

**NATIONAL BUREAU OF STANDARDS REPORT**

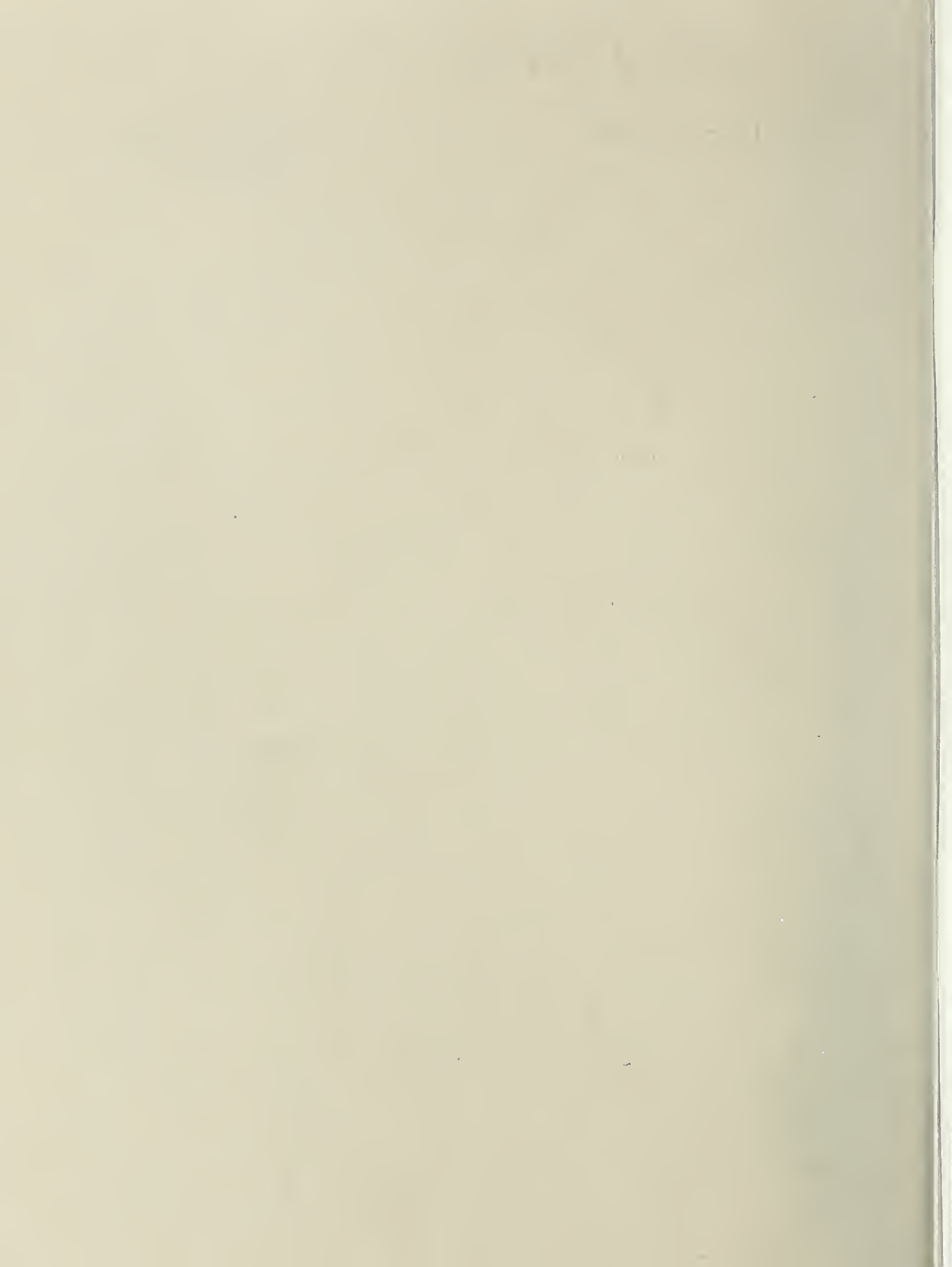
10350

**PROJECTS and PUBLICATIONS**  
of the  
**APPLIED MATHEMATICS DIVISION**

**A Semi-Annual Report**  
**January through June 1970**



**U.S. DEPARTMENT OF COMMERCE**  
**NATIONAL BUREAU OF STANDARDS**



# NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT

205.0

NBS REPORT

10350

## PROJECTS and PUBLICATIONS of the APPLIED MATHEMATICS DIVISION

A Semi-Annual Report  
January through June 1970

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U.S. DEPARTMENT OF COMMERCE  
NATIONAL BUREAU OF STANDARDS

## APPLIED MATHEMATICS DIVISION FUNCTIONS

APPLIED MATHEMATICS DIVISION (205.00): Conducts research and provides consulting services to the Bureau and other Federal agencies in various fields of mathematics important in science and engineering, including automatic data processing and operations research, with emphasis on statistical, numerical and combinatorial analysis, and on mathematical physics. Develops tools for mathematical work such as mathematical tables, handbooks, manuals, mathematical models and computational methods, and advises on their use. Provides training in disciplines related to these functions.

MATHEMATICAL ANALYSIS SECTION (205.01): Conducts research and provides consulting services in core and applied mathematics as they impact on science and engineering, involving research supporting the advancement of computation, particularly in the development of computing algorithms and criteria for their evaluation. Performs mathematical analysis of complex physical systems for the purpose of developing rigorous analytic procedures. Simulates the behavior of physical systems by means of electronic computers, using approximation techniques and semi-analytic methods. Studies the properties and representations of special functions encountered in research and consultation. Develops methods for computing these special functions, and critically evaluates methods commonly used. Collaborates with representatives of government agencies, industry, and universities in an effort of extensive testing, evaluation and documentation of algorithms and computer programs for scientific calculation.

OPERATIONS RESEARCH SECTION (205.02): Develops and applies mathematical-computational techniques for and provides consulting services in the analysis, improvement or optimization of complex systems or activity patterns. Conducts investigations in the art of constructing useful mathematical models of complex systems. Studies such systems by applying analytic or simulation methods. Applies these techniques to problems arising in the work of the Bureau or of other Government agencies lacking specialized personnel in this field. Performs research in underlying areas of mathematics, such as linear programming, the theory of linear graphs, and the theory of strategic contests.

STATISTICAL ENGINEERING SECTION (205.03): Provides consulting services in the application of mathematical statistics to physical science experiments and engineering tests, particularly in the design of experiments and in the analysis and interpretation of data. Contributes to the development of appropriate statistical techniques on a foundation of research on pertinent topics in probability and mathematical statistics. Conducts studies of computational methods, and prepares reports, manuals, tables, and handbooks to facilitate the application of modern statistical methods.

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<sup>o</sup>Only unclassified material is included in this report.

# APPLIED MATHEMATICS DIVISION

January 1, 1970 through June 30, 1970

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	Sally T. Peavy, B.A.*	

\*Part-time  
\*\*Postdoctoral Research Associate

\*\*\*Guest Worker  
<sup>o</sup>On Leave of Absence

<sup>1</sup>Effective April 5, 1970, the Numerical Analysis Section, 205.01, and the Systems Dynamics Section, 205.04, were combined into the Mathematical Analysis Section, 205.01. Dr. Morris Newman, formerly Chief of Numerical Analysis Section was designated Senior Research Mathematician, 205.00. Dr. Hans J. Oser, formerly Chief, Systems Dynamics Section was designated Acting Chief, 205.01.

# Status of Projects

## 1. MATHEMATICAL ANALYSIS

### RESEARCH IN SYSTEMS DYNAMICS AND RELATED FIELDS

Task 20540-12-2050141/55-57

1550-11

Origin: NBS

Authorized 9/1/54

Manager: H. J. Oser

Full task description: July-September 1954 issue, p. 27

Status: CONTINUED.

