217.—NILS PIPPING, "Die Goldbachsche Vermutung und der Goldbach-Vinogradowsche Satz," Åbo, Finland, Akad., *Acta Math. Phys.*, **v. 11**, no. 4, 1938, p. 1–25.

x	*for* m_x	*read*
6944	61	37
10006	149	83
23926	47	17
31004	73	67

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UNPUBLISHED MATHEMATICAL TABLES

In this issue there is a reference to an unpublished table in RMT **1041**.

150[F].—D. D. WALL, *Table of Wilson's Quotient*. 11 leaves tabulated from punched cards. Deposited in the UMT FILE.

For each of the 709 primes $p \leq 5381$ the table gives the least positive remainder on division of $\{(p-1)!+1\}/p$ by p. This remainder is zero for $p = 5$, 13, and 563. The table was produced on the IBM Card Programmed Calculator. [See also *MTAC*, v. 5, p. 81, MTE **182**.]

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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, 415 South Building, National Bureau of Standards, Washington 25, D. C.

DISCUSSIONS

ASYNCHRONOUS SIGNALS IN DIGITAL COMPUTERS

It is frequently necessary, during the operation of a digital computer, to inject signals from sources that are not synchronized with the computer itself, for example, the manual signals. This operation may be initiated by pressing an appropriate push button. In this discussion, we will not be concerned with such problems as "bounce" of contacts, wavering pressure or the possibility of repeated operation because of completion of computation before the button is released, but only with the fact that the contact is made (or broken) at a random moment with respect to the computer timing pulses or "clock." Probably the most important source of automatically generated signals asynchronous with the computer proper is the input equipment. Whether data are introduced by magnetic tape, punched cards, manual keyboard or other means, it is generally introduced at a much lower rate than transfers within the computer itself and at intervals which do not synchronize with the main "clock."

The presence of asynchronous signals creates a problem of special type in that their effect under certain conditions is not strictly determined in the digital sense. That is, examination of such a signal at a time synchronous with the machine proper may not be interpretable as either "yes" or "no" over a narrow range of relative timing of the signal to the machine, but only as "maybe." If an entity similar to one of Maxwell's famous demons were available to convert such "maybe's" to either "yes" or "no," even in arbitrary fashion, the problem would be solved. Automatic equipment, however, responds in continuous fashion to signal amplitudes and durations, and these must have a transition range between any discrete set of states. When one is dealing with wholly synchronous signals, such transitions can be made to take place between examining times and thus do not cause difficulty. With asynchronous signals, the random relative timing causes randomness in the transition durations and thus permits conditions under which examination of the signal may occur during the period of transition.

One might reply to the above discussion that the existence of an indefinite "maybe" is not of much importance since, no matter whether the remaining equipment behaves as if it were "yes" or as if it were "no," operation would be satisfactory. This is true if *all* the remaining equipment made the same interpretation of the "maybe," and, in fact, in certain cases it suffices to "weight" one element deliberately so that its interpretation of the "maybe" can never be "yes" when any of the other elements behave as if the "maybe" is "no." In most cases, however, error results if any two elements do not interpret the signal in the same manner. The "maybe" condition thus usually implies error. An otherwise perfect machine therefore is not error free in the presence of asynchronous signals, but has a finite probability of error. The problem is to make this probability extremely small.

This problem was recognized at an early stage in computer development. Thus the designers of the ENIAC incorporated additional "flip-flops" as buffers between the asynchronous signals and the remainder of the machine. The designers' reasoning as expressed in lectures and operating manuals was essentially as follows. The asynchronous signal, being random, could occur at a time when it caused passage of only a partial "clock" pulse thus making operation indefinite. By using this partial pulse, however, to set a flip-flop, and gating a later pulse through it, a "full" output pulse is obtained if the flip-flop sets and no output pulse if it remains unset. In the latter case, a full pulse will be obtained during the next cycle (since the asynchronous signal is of long duration) which will be certain to set the flip-flop. This scheme has, apparently, yielded equipment which functions quite satisfactorily. There is, however, a flaw in the above reasoning in the assumption that the flip-flop is definitely either set or not set when it gates the interrogating pulse. From our previous discussion, there must be a finite, although very small, probability that the gated pulse is also "partial." It seems obvious, nevertheless, that the method is effective in markedly reducing the probability of error.

