During World War II the values of L(h,k,r) became necessary in connection with certain work in the Statistical Laboratory under a contract with the Applied Mathematics Panel, N.D.R.C. However, for the most part, the values needed corresponded to h, and kexceeding the range of the table then available. Also, the requisite values of r were extremely close to ± 1 in which region interpolation in Pearson's table is difficult.

The persistent need of values of L(h,k,r) suggested that it might be useful to solve the difficulty once and for all by computing an extension of Pearson's tables. Dr. LEO AROIAN and Dr. MADELINE JOHNSEN (then in the employ of the Statistical Laboratory) were entrusted with calculating the extension of the tables. Their work was interrupted by the cessation of hostilities in September, 1945, and the subsequent discontinuance of the N.D.R.C. project. Thereafter the work on the tables continued sporadically. Some computations were done by Drs. Aroian and Johnsen. Later on a check of the tables was made in the Statistical Laboratory by Dr. EVELYN FIX. This was followed by extensive recalculations by Miss MARY Woo and Miss ESTHER SEIDEN under the direction of Dr. Fix. It is now believed that the errors in the table do not exceed one half unit in the sixth decimal. The combination of the two sets of tables, Karl Pearson's and the new tables, covers the ranges of h,k = 0(.1)4; $\pm r = 0(.05).95(.01).99$.

It may be hoped that some way will be found for the combined tables to appear in a single publication.

J. NEYMAN

Statistical Laboratory Univ. of California, Berkeley

AUTOMATIC COMPUTING MACHINERY

Edited by the Staff of the Machine Development Laboratory of the National Bureau of Standards. Correspondence regarding the Section should be directed to Dr. E. W. CANNON, 418 South Building, National Bureau of Standards, Washington 25, D. C.

TECHNICAL DEVELOPMENTS

Our contribution under this heading, appearing earlier in this issue, is "Coding of a Laplace boundary value problem for the UNIVAC," by FRANCES E. SNYDER & H. M. LIVINGSTON.

DISCUSSIONS

A Comparison of Various Computing Machines Used in the Reduction of Doppler Observations

Introduction. DOVAP (Doppler Velocity and Position) is a radio-DOPPLER method for the determination of the coordinates of the trajectories of long-range V-2 rockets launched at the Army's White Sands Proving Ground, New Mexico. The method has been in use for the past two years. In this system, continuous-wave radio signals are sent from a transmitter to a transceiver in the missile and to each of several ground station receivers. In the missile-transceiver the signals are modified by a frequency-doubling operation and then are retransmitted to each of the several ground stations. In the ground receivers the frequency of the signals received directly from the transmitter is likewise doubled, and these double-frequency signals are mixed with those received from the missile. The mixed signals are recorded on 35 mm movie film simultaneously for the several receivers at one master receiver station. The film records present the traces of sinuous waves of changing frequency accompanied by a series of time pulses. Each successive cycle of the recorded wave indicates that the total distance from transmitter to missile to receiver has changed by one Doppler wave-length. If the initial (launching) value of this combined distance is known, all subsequent values are found simply by counting the Doppler cycles on the film record. Refraction and other physical effects will introduce differential errors, which are, however, ignored in the first approximations which are discussed here.

For V-2 missiles more than 50,000 cycles may have to be counted for the maximum ordinate of the trajectory. The distances from transmitter to missile to receiver involve numbers of six-digit accuracy. In the determination of one point on the trajectory, approximately 40 additions, multiplications, divisions and square roots are performed. The numerical work necessary for the calculation of the positions of the required number of points on a long trajectory justifies the utilization of high-speed computing machines.

