Catalogue 74:

Origins of Electronic Computing and Software

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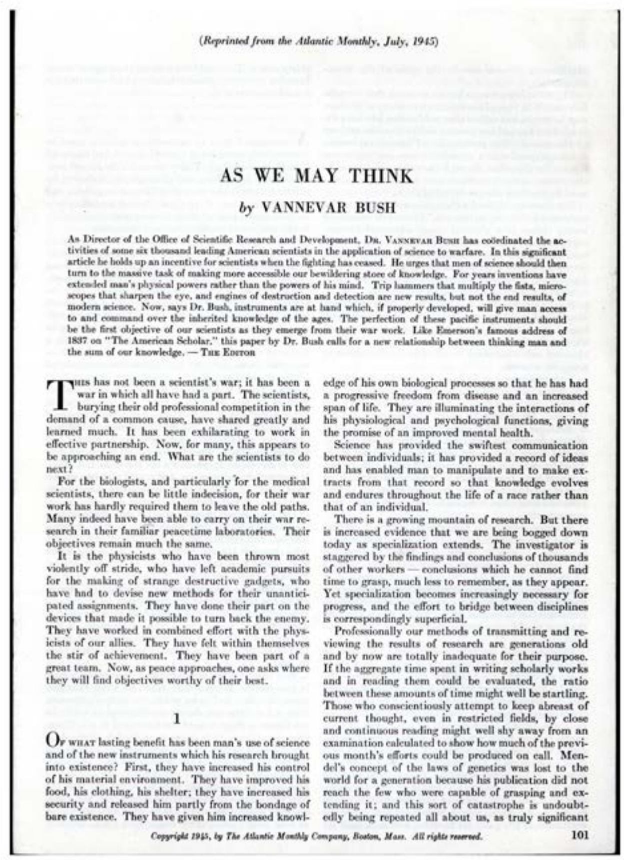
Table of Contents

1. The Only Recorded Copy of the Offprint of Vannevar Bush's Paper Anticipating Hypertext .... page 3
2. The Original Drawing of the First Cartoon Depicting an Electronic Computer—the ENIAC—to Appear in the Popular Press; From the Collection of the ENIAC's Co-Inventor, Pres Eckert........ 4
3. The First Operating Manual for the ENIAC, the World's First General-Purpose Electronic Computer 5
4. Rare Technical Description of the ENIAC 8
5. Harry Huskey's Report on the ENIAC: One of 25 Copies Printed........ 9
6. Unique Collection of ENIAC Artifacts 11
7. Sharpless's Report on the EDVAC: One of Only 20 Copies, from the Libraries of Martin Weik & Winifred S. Jonas........ 12
8. Realization of Vannevar Bush's "Memex" Concept........ 15
9. Extremely Rare Pre-Publication Dittoed Version of the First Textbook on Software........ 17
10. Two Rare Early Reports on Alan Turing's ACE and Pilot ACE Computers, Including Some of Turing's Earliest Published Programs 18
11. First Published Description of the Completed Pilot ACE Computer........ 20
12. Origins of Cyberspace: Deluxe Edition........ 21
13. Origins of Cyberspace: Regular Edition........ 21


(*Reprinted from the Atlantic Monthly, July, 1945*)

AS WE MAY THINK

by VANNEVAR BUSH

As Director of the Office of Scientific Research and Development, Dr. Vannevar Bush has coördinated the activities of some six thousand leading American scientists in the application of science to warfare. In this significant article he holds up an incentive for scientists when the fighting has ceased. He urges that men of science should then turn to the massive task of making more accessible our bewildering store of knowledge. For years inventions have extended man's physical powers rather than the powers of his mind. Trip hammers that multiply the fists, microscopes that sharpen the eye, and engines of destruction and detection are new results, but not the end results, of modern science. Now, says Dr. Bush, instruments are at hand which, if properly developed, will give man access to and command over the inherited knowledge of the ages. The perfection of these pacific instruments should be the first objective of our scientists as they emerge from their war work. Like Emerson's famous address of 1837 on "The American Scholar," this paper by Dr. Bush calls for a new relationship between thinking man and the sum of our knowledge. — The Editor

This has not been a scientist's war; it has been a war in which all have had a part. The scientists, burying their old professional competition in the demand of a common cause, have shared greatly and learned much. It has been exhilarating to work in effective partnership. Now, for many, this appears to be approaching an end. What are the scientists to do next?

For the biologists, and particularly for the medical scientists, there can be little indecision, for their war work has hardly required them to leave the old paths. Many indeed have been able to carry on their war research in their familiar peacetime laboratories. Their objectives remain much the same.

It is the physicists who have been thrown most violently off stride, who have left academic pursuits for the making of strange destructive gadgets, who have had to devise new methods for their unanticipated assignments. They have done their part on the devices that made it possible to turn back the enemy. They have worked in combined effort with the physicists of our allies. They have felt within themselves the stir of achievement. They have been part of a great team. Now, as peace approaches, one asks where they will find objectives worthy of their best.

1

Of what lasting benefit has been man's use of science and of the new instruments which his research brought into existence? First, they have increased his control of his material environment. They have improved his food, his clothing, his shelter; they have increased his security and released him partly from the bondage of bare existence. They have given him increased knowledge of his own biological processes so that he has had a progressive freedom from disease and an increased span of life. They are illuminating the interactions of his physiological and psychological functions, giving the promise of an improved mental health.

Science has provided the swiftest communication between individuals; it has provided a record of ideas and has enabled man to manipulate and to make extracts from that record so that knowledge evolves and endures throughout the life of a race rather than that of an individual.

There is a growing mountain of research. But there is increased evidence that we are being bogged down today as specialization extends. The investigator is staggered by the findings and conclusions of thousands of other workers — conclusions which he cannot find time to grasp, much less to remember, as they appear. Yet specialization becomes increasingly necessary for progress, and the effort to bridge between disciplines is correspondingly superficial.

Professionally our methods of transmitting and reviewing the results of research are generations old and by now are totally inadequate for their purpose. If the aggregate time spent in writing scholarly works and in reading them could be evaluated, the ratio between these amounts of time might well be startling. Those who conscientiously attempt to keep abreast of current thought, even in restricted fields, by close and continuous reading might well shy away from an examination calculated to show how much of the previous month's efforts could be produced on call. Mendel's concept of the laws of genetics was lost to the world for a generation because his publication did not reach the few who were capable of grasping and extending it; and this sort of catastrophe is undoubtedly being repeated all about us, as truly significant

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The Only Recorded Copy of the Offprint of Vannevar Bush's Paper Anticipating Hypertext

1. Bush, Vannevar (1890-1974). As we may think. Offprint from *Atlantic Monthly* 176, no. 1 (July 1945). 101-108pp. 266 x 190 mm. Without wrappers; boxed. Light creasing, minimal edgewear but very good. $25,000

First Edition, Extremely Rare Offprint Issue of Bush's remarkable early statement of some of the foundational concepts underlying the Internet and World Wide Web, including the concept of what later came to be called hypertext. OCLC cites no copies of the offprint, and we know of no other copies that have ever appeared on the market.

Bush's article describes his proposed "Memex" system for organizing, storing, retrieving, and linking information, anticipating hypertext links on the internet. Inspired by microfilm technology—which in 1945 represented the most advanced means of storing large amounts of information—Bush conceived of the Memex as consisting of a desk equipped with projection screens, buttons and levers, a keyboard, and a storage system designed to provide instant access to microfilmed books, periodicals, documents, photographs, etc. The Memex system, which relied on the unique relationship between user and machine, would allow pieces of data to be linked into permanent "information trails" dictated by the individual user's needs, which could be called up again and modified at any future date. The Memex thus represented (to Bush's mind) a mechanical analog of the associative faculty of the human brain, one whose function was to support and extend the powers of human memory and association. *Origins of Cyberspace* 519 (magazine version only). 43393

The Original Drawing of the First Cartoon Depicting an Electronic Computer—the ENIAC—To Appear in the Popular Press; From the Collection of the ENIAC's Co-Inventor, Pres Eckert