This use of "trigger" circuits between an asynchronous signal and the remainder of the machine is, to the author's knowledge, resorted to by all computer designers. The purpose of this paper is to point out that the effect is to reduce but not eliminate probability of error, and that material improvement is possible by consideration of the various factors involved in such an arrangement. It is easy to see that the region of indefiniteness is decreased by "squaring" up of the signal and interrogating pulses, by speeding up of the "flipping" of the trigger circuit and by increasing the time interval between the pulse gated by the signal and acting upon the trigger and the pulse gated by the trigger and applied to the balance of the machine. The "squaring" of the signal and pulses reduces the probability of error in a smaller proportion than the decrease in rise or fall times since duration is a factor as well as slope. Moreover, the rise time cannot be readily increased indefinitely because of the usual circuit limitations. The improvement that can be achieved by careful attention to the shape of the pulse is thus quite limited. As concerns time of response of triggers and time interval between interrogating pulses, the probability of error will, in most cases, be an exponential function of the ratio of the two times. Decrease of this ratio by increasing the rate of response of the trigger or by increasing the time interval between gating and reading the trigger is therefore extremely effective in reducing probability of error.

We will conclude by indicating, for a particular configuration, how probability of error may be evaluated, at least as concerns order of magnitude. For this purpose, we assume perfectly "square" pulses and signal and a trigger whose output builds up exponentially to a steady state proportional to the input, and which is provided with positive "feed-back" for outputs in excess of both the input and a fixed noise suppression voltage. Such a trigger is approximated by a linear amplifier with ideal diode gating. If we take the input as E_1, and the trigger output as E, we have $E = AE_1(1 - e^{-t/k})$, where A is the steady state amplification, t is the duration of the input and k is the time constant of the circuit. If E ever reaches the value E_1, the feed-back replaces the signal and the trigger is fully set. If E does not reach the value E_0 which is the noise suppression voltage, no feed-back takes place when the input signal ends and the trigger is fully reset. We are interested in the intermediate condition where, at time t when the input ends, $E_1 + E_0 > E > E_0$. In this case, the feed-back becomes effective at time t and we get the equation

$$k\frac{dE}{dT} + E = A(E - E_0)$$

whose solution is

$$E = \left[AE_1(1 - e^{-t/k}) - \frac{AE_0}{A - 1}\right]e^{(A-1)T/k} + \frac{AE_0}{A - 1}$$

for the period following cessation of the first interrogating pulse, where T is the time interval during this period. Since $A > 1$ for satisfactory trigger operation, this solution represents an exponential build-up. If E falls between certain limits, say E_2 and E_3, at the time the trigger is examined, error results. The probability of error is thus the probability that t is such as to make

$$E_2 < \left[AE_1(1 - e^{-t/k}) - \frac{AE_0}{A - 1}\right]e^{(A-1)T/k} + \frac{AE_0}{A - 1} < E_3$$

so that $t_1 < t < t_2$, where

$$t_1 = -k \ln (S - E_2/AE_1) + (A - 1)T$$

and

$$t_2 = -k \ln (S - E_3/AE_1) + (A - 1)T,$$

where

$$S = \left[1 - \frac{E_0}{(A - 1)E_1}\right] e^{(A-1)T/k} + \frac{E_0}{(A - 1)E_1}.$$

If Q is the repetition period for the interrogating pulses, this probability is given by

$$P = \frac{(t_2 - t_1)}{Q}$$

$$= \frac{k}{Q} \ln \frac{S - E_2/AE_1}{S - E_3/AE_1}.$$

In view of the natural choice of T large compared to k and E_1 large compared to E_0, S is given approximately by $e^{(A-1)T/k}$ and P is approximated as

$$P \doteq \frac{k}{Q} \ln \left[1 + \frac{(E_3 - E_2)}{ASE_1}\right]$$

$$\doteq \frac{k}{Q} \frac{(E_3 - E_2)}{AE_1} e^{-(A-1)T/k},$$

which summarizes the important factors. If, in a particular case, we have $(E_3 - E_2)/E_1 = 0.1$; $A = 2$; $k = 1$ microsecond; $T = 10$ microseconds and $Q = 25$ microseconds, we find

$$P = \frac{1}{500} e^{-10} \doteq 10^{-7},$$

which is too high for comfort. However, increase of T or decrease of k by a factor of 2 makes

$$P = \frac{1}{500} e^{-20} \doteq 4 \times 10^{-12},$$

which may be acceptable. Similar evaluation of effectiveness may be made for other types of trigger circuits.