In collaboration with Dr. John A. Simmons of the Metallurgy Division, NBS Institute for Materials Research, J. T. Fong continued to investigate the problem of characterizing the thermomechanical behavior of simple and composite materials with phenomenological theories consistent with general physical principles and experimental data. In a manuscript entitled "Generalizations of the Isothermal Bernstein-Kearsley-Zapas Theory to Include Materials with Both Memory and Anisotropy", it was shown that there are two natural ways of generalizing the isothermal BKZ fluid theory (1963): one having a natural interpretation in terms of the so-called second Piola-Kirchhoff stress, and the other corresponding to a generalized hyperelastic theory which implies a variational formulation. By proving that the two generalizations are equivalent, J. T. Fong and J. A. Simmons completed the formulation of a nonlinear viscoelastic and anisotropic theory which may prove both experimentally and computationally attractive. The above-mentioned manuscript has been completed and is being submitted to a technical journal for review.

During the month of May, at the request of Mr. R. Bloss, Chief, Engineering Mechanics Section, Mechanics Division, NBS Institute for Basic Standards, J. T. Fong acted as a full-time consultant on the investigation of the torsional buckling of aluminum cylinders reinforced with boron-epoxy composites under the NBS project 2130445, sponsored by the NASA Langley Field Research Center, Hampton, Va. In particular, J. T. Fong assisted Dr. L. Mordfin and Mr. D. E. Marlowe, both of the Engineering Mechanics Section, in their attempts to apply a computer code that was developed at the Case Western Reserve University, Cleveland, Ohio, on a similar but not equivalent problem in structural instability.

S.R. Kraft pursued research in 3 areas: 1) He obtained a result which extended earlier ideas on establishing convergence of semi-discrete approximations of pure initial problems for linear transport equations to boundary initial problems. A paper on this subject is being prepared. 2) An idea for generalizing the author's method of analytic continuation was studied. A preliminary report on this idea has been published in the Notices of the American Mathematical Society. 3) In a problem suggested by the Photometry Section of NBS and working with other section members, an integral equation was found for determining reflected light intensity inside "integrating spheres". Physical and mathematical implications of the integral equation are being studied with the objective of producing a better integrating sphere design. This is important for the lighting industry where no uniform measurement standards for light output of bulbs exists.

Consulting services within NBS and to other agencies continued throughout the reporting period. Cooperative work by H. J. Oser and J. E. McKinney on the propagation of acoustic waves with the Mechanics Division of NBS was concluded.

#### Publications:

- (1) Stability of Acoustic Waves within a Viscous, Compressible, Heat-Conducting Fluid. J. E. McKinney and H. J. Oser. To appear in the Jour. of Acoustical Society of America, Vol. 47, No. 1, Jan. 1970.
- (2) Acoustic Propagation and Stability Within an Inviscid, Heat-Conducting Fluid. J. E. McKinney and H. J. Oser. Journal of Research NBS, 74B (1970), pp. 67-84.
- (3) Analyticity and Reflectivity for First Order Systems of Elliptic Type in Two Independent Variables. R. Kraft. Jour. of Math. Anal. & Appl., Vol. 29, No. 1, Jan. 1970.

FORTRAN LIBRARY IMPROVEMENT AND ALGORITHM DEVELOPMENT

Task 20501-2053587

1550-23

Origin and Sponsor: NBS  
Manager: H. J. Oser

Authorized 4/27/70

Objective: (a) To test thoroughly, and revise where necessary, the FORTRAN library on the Bureau's UNIVAC 1108 computer.

(b) To develop tests and criteria of evaluation for computer algorithms used for the computation of special functions in mathematical physics and for other important computational problems of linear and nonlinear algebra.

Background: This project is financed by the NBS Center for Computer Sciences and Technology in an effort to improve the existing mathematical software. There is increasing concern over the quality of mathematical subroutines and the lack of warning to the user when something does go wrong during a calculation.

Status: NEW. Initial test runs by I.A. Stegun and R. Zucker showed that our library program for the double-precision sine function (not UNIVAC supplied) had faulty argument reduction and produced answers with relative errors as large as 100% in the vicinity of  $x$  equals zero. Corrections have been suggested to remedy that situation.

Similarly, Z. G. Ruthberg and D. Lozier showed that the hyperbolic sine and tangent routines lose all accuracy near zero and alternate mathematical expressions are being incorporated that are numerically stable.

Minimum criteria that a mathematical subroutine for  $f(x)$  has to satisfy in order to be acceptable are the following:

- (1) For all arguments  $x$  for which  $f(x)$  is defined and representable by the machine the answer should be obtained with as small a bit error as is reasonably achievable.
- (2) If less than stated bit accuracy (for example, more than two bits in error) occurs, the user should be warned on-line if he so desires.
- (3) Storage considerations have lower priority than execute speed which in turn has lower priority than the accuracy of the result. A separate hierarchy of routines will ultimately have to satisfy other priority orders.

Quality of documentation. A standard format of documentation is suggested that is useful and informative to the user and uniform in its application to all subroutines. The present state of affairs in subroutine documentation is quite abominable and efforts are underway to achieve an agreement among users as to the criteria that subroutines ought to satisfy and to state for each routine the compliance or degree of compliance with the set of criteria that are agreed upon.

The initial phase of this work will be completed as soon as known errors in the present FORTRAN subroutine library have been corrected and work will concentrate on the refinement of developed test methods that will be made portable so that they may be used by other computer installations concerned about the quality of numerical algorithms.



MATHEMATICAL METHODS IN PLASMA PHYSICS

Task 20504-12-2050140/59-422

1540-11

Origin: NBS

Authorized 10/13/61

Manager: Walter L. Sadowski

Full task description: October-December 1961 issue, p. 12

Status: CONTINUED.

Walter L. Sadowski continued with the development of new algorithms for integrating partial differential equations (in particular the nonlinear Vlasov equation of plasma physics) leading to a new application of the Taylor series method which has become very attractive in view of the possibility of obtaining a very good error bound for the method.

Daniel W. Lozier continuing to provide mathematical and computer programming support for W.L.Sadowski, helped in the development of a new algorithm for numerically solving the nonlinear Vlasov equation using a Chebyshev expansion in velocity space instead of a Hermite expansion. Together with the Fourier-Hermite and the Fourier-Chebyshev eigenfunction expansions three independent methods are now available which check out extremely well against each other.

The Taylor series method is also amenable to a strictly symbolic solution method, i.e. an almost completely analytic process that was actually carried out on the computer by a symbol manipulation program that is intrinsically exact, i.e. no numerical process is involved.

Zella G. Ruthberg and Walter L. Sadowski developed a symbol manipulation program in FORTRAN that calculates the Taylor series expansion of the solution of a partial differential equation of the form

$$\frac{\partial f}{\partial t} + [a(x,y) \frac{\partial}{\partial x} + b(x,y) \frac{\partial}{\partial y}] f = 0.$$

The newly developed algorithm on which it is based requires considerably less space and time than a previously developed FORTRAN program.

The results were reported in two papers presented before the ACM One-Day Technical Symposium on June 25, 1970, here at NBS.<sup>1,2</sup>

Publications

- (1) Taylor series expansion with the aid of combinatorics. Walter L. Sadowski and Zella G. Ruthberg.
- (2) An integer program for the n-th power of a non-commutative binomial operator. Zella G. Ruthberg and Walter L. Sadowski.