The General Problem. In the determination of the missile location from DOVAP data, it is assumed that the coordinates of one point on the trajectory are known accurately. This point is usually the position of the transceiver in the missile at the time the missile is launched. If u_i is the distance from the transmitter to the missile to receiver *i*, the survey data of the launching and station sites furnish the initial values of $(u_i)_0 = c_i$. The difference between u_i and c_i at any time *t* can be obtained from the Doppler records. Given c_i and λ , the Doppler wave-length corresponding to twice the transmitted frequency, we have therefore, $u_i = c_i + N_i \lambda$, where N_i represents the number of Doppler cycles observed on the DOVAP records between the initial point of the *i*th trace and the point corresponding to the time *t*.

This paper treats the case in which three receivers are used in the DOVAP system. To determine the missile coordinates, three receivers are sufficient. The data from any one receiver prescribe that the missile is somewhere on the surface of a prolate spheroid, one of whose foci is located at the transmitter and the other at the receiver. The actual location of the missile is a common intersection of three such prolate spheroids having in common one focus, located at the transmitter. For three receivers there are two such solutions, one of which, generally being underground, is obviously rejected.

Briefly, the equations for the solution of the problem are:¹

$$\sqrt{x^2 + y^2 + z^2} + \sqrt{(x_i - x)^2 + (y_i - y)^2 + (z_i - z)^2} = u_i(i = 1, 2, 3),$$

x,y,z referring to the coordinates of the missile, and x_i, y_i, z_i referring to those of the receiver stations, relative to the transmitter as origin. If r and r_i are the corresponding slant ranges, the equations become,

$$2(x_ix + y_iy + z_iz) = 2ru_i - u_i^2 + r_i^2, \qquad (i = 1, 2, 3).$$

By substituting $2r = u_3 - \epsilon$, the solution of the problem is obtained rapidly by successive approximations in the following formulae, in the first approximation of which a value is assumed for $z: \epsilon = az_{(1)} + b$, $r_{(1)} = \frac{1}{2}(u_3 - \epsilon)$, $x_{(1)} = c\epsilon + d$, $y_{(1)} = e\epsilon + f$, $z_{(2)} = (r^2 - x^2 - y^2)^{\frac{1}{2}}$.

The corrections for successive approximations become: $\Delta z = z_{(2)} - z_{(1)}$, $\delta \epsilon = a\Delta z$, $\delta r = \frac{1}{2}\epsilon$, $\delta x = c\epsilon$, $\delta y = e\epsilon$, and $z_{(3)} = (r_{(2)}^2 - x_{(2)}^2 - y_{(2)}^2)^{\frac{1}{2}}$.

The coefficients a through f are all functions of u_i . More than two approximations in z are seldom necessary in the cases where the transmitter is close to one of the receivers. When, however, all receivers are located from 10 to 15 miles from the transmitter, as many as 5 approximations have occasionally been found necessary for the early parts of the trajectory in order to get agreement to within one foot in successive values for z.

Equipment Available for Computations. The computations of coordinates by human computers using desk machines (i.e., Friden, Marchant or Monroe) require between 15 and 45 minutes per trajectory point, the actual time required depending on the skill of the individual, his familiarity with the detailed formulae, and the number of approximations necessary. For detailed trajectory information, many points on the trajectory must be considered, and the computations by hand are laborious. For example, to compute the coordinates of the 800 points at half-second intervals on the trajectory of a 400-second time-of-flight missile, about 10 man-weeks would be required. Fortunately, this time can be greatly reduced by the use of modern high-speed computing machinery. In chronological order of availability, we at the BRL, Aberdeen Proving Ground, Md., have experimented with the following machines: 1. standard IBM equipment, 2. IBM Relay Multipliers, 3. the ENIAC, 4. the Bell Telephone Laboratories' Computing Machine.

The standard IBM equipment is impractical for the complete solution of the problem for several reasons. The large number of digits involved taxes the capacity of the multipliers. Furthermore, the problem has to be broken down into too many discrete steps, since the most complicated single operation that can be performed on these IBM machines² is of the form A + Bx. Moreover the capacity of a single card is soon exhausted, necessitating frequent reproduction of partial results onto new card sets in order that the computations may be continued. The multiplier operations are all slow, and machine break-downs are a frequent cause of interruption. Thus, while the complete computations for an 800-point trajectory should theoretically require much less than a week on this equipment, the actual time is more nearly comparable with human computer time.

