Butler, and Agnes Stroud***, Mammalian Cytology and Somatic Cell Genetics Conference, Puerto Rico, November 12-14, 1964.
- 15) Asymptotic Solution of the Compound Decision Problem with m x n Finite Loss Matrix, by J. R. Van Ryzin, Institute of Mathematical Statistics Central Regional Meeting, Chicago, Illinois, December 28-29, 1964.
- 16) Computer Methods in Electron Lens Design, by J. W. Butler, Conference on Non-Conventional Electron Microscopy, University of Cambridge, Cambridge, England, March 31 - April 2, 1965.
- 17) Repetitive Play in Finite Statistical Games with Unknown Distributions, by J. Van Ryzin, Institute of Mathematical Statistics 104th Central Regional Meeting, Lincoln, Nebraska, April 1965.
- 18) The AROMA Program for the Recognition and Measurement of Spark Images and Fiducials, by Paul Pennock, Purdue Conference on Instrumentation for High Energy Physics, May 12-14, 1965.
- 19) A Synopsis of the Argonne Automatic Spark Chamber Processing System, by R. J. Royston, Purdue Conference on Instrumentation for High Energy Physics, May 12-14, 1965.
- 20) Use of Graph Theory in the Analysis of Spark Chamber Data (a movie and commentary) by Robert Clark, Purdue Conference on Instrumentation for High Energy Physics, May 12-14, 1965.
- 21) Activities of the ANL-ENEA Computer Program Libraries and the ORNL Radiation Shielding Information Center, by M. Butler, B. Maskewitz (ORNL)++, and J. Rosen (ENEA)+++ , ANL-ANS-ENEA Meeting on Application of Computing Methods to Reactor Problems, May 17-19, 1965.
- 22) Dichotomous Pattern Recognition: A Dynamic Decision Theoretic Approach, by J. Van Ryzin, IFIP Congress 65 (International Federation for Information Processing), New York City, May 24-29, 1965.
- 23) A Solution to the Translation Problem and the Importance of the Set of Support Strategy in Theorem Proving, by Lawrence Wos, George Robinson, and Daniel Carson, IFIP Congress 65 (International Federation for Information Processing), New York City, May 24-29, 1965.

- 24) Variable Metric Method for Minimization of W. C. Davidon, by B. S. Garbow, Workshop on Computer-Oriented Statistical Techniques, Albuquerque, New Mexico, June 2-4, 1965.
- 25) A Description of the ANL Code Center, by M. Butler, AEC Specialized Information Division of Technical Information and Data Center Directors' Meeting, Washington, D.C., June 3, 1965.
- 26) Vacancy Clustering During the Quenching of a "Typical" Noble Metal, by L. T. Bryant, and R. M. J. Cotterill††††, American Physical Society Meeting, New York City, June, 1965.
- 27) Recent Progress in Automation of Chromosome Analysis, by J. W. Butler, at Yale University, New Haven, Conn. (Conference on Automatic Analysis of Chromosomes Data), June 28, 1965.

*Physics Division

**Reactor Physics Division

***Biological and Medical Research Division

****High Energy Physics Division

†University of Illinois

††Oak Ridge National Laboratory

†††European Nuclear Energy Agency

††††Metallurgy Division

SEMINARS AND SYMPOSIA

Applied Mathematics Division Seminars

- August 18, 1964 Celestial Mechanics I, by Prof. Harry Pollard,
Department of Mathematics, Purdue University,
Lafayette, Indiana.
- August 20, 1964 Strength and Weakness of Three-Term Recurrence
Relations, by Prof. Walter Gautschi, Department
of Mathematics, Purdue University, Lafayette,
Indiana.
- August 24, 1964 Celestial Mechanics II, by Prof. Harry Pollard,
Department of Mathematics, Purdue University,
Lafayette, Indiana.
- August 25, 1964 Invariant Subspaces of Certain Linear Operators,
by Prof. Ky Fan, Department of Mathematics,
Northwestern University, Evanston, Illinois.
- September 1, 1964 On Extrapolated Jacobi Methods for the Solution
of Matrix and Operator Equations, by Prof. Walter
Petryshyn, Department of Mathematics, University
of Chicago, Chicago, Illinois.
- September 3, 1964 The Stability of Dissipative Difference Schemes
for First Order Hyperbolic Equations, by
Prof. B. Parlett, Courant Institute of Mathematical
Sciences, New York University, New York, N. Y.
- October 1, 1964 The Role of Eye Movements in Certain Pattern
Recognition Tasks, by Prof. Derek H. Fender,
Department of Electrical Engineering, California
Institute of Technology, Pasadena, California.
- November 5, 1964 Recent Advances in Scattering Theory, by
Dr. Reese T. Prosser, Lincoln Laboratory, Massa-
chusetts Institute of Technology, Lexington,
Massachusetts.
- November 12, 1964 Computing Functions Efficiently, by Prof. John R. Rice,
Computer Science Department, Purdue University,
Lafayette, Indiana.
- November 19, 1964 Pattern Recognition and the Digital Computer Solution
of Jigsaw Puzzles, by Prof. H. Freeman, Department of
Electrical Engineering, New York University, New York.
- November 20, 1964 Computer Simulation of a Model for the Distribution of
Individuals by Species in an Environment, by
Mr. J. W. McCloskey, Department of Statistics,
Michigan State University, East Lansing, Michigan.