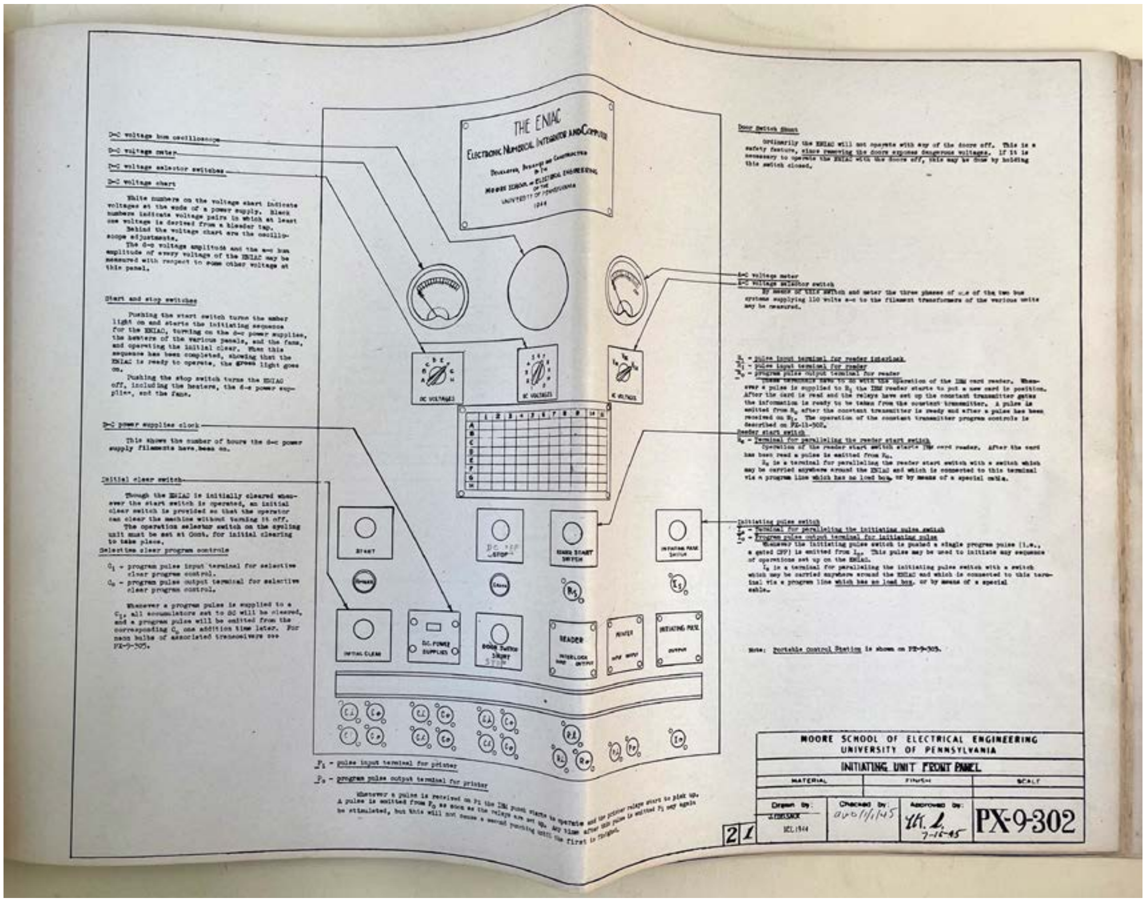
2. [ENIAC.] Alexander, Franklin Osborne (1897-1993). Completed just in time. Pen-and-ink drawing for the political cartoon published in the *Philadelphia Bulletin* newspaper on 22 March 1946, framed with a copy of the printed cartoon. 314 x 283 mm. (drawing); 220 x 185 mm. (printed cartoon); 648 x 403 mm. (frame). Fine. $20,000

The original, unique drawing for the first cartoon depicting an electronic digital computer. The drawing comes from the personal papers of J. Presper Eckert (1919-95), the co-inventor of the ENIAC, and was most probably given to him by the cartoonist.

F. O. Alexander's cartoon was published five weeks after the initial press conference announcing the ENIAC held on 14 February 1946 at the Moore School of Engineering at the University Pennsylvania, where the ENIAC had been designed and built during World War II. At that press conference photographs were taken of the machine, and reproduced in newspaper articles during the following days. Those photographs were also reproduced in the first magazine article about the ENIAC entitled "Lightning strikes mathematics," written by Allen Rose and published in *Popular Science* in April 1946.

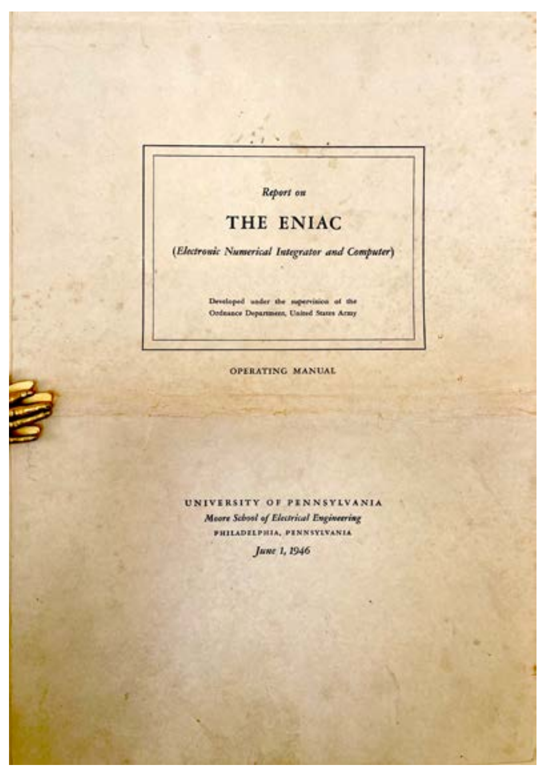
The cartoon depicts three men standing in bewilderment before the room-sized ENIAC: U.S. Treasury secretary John W. Snyder (1895-1985); Chester Bowles (1901-86) of the Office of Price Administration; and Paul R. Porter, who chaired the War Production Board's Shipbuilding Stabilization Committee during World War II. The three men, who obviously understand nothing about computers, are looking to the machine to calculate all the data they need to control postwar inflation; Bowles holds in his right hand a paper headed "Umpty-ump hundreds of wage-price ratios."

The cartoonist Franklin Osborne Alexander, commonly known as F. O. Alexander, was the staff editorial cartoonist at the *Philadelphia Evening Bulletin* from 1941 to 1967. *Origins of Cyberspace* 1115. 44694



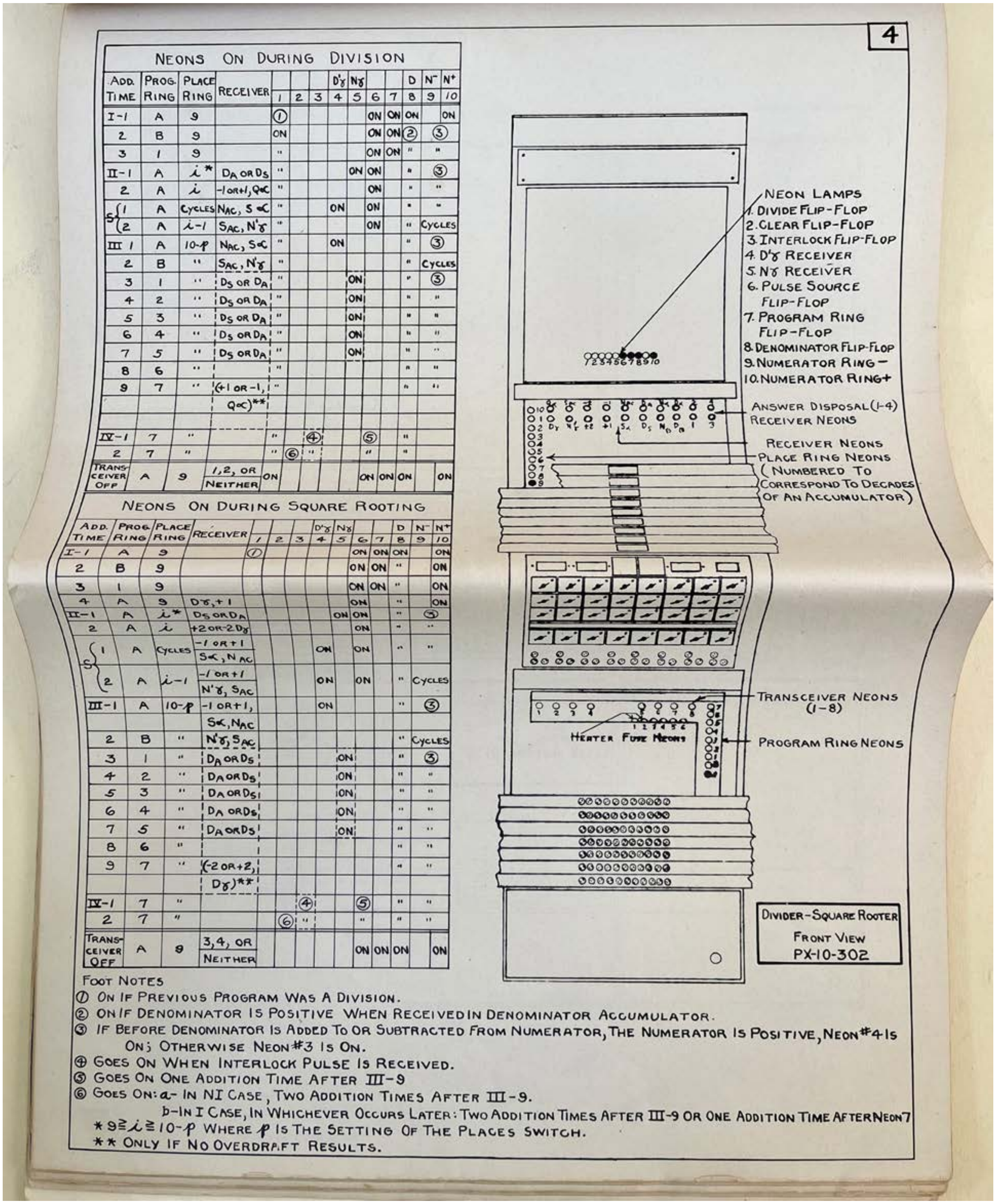
The First Operating Manual for the ENIAC, the World's First General-Purpose Electronic Computer

3. [ENIAC.] Burks, Arthur W. (1915-2008) and **Harry D. Huskey** (1916-2017). A report on the ENIAC (Electronic Numerical Integrator and Computer). ENIAC operating manual. Mechanically reproduced typescript, printed on rectos only. [2], 13ff. 34 folding blueprint plates. Philadelphia: University of Pennsylvania, Moore School of Engineering, 1 June 1946. 280 x 218 mm. Original printed stiff paper chemise, one edge reinforced with cloth tape. Light spotting and wear, but very good. From the library of Winifred S. Jonas (1924-2021), an early programmer and operator of the ENIAC. $12,500



Extremely Rare First Edition of the first operating manual for the ENIAC, the world's first general-purpose programmable electronic computer. *This is the first copy of this manual that we have ever handled in our fifty years of experience buying and selling rare computing literature. It is also the first copy that we can recall appearing on the market during the past fifty years.*