## 2. OPERATIONS RESEARCH

### CONSULTATION IN MATHEMATICAL OPERATIONS RESEARCH

Task 205-12-2050151

Origin and Sponsor. NBS

1570-11

Authorized 12/30/60

Manager: A.J. Goldman

Full task description: October-December 1960 issue, p.3

Status: CONTINUED.

(1) Demand for miscellaneous consulting and advisory services remained heavy, but their provision was limited by budget problems. Section staff provided such services in 90 recorded instances, 60 involving assistance to NBS staff. The 90 instances totalled to 643 recorded man-hours. Other agencies assisted included the National Research Council, Bureau of Mines, Law Enforcement Assistance Agency, Social Security Administration, Office of Naval Research, Public Health Service, and Urban Mass Transit Administration. Requests from universities, industries, professional groups and journals were also met so far as possible.

(2) J. Gilsinn continued collaboration with the Information Processing Technology Division in a study, for the Federal Aviation Authority, to improve air traffic designation procedures. A previously-written simulation program was modified to permit greater sophistication, and applied to test relatively complex schemes for assigning radar-beacon codes to airplane flights. (Reported here for convenience; supported under Project 6505453.)

(3) Two new studies for the FAA were initiated in collaboration with the Technical Analysis Division. One (involving J. Gilsinn, A.J. Goldman, W.A. Horn, J. Levy and M.H. Pearl) builds in part on a previously-reported NBS effort, aiming to extend the "NBS-type" capacity concept to configurations more complicated than a single stream of customers at a single runway; its other prong is a simulation effort to predict measures of delay and throughput for a variety of airport configurations and traffic mixes. The second study (involving L.S. Joel as well as Goldman, Levy and Pearl) is an attempt to assist the FAA in what has proven over the years to be a very difficult problem: that of estimating the effects, on safety and flow regulation, of VFR towers at small airports. (Reported here for convenience; supported under Projects 4314569 and 4314427 respectively.)

(4) W.G. Hall continued assistance to the Army Data Field Systems Command relative to a new tactical artillery-fire control system. He also collaborated in a feasibility study of regional centers for computerized processing of urban-renewal data. J. Gilsinn and A.J. Goldman began collaboration with Technical Analysis Division staff in a study for HUD to aid in estimating the consequences of transport changes for concentrated urban-activity areas. P. Saunders continued assistance in a simulation study of Coast Guard search and rescue operations, contributing in particular to a statistical analysis of the demands for such services. (Reported here for convenience; supported under respective Projects 6505425, 4314561.)

(5) P.R. Meyers, continuing an investigation of converses of the Banach Contraction Theorem, has shown that for a continuous semigroup  $\{T_t : t \geq 0\}$  of operators on a metrizable topological space  $X$ , if there is a metric on  $X$  which makes any one  $T_t$  a contraction, then for any  $\lambda \in (0,1)$  there is a single metric relative to which each  $T_t$  ( $t \geq 0$ ) is a contraction with constant  $\lambda^t$ .

#### Publications

- (1) R.H. Jordan (Div. 431), J. Gilsinn, A.J. Goldman et al. Systems analysis of inland consolidation centers. To appear as an NBS Technical Note (1970).
- (2) A.J. Goldman. Systems analysis and urban problems (Discussion). To appear in Proc. Symposium on Systems Analysis for Social Problems, 5/69.
- (3) A.J. Goldman. The adequacy of management science technology for non-military applications in the Federal government. To appear in Proc., Amer. Soc. Public Admin. Workshop on Management Science in the Federal Government (11/69).

- (4) A.J. Goldman. Analysis of a capacity concept for runway and final-approach path airspace. Proc. 1970 Nat. Air Meeting, Institute of Navigation (4/70); pp. 119-131.
- (5) W.A. Horn. Some fixed point theorems for compact maps and flows in Banach spaces. To appear in Trans. Amer. Math. Soc.
- (6) W.A. Horn. Convex homotopy. Submitted to a technical journal.
- (7) P.R. Meyers. Contractive semigroups and uniform asymptotic stability. To appear in Journal of Research NBS, 74B (1970).
- (8) P.R. Meyers. Contractifiable semigroups. To appear in Journal of Research NBS, 74B (1970).

COMBINATORIAL METHODS

Task 205-12-2050152

Origin and Sponsor: NBS 1540-11 Authorized 12/30/60  
 Manager: A.J. Goldman  
 Full task description: October-December 1964 issue, p.3; April-June 1962, p.15

- (1) J. Gilsinn (and C. Witzgall of Boeing Scientific Research Labs) continued experiments and documentation on the comparison of shortest-path algorithms.
- (2) A.J. Goldman continued studies relating to the optimal location of facilities in networks. He developed simple one-pass algorithms for optimal (total-cost-minimizing) location of a single facility in acyclic or unicyclic networks.
- (3) W.A. Horn examined a variety of network optimization problems. In particular, he developed algorithms for the delay-minimizing sequence in which sorting operations should be carried out by a single device.

Publications

- (1) J. Edmonds and D.R. Fulkerson (RAND). Bottleneck extrema. J. Combinatorial Theory 8 (1970), pp.299-306.
- (2) J. Edmonds and O. Shisha (Wright-Patterson A.F.B.). Acute bijections. To appear in J. Combinatorial Theory.
- (3) A.J. Goldman and C. Witzgall (Boeing Scientific Research Labs). A localization theorem for optimal facility location. Submitted to a technical journal.
- (4) A.J. Goldman. Optimal center location in simple networks. Submitted to a technical journal.

LINEAR AND NON-LINEAR PROGRAMMING

Task 205-12-2050153

Origin and Sponsor: NBS 1540-11 Authorized 12/30/60  
 Manager: W.G. Hall  
 Full task description: October-December 1960 issue, p. 3

Status: CONTINUED.

- (1) W.G. Hall and P. Saunders continued work to improve NBS capabilities for linear programming calculations. Support from the Computer Services Division for the second half of the reporting period (Project 2053587) permitted intensification of effort. Drawbacks of existing codes were explored more thoroughly. (A repeated error is to label a problem infeasible because after Phase 1 the basis still contains an artificial variable, although at a zero level.) A core-limited code for the ordinary

simplex method has been devised, tested, and used by patrons of the NBS installation with satisfactory results. Further "polishing", and a code for the revised simplex method, are well along. Information-exchange relationships with several other installations have arisen quite naturally.

(2) A.J. Goldman completed draft documentation of the minimax-error approach to disaggregating a discrete probability distribution. He and P.R. Meyers are examining the applicability of this approach to estimating transport-network origin-destination volumes from link loads.

#### Publications

- (1) W.A. Horn. Optimal container inventory and routing. Submitted to a technical journal.
- (2) C. Witzgall (now with Boeing Scientific Res. Labs). On complementary polar conical sets. To appear in Journal of Research NBS 74B (1970).

#### SCHEDULING AND ROUTING IN INTER-URBAN TRANSPORT

Task 205-12-2058456

Origin: Technical Analysis Division, NBS 1550-22  
Sponsor: Northeast Corridor Transportation Project, Dept. of Transportation  
Manager: P.B. Saunders

Full task description: July-December 1969

Status: TERMINATED

(1) P. Saunders prepared a draft document giving an overview of research on scheduling and routing supported by the Northeast Corridor Transportation Project.

(2) Unanticipated funding reductions required project termination. We hope subsequently to complete and issue the documentation of (1) above, of D. Klavan's work on computer algorithms for jointly optimal scheduling of local and express service, and of the A.J. Goldman-S. Haber research on asymptotic properties of delay-minimizing schedules.