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1. ANON., "Analog-digital converter," *Rev. Sci. Instr.*, v. 22, Oct. 1951, p. 800.

   Expository article.

2. ANON., "Digital computers," *The Electrician*, v. 148, March 14, 1952, p. 818.

   This is an expository article which very briefly describes certain features of the digital computer at Manchester University, England. This machine is one of a series of machines which Ferranti, Ltd., is producing. The second one of this series will be located in Toronto, Canada, at the university.

EDITH T. NORRIS

NBSMDL

3. R. C. M. BARNES, E. H. COOKE-YARBOROUGH & D. G. A. THOMAS, "An electronic digital computor using cold cathode counting tubes for storage," *Electronic Engineering*, v. 23, Aug. 1951, p. 286–291, and Sept. 1951, p. 341–343.

In this sequence controlled computor, whose numbers contain eight decimal digits and a sign, speed was sacrificed to achieve small size and simplicity by using relays for switching and "Dekatron" 10-position cold cathode discharge tubes for up to 90 words of storage. Numbers and the instructions in sequence are read from perforated tape by up to eight tape readers and results are printed or punched by up to eight printers or perforators. The computor contains about 380 relays, 18 Dekatrons, 80 thermionic tubes, and 40 cold cathode triodes, plus 28 relays and 90 Dekatrons per 10 words of storage. It occupies three 7 ft. relay racks, together with an additional rack per 49 words of storage, one smaller rack for power supplies, and a table for tape readers and printers. Total power consumption is about 1 kilowatt.

The computor operates in parallel mode, and for transfer within the machine a decimal digit is represented by a train of 0 to 9 pulses in its appropriate channel while on the tapes a 2 out of 5 code is used. Round off is performed by adding 1 or 0 at random in the 8th place. Negative numbers are represented by 9's complements with end around carry correction.

R. D. ELBOURN

NBSCML

4. H. J. GEISLER, "R. F. bursts actuate gas tube switch," *Electronics*, v. 25, Feb. 1952, p. 104–105.

The article gives a brief description of a gas tube gate, requiring radio-frequency excitation of one of its inputs. The r-f energy is coupled to the tube through the d-c electrodes and a conducting band around the tube envelope. Cold open-circuit resistance is several megohms, and the capacitance between electrodes and also between the band and the electrodes is less than 1 $\mu\mu$f.

The characteristics of the IBM-36 developmental gas tube switch are given, and the application of the tube in computer storage and accumulator read-in circuits is discussed.

E. W. C.

NBSMDL

5. J. A. GOETZ & A. W. BROOKE, "Electron tube experience in computing equipment," *Electrical Engineering*, v. 70, Feb. 1952, p. 154–157.

The IBM Corporation has 2,500,000 electron tube sockets which are used in commercial computation equipment. Two years ago the IBM Tube Laboratories established a defective tube analysis program. This paper describes the methods used for preventive maintenance testing of tubes before installation, and for analyses of causes of failure or rejection for several tube types used in number by IBM. It shows how an appreciable gain in machine reliability has been accomplished since this program has been in effect. The analysis of common causes of tube failures and vacuum tube life expectancy and survival data is of special interest to the computer design and maintenance engineer.

P. D. SHUPE

NBSCML

6. W. E. MUTTER, "Improved cathode-ray tube for application in Williams' memory system," *Electrical Engineering*, v. 71, Apr. 1952, p. 352–356.

This article describes the IBM-79 (RTMA 3VP1), a cathode-ray tube designed specifically for use in a Williams' electrostatic storage system. Attempts were made to reduce spot size, to improve "spill" characteristics and to reduce deflection defocusing and noise pickup. As in all tubes, the tube was designed to effect a compromise of conflicting requirements. The three-inch size represents a compromise between "bits" per tube and "bits" per unit volume.