- December 3, 1964 Maximum Principles for Linear Systems, by Dr. David L. Russell, Mathematics Research Center, U.S. Army, University of Wisconsin, Madison, Wisconsin.
- December 10, 1964 Random Number Generators, by Dr. Donald MacLaren, Applied Mathematics Division, Argonne National Laboratory.
- December 22, 1964 Numerical Methods for Solving Least Squares Problems, by Prof. Gene Golub, Computer Sciences Department, Stanford University, Stanford, California.
- January 29, 1965 On the Condition of a Certain System of Non-Linear Equations, by Prof. Walter Gautschi, Department of Mathematics, Purdue University, Lafayette, Indiana.
- February 4, 1965 Solution of Boundary Value Problems by Orthogonal Expansions, by Prof. C. Lanczos, Ford Scientific Laboratories, Dearborn, Michigan.
- February 10, 1965 On-Line Computer Control of Nine Neutron Experiments at Brookhaven HFBR, by Dr. Walter Hamilton, Chemistry Department, Brookhaven National Laboratory, Upton, L.I., New York.
- February 24, 1965 Complementary Variational Principles in Applied Mathematics, by Prof. Ben Noble, Army Mathematics Research Center and University of Wisconsin, Madison, Wisconsin.
- February 25, 1965 Mixed Simple Multi-Step Methods for Ordinary Differential Equations, by Prof. C. W. Gear, Department of Computer Science, University of Illinois, Urbana, Illinois.
- March 4, 1965 Characteristics and Applications of Hybrid Computers, by Dr. Harold K. Skramstad, Associate Technical Director, U.S. Naval Ordnance Laboratory, Corona, California.
- March 23, 1965 Joint Applied Mathematics Division and Theoretical Physics Seminar - "Quantum Theory and Algebra," by Prof. Rudolf Haag, University of Illinois, Urbana, Illinois.
- March 25, 1965 Solving Finite Difference Equations by the Method of Summary Representation, by Mr. G. J. Tee, Department of Mathematics, The University of Lancaster, Lancaster, England.

- March 24-25, 1965 Applied Mathematics and Theoretical Physics Joint Seminar - "Scattering Theory for the Wave Equation," by Prof. Peter Lax, Director, Computing Center, Courant Institute of Mathematical Sciences, New York University, New York, N.Y., and Prof. Ralph A. Phillips, Department of Mathematics, Stanford University, Stanford, California.
- April 6, 1965 Applied Mathematics and Theoretical Physics Joint Seminar - "Algebraic Axioms for Quantum Theory," by Dr. Donald MacLaren, Applied Mathematics Division, Argonne National Laboratory.
- April 8, 1965 A Procedure and a Program for Finding Roots of a Polynomial, by Prof. Ronald Hamelink, Department of Mathematics, Michigan State University, East Lansing, Michigan.
- April 20, 1965 Applied Mathematics Division and Theoretical Physics Joint Seminar - "Algebraic Axioms for Quantum Theory II," by Dr. Donald MacLaren, Applied Mathematics Division, Argonne National Laboratory.
- April 29, 1965 Ignoring the Singularity in Numerical Integration, by Prof. Philip Rabinowitz, Computation Laboratory, Brown University, Providence, Rhode Island.
- May 4, 1965 Applied Mathematics and Theoretical Physics Joint Seminar - "Foundations of Quantum Field Theory," by Prof. Rudolf Haag, Physics Department, University of Illinois, Urbana, Illinois.
- May 6, 1965 Repetitive Play in Finite Statistical Games with Unknown Distributions, by Dr. John Van Ryzin, Applied Mathematics Division, Argonne National Laboratory.
- May 13, 1965 Some Renewal Theory with Application to the First Passage Problem for a Random Walk, by Prof. C. C. Heyde, Department of Statistics, Michigan State University, East Lansing, Michigan.
- May 13, 1965 Approximation of Eigenvalues, by Prof. G. Fichera, University of Rome and the Department of Mechanics, Johns Hopkins University, Baltimore, Maryland.
- May 17, 1965 Sequential Design of Experiments, by Prof. Herman Chernoff, Department of Statistics, Stanford University, Stanford, California.
- May 18, 1965 Applied Mathematics Division and Theoretical Physics Joint Seminar - "The Principle of Locality," by Prof. Rudolf Haag, Physics Department, University of Illinois, Urbana, Illinois.