#### PASSENGER DEMAND MODELS FOR INTER-URBAN TRANSPORT

Task 205-12-2050457

Origin: Technical Analysis Division, NBS 1550-22  
Sponsor: Northeast Corridor Transportation Project, Dept. of Transportation  
Manager: A.J. Goldman

Full task description: July-December 1969

Status: TERMINATED

(1) L.S. Joel completed an analysis of additional explanatory variables. He also completed examining the relationship between intercity passenger travel volumes (in toto and by mode) and telephone calls; some interesting correlations were noted.

(2) R. Ku (Division 431), and A.J. Goldman together with M. Cheslow (DOT), continued draft documentation efforts.

(3) Unanticipated funding reductions required project termination. It is problematical whether the documentation efforts noted in (2) will subsequently be completed.

MISCELLANEOUS MATH SERVICES CONCERNING INTER-URBAN TRANSPORT

Task 205-12-2058458

Origin: Technical Analysis Division, NBS 1550-22  
Sponsor: Northeast Corridor Project, Department of Transportation  
Manager: A.J. Goldman  
Full task description: July-December 1969

Status: TERMINATED

(1) J. Levy and M.H. Pearl completed draft documentation of (a) a comparison of non-feedback, feedback, and "prophesying" regulation of traffic at a merge-point of two streams, and (b) an overview of past research for the Northeast Corridor Transportation Project on feedback vs. non-feedback control of traffic at merge-points.

(2) W.A. Horn completed draft documentation of an overview of "accessibility" research supported by the Northeast Corridor Transportation Project.

(3) Unexpected funding reductions required project termination. We hope subsequently to complete and issue the documents mentioned in (1) and (2) above.

### 3. PROBABILITY AND MATHEMATICAL STATISTICS

#### RESEARCH IN PROBABILITY AND MATHEMATICAL STATISTICS

Task 20503-12-2050131/63-1259

1550-11

Origin: NBS

Authorized 10/1/62

Manager: Joan Raup Rosenblatt

Full task description: July - December 1962

Status: CONTINUED. Janace A. Speckman has continued collaboration with J. M. Cameron (Office of Measurement Services) and W. H. Clatworthy (State University of New York, Buffalo) on preparation for publication of the revised and expanded version of "Tables of Partially Balanced Designs with Two Associate Classes" by Bose, Clatworthy and Shrikhande. All of the numerical plans to be listed have been verified to be partially balanced incomplete block designs with two associate classes of the type specified. Output from the verification program will be put on magnetic tape to utilize computer typesetting techniques (LINATRON) so that typographical errors as well as construction errors will be minimized.

Roy H. Wampler has continued his study of the accuracy of linear least squares computer programs. One measure of ill-conditioning in least squares problems is the quantity

$$\gamma = \frac{\kappa(X) \|\delta\|}{\|X\| \|\hat{\beta}\|}$$

where  $X$  is an  $n$  by  $k$  least squares matrix,  $\kappa(X) = (\lambda_1/\lambda_k)^{1/2}$ ,  $\lambda_1$  is the largest eigenvalue and  $\lambda_k$  is the smallest eigenvalue of  $X'X$ ,  $\delta$  is the vector of residuals,  $\hat{\beta}$  is the vector of coefficients, and  $\|\cdot\|$  denotes the Euclidean norm. Systems for which  $\gamma$  is large are more ill-conditioned than those for which  $\gamma$  is small ( $\gamma \ll 1$ ). Two algorithms have proven to be effective in handling problems where  $\gamma$  is large. These are (1) the algorithm of Björck and Golub which uses Householder transformations, and (2) Björck's modified Gram-Schmidt algorithm. These two methods are successful when there is an iterative refinement scheme which iterates both residuals and coefficients and which accumulates inner products in double precision.

#### Publications:

- (1) The percent point function. James J. Filliben. Submitted to a technical journal.
- (2) An author and permuted title index to selected statistical journals. Brian L. Joiner, N. F. Laubscher (National Research Inst. for Math. Sciences, South Africa), Eleanor S. Brown, and Bert Levy (Harry Diamond Labs., U. S. Army). To appear as NBS Special Publication 321.
- (3) Some properties of the range in samples from Tukey's symmetric lambda distributions. Brian L. Joiner and Joan R. Rosenblatt. To appear in J. Amer. Statist. Assoc.
- (4) Analysis of information -- An alternative approach to the detection of a correlation between the sexes of adjacent sibs in human families. H. H. Ku. To appear in Biometrics.
- (5) Analysis of multidimensional contingency tables. H. H. Ku, R. N. Varner, and S. Kullback (G.W.U.). Proc. Fourteenth Conf. on the Design of Experiments in Army Research Development and Testing, Edgewood Arsenal, 23-25 October 1968, U. S. Army Research Office - Durham, ARO-D Report 69-2, September 1969, pages 141-180.
- (6) Symmetry and marginal homogeneity of an  $r \times r$  contingency table. C. T. Ireland (G. W. U.), H. H. Ku, and S. Kullback (G.W.U.). J. Amer. Statist. Assoc. 64 (1969), 1323-1341.
- (7) An evaluation of linear least squares computer programs: A summary report. Roy H. Wampler. Proc. Fourteenth Conf. on the Design of Experiments in Army Research Development and Testing, Edgewood Arsenal, 23-25 October 1968, U. S. Army Research Office - Durham, ARO-D Report 69-2, September 1969, pages 103-126.

DEVELOPMENT OF "OMNITAB"

Task 20503-12-2050131  
1550-11

Origin and Sponsor: NBS  
Managers: David Hogben, Sally T. Peavy  
Full task description: July - December 1968

Authorized 11/1/68

Status: CONTINUED. David Hogben, Sally T. Peavy, Ruth N. Varner, and Shirley G. Bremer continued work on the development of the OMNITAB computing system. Five new versions were implemented which were described in two newsletters distributed to users. Thirty-two new instructions were added to the system consisting of nine for statistical analysis, nine for thermodynamics, six for complex arithmetic, three for printing, two special function instructions, one manipulative instruction, one branching instruction and one arithmetic instruction. The new instructions for statistical analysis include one for the analysis of a one-way table and one for a correlation analysis, each of which produces an automatic printing of a very comprehensive set of results. Several modifications of the system were made including a partial revision of the vocabulary to make the rules about abbreviations and spelling more consistent.

Newsletter No. 6 described Version 5.0 and contained a new up-to-date list of instructions. Version 5.0 is the version of OMNITAB that will soon be released to the Clearinghouse for sale to the public. The list of instructions will be part of the documentation of OMNITAB that is being prepared.

Publications:

- (1) OMNITAB - Rapid statistical manipulation. Joan R. Rosenblatt, Brian L. Joiner, and David Hogben. Pages 46-59 in U. S. Bureau of the Census, Census Tract Papers, Series GE-40, No. 6, Final 1970 Census Plans and Four Programming Systems for Computerized Data Retrieval and Manipulation (Conference on Small-Area Statistics, American Statistical Association, New York, N. Y., August 21, 1969). U. S. Government Printing Office, January 1970.

#### 4. STATISTICAL ENGINEERING SERVICES

##### COLLABORATION ON STATISTICAL ASPECTS OF

##### NBS RESEARCH AND TESTING

Task 13911-612050950/51-1

9500-42

Origin: NBS

Authorized 7/1/50

Managers: H. H. Ku, J. R. Rosenblatt

Full task description: July - September 1950 issue, p. 60

Status: CONTINUED. This is a continuing project involving cooperation with other Bureau scientists on the statistical aspects of their investigations. These services vary from short (one-hour) sessions to extended collaborations involving several man-months; and are concerned primarily with statistical design of experiments, analysis and interpretation of data, and the use of computers in statistical analysis of data. Typical examples of the services performed are the following.