The new relay calculators, which performed their initial work on this problem, are much more practical, though not nearly so expeditious as their theoretical operation rates would indicate. It has been our experience that about two weeks are required for the determination on a 400-second trajectory of the coordinates of positions, with successive first and second differences, and velocities at half-second intervals. (The theoretical time would be about 4 days.)

The Ballistic Research Laboratories have two of the new IBM relay calculators. These two units have been connected so that they may now operate as a single unit. Test runs indicate that this Siamese-twin computer will be able to determine missile coordinates at a rate of 5 to 8 minutes per point. Computations for sizeable runs of points have not as yet been completed by this new method. Hence, we can at present comment only on the promise of this arrangement; we cannot examine, by use of actual statistics, its long-range dependability.

The ENIAC is very much faster and more economical in the use of cards than the IBM relay calculators. Only the input data and required

results are punched on the cards. It is partly for this reason that the ENIAC can achieve a greater speed, since even the punching of results on the cards takes longer than the actual computing. The most time-consuming factor occurring in the use of the ENIAC is the "programming" (i.e. setting up the machine for a specific problem). For the particular DOVAP problem, the programming for the computations of only trajectory point coordinates requires from one to two days. Approximately one more day of programming would be required to determine the velocities in addition to the coordinates.

Machine failures are frequent on the ENIAC. 10% failure (in percentage of operating time) is not unusual; on a few problems the failure ratio has been as high as 75%. Nevertheless, the ENIAC excels all other present available machines in the speed with which it is capable of computing DOVAP results. Barring machine failures (including failures due to warped cards or cards affected by humidity or static charges) the actual computations of trajectories on the ENIAC require little more time than the time of flight of the missile. A computation time of 15 minutes for the 800-point trajectory would be normal. Clearly, even though the programming time for the ENIAC is relatively long, the machine is very efficient for the performance of a long series of calculations of the same type.

For the reduction of a limited amount of data, or for computing check points on very long ENIAC runs, the Bell Telephone Laboratories' Computing Machines (designed by Dr. G. R. STIBITZ) are more practical, though slower in performing the basic arithmetic operations than the other machines tried. These machines require approximately 5 minutes for the computation of the coordinates of a trajectory point, but the preparatory time for programming the problem prior to actual computations is negligible, once the data have been coded on the machine data tapes. These machines are now being used to reduce at half-second intervals the data pertaining to a missile flight through burn-out only (which requires about one minute of flight), and for points at 10-second intervals for all long flights. Although the time, 5 minutes per point, is comparable with the over-all time required by the IBM relay calculators, the efficiency of the Bell machines is greater. Thus far, these machines have made few errors. Only one error was found in the results for approximately 1200 points computed.

These machines have the added advantage over the IBM equipment in that they require less supervision. Provided that sufficient data tapes are stored in the Bell machines, they can be left operating all night. Moreover, in case errors in data or other handicaps which make a problem insolvable are encountered, the problem is automatically switched off, or the machines proceed to the next computation that the instruction tapes specify. The IBM machines do not have this facility. Because they are able to operate unattended all night, the Bell machines, can produce much greater output per operator hour than the IBM relay machines and indeed they run a close second to the ENIAC in utility on the DOVAP problem—the 800point trajectory, requiring less than 70 hours, would take only three working days if run continuously.