Designed and constructed at the University of Pennsylvania's Moore School of Engineering, the ENIAC went online in



4

NEONS ON DURING DIVISION

Add. Time	Prog. Ring	Place Ring	Receiver	1	2	3	D'γ 4	Nγ 5	6	7	D 8	N⁻ 9	N⁺ 10
I-1	A	9		①					ON	ON	ON		ON
2	B	9		ON					ON	ON	②	③	
3	1	9		"					ON	ON	"	"	
II-1	A	i*	D_A or D_S	"				ON	ON		"	③	
2	A	i	-1 or +1, Qα	"					ON		"	"	
S{1	A	Cycles	N_{AC}, Sα	"			ON		ON		"	"	
S{2	A	i-1	S_{AC}, N'γ	"					ON		"	Cycles	
III 1	A	10-p	N_{AC}, Sα	"			ON				"	③	
2	B	"	S_{AC}, N'γ	"							"	Cycles	
3	1	"	D_S or D_A	"				ON			"	③	
4	2	"	D_S or D_A	"				ON			"	"	
5	3	"	D_S or D_A	"				ON			"	"	
6	4	"	D_S or D_A	"				ON			"	"	
7	5	"	D_S or D_A	"				ON			"	"	
8	6	"		"							"	"	
9	7	"	(+1 or -1, Qα)**	"							"	"	
IV-1	7	"		"		④			⑤		"		
2	7	"		"	⑥	"			"		"		
Transceiver Off	A	9	1,2, or Neither	ON					ON	ON	ON		ON

NEONS ON DURING SQUARE ROOTING

Add. Time	Prog. Ring	Place Ring	Receiver	1	2	3	D'γ 4	Nγ 5	6	7	D 8	N⁻ 9	N⁺ 10
I-1	A	9		①					ON	ON	ON		ON
2	B	9							ON	ON	"		ON
3	1	9							ON	ON	"		ON
4	A	9	Dγ, +1						ON		"		ON
II-1	A	i*	D_S or D_A					ON	ON		"	③	
2	A	i	+2 or -2 Dγ						ON		"	"	
S{1	A	Cycles	-1 or +1 / Sα, N_{AC}				ON		ON		"	"	
S{2	A	i-1	-1 or +1 / N'γ, S_{AC}				ON		ON		"	Cycles	
III-1	A	10-p	-1 or +1, Sα, N_{AC}				ON				"	③	
2	B	"	N'γ, S_{AC}								"	Cycles	
3	1	"	D_A or D_S					ON			"	③	
4	2	"	D_A or D_S					ON			"	"	
5	3	"	D_A or D_S					ON			"	"	
6	4	"	D_A or D_S					ON			"	"	
7	5	"	D_A or D_S					ON			"	"	
8	6	"									"	"	
9	7	"	(-2 or +2, Dγ)**								"	"	
IV-1	7	"				④			⑤		"	"	
2	7	"			⑥	"			"		"	"	
Transceiver Off	A	9	3,4, or Neither						ON	ON	ON		ON

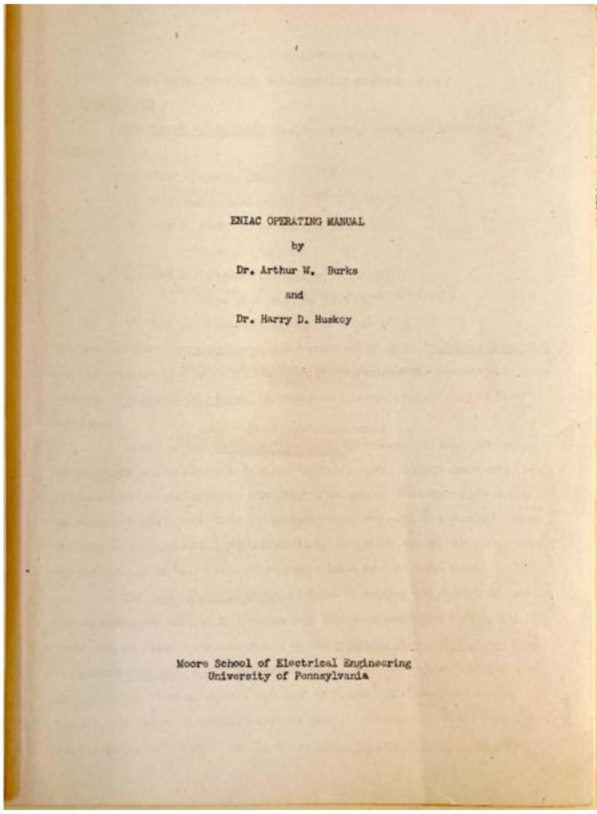
Neon Lamps
1. Divide Flip-Flop
2. Clear Flip-Flop
3. Interlock Flip-Flop
4. D'γ Receiver
5. Nγ Receiver
6. Pulse Source Flip-Flop
7. Program Ring Flip-Flop
8. Denominator Flip-Flop
9. Numerator Ring −
10. Numerator Ring +

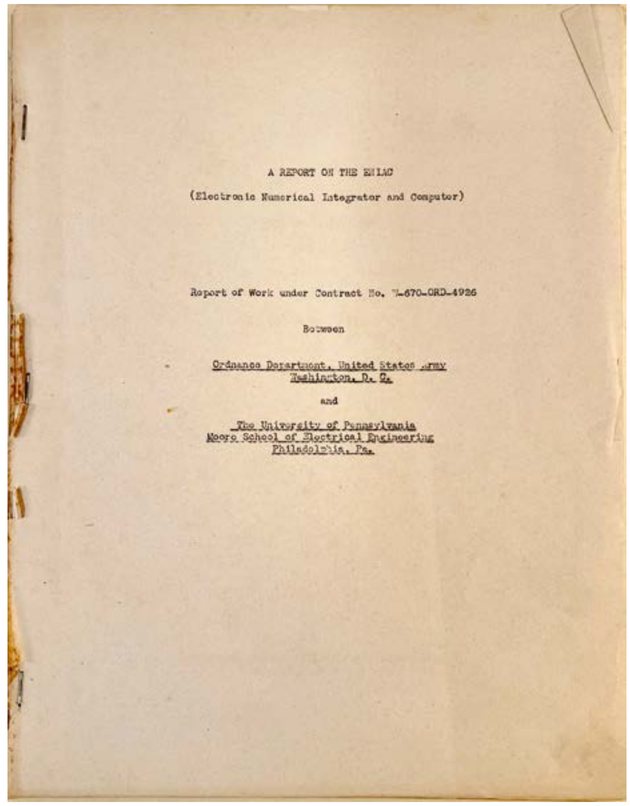
Answer Disposal (1-4)
Receiver Neons
Receiver Neons
Place Ring Neons (Numbered To Correspond To Decades Of An Accumulator)
Transceiver Neons (1-8)
Heater Fuse Neons
Program Ring Neons

Divider-Square Rooter
Front View
PX-10-302

Foot Notes
① On If Previous Program Was A Division.
② On If Denominator Is Positive When Received In Denominator Accumulator.
③ If Before Denominator Is Added To Or Subtracted From Numerator, The Numerator Is Positive, Neon #4 Is On; Otherwise Neon #3 Is On.
④ Goes On When Interlock Pulse Is Received.
⑤ Goes On One Addition Time After III-9
⑥ Goes On: a- In NI Case, Two Addition Times After III-9.
b- In I Case, In Whichever Occurs Later: Two Addition Times After III-9 Or One Addition Time After Neon 7
* $9 \geq i \geq 10-p$ Where p Is The Setting Of The Places Switch.
** Only If No Overdraft Results.

December 1945 and remained in continuous operation until 1955. Using 18,000 vacuum tubes as switches, the ENIAC could perform calculations at 10,000 times the speed of a human "computer," making it 99 percent faster than the electro-mechanical Harvard Mark 1. As soon as the ENIAC became operational, that enormous speed difference immediately convinced all computer pioneers that electronic computing, rather than electro-mechanical computing, was the technology through which computing machines would evolve.