James J. Filliben assisted Thomas Hoover (Electrochemical Analysis Section) in the determination of "cell constants" in a calibration experiment for conductivity cells used in conductimetric analysis of solutions. Five geometrically different cells were involved in the study. The effects of concentration, temperature, and ampule were examined. The resistance measuring device was shown to be of varying precision depending on the magnitude of the resistance, and a negative bias was detected in the device for very large resistances.

H. H. Ku collaborated with K. Leedy of the Electronic Technology Division in the development of a method for the evaluation of ultrasonic wire bonding systems used for attaching leads to integrated circuits. Levels of basic factors - power, pressure, time - were explored and determined for making bonds of consistent pull strengths. Control charts for the mean and standard deviation are kept for routine runs of five tests while the effects of other parameters are being studied.

The up-and-down method of analysis was introduced to J. Oroshnik of the same division in his investigation of adhesion of their aluminum film to various substrates by the Scratch Test.

David Hogben performed a comprehensive statistical analysis of data from a designed (unbalanced) experiment for John Evans and Sharill Dittman (Temperature Section), in the intercomparison of thermocouples and resistance thermometers in the temperature range 600°C to 1000°C. Nine thermometers and four pairs of thermocouples were studied for three different sets of temperatures. "Well," thermometer, and thermocouple effects were studied after the temperature effect had been removed. For thermometers, three different kinds of measurement were compared. Also, the estimates of the true temperature from using both thermometers and thermocouples were compared. The data analyses included extensive use of the FIT command in OMNITAB and also included a  $\chi^2$  probability plot of residual contrast sums of squares. A FORTRAN subroutine written by Morris Newman, to compute the rank of a matrix of integers exactly, proved very helpful in determining the appropriate analyses. The results showed the resistance thermometers to have substantially better precision and to vary less amongst themselves than the thermocouples.

Brian L. Joiner, who is on temporary assignment to the Boulder Laboratories of the National Bureau of Standards, has continued consultations with several people in the Electromagnetics Division concerning the gathering and documentation of evidence to support accuracy claims of the various calibration services. This work has led to the establishment of two new projects in the Electromagnetics Division, providing for intensified investigations of systematic and random errors; Dr. Joiner will collaborate in the development of experiment designs, control chart procedures, and other analyses for these projects.

Brian L. Joiner has collaborated with the Cryogenics Division in the experimental evaluation of a cryogenic flow meter and the electrical resistivity of copper. The flow meter experiments required unbalanced designs because of physical limitations upon the factors that might affect the meter's performance. Complex and interrelated temperature and time-drift effects were discovered through plotting and analysis of residuals from a sequence of fitted models. He has also consulted with the Quantum Electronics Division concerning the measurement of laser power and energy, and with the Joint Institute for Laboratory Astrophysics on the photo disassociation of  $H_2^+$  and  $D_2^+$ . The latter study involves the least squares fitting of non-linear models.



Publications:

- (1) Interlaboratory comparison of the potential heat test method. D. Gross (Fire Research Section) and M. G. Natrella. Fire Test Performance, ASTM STP 464, Amer. Soc. for Testing and Materials, 1970, pp. 127-152.
- (2) Designs for surveillance of the volt maintained by a small group of saturated standard cells. W. G. Eicke (Electricity Division) and J. M. Cameron. M and D Measurements and Data, Vol. 4, No. 2, March-April 1970, pp. 85-102. (Reprint of NBS Technical Note 430.)

STATISTICAL SERVICES

Task 20503-40-2050132/58-346

155G-11

Origin and Sponsors: Various Agencies

Authorized 3/31/58

Manager: J. R. Rosenblatt

Full task description: January - March 1958 issue, p. 45

Status: CONTINUED. This is a continuing project which involves providing, upon request, statistical services to other governmental agencies, universities, industrial organizations, and other non-governmental agencies. Approximately 30 such requests are handled per month ranging from short conferences to collaboration involving several days work.

Ruth N. Varner prepared 13 tapes of card images of the KKV-68A and B programs upon requests from universities (4), government agencies (6), and industrial concerns (3). These programs were written in FORTRAN V language to facilitate computations used in the paper "Analysis of Multi-dimensional Contingency Tables," by H. Ku, R. Varner, and S. Kullback (GWU), Proceedings of the Fourteenth Conference on the Design of Experiments, 1969.

James J. Filliben and Joan R. Rosenblatt prepared 25 "random calendars" and 25 "random permutations" for use by the Selective Service System in preparations for the July 1, 1970, drawing of birthdates to determine the order in which men born in 1951 will be called for induction into military service. Other members of the SEL participated in the work, and in the use of OMNITAB for making randomness tests. Random permutations of 1-365 were derived from published tables (L. E. Moses and R. V. Oakford, Tables of random permutations, Stanford University Press, 1963).

Dr. Michael Boretzky, Office of the Secretary of Commerce, was assisted by Roy H. Wampler who provided least squares computations -- linear and log-linear -- for international import and export trends and projections. OMNITAB was used to produce 50 pages of tables giving results for 5 regions and some 20 commodities with subtotals for groups of commodities. The work was completed within 48 hours, to be available for use by the Secretary.

RESEARCH IN NUMERICAL ANALYSIS AND RELATED FIELDS

Task 20501-12-2050110/55-55

1540-11

Origin: NBS  
 Manager: Morris Newman  
 Full task description: July - September 1954 issue, p. 1

Authorized 8/29/54

Status: CONTINUED. M. Newman has shown that if  $A, B$  are non-singular  $n \times n$  matrices over a principal ideal ring, then the invariant factors of  $AB$  are divisible by the corresponding invariant factors of  $A$  and of  $B$ . A consequence of this is that if  $(\det A, \det B) = 1$ , then  $S(AB) = S(A)S(B)$ , where  $S(A)$  denotes the Smith normal form of  $A$ .

Using the result above, M. Newman has determined the Smith normal form of certain combinatorial matrices, such as Hadamard matrices of order  $4m$ ,  $m$  square-free.

M. Newman and L. Greenberg have proved a number of theorems about the classical modular group. As an example, it was shown that any normal subgroup of square-free index is necessarily of genus 1, apart from four exceptions when it is of genus 0.

A FORTRAN program to determine the Smith normal form of an integral matrix has been prepared by M. Newman, and has been used to prove that certain statistical designs are non-isomorphic.

M. Newman and S. Pierce have proved that if any given non-constant matrix function is uniformly bounded for all the elements of an irreducible matrix group  $G$ , then  $G$  is bounded and thus equivalent to a unitary group.

M. Newman has determined the automorphisms of the free product of finitely many cyclic groups.

K. Goldberg has continued to compile results for a projected A.M.S. publication of solutions, identities and tables in combinatorial analysis.

S. Haber found new bounds for the norms of the errors of Gaussian and certain other quadrature formulas, when the errors are regarded as functionals on certain spaces of analytic functions.

S. Haber showed that the "optimal" quadrature formulas of V.L.N. Sarma, which were defined in terms of a probabilistic theory, are the same as certain formulas which were defined earlier by P.J. Davis in terms of analytic function theory.

R. Merris proved the following inequality for permanents of submatrices: Let  $A$  be a positive semidefinite  $n$ -square matrix. Let  $s_i$  be the  $i$ th row sum of  $A$  and  $s$  be the sum of the elements of  $A$ . Suppose  $s \neq 0$ . Then

$$0 \leq \sum_{i,j=1}^n s_i \bar{s}_j \text{ per } A(i|j) \leq n s \text{ per } A$$

where  $A(i|j)$  is the submatrix of  $A$  obtained by deleting row  $i$  and column  $j$ .