Compared with the 3KP1, the best commercially available tube of the same size, there is a decided improvement as shown by the following: 1) spot separation for a given "spill" number is about 60 percent of that of the 3KP1 in a two-dot test; 2) spot size is about 76 percent of that of the 3KP1; and 3) deflection defocusing (from the illustrations) is about 90 percent of that of the 3KP1 at one inch from the center of the tube. These improvements were obtained by reducing the magnification ratio, masking down the beam, and shaping the deflection plates. In addition, the capacities of the deflection plates, especially to the grid, were balanced to reduce deflection caused by beam pulsing. Extreme cleanliness in assembly and processing and "sparking" were used to produce a larger percentage of blemish-free tubes. Noise pickup may be reduced by an external silver coating, grounded near the output end. The smaller spot size gives a reduced, but still ample, output signal. No attempt was made to reduce the "gentle rain" of secondary electrons on the storage surface.

D. C. FRIEDMAN

NBSCML

7. T. J. REY, "On the background of pulse-coded computers, part 1," *Electronic Engineering*, v. 24, Jan. 1952, p. 28–32; part 2, *Electronic Engineering*, v. 24, Feb. 1952, p. 66–69.

Part 1 develops the background of the present day digital computer. Then the functions of and relations between the Input-Output, Control, Memory and Arithmetic units is explained, and the distinction is made between serial and parallel operations. The remainder and major portion of part 1 is concerned with the representation of numbers within a digital machine based on the binary number system and the congruence relationship of number theory.

Part 2 describes how the basic building blocks of digital computers may be represented by Boolean algebra. There are several examples of the design of such sub-units as an adder from a truth table to a logical circuit. The article is concluded by a comparison between digital and analog systems.

WILLIAM A. NOTZ

NBSCML

8. JOHN J. WILD, "High-speed printer for computers and communications," *Electronics*, v. 25, May 1952, p. 116–120.

A novel printer, which has produced, under experimental operation, up to 900 eighty-character lines a minute without serious degradation of impression, has been developed by the Potter Instrument Company. The device consists of a "Flying Typewriter" and electronic control, the former being a rotating-type-wheel typewriter and the latter essentially a flexible electronic counter with certain special features incorporated to trigger 80 solenoid-controlled hammers facing the periphery of the type wheel. The time when a hammer strikes the type wheel through ribbon and paper determines the character printed in the corresponding column.

The control system automatically distributes the printing of the characters in the proper order during a revolution of the type wheel, although the order of printing is not necessarily in positional sequence around the wheel.

The hammers are resilient to cause them to bounce back swiftly after striking the type. Time of contact of hammer and type face is under 0.1 millisecond, and the time of operation of the hammer is about 2.5 milliseconds. The pulses operating the hammers are timed with a lead of 2.5 milliseconds to cause the striking of the type character in the center. Even at extremely high rates of operation no appreciable blur of print occurs. The printing is equivalent, in clearness, to that of a good typewriter.

The time of operation of each of the 80 hammers is controlled by information set into a trigger tube storage called a PASS unit (printer actuator serial storage unit). A motor-driven notched disc and phototube arrangement provide the necessary synchronizing pulses. The PASS unit has 80 columns of 6 binary-digit storage, with shifting circuits for loading and special gating circuits for driving the printer. PASS may be loaded a column at a time, with a 6 binary-digit code, or it may be loaded a pulse at a time. Each of its 80 columns can be used as a scale of 10 or 64 counter. In fact, the PASS unit is essentially an accumulator and shift register and is capable of use by an automatic computer as a part of its arithmetic unit, when printing is not being performed.

The loading of the PASS unit with the information to be printed may be thought of as the pre-setting of the 80 counters in the unit. The pulses generated by the photo-electric disc are fed individually to step the counters, with time lag between columns to prevent the call for printing of the same character in more than one column at the same time. When each of the various counter columns in the PASS overflows, an output pulse is generated which causes the firing of a thyraton and the consequent energizing of the solenoid-controlled hammer. The characters around the rotating-type wheel and the photo-electric disc are so placed that when the hammer strikes, the correct type character is opposite it.