- June 1, 1965 Well-Translatable Grammar in Algol-Like Languages,
by Dr. Karel Culik, Mathematical Institute of
Czechoslovakia Academy of Sciences.
- June 2, 1965 On Convergence of LR, QR and Related Algorithms,
by Dr. J. H. Wilkinson, Mathematics Division, National
Physical Laboratory, Teddington, Middlesex, England.
- June 8, 1965 On Calculating Minimax Approximations to a Continuous
Function of One Variable, by Mr. M. J. D. Powell,
Theoretical Physics Division, Atomic Energy Research
Establishment, Harwell, England.
- June 24, 1965 Design Philosophy for Model 92, by Dr. T. C. Chen,
Member of Machine Design Group, Systems Development
Division, International Business Machines Corporation,
Poughkeepsie, New York.

Applied Mathematics Division Summer Meetings, September 8-12, 1964

Numerical Methods, Partial Differential Equations

Participants:

J. Cody	G. Birkhoff	B. Parlett
E. Bareiss	M. Lees	D. Young
D. Taylor	S. Parter	C. Wilcox
M. MacLaren	J. Ortega	C. V. L. Smith
T. Hughes	R. Varga	

Non-numerical Computer Methods

Participants:

G. Robinson	J. A. Robinson
L. Wos	M. Reed
D. Carson	John Pasta
W. Cowell	M. Minsky
W. F. Miller	D. Luckham
D. Hodges	John McCarthy

Conference on Reactor Computations

On May 17-19, 1965, Argonne played host to an international meeting on the Application of Computing Methods to Reactor Problems. Two hundred and forty-two people attended the Conference, which was jointly sponsored by the Mathematics and Computation Division of the American Nuclear Society, the European Nuclear Energy Agency, and Argonne.

Six sessions were held, covering the topics of "Numerical Analysis and Reactor Mathematics," "Linked Calculations," "Kinetics Studies," "Special Methods," and "Monte Carlo Computations."

The proceedings of the meeting appear as an Argonne report, ANL-7050.

Applied Mathematics Division Special Interest Seminars

July 2, 1964	<u>ALGOL Seminar</u> , by Mr. Robert Stueland, Control Data Corporation.
July 8, 1964	<u>Spectral Analysis in the Distribution Space</u> , by Prof. Avner Friedman, Northwestern University, Evanston, Illinois.
July 27, 1964	<u>Engine No. 2 Software</u> , by Mr. Donald Hodges, Applied Mathematics Division, Argonne National Laboratory.
July 31, 1964	<u>Named Storage (A Dynamic Storage Allocation Scheme)</u> , by Dr. Stanley Cohen, Physics Division, Argonne National Laboratory.
August 28, 1964	<u>Finite Difference Methods</u> , by Dr. Milton E. Rose, Mathematics Section of the National Science Foundation, Washington, D.C.
October 19, 1964	<u>First Passage Markov Processes in Space and Space-Time</u> , by Dr. J. E. Moyal, Applied Mathematics Division, Argonne National Laboratory.
October 30, 1964	<u>Detailed Investigation of Bubble Chamber Tracks</u> , by Mr. Louis C. Just, Chemical Engineering Division Seminar Series.
January, 1965	<u>Series of three GRIND Seminars</u> , by Mr. Richard J. Royston, High Energy Physics Division Seminar.
April 21, 1965	<u>A Statistical Mechanical Derivation of the Neutron Transport Equation</u> , by Dr. J. M. Cook.
June 14 - July 9, 1965	<u>Series of Lectures in Numerical Methods</u> , by Mr. Burton S. Garbow, ISE Summer Institute in Digital and Analog Computing.

Study Seminar in Lie Groups

A series of study seminars in Lie Groups, conducted by Dr. Ronald Hamelink, was held in the Applied Mathematics Division during the summer of 1964.