### Status of Projects

R. Merris discovered a simple proof of an inequality better than the classical Fischer inequality. It improves the Hadamard determinant theorem: If  $A = (A_{ij})$  is positive semidefinite hermitian then

$$\prod_{t=1}^n A_{tt} - \det A \geq \frac{\det A}{\lambda^2} \sum_{i < j} |A_{ij}|^2$$

where  $\lambda$  is the largest eigenvalue of  $A$ .

S. Pierce and R. Merris discovered a characterization of  $r$ -fold transitivity in terms of the Bell numbers. Let  $G$  be a permutation group. For  $g \in G$ , let  $\theta(g)$  be the number of points fixed by  $g$ . Then

$$\sum_{g \in G} (\theta(g))^r \geq X_r |G|$$

with equality if and only if  $G$  is  $r$ -fold transitive. Here  $X_r$  is the  $r$ th Bell number.

S. Pierce and R. Merris proved some monotonicity theorems for positive semidefinite hermitian matrices.

F.W.J. Olver has continued work on the method of stationary phase and has also been investigating a paradox in the theory of asymptotic sums.

#### Publications:

- (1) Stochastic quadrature formulas. S. Haber. Math. Comp., Vol. 23, No. 108, pp. 751-764 (1969).
- (2) Sequences of numbers that are approximately completely equidistributed. S. Haber. Jour. of the Association for Computing Machinery, Vol. 17, No. 2, pp. 269-272 (1970).
- (3) On the sum  $\sum \langle \alpha_n \rangle^{-t}$  and numerical integration. S. Haber and C.F. Osgood. Pacific Jour. of Math., Vol. 31, No. 2, pp. 383-394 (1969).
- (4) Numerical evaluation of multiple integrals. S. Haber. Submitted to a technical journal.
- (5) The error in numerical integration of analytic functions. S. Haber. Submitted to a technical journal.
- (6) Normal subgroups of the modular group. L. Greenberg and M. Newman. To appear in J. of Research NBS.
- (7) Some results on solvable groups. L. Greenberg and M. Newman. To appear in Arch der Math.
- (8) Lectures on modular forms. J. Lehner. AMS 61, pp.1-77(1969).
- (9) Partitioned hermitian matrices. R. Merris. J. of Research NBS, 74B, No. 1, 45-46 (1970).

- (10) Trace functions I . R. Merris. Submitted to a technical journal.
- (11) Elementary divisors of higher degree associated transformation. R. Merris and S. Pierce. Submitted to a technical journal.
- (12) A class of representations of the full linear group. R. Merris and S. Pierce. Submitted to a technical journal.
- (13) Conjecture and theorem on permanents. R. Merris. Submitted to a technical journal.
- (14) An improvement of the Fischer inequality. R. Merris. Submitted to a technical journal.
- (15) The Bell numbers and r-fold transitivity. R. Merris and S. Pierce. Submitted to a technical journal.
- (16) Isomorphic symmetry classes of tensors. R. Merris and W. Watkins. Submitted to a technical journal.
- (17) Some results on unitary matrix groups. M. Newman and M. Marcus. Linear Algebra and its Applications 3, 173-178 (1970).
- (18) A table of the first factor for prime cyclotomic fields. M. Newman. Math. Comp., Vol. 24, No. 109, pp. 215-219 (1970).
- (19) An enumeration problem for a congruence equation. M. Newman and R. Brualdi. J. of Research NBS, 74B, No. 1, 37-40 (1970) .
- (20) Bounded matrix groups. M. Newman and S. Pierce. To appear in Journal of Linear Algebra.
- (21) Units in cyclotomic number fields. M. Newman. To appear in J. ~~Reine~~ Angew Math.
- (22) Why steepest descents? F.W.J. Olver. Proceedings of the 1969 SIAM National Meeting June 10-12, 1969, Vol. 12, No. 2, pp. 228-247 (1970) .
- (23) Orthogonal decompositions of tensor spaces. S. Pierce. J. of Research NBS, 74B, No. 1, 41-44 (1970) .
- (24) Multiplicative maps of matrix semigroups over Dedekind rings. S. Pierce. Submitted to a technical journal.
- (25) Orthogonal groups of positive definite multilinear functionals. S. Pierce. To appear in Pacific Jour. of Math.

BIOMEDICAL IMAGE AND LANGUAGE PATTERN PROCESSING

Task 20500-2050404

1550-22

Origin: NBS

Authorized: 1/21/64

Sponsor: National Institutes of Health

Manager: Russell A. Kirsch

Full task description: January-June issue 1964, p.19

Status: CONTINUED. Further efforts were made to finalize the conversion of the LISPAX system from the Q32 computer to the PDP-10 computer at NIH. The construction of scanning microscope modifications and additions continues as the linkage between the controller computer of the scanning process and the processor computer is perfected. Programs were written to enable conversion of the data through the microscope and computer for eventual display on the Stromberg Carlson. Analysis work continued on photographic data for single and double neurons in tissue sections.

Publications: (1) Computer determination of the constituent structure of biological images Part I. Russell A. Kirsch. NBS Report 10173 (1969). Submitted to Computers and Biomedical Research.

(2) A LISP conversion of grayness profiles. Anne A. Holston. NBS Report 10148 (1970).

SCANNING MICROSCOPE PROCESSING

Task 20500-2050408

1550-22

Origin: NBS

Authorized: 6/18/68

Sponsor: National Institutes of Health

Manager: Russell A. Kirsch

Full task description: July-December issue 1968, p. 14

Status: CONTINUED. Algorithms were constructed on remote time-sharing computers to process images of white blood cells as part of a study of cell kinetics using autoradiograph data. The PDP-10, supplied by information from the PDP-8, converted the images into display and numeric formats.

CHEMICAL BIOLOGICAL INFORMATION PROCESSING

Task 20500-2050410

1550-22

Origin: NBS

Authorized: 6/27/68

Sponsor: National Institutes of Health

Manager: Russell A. Kirsch

Full task description: July-December issue 1968, p. 14

Status: CONTINUED. Advisory work continued on Chemical Biological Information Handling techniques. Advisory capacity consisted of periodic site visits to review project and research proposals in connection with the development of a Chemical Biological Information Processing System. Studies were continuing of proposals for the development of computer graphics and data management systems for use in pharmacology.

MATHEMATICAL TABLES

Task 20500-40-2050121/57-216

1550-11

Origin and Sponsor; NBS

Manager: I. A. Stegun

Full task description: July-December 1964 issue, p.4.

Status: CONTINUED. In line with the program of providing not only tables of the special functions but also methods of computing them, I. A. Stegun and R. Zucker ran exploratory tests in particular for the Sievert integral and the exponential integral. A paper is being prepared including the pitfalls of their computation as well as their possible avoidance. A detailed description of the computing methods will be given. The implementing FORTRAN program, test ("driver") program and test results will also be included.

An updated errata list is being maintained for AMS 55- the Handbook of Mathematical Functions. Corrections are made in subsequent printings of the volume.

A FORTRAN program of various test matrices was also prepared in order to check on the accuracy of computer programs for obtaining eigenvalues and eigenvectors. These test programs serve as a "quality control" not only of the mathematics involved, but also of the software and hardware including timing. The universality of the computer language is likewise being checked.

Assistance at the rate of about twelve consultations per month was given to the staff of NBS, other government agencies, industry and universities. The topics covered were computer programs, tables of special functions, computing techniques and pitfalls.

Publications:

(1) Mathematics Bibliography. Irene A. Stegun and Constance Carter (Library of Congress). To appear as Section 1A of the American Institute of Physics Handbook, 3rd Edition.

(2) Automatic Computing Methods for Special Functions. Part 1. Error, Probability and Related Functions. Irene A. Stegun and Ruth Zucker. To appear in the J. of Research NBS, 74B, July-September 1970.