The new Potter Instrument Company printer was designed to operate at high speed, and also to be capable of accepting data for printing from punched cards, tapes, or directly from automatic digital computers. Presetting of selected columns in the control storage inhibits printing in the corresponding columns of a line; this feature facilitates the arrangement of the output format. This feature, together with the high printing speed, if the printer is reliable, should make the unit a useful addition to high-speed computer accessories.

E. W. C.

NBSMDL

News

Institute for Advanced Study.—A high-speed electronic digital computing machine has been completed and put into operation at the Institute for Advanced Study in Princeton, New Jersey. The machine is designed to perform very high-speed calculations in pure and applied mathematics and in mathematical physics.

Prior to this public announcement the machine had successfully completed a number of quite extensive and important problems. These problems include among others the following:

1) A large number-theoretical problem to test a conjecture, which has never been established, of the famous 19th century mathematician, E. E. Kummer. This calculation required the instrument to perform about 20,000,000 multiplications and took six hours of continuous computing.

2) Two considerably shorter astro-physical problems, each requiring the solution of three simultaneous differential equations.

3) Solutions of a number of cubic diophantine equations.

4) Several twelve-hour meteorological predications covering the continental United States, each amounting to about 800,000 multiplications and requiring about one hour of continuous computing time. This last work is only the first step in an extensive research program in theoretical meteorology being carried out at the Institute for Advanced Study.

This machine took six years to design, develop and construct by a staff under the direction of Prof. John von Neumann at the Institute for Advanced Study. The initial sponsorship of the project came from the Research and Development Service of the Ordnance Corps, U. S. Army. It has continued under the joint sponsorship of that agency, together with the Office of Naval Research, U. S. Navy; the U. S. Air Force; and the U. S. Atomic Energy Commission. Throughout its history, the project had the support and encouragement of the Institute for Advanced Study. In addition, the Office of Naval Research, since 1946, and since 1951 in cooperation with the Geophysics Research Division, Air Force Cambridge Research Center, Cambridge, Mass., has sponsored the work in dynamic meteorology. The Office of Naval Research also supported a complementary research program in numerical analysis.

The machine has been the prototype for various subsequent machine developments, including three for the AEC and one recently completed by the University of Illinois for the U. S. Army Ordnance Corps, Ballistic Research Laboratories at the Aberdeen Proving Ground.

The engineering design was due to Julian Bigelow, its execution to Julian Bigelow and James Pomerene, assisted by Gerald Estrin, Hewitt Crane, Richard Melville, Norman Emslie, and Ephraim Frei, as well as by Gordon Kent, Peter Panagos, and others. The mathematical and logical design was due to John von Neumann and Herman H. Goldstine. The work on meteorology is under the joint direction of Jule Charney and John von Neumann.

Data can be introduced into the machine in decimal or in binary form, but the instrument proper carries out the calculation in the binary number system since the use of this number system is more convenient electronically. Each number handled by the machine consists of a sign and 39 binary digits which is the equivalent of a decimal number with a sign and approximately 12 decimal places. The machine produces 2,000 multiplications per second, 1,200 divisions per second or 100,000 additions per second. For a machine of this degree of precision it is the fastest one now operating. The machine consists of four principal organs: namely, an arithmetic organ which carries out the processes indicated above, a control organ which executes the instructions given the machine, a memory organ in which both the numerical data of the problem and the instructions which characterize the problem are stored and, lastly, an input-output organ which intervenes between the human operator and the machine itself. The memory is a system of 40 cathode ray tubes, based on an invention of F. C. WILLIAMS in Manchester, England. The machine can get access to the memory organ in 25 microseconds. This organ is capable of storing 1,024 numbers each of 40 binary digits.

It is unusually small in physical size, being approximately 2 × 8 × 8 feet, and its total power requirements including ventilators, etc., are about 15 kilowatts. It contains about 2,340 vacuum tubes, almost all of which are double triodes.

Reeves Instrument Corporation.—Project Cyclone Symposium II on Simulation and Computing Techniques was held in New York City, April 29–May 2, 1952, under the sponsorship of the Reeves Instrument Corporation with the approval of the U. S. Navy Special Devices Center. The program consisted of three sessions, under the chairmanship of RAWLEY D. MCCOY, Reeves Instrument Corporation.