Applied Mathematics Division Engineering Seminars

J. Byram	August 7, 1964	Real Time Communicator
J. Carter	September 3, 1964	Review of Thin Film Techniques
R. Ulhorn	September 8, 1964	Read Amplifiers for Thin Film Memories
R. Shevlin	September 9, 1964	New Developments in Memories
R. Vonderohe	October 2, 1964	Principles of Lasers
F. Sato	October 22, 1964	Neuron Literature Survey
L. Amiot	December 21, 1964	The GUS-IBM 1401 Communication Link, A Summary of Memory Systems Available Today
D. Jacobsohn	December 28, 1964	Comments on Hardware Realizable Base Conversion Methods
F. Salter	January 4, 1965	GUS: Its Present State and Future Potential
D. Hodges	January 25, 1965	No. 1 ESS, The Bell Telephone System Computer Controlled Central Office
J. Butler	February 1, 1965	The Role of the Engineering Section
R. Vonderohe	February 8, 1965	PAULETTE, An Emulsion Plate Scanner
C. B. Shelman	February 15, 1965	Active Filter Design in the Audio Frequency Range
H. Gray	February 22, 1965	Proposal for an On-Line GUS System
F. Salter	February 22, 1965	An Engineering Description of the 221-362 Microwave Link
D. Hodges	March 1, 1965	The Organization of a Complete Argonne Computer and Data Gathering Facility
D. Jacobsohn	March 8, 1965	Comments on the IBM 360 Series of Computers
W. Cowell	March 15, 1965	Coding for Error Control in Digital Data Transmission
F. Salter	March 22, 1965	A Review of Data Transmission Rates and Available Commercial Equipment

R. Schwanke	March 29, 1965	Vacuum and Thin Film Deposition Techniques
A. Roberts*	April 5, 1965	Direct Digitizing Spark Chambers
D. Jacobsohn	April 19, 1965	Discussion of Balances between Core Buffers and Disc Memories for Unit Record Equipment
D. Hodges	April 26, 1965	A Preliminary Description of a Film Scanning and Measuring System Called POLLY
V. Tantillo	May 3, 1965	Magnetic Tape Recording
C. B. Shelman	May 17, 1965	A Proposal for the Use of the GUS Drum System on the Engineering Section's Small Computers
L. Amiot	June 7, 1965	IBM System 360 Data Communication Methods
W. Snow	June 14, 1965	The BASIC Language (An Elementary FORTRAN-Like Language) Used on a Remote Device to Communicate with a Time-Sharing Computer System
J. Byram	June 21, 1965	Logical Design Using J-K Flip-Flop Circuits
C. W. Gear**	June 28, 1965	The Proposed Time-Sharing System on Illiac II

University and Symposium Presentations

Data Analysis Systems PHYLIS and CHLOE, by W. F. Miller, at the Florida State University, Tallahassee, Florida, September 24, 1964.

Organization and Functioning of the Applied Mathematics Division at Argonne, by J. W. and M. K. Butler, at EURATOM Research Center, Ispra, Italy, October 15, 1964.

Computer Analysis of Chromosome Data, by J. W. Butler and M. K. Butler, at Christie Hospital and Holt Radium Institute, Manchester, England, October 23, 1964.

List Processing and Game Playing Programs, by W. R. Cowell, at the University of Michigan, Ann Arbor, Michigan, November 24, 1964.

Zeros of Polynomials and the Resultant Procedures, by Erwin H. Bareiss, at Northern Illinois University, DeKalb, Illinois, December 15, 1964.

*High Energy Physics Division

**University of Illinois

The COGENT System - A Proposed Compiler-Compiler Technique, by John Reynolds, at Seminar, Computation Center, Carnegie Institute of Technology, January 11, 1965.

Computer-Oriented Theorem-Proving Strategies, by G. A. Robinson, at Colloquium, Mathematics Research Center, Madison, Wisconsin, January 11, 1965.

A General Theory of First Passage Probabilities in Transport Processes, by J. E. Moyal, at Michigan State University, February 15, 1965.

The Sequential Compound Decision Problem for $m \times n$ Loss Matrix, by J. Van Ryzin, at Michigan State University, February 22, 1965.

Repetitive Play in Finite Statistical Games with Unknown Distributions, by J. Van Ryzin, at Michigan State University, February 23, 1965.

Compound Decision Theory, by John Van Ryzin, at The University of Chicago, March 5, 1965.

Digital Computers as Mathematical Machines, by Wallace Givens, at Washington University, St. Louis, Missouri, March 16, 1965.

Computing with Matrices, by W. Givens, at Western Michigan University, Kalamazoo, Michigan, May 10, 1965.