To conclude, it has been found that the ENIAC is most efficiently used in the solutions of many complete runs of the same type of problem. Since the limiting factor in the use of this machine is the actual time required for

the programming of the problem, once the problem has been set up the ENIAC can provide the complete solution of many long DOVAP trajectory problems at amazingly high speed. The IBM machines, because of the relatively short set-up time and long computing time, are best suited to the simultaneous solution of one particular phase of the problem for all the trajectory points. In addition, very detailed checks are necessary, when the IBM machines are used, in order to determine the adequacy of these partial results before the completion of the total trajectory computation. Otherwise an error in any one of the 40 odd steps in the computations for one point might not be detected until the work for all 800 points had been completed. The Bell machines, however, are both flexible and reliable. They compute complete data for successive trajectory points, and they require very little set-up time. They are particularly useful for the solution of small, varied problems and are consequently desirable for providing the ENIAC with isolated check results whenever the data at hand are justifiably abundant for the utilization of the ENIAC.

It appears from the tests to date at the BRL that the complete DOVAP computations for a single 800-point trajectory are done equally expeditiously on the ENIAC or the Bell machines (and perhaps as efficiently on the twin IBM relay calculators-although limited experience with these machines precludes any accurate appraisal at the present time of their use in the solution of the DOVAP problem). Because of the high programming time of the ENIAC, however, the Bell machines are to be preferred for shorter problems like the computation for a few points on a single trajectory. For longer problems the picture changes. For example, the computations on 10 trajectories for which the raw data are available simultaneously would be completed in about $2\frac{1}{2}$ days on the ENIAC, unless grave machine failures occurred (2 days preparatory plus 15 minutes per trajectory), but would require almost 30 days of continuous day and night running time on the Bell machines. Both the ENIAC and the Bell Relay Machine are extremely useful in the fast reduction of DOVAP data. By comparison, the standard IBM machines are quite limited in utility on this type of problem.

DORRIT HOFFLEIT

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EDITORIAL NOTE: Dr. Hoffleit's paper is a revision of the one to which we referred, MTAC, v. 3, p. 133 (7). ¹ The detailed mathematical solutions were carried out by Dr. BORIS GARFINKEL of the

¹ The detailed mathematical solutions were carried out by Dr. BORIS GARFINKEL of the Ballistic Research Laboratories (BRL), Aberdeen, Md.

 2 We refer in particular to Multiplier Model 601. Newer models are both faster and more flexible.

BIBLIOGRAPHY Z-VI

 HOWARD H. AIKEN & GRACE M. HOPPER, "The Automatic Sequence Controlled Calculator," II, III *Electrical Engineering*, v. 65, Oct.-Nov., 1946, p. 449-454, 522-528. 21.6 × 27.9 cm. See *MTAC*, v. 2, p. 185-187, p. 316; v. 3, p. 210.

These articles continue a discussion of the functions of the ASCC developed for Harvard University by the IBM Corporation. The calculator will carry out any selected sequence

AUTOMATIC COMPUTING MACHINERY

of the four fundamental operations of arithmetic (addition, subtraction, multiplication, division), and reference to tables of previously computed results under completely automatic control. The functions considered herein are those of the multiplication and division registers and of the functional units. The preparation and planning of the sequence controlled tapes are discussed.

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- ANON., "Relay computer for the army," Bell Laboratories' Record, v. 26, 1948, p. 208–209. 17.8 × 25.4 cm.
- 3. ANON., "The Univac," *Electronic Industries*, v. 2, May, 1948, p. 9, 19; illustr. 20.3 \times 27.9 cm.

"An extremely high-speed electronic digital computer, designed by the Eckert-Mauchly Computer Corporation, Philadelphia, is an advance in the new science of planning industrial and military operations by solutions of formulas."

MDL

4. JULIAN H. BIGELOW, JAMES H. POMERENE, RALPH J. SLUTZ, & WILLIS H. WARE, Interim Progress Report on the Physical Realization of an Electronic Computing Instrument, Princeton, N. J., Institute for Advanced Study, 1 Jan., 1947, viii, 101 leaves. Mimeographed. 21.6 × 27.9 cm.

This report had been previously circulated to some degree in preliminary form but has only recently been reproduced in quantity and made available for wider distribution. The contents appear to be identical with those of the copies previously issued.