# Lectures and Technical Meetings

## Mathematics Division Lectures

- FLATTO, Leopold (Department of Mathematics, Yeshiva University, New York, N. Y.).  
Invariants of Finite Reflection Groups, and Mean-Value Problems,  
February 4, 1970.
- SHISHA, Oved (Aerospace Research Laboratories, Wright-Patterson Air Force Base, Ohio).  
Rearrangements of Numerical Sequences and their Geometric Interpretation.  
April 20, 1970.

## Mathematics Division Expository Lectures

- MERRIS, Russell An Inner Product of Tensor Spaces. January 21.
- STEGUN, Irene A. Automatic Computing - Special Functions. February 18.
- KU, Richard (Technical Analysis Division, IAT) Mathematical Models to Forecast  
Travel Demand. March 18.
- LEVY, Joel Feedback Control of Traffic at an Intersection. April 15.
- SALTMAN, Roy G. (Systems Development Division, Center for Computer Sciences and Technology)  
Some Methods of Optimal Multi-Commodity Network Design Part I. A Heuristic  
Design for the U. S. Government Telecommunications Network. April 28.
- BELLMORE, Mandell (The Johns Hopkins University) Some Methods of Optimal Multi-Commodity  
Network Design Part II. Mathematical Programming; Set Covering and  
Involutionary Bases. May 5.
- FILLIBEN, James J. The Percent Point Function. May 20.
- KRAFT, Richard The Finite Difference Approach to the Solution of Partial Differential  
Equations. June 17.

## Statistics for Metrologists

Lectures by JOINER, BRIAN L. at the NBS Boulder Laboratories

1. The Utilization of Basic Statistical Methods in the Interpretation of Data. March 24.
2. Planning Experiments. March 31.
3. Error Analysis of a Measurement Process. April 7.
4. Control Charts and Measurement Stability. April 14.
5. Propagation of Error. April 21.

## Statistics Seminar

- LANCASTER, H. O. (University of Sydney, Australia). Bibliography and History: Problems  
of Bibliography in Statistics. May 25.

## Systems Dynamics Seminar

- MURA, Toshio (Materials Research Center, Northwestern University, and Visiting Scientist,  
Metallurgy Division, NBS) Green's Tensor Functions for a Continuum with  
Dislocations. January 14.

CHANG, Shih-Jung (Mathematics Division, Oak Ridge National Laboratory) A Crack Problem for Viscoelastic Plates. February 11.

In-Hours Courses

VARNER, Ruth N. New Topics in FORTRAN, NBS M123.

Papers and Invited Talks  
Presented by Members of the Staff at Meetings  
of Outside Organizations

FILLIBEN, J. J. The Percent Point Function. Department of Statistics, Johns Hopkins Univer., April 22.

FILLIBEN, J. J. The Percent Point Function. Virginia Academy of Science, Richmond, May 8.

GILSINN, J. F. A Computer Comparison of Labelling Algorithms for Calculating Shortest Path Trees. Spring 1970 National Meeting of Operations Research Society, Washington Hilton Hotel, Washington, D. C. April 21.

GOLDMAN, A. J. Minimax-error Disaggregation of a Distribution. Spring 1970 National Meeting of Operations Research Society, Washington Hilton Hotel, Washington, D. C. April 22.

GOLDMAN, A. J. Analysis of a Capacity Concept for Runway and Final-Approach Path Airspace. 1970 National Meeting of Institute of Navigation. Stouffer's Riverfront Inn, St. Louis. April 16.

GOLDMAN, A. J. Roles and Criteria for Demand Models in the Northeast Corridor Transportation Project. Third Annual Meeting of Users and Producers of Operations Research, NBS. May 8.

GOLDMAN, A. J. Some Interactions between Operations Research and Statistics. 1970 National Meeting of Administrative Applications Division, American Society for Quality Control. Crystal City Marriot Hotel, Arlington, Va. March 13.

HALL, W. G. A Simulation of a Highway Maintenance Depot. Spring 1970 National Meeting of Operations Research Society, Washington Hilton Hotel, Washington, D. C. April 22.

HORN, W. A. Optimizing Sorting Networks. Spring 1970 National Meeting of Operations Research Society, Washington Hilton Hotel, Washington, D. C. April 20.

JOEL, L. S. Alternative Player Types in Games. Spring 1970 National Meeting of Operations Research Society, Washington Hilton Hotel, Washington, D. C. April 20.

JOINER, B. L. Tukey's Lambda Distributions. Colorado-Wyoming Chapter, Amer. Statist. Assoc., Boulder. February 17.

JOINER, B. L. Statistics in Radio Frequency Electrical Measurements. Precision Measurements. Precision Measurement Assoc., Gaithersburg, Md. June 17.

KIRSCH, R. A. Problems in Future Use of Computers in Biomedicine. Presented at a Mathematical Medicine Conference, Riverside Hospital, Toledo, Ohio. May 12.

KU, H. H. The Analysis of Calibration Data. NBS. Seminar on Precision Force Measurement. April 6.

KU, H. H. Data Analysis and the Measurement Process. NBS. Precision Measurement Seminar on Radiation Quantities. May 12.

LEVY, J. and PEARL, M. H. Traffic Loss at a Merge-Point Controlled by Non-Feedback Regulation. Spring 1970 National Meeting of Operations Research Society, Washington Hilton Hotel, Washington, D. C. April 21.



MERRIS, Russell           Elementary Divisors of Higher Degree Associated Transformations, Convention Center, San Antonio, Texas. January 23.

NEWMAN, Morris           Solving Equations Exactly, University of Toledo, Toledo, Ohio. May 20.

PIERCE, Stephen          Isometries with Respect to a Multilinear Function, University of Arizona, Tuscon, Arizona. February 12.

RUTHBERG, Zella G.       An Integer Program for the Nth Power of a Noncommutative Binomial Operator. Association for Computing Machinery, Washington, D. C. Chapter- 9th Annual Technical Symposium. June 25.

SADOWSKI, Walter L.      Taylor Series Expansion with the Aid of Combinatorics. Association for Computing Machinery, Washington, D. C. Chapter-9th Annual Technical Symposium. June 25.

SAUNDERS, P. B.          Practical Algorithms for Scheduling Ground Transportation Systems. Spring 1970 National Meeting of Operations Research Society, Washington Hilton Hotel, Washington, D. C. April 20.

WAMPLER, Roy H.          A Report on the Accuracy of Some Widely Used Linear Least Squares Computer Programs. Washington Statistical Society. February 9.

WAMPLER, Roy H.          A Report on the Accuracy of Some Widely Used Linear Least Squares Computer Programs. American Society for Quality Control, Administrative Applications Division Conference, Arlington, Va. March 13.

# Publication Activities

## 1.0 PUBLICATIONS THAT APPEARED DURING THIS PERIOD

### 1.2 Monographs

Lectures on modular forms. J. Lehner. AMS 61 pp. 1-73 (1969).

### 1.3 Technical Papers

Designs for surveillance of the volt maintained by a small group of saturated standard cells. W. G. Eicke (Electricity Division) and J. M. Cameron. M and D Measurements and Data Vol. 4, No. 2, March-April 1970, pp. 85-102. (Reprint of NBS Technical Note 430.)

Bottleneck extrema. J. Edmonds and D. R. Fulkerson (RAND). J. Combinatorial Theory 8 (1970), pp. 299-306.

Analysis of a capacity concept for runway and final-approach path airspace. A. J. Goldman. Proc. 1970 Nat. Air Meeting, Institute of Navigation (4/70), pp. 119-131.