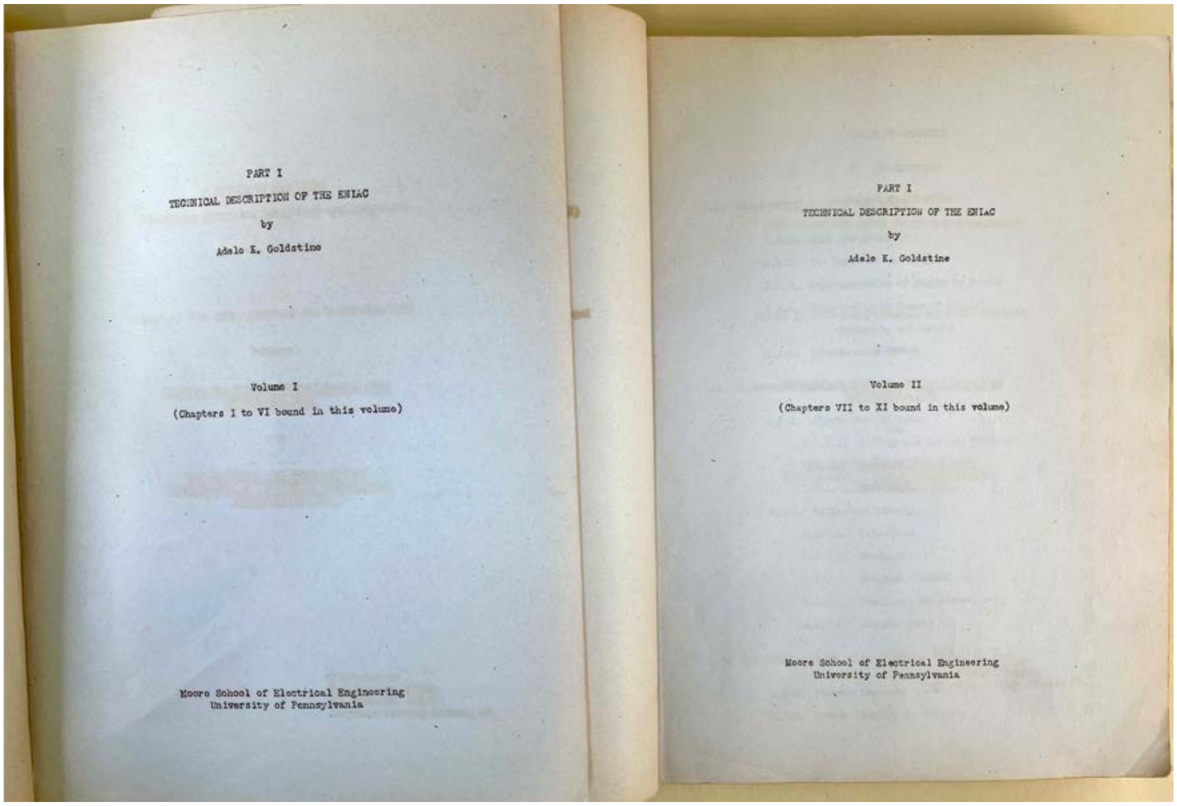


The ENIAC's first operating manual, written by two of the project's engineers, Arthur W. Burks and Harry Huskey, contains a complete set of instructions for operating the machine. The accompanying large blueprint plates illustrate the machine's floor layout, wiring configurations and various components. The blueprints in this manual, drawn at the Moore School before the ENIAC was fully operational, are essentially unobtainable except through this, or another one of the founding publications in this catalogue.

Both authors of the *ENIAC Operation Manual* went on to have brilliant careers in computing. Arthur Burks, a senior engineer on the ENIAC project's design team, contributed the design of the ENIAC's high-speed multiplier unit and co-wrote the earliest technical reports on the machine. After leaving the Moore School he joined the Institute for Advanced Study at Princeton, where he helped John von Neumann develop the logical design for the IAS computer and co-authored, together with von Neumann and Herman Goldstine, the *Preliminary Discussion of the Logical Design of an Electronic Computing Instrument*. Burks later joined the philosophy department of the University of Michigan and founded a research group in the logic of computers.

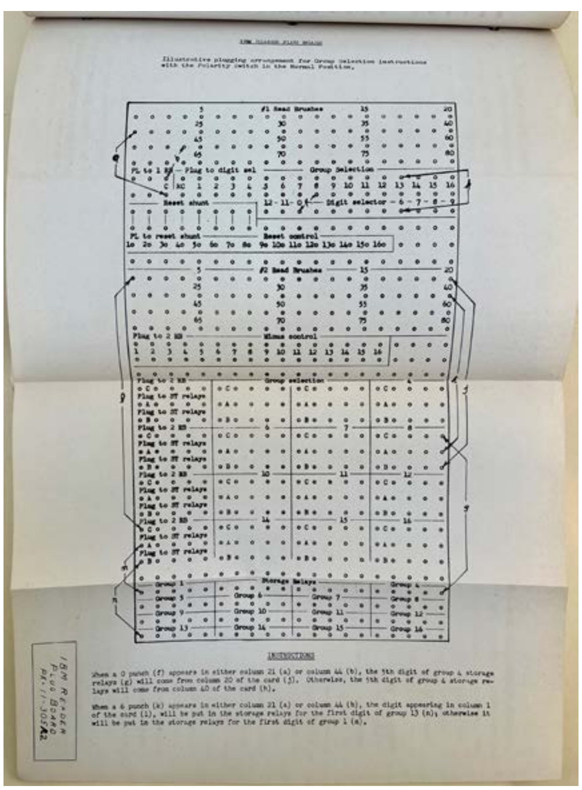
Harry Huskey worked on both the ENIAC and EDVAC computers during his time at the Moore School; afterwards he worked in London with Alan Turing on the ACE, and the Pilot ACE, and designed and built two important early American electronic computers: The National Bureau of Standards' Western Automatic Computer (SWAC), the fastest computer of its time; and the refrigerator-sized 965-pound Bendix G-15 computer, marketed as the world's first "personal" computer. Huskey later founded the computing and information science program at the University of California at Santa Cruz, and helped to set up academic computer science programs in universities throughout the world.

This copy of the *ENIAC Operating Manual* is from the library of Winifred S. Jonas, a mathematician at Aberdeen Proving Ground's Ballistic Research Lab (BRL) who became a programmer and operator of the ENIAC after the machine was moved from the Moore School to the Aberdeen Proving Ground (APG) in 1947. She worked on many special computing projects during the ENIAC's active years, including the German V-2 rocket tests at White Sands and the Atomic Energy Commission's studies on the hydrogen bomb. Not in *Origins of Cyberspace.* 50602



Rare Technical Description of the ENIAC,

4. [ENIAC.] Goldstine, Adele K. (1920-64). Report on the ENIAC (Electronic Numerical Integrator and Computer). Technical report I. Mechanically reproduced typescript, printed on rectos only. 2 vols. [8], xviii, [164]; [2], xviii, [132]ff., variously numbered. 108 blueprint diagrams, many folding, folding diagram in pocket inside back wrapper of Vol. 1. Philadelphia: University of Pennsylvania, Moore School of Engineering, 1 June 1946. 279 x 220 mm. Original printed stiff wrappers, 3-hole punched and bound with metal fastener. Wrappers a bit creased, light soiling and wear. Boxed. Very good. From the library of Winifred S. Jonas (1924-2021), an early programmer and operator of the ENIAC. $9500



Blueprint illustration of one of the ENIAC's plugboards

Extremely Rare First and Only Edition. *This is the first copy that we have handled in 50 years.* The ENIAC, designed and constructed at the University of Pennsylvania's Moore School of Engineering, was the world's first programmable electronic general-purpose computer; it went online in December 1945 and remained in continuous operation until 1955.

The author of this very comprehensive report was computer pioneer Adele Goldstine (wife of Herman Goldstine), a mathematician at the University of Pennsylvania's Moore

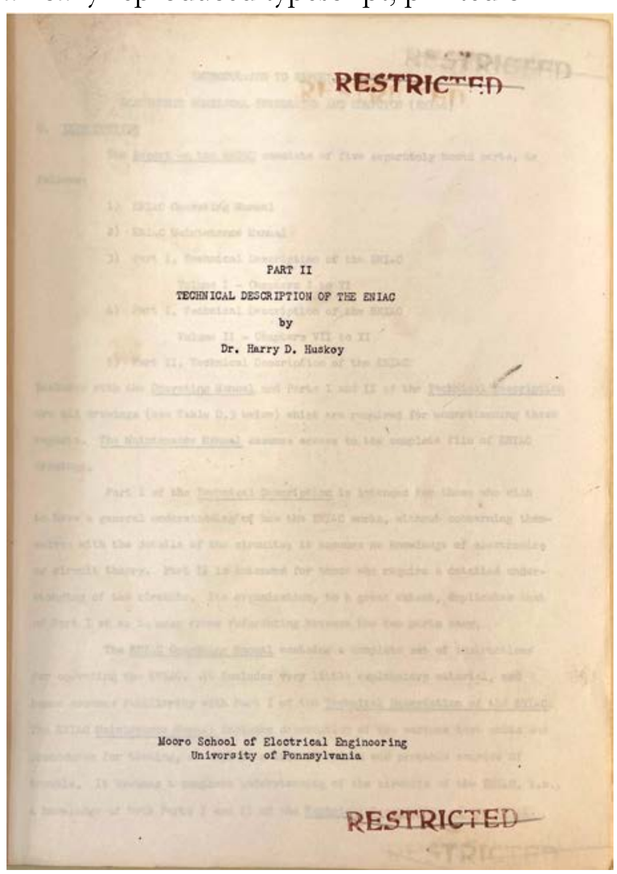
School of Engineering. Adele Goldstine was one of the ENIAC's original programmers; together with a team of six other women "computers," she was responsible for the majority of the programming and maintenance of the ENIAC. Setting up a program on the ENIAC originally required laboriously plugging and unplugging its many cables, but in 1946 Goldstine and fellow "human computer" Jean Bartik teamed up with John von Neumann to convert the ENIAC into a stored-program machine, eliminating the need to physically reconfigure the machine's cables for each new computing task.

Goldstine's *Technical Report* was "intended for those who wish to have a general understanding of how the ENIAC works, without concerning themselves with the details of the circuits" (Preface). The report includes 108 illustrations, including front panel drawings, block diagrams, cross-section diagrams and detail drawings, depicting the machine's features and the logical essentials of its internal circuits. These technical drawings and blueprints, drawn at the Moore School before the ENIAC was fully operational, are mostly unobtainable except through this publication or another one of the original ENIAC reports in this catalogue. The *Technical Report* was Adele Goldstine's primary publication; she died of cancer at the age of 44.