The report describes the engineering phases of the work on electronic digital computers at the Institute for Advanced Study in an attempt to obtain the physical realization of the machine which was discussed from the logical standpoint in a companion report issued by the Institute, 28 June, 1946, entitled *Preliminary Discussion of the Logical Design of an Electronic Computing Instrument;* see MTAC, v. 3, p. 50-53 for a review of this report. Beginning with an outline of the objective and organization planned to meet it, the report continues with a general discussion of the arrangement and components of the entire computer. It then goes on to present a detailed description of analysis tests and conclusions drawn from them on the use of a magnetic wire or tape for external memory and operation of elementary circuit components such as the "flip-flop" and the "counter." The report ends with a brief statement of the future plans of the group at the time the report was issued.

It is to be noted that two years have elapsed since the date of this report. In a field as rapidly developing as electronic digital computing, this is a relatively enormous lapse of time. In addition, development of the "selectron" has been disappointing, at least, as concerns the time schedule. In view of these two facts, the report is somewhat outdated. It is believed, however, that much of the content is applicable even at this date, provided the reader overlooks the multitude of typographical errors scattered throughout the report. This is the more true in view of the relatively small amount of development that has taken place elsewhere in regard to input and output equipment for high-speed computers as compared to work on the more glamorous phases of high-speed memory, control, and electronic computation.

MDL

5. LOUIS COUFFIGNAL, "Les travaux français sur les machines mathématiques," Atomes, v. 3, no. 23, Feb., 1948, p. 44-48. 21 × 26.7 cm.

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6. ANDREW V. HAEFF, "A memory tube," *Electronics*, v. 20, 1947, p. 80-83. 20.3 × 29.8 cm. See *MTAC*, v. 3, p. 281-286.

A pattern is produced, stored, and scanned on dielectric screen by electron beams. The special cathode-ray tube can be used to store for protracted periods television pictures, radar indicator patterns, oscilloscope traces, or other information.

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- 7. ANDRE LION, "Atom taming equations turn to peace tasks—pure science, higher mathematics get bigger industrial roles," *Barron's National Business Weekly*, Jan. 6, 1947. Newspaper.
- 8. MOORE SCHOOL OF ELECTRICAL ENGINEERING, University of Pennsylvania, *Progress Report on the EDVAC* (Electronic Discrete Variable Computer). Prepared by the staff of the EDVAC project and edited by T. KITE SHARPLESS. 2 v., Philadelphia, Pa., June 30, 1946, about 600 leaves, tables and diags. 21.6×27.9 cm.

The Ordnance Department of the United States Army, seeing the need for tremendous amounts of computation in military and civilian scientific work, is sponsoring the design and construction of an extremely fast electronic computer at the Moore School of Electrical Engineering of the University of Pennsylvania.

The EDVAC Report presents the state of thinking about electronic computers at the Moore School at the date of writing (1946). The content of the Report is largely determined by one of its objectives, namely, to give the Ordnance patent department material on which to base patent applications. For this reason, and because it was written while the project was in the early exploratory stage, the Report describes a great many conceivable ways of designing parts of the computer. For example, a chapter on "adders" treats a number of circuits using standard triodes, standard pentodes, and tubes associated with resistance matrices or "function tables," as well as proposed special adder tubes; and these elements are combined into adders for binary, bi-quinary, shifted binary, and decimal notations.

The report contains nine chapters dealing with the components of a digital computer and their organization. Chapter I deals with adders, multipliers, miscellaneous circuits, and "computers." The discussion on adders has been mentioned, and the remarks about that section apply to the sections on other components. Among the miscellaneous circuits are gating circuits to control the flow of signals along a path, circuits to produce complements of numbers, and circuits that will in effect align the "binary point" when binary numbers of different orders of magnitude are to be added. The computer section explains how adders and multipliers can be controlled to carry out the fundamental arithmetic operations.