Session I

Analogue Computer Techniques and Applications	Wednesday, April 30, Morning:
REAC solution of problems in structural dynamics	C. W. BRENNER, Mass. Inst. of Technology
The use of an analogue computer and feedback theory for the solution of structural problems in the static case	G. MARTIN and L. M. LEGATSKI, University of Michigan
Application of the Electronic Differential Analyzer to eigenvalue problems	G. M. CORCOS, R. M. HOWE, L. L. RAUCH and J. R. SELLARS, University of Michigan
Some REAC techniques employed at the David Taylor Model Basin	L. PODE, David Taylor Model Basin
	Afternoon:
Simulation studies of a relay servomechanism	N. P. TOMLINSON, Goodyear Aircraft Corp.
Use of the REAC as a curve fitting device	C. H. MURPHY, Ballistic Research Laboratories, Aberdeen Proving Ground
Precision in high-speed electronic differential analyzers	H. BELL, JR., and V. C. RIDEOUT, University of Wisconsin
On an application of the use of analogue computers to methods of statistical analysis	J. H. LANING, JR., and R. H. BATTIN, Massachusetts Inst. of Technology
Solution of linear differential equations with time varying coefficients by the Electronic Differential Analyzer	C. E. HOWE, R. M. HOWE and L. L. RAUCH, University of Michigan

Session II

General Papers	Thursday, May 1, Morning:
JAINCOMP computers and their application to simulation problems	D. H. JACOBS, The Jacobs Instrument Co.

The Decimal Digital Differential Analyzer CRC 105 as a tool for simulation and checking analogue computer solutions	E. WEISS, Computer Research Corp.
Problems encountered in the operation of the MIT Flight Simulator	W. W. SEIFERT and H. JACOBS, JR., Massachusetts Institute of Technology
Automatic REAC operation for statistical studies	R. R. BENNETT and A. S. FULTON, Hughes Aircraft Co.
	Afternoon:
Mathematical error analysis for continuous computers	F. J. MURRAY, Columbia University
Checking analogue computer solutions	W. F. RICHMOND, JR., and B. D. LOVEMAN, The Glenn L. Martin Co.
Analogue computation of blade designs	D. B. BREEDON, M. M. MATTHEWS and E. L. HARDER, Westinghouse Electric Corporation
Solution of partial integral-differential equations of electron dynamics using analogue computers with storage devices	C. C. WANG, Sperry Gyroscope Co.
Session III	
Computer Components	Friday, May 2, Morning:
Modification of REAC	J. W. FOLLIN, JR., G. F. EMCH and F. M. WALTERS, Applied Physics Laboratory, Johns Hopkins University
REAC servo response	A. H. MILLER, University of Minnesota
Applications of differential relays to solution of REAC problems	L. M. WARSHAWSKY and W. BRAUN, Wright Air Development Center
The design and test of a Linear Wiener Filter	G. NESTOR, Avion Instrument Corp.
	Afternoon:
The role of diodes in an Electronic Differential Analyzer	C. D. MORRILL and R. V. BAUM, Goodyear Aircraft Corp.
A high accuracy time division multiplier	E. A. GOLDBERG, Radio Corporation of America
An AM–FM Electronic Analogue Multiplier	W. A. MCCOOL, Naval Research Laboratory
Discussion Period on Electronic Multiplication	

UNIVAC Acceptance Tests.—On April 22, 1952, the third UNIVAC system, this one constructed for the U. S. Army Map Service by the Eckert-Mauchly division of Remington-Rand, Inc., under NBS contract, passed the final test for its acceptance. This was the same magnetic tape reading and writing test given the second UNIVAC (see *MTAC*, v. 6, Apr. 1952, p. 119). It required reading 142 million decimal digits and writing 85 million; however, in this test the central computer controlled 10 tape systems. Error detecting circuits stopped the computer in 8 out of 25 fifteen-minute test units; however, there were no undetected errors, and the operator in every case corrected the trouble without assistance from an engineer or maintenance technician. That this rate of stoppages, barely low enough for acceptance, was not achieved until the seventh attempt at the test indicates that a considerable improvement in reliability of tape reading would be desirable. However, this should not be used for unfavorable comparison with any other machine. To this writer's knowledge no other machine approaches the UNIVAC's speed in reading and writing on magnetic tapes, much less has any other computing system been subjected to so rigorous a test.