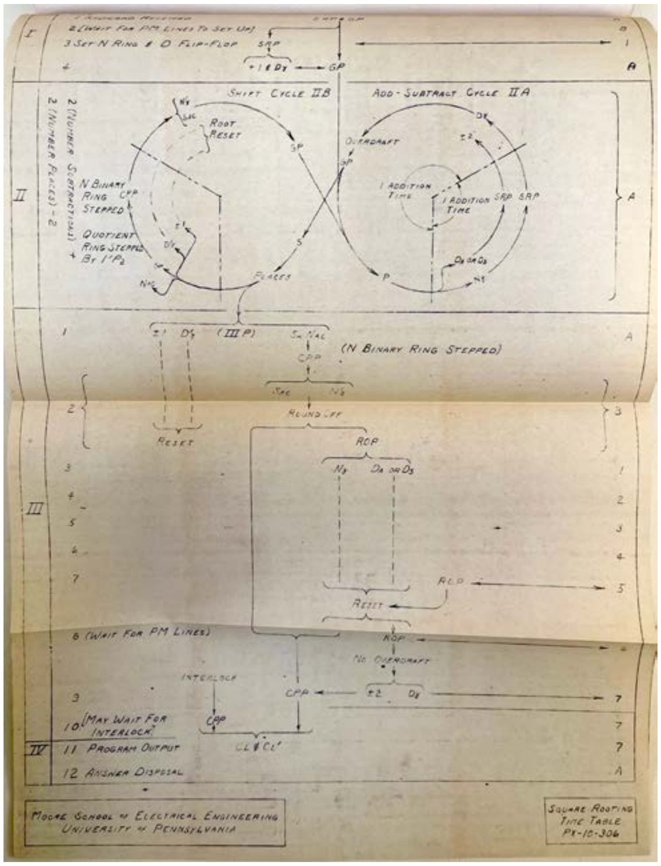
This copy of the *Technical Report* is from the library of Winifred S. Jonas, a mathematician at Aberdeen Proving Ground's (APG) Ballistic Research Lab (BRL), who became a programmer and operator of the ENIAC after the machine was moved from the University of Pennsylvania's Moore School to the APG in 1947. She worked on many special projects during the ENIAC's active years, including the V-2 rocket tests at White Sands and the Atomic Energy Commission's studies on the hydrogen bomb. Not in *Origins of Cyberspace*. 50599

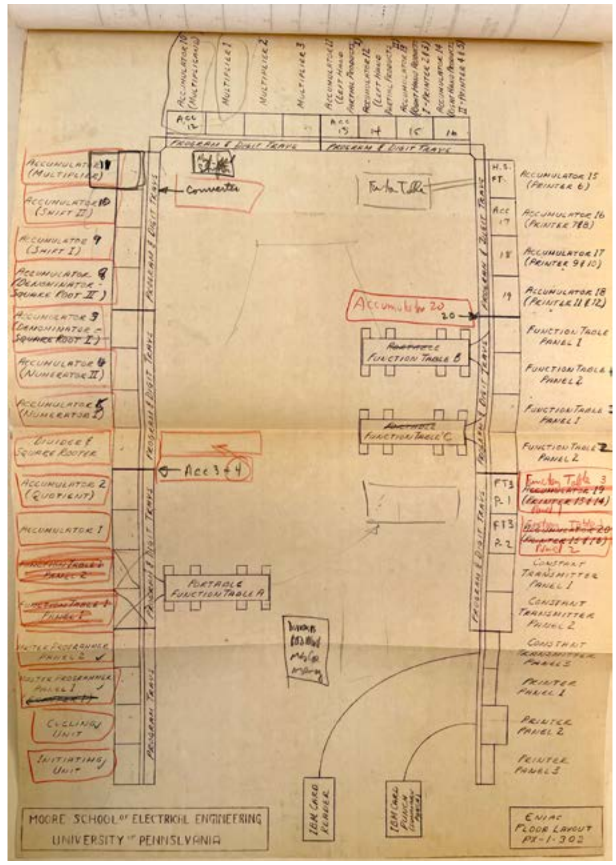
Harry Huskey's Report on the ENIAC: One of 25 Copies Printed

5. [ENIAC.] Huskey, Harry D. (1916-2017). Report on the ENIAC (Electronic Numerical Integrator and Computer). Technical report II. Mechanically reproduced typescript, printed on rectos only. No. 14 of 25 copies printed. [8], ix, 332, [175]ff., variously numbered. 12 blueprint plates. Philadelphia: University of Pennsylvania, Moore School of Engineering, 1 June 1946. 280 x 217 mm. Original printed stiff wrappers, cloth backstrip repaired with clear tape, light wear and creasing. Edge of one blueprint plate frayed, but very good." Boxed. Restricted" stamps on front wrapper and first few leaves; declassified stamp with ink date and signature on the front wrapper. From the library of Winifred S. Jonas (1924-2021), an early programmer and operator of the ENIAC. $9500

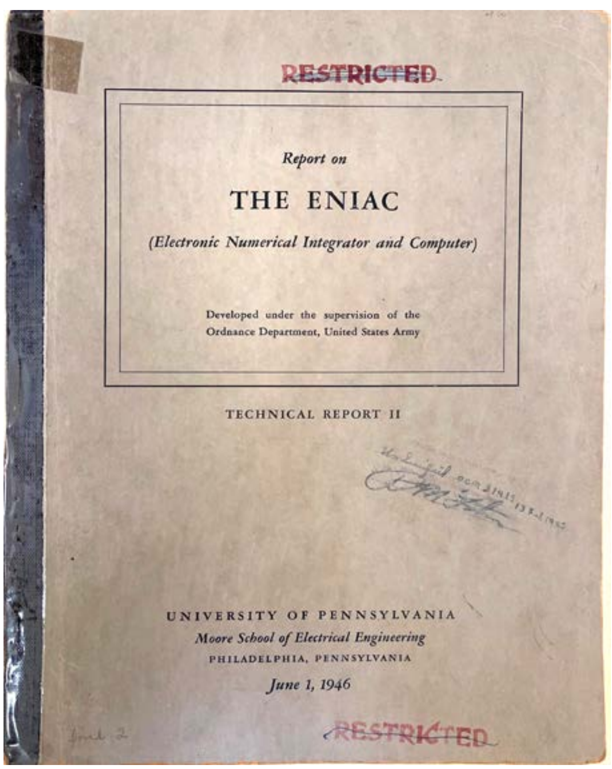


Extremely Rare First Printing, one of only 25 copies printed. Harry Huskey, a pioneering American computer scientist, got his formal introduction to computing in 1945 when he was hired to work on the ENIAC and EDVAC computers at the University of Pennsylvania's Moore School of Engineering. The ENIAC project was classified at the time and Huskey's *Technical Report II*, issued on the same date as Adele Goldstine's *Technical Report I,* was originally designated a "Restricted" document; it was declassified in 1947. Unlike Goldstine's report, Huskey's report was "intended for those who require a detailed understanding of the circuits."





After leaving the Moore School Huskey worked with Alan Turing on the ACE and Pilot ACE, and designed and built two important early electronic computers: The National Bureau of Standards' Western Automatic Computer (SWAC), the fastest computer of its time; and the 966-pound refrigerator-sized Bendix G-15 computer, described as the world's first "personal" computer. Huskey later founded the computing and information science program at the University of California at Santa Cruz and helped to set up academic computer science programs in universities throughout the world.



This copy of Huskey's report is from the library of Winifred S. Jonas, a mathematician at Aberdeen Proving Ground's Ballistic Research Lab, who became a programmer and operator of the ENIAC after the machine was moved from the Moore School to the APG in 1947. She worked on many special projects during the ENIAC's active years, including the V-2 rocket tests at White Sands and the Atomic Energy Commission's studies on the hydrogen bomb. Not in *Origins of Cyberspace*. 50606

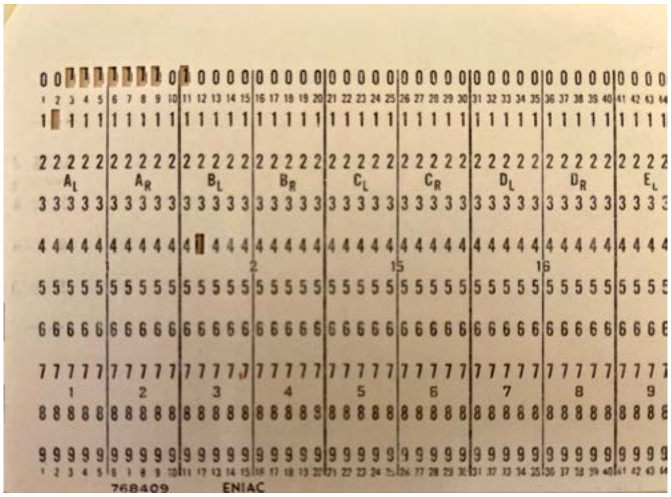
Unique Collection of ENIAC Artifacts

6. [ENIAC.] Collection of artifacts: (1) The ENIAC Electronic Numeral Integrator And Computor [sic] developed, designed and constructed by the Moore School of Electrical Engineering of the University of Pennsylvania 1944. Engraved name plate on black-painted metal (probably aluminum). 120 x 210 mm. A few minor scratches. (2) "ENIAC Engineer" desk sign. Black and white plastic plaque on wooden base. 50 x 210 mm. Light wear, corners chipped. (3) ENIAC Section bank deposit book, issued by the First National Bank, Aberdeen, MD. 120 x 174 mm. Beige cloth covers, front cover with inked account information: "ENIAC Section, Winifred Jonas, Treas., c/o BRL, A.P.G. Ind." (4) 3 ENIAC input/output punch cards. 83 x 187 mm. each, one with punched holes. A few stains, mathematical calculations in ballpoint on the verso of one card. All three punch cards have ENIAC printed in small letters in their lower left margin. (5) [Mayer, Maria Goeppert (1906-72).] Painted tin cigar box, Du Maurier brand, carried by Mayer during her visit to the ENIAC in 1949, with note inside providing details. 85 x 75 x 22 mm. Heavy wear, dents, paint scuffed.