Chapter II is a general discussion of acoustic wave propagation in tubular spaces, with special attention to the generation, propagation, detection, and distortion of signal pulses thru tubes containing piezoelectric crystal transducers for converting electrical into acoustic pulses. The chapter includes a detailed theoretical analysis of reflection at the ends of the tube, the cutting and mounting of the crystals, and the characteristic impedances of the resulting acoustic delay line. Data in the form of a sequence of pulses can be fed into one end of a delay line, picked up at the other end, reshaped by an amplifier and fed back into the line. Fairly complete circuits for the reshaping amplifier are given, and the problem of synchronizing several delay lines, so that they can work in parallel, is treated.

Chaper III is a short discussion of ways of remembering data in cathode-ray tubes (similar to television tubes) and in the RCA Selectron. Chapter IV describes briefly, and in very general terms, magnetic recording on tapes and discs, and a calculator based on such recording. Chapter V points out the requirements of the typewriter, or manually operated input device, and of the printer, or automatically operated output, for a computer. Several proposals for each are mentioned. In a large computer, the equipment needed to steer numbers and instructions over the various possible paths within the computer is a major part of the entire machine. Chapter VI treats this part of the subject in some detail. The last three chapters of the report deal with various proposed forms of EDVAC, namely, a Serial Acoustic, a 4-Channel Electrostatic, and a 4-Channel form.

The EDVAC Report suffers less from incoherence than most group reports; it is carefully arranged and edited, and records a wide variety of ideas in accessible form. In many ways it is unfortunate that publication of reports on computer techniques must be so long delayed. A review of a report from the EDVAC group on the changes in the picture that have occurred in the two and one half years since the present report was written would be valuable.

George R. Stibitz

9. Institute of Radio Engin., Proc., v. 36, Mar., 1948, p. 377. 20.3 × 27.9 cm.

On this page are abstracts of papers dealing with high-speed computers, presented at a meeting of the Institute, March 24, 1948.

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News

Association for Computing Machinery .- The proposed form, dated February 15, 1948, of the Constitution and Bylaws for the Association, sent out to the members for balloting, was not adopted. Because of the high proportion of ballots in favor of its adoption, however, the Council of the Association, at a meeting on May 27th, resolved "to act in accordance with the proposed Constitution and Bylaws." The Association's Committee on Constitution and Bylaws will consider the suggestions for its revision (particularly the proposed limitation of the number of Members-at-Large on the Council, and the proposed specification of the manner in which election ballots shall be counted), formulate their recommendations, and submit them to the Council. An improved draft of a proposed Constitution and Bylaws will then be resubmitted to the members of the Association. Also at its May 27th meeting, the Council resolved to hold elections promptly for President, Vice-President, Section Officers, and Members-at-Large, for the period until May 31, 1949. The President, John Curtiss, appointed a nominating committee consisting of G. R. STIBITZ, S. N. ALEXANDER, and C. V. L. SMITH. They met on June 10, 1948, and made the following nominations: for president: J. W. MAUCHLY (E-MCC); for vice-president: F. L. ALT (BRL, Aberdeen); for section officer-s.o. (Boston): F. L. VERZUH (MIT); for s.o. (New York): SAMUEL LUBKIN (NBS); for s.o. (Philadelphia and Aberdeen): T. K. SHARPLESS (Technitrol Engin. Co.); for s.o. (Washington): MINA REES (ONR); for member at large-m.a.l. (mathematics): HANS RADEMACHER (Univ. Pa.); for m.a.l. (statistics): J. L. McPherson (BC); for m.a.l. (communications): C. B. TOMPKINS (Engin. Res. Assoc.); for m.a.l. (business and finance): HENRY RAHMEL (A. C. Nielsen Co.); for m.a.l. (engineering): CHARLES CON-CORDIA (G.E. Co.). The Secretary and Treasurer are elected by the Council. The Association now has 465 members; a roster of members as of May 21, 1948, was prepared and distributed to the members.