A Checker Playing Program and Engine No. 2, by W. R. Cowell, at Northwestern University, Evanston, Illinois, May 11, 1965.

Global Error Analysis, by Wallace Givens, at Annual Meeting of Illinois Section of The Mathematical Association of America, Southern Illinois University, Carbondale, Illinois, May 14, 1965.

On the Mathematical Theory of the Boltzmann Transport Equation - New Numerical Techniques, by Erwin H. Bareiss, at the Pennsylvania State University, University Park, Pennsylvania, May 14, 1965.

The Digital Computer as a Logical Engine, by Wallace Givens, at Annual Meeting of Illinois Section of The Mathematical Association of America, Southern Illinois University, Carbondale, Illinois, May 15, 1965.

Chromosome Analysis by a Computer System, by A. Stroud*, J. W. Butler, M. K. Butler, and N. Monroe*, at the 16th Annual Meeting of the Tissue Culture Association, Miami, Florida, May 31, June 1-2, 1965, presented by A. Stroud.

Recent Progress in Computer Analysis of Chromosome Data, by J. W. Butler, at the Argonne Cancer Research Hospital, June 8, 1965.

*Biological & Medical Research Division.

COMPUTING FACILITIES

The computing equipment described below is currently available in the Applied Mathematics Division for carrying out computations. Numerous peripheral devices, such as keypunches and paper tape reproducers, are also available. With the exception of items 6) and 7) below, scheduling and operation are handled by the Division's Operations Section.

- 1) A Control Data Corporation 3600 system including:
 - a compute module with real-time clock,
 - a 65,536-word magnetic core memory,
 - 4 printers (1,000 lines/minute),
 - 2 card readers (1,200 cards/minute),
 - 20 magnetic tape units,
 - 2 auxiliary Control Data 160-A computers, one of which as a satellite shares the compute module with the 3600; it also shares the line printers with the other 160-A; the other 160-A controls four tape units and a card reader and punch,
 - a 250 cards/minute card punch,
 - a 100 cards/minute card punch,
 - 3 input/output typewriters,
 - a data display unit with camera plus console unit for viewing,
 - 2 paper tape readers (on the 160-A computers),
 - a microwave transmission unit and digital data terminal linking to the High Energy Physics Building, and
 - a real-time channel for access from other systems such as the Physics Division's PHYLIS.
- 2) A Control Data 160-A system (located in the Reactor Physics and Engineering Building) including:
 - a central computer,
 - an 8192-word magnetic core memory,
 - a printer (1,000 lines/minute),
 - a card reader (250 cards/minute)
 - a card punch (100 cards/minute),
 - a paper tape reader (350 frames/second),
 - a paper tape punch (110 frames/second),
 - a typewriter,
 - 2 magnetic tape units, and
 - an incremental plotter.
- 3) A Control Data 160-A system (located in the High Energy Physics Building) including:
 - the same configuration as that in item 2) above except the card reader is 1200 cards/minute, plus a microwave transmission unit and digital data terminal linking the system to the Applied Mathematics Building.

- 4) An IBM-704 computer including:
 - a central processing unit,
 - a 32,768-word magnetic core memory,
 - an 8,192-word magnetic drum memory,
 - a card reader (250 cards/minute),
 - a card punch (100 cards/minute),
 - a printer (150 lines/minute), and
 - 9 magnetic tape units.

- 5) An IBM-1401 system consisting of:
 - a processing unit with a 4,000-character magnetic core memory,
 - a card reader and punch (800 cards/minute),
 - a printer (600 lines/minute),
 - a paper tape reader (500 frames/second),
 - 3 magnetic tape units, and
 - the following features:

multiply-divide	read-punch release
print storage	additional print control
column binary	and print storage
high-low-equal compare	10 sense switches
advanced programming	space suppress
buffered paper tape input	

- 6) A PACE analog computer, consisting of two computing consoles (which can be coupled), each complete with:
 - 28 integrating amplifiers,
 - 28 summing amplifiers,
 - 10 servo-mechanisms,
 - 5 electronic multipliers,
 - 5 diode function generators, and
 - 80 scale-factor potentiometers.

- 7) CHLOE, an automatic data-processing system for analyzing spark-chamber and other photographs, including:
 - a fiber optics cathode-ray-tube scanner, and
 - an Advanced Scientific Instruments 210 digital computer with
 - paper tape reader and punch, one magnetic tape, and a
 - typewriter for input/output.

- 8) A California Computer Products incremental plotter with its associated magnetic tape drive.