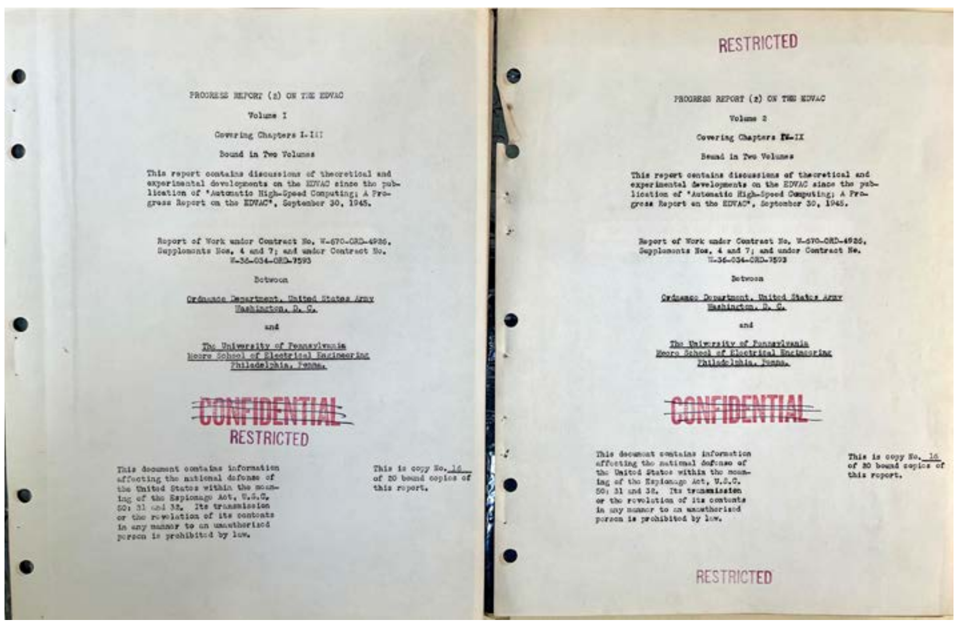
$12,500

Fascinating and unique collection of ENIAC artifacts once owned by Winifred S. Jonas (1924-2021), a mathematician and "human computer" at the Aberdeen Proving Ground who was one of the ENIAC's first programmers. We have never seen any comparable collections of ENIAC memorabilia on the market. The three ENIAC punch cards are examples of the first punch cards produced for an electronic computer.

Note that in the spelled-out version of the ENIAC name n the nameplate (Electronic Numeral Integrator And Computor) the word "computer" is spelled with a final "-or"; this alternate spelling appears throughout the original ENIAC blueprints and other documentation offered in this catalogue.

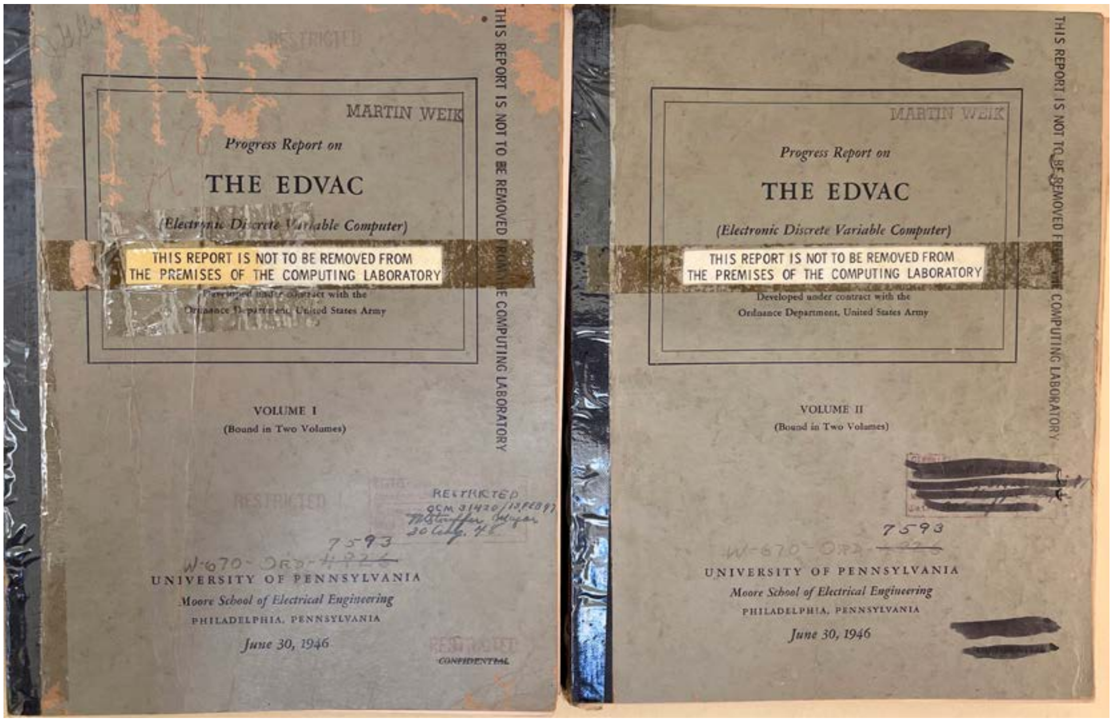


In 1947 the ENIAC was moved from the University of Pennsylvania's Moore School to the U.S. Army's Aberdeen Proving Ground, where it was used primarily to calculate artillery firing tables at the Ballistics Research Lab. Four years later President Harry Truman viewed the ENIAC during his 17 February 1951 visit to the APG; no. (1) is an unused name plate created for the occasion. The collection also includes an "ENIAC Engineer" desk sign (no. [2]); three ENIAC punch cards used for data input / output (no. [3])with the name ENIAC printed in very small letters in the lower left corner of each card; a bank book for the APG's ENIAC section, recording a single deposit of $31 (no. [4]); and a cigar tin carried by Nobel Laureate Maria Goeppert Mayer when she visited the APG in 1949 (no. [5]). Inside the tin is a laminated note reading: "This small cigar box contained very smelly small cigars—that were smoked by Dr. Maria Mayer 1949 in the outer ENIAC room (which contained the IBM printer & reader for reading data to be used in ENIAC computations.) Dr. Mayer, a Nobel prize winner in physics, gave the box to Winifred Smith (Jonas) who was a mathematician—operating hydrogen bomb research program brought from Los Alamos, N. Mex., U. of Chicago and Rand Institute [i.e. Rand Corporation], California." Not in *Origins of Cyberspace*. 50548

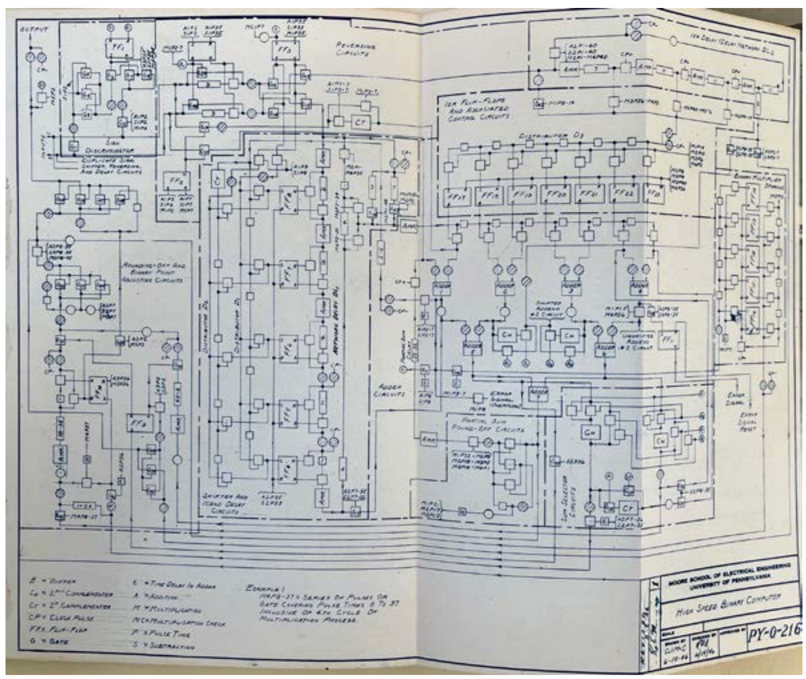


Sharpless's Report on the EDVAC: One of Only 20 Copies, from the Libraries of Martin Weik & Winifred S. Jonas

7. [EDVAC.] Sharpless, Thomas Kite (1913-67). Progress report (2) on the EDVAC (Electronic Discrete Variable Computer. Mechanically reproduced typescript, printed on rectos only. No. 16 of 20 copies printed. 2 vols. [4], v, [135]; [4], vi-ix, [129]ff., variously numbered. 111 blueprint plates. Philadelphia: University of Pennsylvania, Moore School of Engineering, 30 June 1946. 279 x 214 mm. Original printed stiff wrappers, cloth spines (perished), worn, some staining from clear tape; boxed. Left margins of text leaves punched for binder, light toning, but very good. "Restricted"