The Institute for Teachers of Mathematics.—The 8th annual session of the Institute for Teachers of Mathematics was held on August 9–20, 1948, at Duke University, Durham, N. C. At that time 24 papers were read illustrating the use of mathematics in various scientific fields of endeavor, and many laboratory classes were held for the benefit of the participating teachers.

One of the sessions was given over to a discussion of automatic digital computing machines by Mrs. IDA RHODES of the NBSMDL. A brief history of computation and tools for computation preceded a detailed discussion of the electronic machines presently being constructed.

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International Business Machines Corporation.—During the week of August 23, 1948, the IBM conducted a Scientific Computation Forum, which was attended by some 70 invited guests.

The first 4 days, sessions were held at Endicott, New York, and 20 papers were presented, dealing with basic techniques for IBM machine computation as applied to differencing of tables, matrix operations, differential equations, and numerous other branches of applied mathematics. A welcome feature of the meeting was the demonstration of the principles and uses of the soon-to-be-released IBM machine no. 604, which, because of its several new features, promises to be a most useful addition to any IBM installation engaged in computation for applied mathematics.

A tour through the IBM factory, guided by a member of the company, and a banquet held in the IBM Homestead completed the first stage of the forum. The last day was spent at the IBM World Headquarters in New York, where 4 additional papers were read and a demonstration of the IBM Selective Sequence Electronic Calculator was given.

The persons participating in this forum represented various government agencies, industrial organizations and academic institutions. Not only were the 24 papers informative and thought provoking, but the opportunity for exchange of opinion was of substantial benefit to anyone faced with computation problems.

Symposia on Modern Calculating Machinery and Numerical Methods.—The symposia were held July 29–31, 1948, at the University of California, Los Angeles, under the joint auspices of the Institute for Numerical Analysis (INA), NBS, and the Departments of Astronomy, Engineering, and Mathematics, UCLA, in cooperation with the AIEE, the Amer. Math. Soc., the Amer. Phys. Soc., the ASME, the ACM, the Engineering Division, Air Materiel Command, U.S.A.F., the Institute of the Aeronautical Sciences, the IRE, the Math. Assoc. Amer., and the ONR. In a sense, the symposia served as a continuation of the very significant symposium on large-scale digital calculating machinery which was held at the Harvard Computation Laboratory, Harvard University, Jan. 7–10, 1947; see MTAC, v. 2, p. 229–238.

The symposia provided those in attendance with up-to-date information regarding the technological and mathematical developments in the field of ultra-high speed numerical calculation. Also the symposia marked the formal opening of the INA which is a section of the NBSNAML. The establishment of the Institute was fostered by the Office of Naval Research (ONR) and has been firmly supported by the ONR and the Air Materiel Command of the USAF. The Institute functions as a center for basic research and training in the types of mathematics essential to the exploitation and the further development of high-speed automatic digital computing machinery; also it provides a computation service for the Southern California area and is concerned with the formulation and analytical solution of important problems in applied mathematics. In addition to the desk calculators and punch-card equipment already installed, the INA will be equipped with at least one general purpose large-scale electronic digital computing machine, as soon as such equipment becomes available.

Program

July 29, Session I: L. M. K. BOELTER, chairman

Addresses of Welcome:

For the University: CLARENCE DYKSTRA, provost UCLA

For the NBS: W. R. BRODE, assoc. director NBS

For the Navy Dept.: A. T. WATERMAN, ONR

For the USAF: O. C. MAIER, Wright Field

Invited address: "Electronic methods of computation" by JOHN VON NEUMANN Session II: J. H. CURTISS, chairman

"General survey of current British developments" by D. R. HARTREE

"General survey of current American developments" by PERRY CRAWFORD, JR.