Stochastic quadrature formulas. S. Haber. Math. Comp., Vol. 23, No. 108, pp. 751-764 (1969).

Sequences of numbers that are approximately completely equidistributed. S. Haber. Jour. of the Association for Comp. Machinery, Vol. 17, No. 2, pp. 269-272 (1970).

On the sum  $\sum < n\alpha >^{-t}$  and numerical integration. S. Haber and C. F. Osgood. Pacific Jour. of Math., Vol. 31, No. 2, pp. 383-394 (1969).

Analysis of multidimensional contingency tables. H. H. Ku, R. N. Varner, and S. Kullback (G.W.U.) Proc. Fourteenth Conf. on the Design of Experiments in Army Research Development and Testing, Edgewood Arsenal, 23-25 October 1968, U. S. Army Research Office - Durham, ARO-D Report 69-2, September 1969, pages 141-180.

Symmetry and marginal homogeneity of an rxr contingency table. C. T. Ireland (G.W.U.), H. H. Ku and S. Kullback (G.W.U.). J. Amer. Statist. Assoc. 64 (1969), 1323-1341.

Partitioned hermitian matrices. R. Merris. J. of Research NBS, 74B, No. 1, 45-46 (1970).

Interlaboratory comparison of the potential heat test method. D. Gross (Fire Research Section) and M. G. Natrella. Fire Test Performance, ASTM STP 464, Amer. Soc. for Testing and Materials, 1970, pp. 127-152.

A table of the first factor for prime cyclotomic fields. M. Newman. Math. Comp., Vol. 24, No. 109, pp. 215-219 (1970).

An enumeration problem for a congruence equation. M. Newman and R. Brualdi. J. of Research NBS, 74B, No. 1, 37-40 (1970).

Some results on unitary matrix groups. M. Newman and M. Marcus. Linear Algebra and its Applications, No. 3, 173-178 (1970).

Why steepest descents? F. W. J. Olver. Proceedings of the 1969 SIAM National Meeting, June 10-12, 1969, Vol. 12, No. 2, pp. 228-247 (1970).

Orthogonal decompositions of tensor spaces. S. Pierce. J. of Research NBS, 74B, No. 1, 41-44 (1970).

OMNITAB - Rapid statistical manipulation. Joan R. Rosenblatt, Brian L. Joiner and David Hogben. Pages 46-59 in U. S. Bureau of the Census, Census Tract Papers, Series GE-40, No. 6, Final 1970 Census Plans and Four Programming Systems for Computerized Data Retrieval and Manipulation (Conference on Small-Area Statistics, American Statistical Association, New York, N. Y., August 21, 1969). U. S. Government Printing Office, January 1970.

An evaluation of linear least squares computer programs: A summary report. Roy H. Wampler. Proc. Fourteenth Conf. on the Design of Experiments in Army Research Development and Testing, Edgewood Arsenal, 23-25 October 1968, U. S. Army Research Office - Durham, ARO-D Report 69-2, September 1969, pages 103-126.

#### 1.4 Notes

A localization theorem for optimal facility location. A. J. Goldman and C. Witzgall. Submitted to a technical journal.

The adequacy of management science technology for non-military applications in the Federal government. To appear in Proc., Amer. Soc. Public Adm. Workshop on Management Science in the Federal government (11/69).

#### 2.0 MANUSCRIPTS IN THE PROCESS OF PUBLICATION

##### 2.3 Technical Papers

The percent point function. James J. Filliben. Submitted to a technical journal.

Optimal center location in simple networks. A. J. Goldman. Submitted to a technical journal.

Normal subgroups of the modular group. L. Greenberg and M. Newman. To appear in J. of Research NBS.

Some results on solvable groups. L. Greenberg and M. Newman. To appear in Arch der Math.

Numerical evaluation of multiple integrals. S. Haber. Submitted to a technical journal.

Some properties of the range in samples from Tukey's symmetric lambda distributions. Brian L. Joiner and Joan R. Rosenblatt. To appear in J. Amer. Statist. Assoc.

Analysis of information -- An alternative approach to the detection of a correlation between the sexes of adjacent sibs in human families. H. H. Ku. To appear in Biometrics.

Conjecture and theorem on permanents. R. Merris. Submitted to a technical journal.

An improvement of the Fischer inequality. R. Merris. Submitted to a technical journal.

Trace Functions I. R. Merris. Submitted to a technical journal.

Elementary divisors of higher degree associated transformation. R. Merris and S. Pierce. Submitted to a technical journal.

A class of representations of the full linear group. R. Merris and S. Pierce. Submitted to a technical journal.

Isomorphic symmetry classes of tensors. R. Merris and W. Watkins. Submitted to a technical journal.

Units in cyclotomic number fields. M. Newman. To appear in J. Reine Angew Math.

Bounded matrix groups. M. Newman and S. Pierce. To appear in Journal of Linear Algebra.

Multiplicative maps of matrix semigroups over Dedekind rings. S. Pierce. Submitted to a technical journal.

Orthogonal groups of positive definite multilinear functionals. S. Pierce. To appear in Pacific Jour. of Math.

Mathematics Bibliography. Irene A. Stegun and Constance Carter (Library of Congress). To appear as Section 1A, American Institute of Physics Handbook, 3rd Edition.

Automatic Computing Methods for Special Functions. Irene A. Stegun and Ruth Zucker. To appear in J. of Research NBS, 74B (1970).

On complementary polar conical sets. C. Witzgall. To appear in J. of Research NBS, 74B, (1970).

##### 2.5 Books

An author and permuted title index to selected statistical journals. Brian L. Joiner, N. F. Laubscher (National Research Inst. for Math. Sciences, South Africa), Eleanor S. Brown, and Bert Levy (Harry Diamond Labs.; U. S. Army). To appear as NBS Special Publication 321.



# NBS TECHNICAL PUBLICATIONS

## PERIODICALS

**JOURNAL OF RESEARCH** reports National Bureau of Standards research and development in physics, mathematics, chemistry, and engineering. Comprehensive scientific papers give complete details of the work, including laboratory data, experimental procedures, and theoretical and mathematical analyses. Illustrated with photographs, drawings, and charts.

*Published in three sections, available separately:*

### ● Physics and Chemistry

Papers of interest primarily to scientists working in these fields. This section covers a broad range of physical and chemical research, with major emphasis on standards of physical measurement, fundamental constants, and properties of matter. Issued six times a year. Annual subscription: Domestic, \$9.50; foreign, \$11.75\*.

### ● Mathematical Sciences

Studies and compilations designed mainly for the mathematician and theoretical physicist. Topics in mathematical statistics, theory of experiment design, numerical analysis, theoretical physics and chemistry, logical design and programming of computers and computer systems. Short numerical tables. Issued quarterly. Annual subscription: Domestic, \$5.00; foreign, \$6.25\*.

### ● Engineering and Instrumentation

Reporting results of interest chiefly to the engineer and the applied scientist. This section includes many of the new developments in instrumentation resulting from the Bureau's work in physical measurement, data processing, and development of test methods. It will also cover some of the work in acoustics, applied mechanics, building research, and cryogenic engineering. Issued quarterly. Annual subscription: Domestic, \$5.00; foreign, \$6.25\*.

## TECHNICAL NEWS BULLETIN

The best single source of information concerning the Bureau's research, developmental, cooperative and publication activities, this monthly publication is designed for the industry-oriented individual whose daily work involves intimate contact with science and technology—for *engineers, chemists, physicists, research managers, product-development managers, and company executives*. Annual subscription: Domestic, \$3.00; foreign, \$4.00\*.

\* Difference in price is due to extra cost of foreign mailing.

## NONPERIODICALS

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