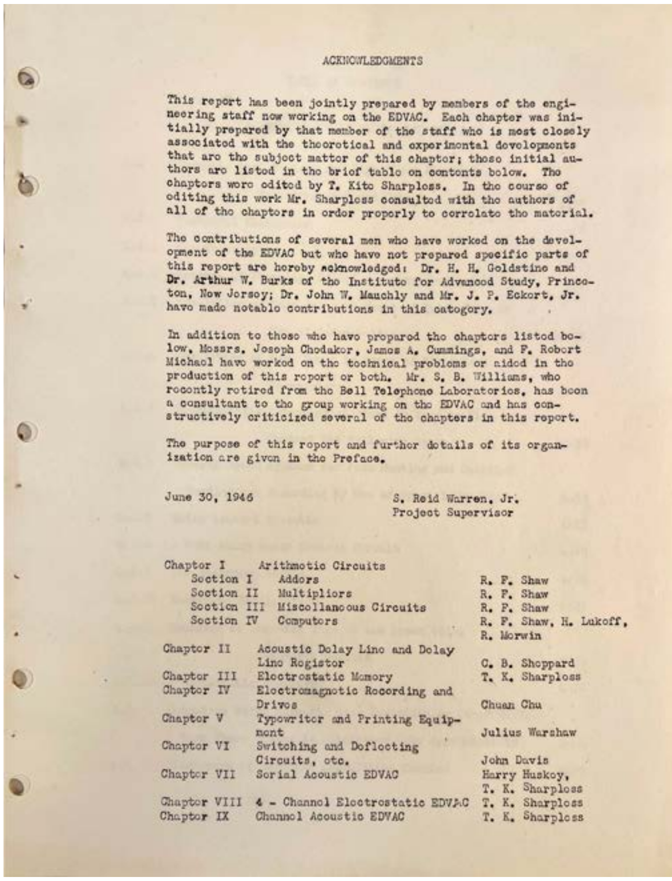


stamps on both front wrappers and some internal leaves. Classification markings crossed out on cover of vol. 2. Note taped to upper cover of both volumes reading "This report is not to be removed from the premises of the computing laboratory." Ownership stamps of Martin Weik (1922-2007), an engineer with the Aberdeen Proving Ground's Ballistics Research Lab, who worked on both the ENIAC and EDVAC. From the library of Winifred S. Jonas (1924-2021), also of the BRL, an early programmer and operator of the ENIAC and EDVAC computers. $10,000



Extraordinarily Rare First and Only Printing, one of only 20 copies issued, of the second progress report on the EDVAC, the first general-purpose electronic stored-program computer to be designed. The EDVAC's revolutionary stored-program concept, initially described by John von Neumann in his privately distributed *First Draft of a Report on the EDVAC* (1945), became the paradigm for many of the first-generation computers, even though the machine itself was not completed until 1949 and did not become fully operational until late 1951.

The idea of a stored-program computer originated around 1943-44 at the University of Pennsylvania's Moore School of Engineering, within the group of engineers charged with designing and constructing the ENIAC for the U.S. Army. The ENIAC, as is well known, was the world's first general-purpose electronic computer, but it was not designed to store its instructions and to process the instructions and data in an electronic memory



ACKNOWLEDGMENTS

This report has been jointly prepared by members of the engineering staff now working on the EDVAC. Each chapter was initially prepared by that member of the staff who is most closely associated with the theoretical and experimental developments that are the subject matter of this chapter; those initial authors are listed in the brief table on contents below. The chapters were edited by T. Kite Sharpless. In the course of editing this work Mr. Sharpless consulted with the authors of all of the chapters in order properly to correlate the material.

The contributions of several men who have worked on the development of the EDVAC but who have not prepared specific parts of this report are hereby acknowledged: Dr. H. H. Goldstine and Dr. Arthur W. Burks of the Institute for Advanced Study, Princeton, New Jersey; Dr. John W. Mauchly and Mr. J. P. Eckert, Jr. have made notable contributions in this category.

In addition to those who have prepared the chapters listed below, Messrs. Joseph Chedaker, James A. Cummings, and F. Robert Michael have worked on the technical problems or aided in the production of this report or both. Mr. S. B. Williams, who recently retired from the Bell Telephone Laboratories, has been a consultant to the group working on the EDVAC and has constructively criticized several of the chapters in this report.

The purpose of this report and further details of its organization are given in the Preface.

June 30, 1946

S. Reid Warren, Jr.
Project Supervisor

Chapter I	Arithmetic Circuits	
Section I	Adders	R. F. Shaw
Section II	Multipliers	R. F. Shaw
Section III	Miscellaneous Circuits	R. F. Shaw
Section IV	Computers	R. F. Shaw, H. Lukoff, R. Merwin
Chapter II	Acoustic Delay Line and Delay Line Register	C. B. Sheppard
Chapter III	Electrostatic Memory	T. K. Sharpless
Chapter IV	Electromagnetic Recording and Drives	Chuan Chu
Chapter V	Typewriter and Printing Equipment	Julius Warshaw
Chapter VI	Switching and Deflecting Circuits, etc.	John Davis
Chapter VII	Serial Acoustic EDVAC	Harry Huskey, T. K. Sharpless
Chapter VIII	4 - Channel Electrostatic EDVAC	T. K. Sharpless
Chapter IX	Channel Acoustic EDVAC	T. K. Sharpless

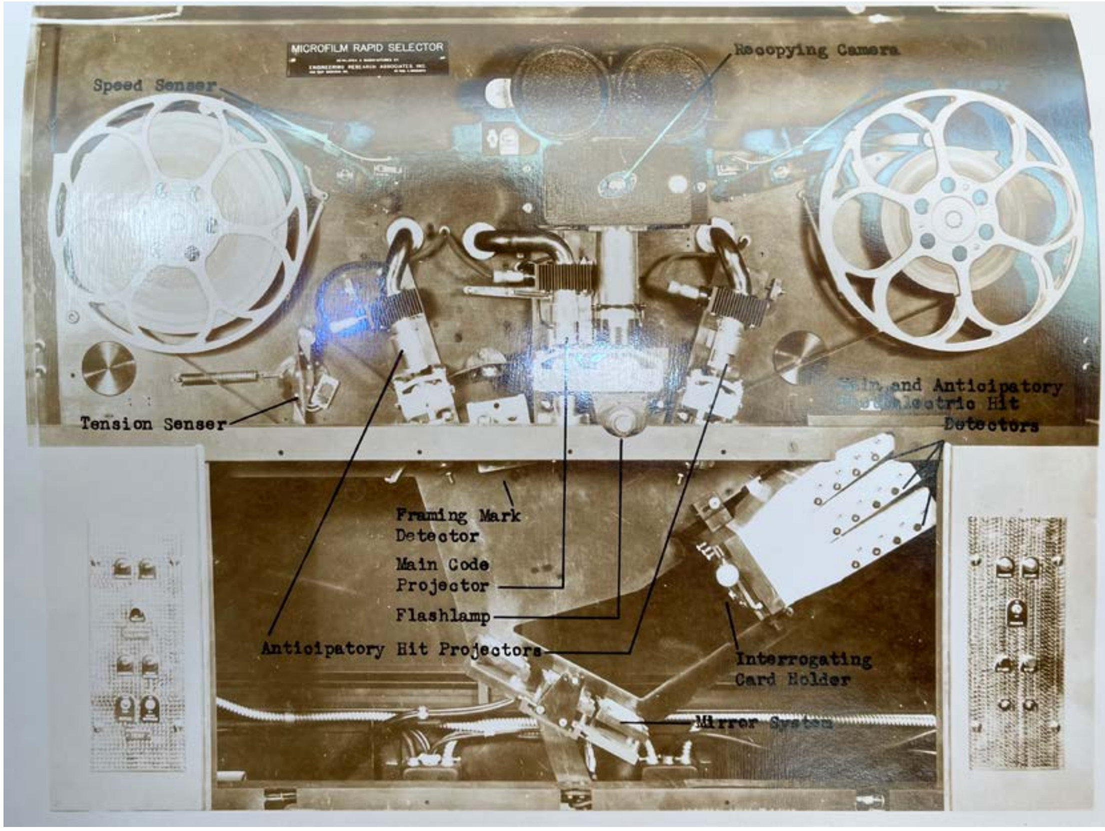
as electronic memory technology did not exist at the time; thus setting up programs on the ENIAC required physically plugging in patch cords from buses to panels for the solution of each problem. By early 1944 some leading members of the ENIAC's design team, including Pres Eckert, John Mauchly and Herman Goldstine, were actively pursuing the stored-program concept, and in September 1944 John von Neumann, the celebrated mathematical genius, joined what would become the EDVAC project. In October 1944 the U.S. Army granted the ENIAC team an additional $105,600 to explore the design of a stored-program computer with electronic memory.

In June 1945 von Neumann wrote the *First Draft of a Report on the EDVAC*, setting forth in organized fashion the results of the EDVAC team's design meetings; it was this document that "first described, in any detail, the concept of the stored-program computer" (Williams, p. 23). The *First Draft* was intended to be an internal working document, and as such it never received a "Restricted" or "Confidential" classification; however, its unclassified status led to the *First Draft* being distributed to a wider audience than anticipated, and since von Neumann was listed as the report's sole author its readers naturally credited him with the stored-program concept. This caused friction between von Neumann and the other leading team members, several of whom—including Eckert and Mauchly—left the Moore School in early 1946, severely hampering further progress on the EDVAC. Prior to their departure Eckert and Mauchly attempted to set the record straight in their own report, titled "Automatic High Speed Computing: A Progress Report on the EDVAC" (30 September 1945), but this was a classified document issued in only 50 copies, and as such had only a limited audience.

After Eckert and Mauchly left the Moore School, responsibility for the EDVAC passed to Thomas Kite Sharpless, who headed the project until 1947. On 30 June 1946 Sharpless issued the second progress report on the EDVAC—the document we are offering here—describing the work done on the project since Eckert and Mauchly's report of 1945. Like the earlier report, *Progress Report (2)* was a classified document, issued in only 20 copies. On the report's "Acknowledgments" page Sharpless paid tribute to his EDVAC predecessors, particularly Herman Goldstine, Arthur W. Burks, John Mauchly and Pres Eckert; von Neumann's name, for whatever reason, is conspicuously absent.