- Session III: Progress Reports from Principal Academic Research Centers, PAUL MORTON, chairman
 - "The electric analog computer" by G. D. MCCANN
 - "Comments on the reliability of operation of computing machinery" by H. H. AIKEN
 - "Project whirlwind at MIT" by J. W. FORRESTER
 - "Recent developments at project EDVAC" by R. L. SNYDER
 - "Recent developments at the Institute for Advanced Study" by H. H. GOLDSTINE
 - "Recent developments at the Illinois Inst. of Techn." by T. J. HIGGINS
- July 30, Session IV: Progress Reports from Principal Commercial Research Laboratories, N. E. EDLEFSEN, chairman
 - "Recent developments-UNIVAC" by J. W. MAUCHLY
 - "Recent developments-REEVAC" by H. I. ZAGOR
 - "Recent developments-Engin. Res. Associates" by C. B. TOMPKINS
 - "Recent developments in electronic computers-IBM" by R. R. SEEBER
 - "Recent developments-Bell Tel. Labs." by B. MCMILLAN
 - "Recent developments-Raytheon Labs." by R. V. D. CAMPBELL
 - Session V: Programming for Automatic Digital Computing Machinery, JOHN TODD, chairman
 - "Programming for the Dahlgren machine" by C. C. BRAMBLE
 - "Programming for the Aberdeen machines" by FRANZ ALT
 - "Programming for the IBM SSEC" by R. R. SEEBER
 - "Programming for machines under development" by H. D. HUSKEY
 - "Programming for machines under construction" by IDA RHODES
 - Session VI: Lecture (illustrated with lantern slides), "Recent developments at the Harvard Computation Laboratory" by H. H. AIKEN. Also
 - General Open Discussion
 - H. H. AIKEN, chairman. F. L. ALT, J. W. FORRESTER and JOHN TODD assisted in answering questions.
- July 31, Session VII: The Future of Numerical Analysis, E. F. BECKENBACH, chairman "Some unsolved problems in numerical analysis" by D. R. HARTREE
 - "Numerical methods in pure mathematics" by D. H. LEHMER & HANS RADEMACHER "Problems in probability and combinatorial analysis" by S. M. ULAM

Session VIII: Numerical Methods in Applied Mathematics, JOHN BARNES, chairman "Numerical calculations in nonlinear mechanics" by SOLOMON LEFSCHETZ

- "Programming in a linear structure" by G. B. DANTZIG
- "Wave propagation in hydrodynamics and electrodynamics" by BERNARD FRIEDMAN
- "Eigenvalues and eigenvectors for symmetric matrices" by H. H. GOLDSTINE

The following 515 members registered for the Symposia:

- H. H. Aiken, Harvard Univ.
- H. F. Allen, Head, Math. and Physics Dept., Coalinga Jr. College
- F. L. Alt, BRL, Aberdeen Proving Ground, Md.
- Alphonso Ambrosio, Engin. Dept., UCLA
- B. F. Ambrosio, USN Electronics Lab., San Diego 52, Cal.
- Ruth K. Anderson, USN Ordn. Test Station, China Lake, Cal.
- E. J. Andrews, N. A. Aviation, Aerophysics Lab.
- Selma Anno, Chicago, Ill.

- R. F. Arenz, USNEL
- W. N. Arnquist, ONR, Pasadena, Cal.
- K. J. Arrow, Univ. Chicago
- S. E. Asplund, AMS, Air Weather Service, USAF
- H. T. Avery, Marchant Calculating Co., Oakland, Cal.
- H. A. Babcock, Cons. Eng., USC
- L. L. Bailin, NBS, UCLA
- L. U. Baldwin, USN Air Missile Test Center, Point Mugu, Cal.
- W. W. Baldwin, Cons. Eng., Henry A. Babcock, Los Angeles, Cal.
- Alfred Banos, Jr., Physics Dept., UCLA
- J. L. Barnes, UCLA
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The equation $x^3 - 11.52x + 9.61 = 0$ is solved by means of three calculated tables, in connection with the simultaneous equations $y = x^3$, y = 11.52x - 9.61.