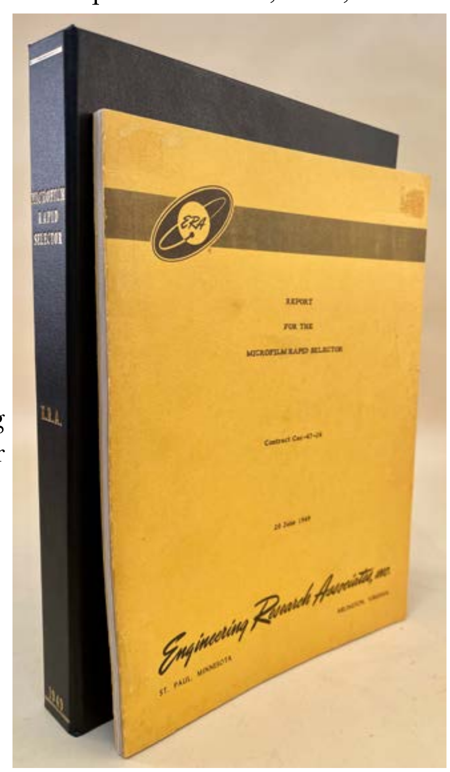
In 1949, five years after the stored-program idea was first conceived, the completed EDVAC was shipped to the Army's Aberdeen Proving Ground for use in the Ballistics Research Lab. The EDVAC turned out to be a somewhat unreliable machine: It was difficult to program and operate, experienced long periods of down time, and had to undergo substantial upgrades to keep up with advancing technology and the BRL's computing needs. Despite these limitations, the EDVAC remained in operation at the BRL until the end of 1962.

This copy of Sharpless's EDVAC report was formerly owned by Martin Weik, an engineer with the Aberdeen Proving Ground's Ballistics Research Lab who worked on both the ENIAC and EDVAC computers; between 1955 and 1964 he published four important surveys of all the known electronic digital computers in the United States. This copy was later owned by Winifred S. Jonas, an early programmer and operator of both the ENIAC and EDVAC. M. R. Williams, "The origins, uses and fate of the EDVAC," *IEEE Annals of the History of Computing* 15 (1993): 22-38. Not in *Origins of Cyberspace*. 50642



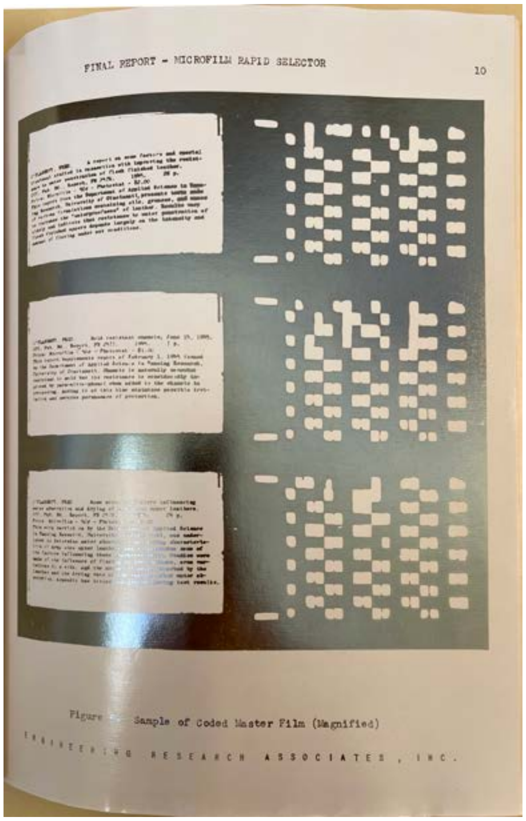
Realization of Vannevar Bush's "Memex" Concept

8. Engineering Research Associates. Report for the microfilm Rapid Selector. v, 30ff., including 10 full-page photographic illustrations, printed from negatives on Kodak Velox paper. St. Paul, MN: Engineering Research Associates, 20 June 1949. 280 x 215 mm. Original printed wrappers with metal fastener, small stain on front wrapper, slight wear; boxed. Very good. $7500



First Edition, and Rare on the Market; this is the only copy we have ever seen for sale in our over 50 years in the trade.

In 1947, two years after Vannevar Bush published his idea for the "Memex" information retrieval system, Ralph R. Shaw, director of libraries for the U.S. Department of Agriculture, began developing a pilot model of the "Rapid Selector" machine for the electronic searching of information recorded on microfilm, working with a team of computer designers at Engineering Research Associates. This pilot model, completed in January 1949, was an attempt to realize the goals outlined in Bush's "As we may think" (1945), which introduced some of the foundational information retrieval concepts underlying the Internet and World Wide Web. We are offering here the *earliest known printed description* of the finished Rapid Selector—the ERA's June 1949 report on the completed machine—which contains detailed illustrated accounts of its design and operation. The ERA's pilot model was the only Rapid Selector ever constructed.



The Rapid Selector's machine-readable optical indexing is shown on the right of this photograph.

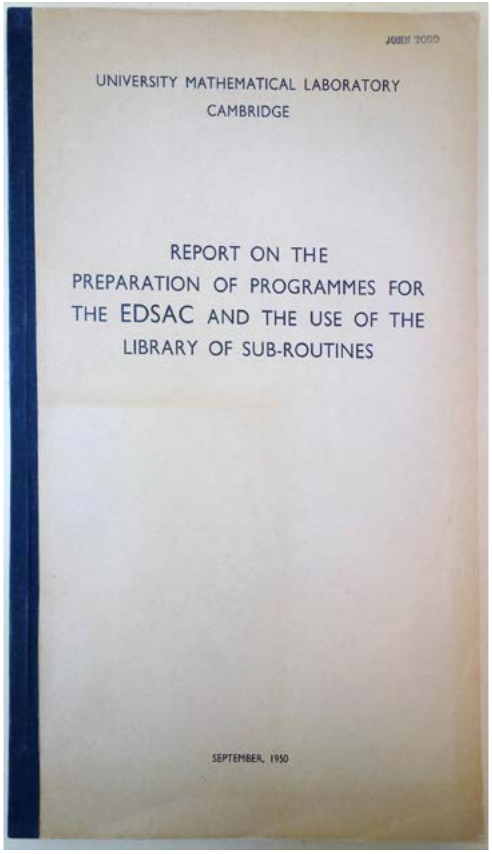
The Rapid Selector project's objective

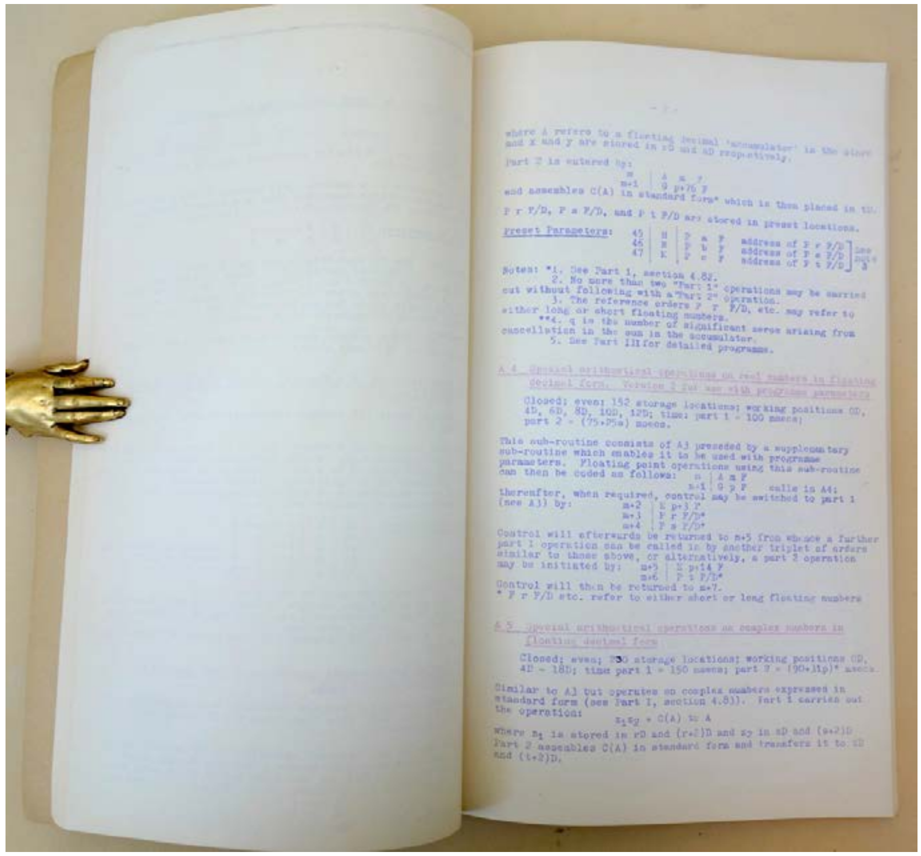
was to develop, within two years, a prototype machine capable of selecting microfilmed business records from microfilm rapidly: A microfilm rapid selector. Bush's selector was indeed rapid because it took advantage of two new developments: Improved photo-electric cell technology; and the stroboscopic lamp pioneered by his colleague Harold E. Edgerton. By creating a bright flash of light lasting only one-millionth of a second, the stroboscopic lamp made it possible to copy a selected microfilm image "on the fly," without stopping the film (and the search) to make a copy (M. K. Buckland, "Emanuel Goldberg, Electronic Document Retrieval, and Vannevar Bush's Memex." *Emanuel Goldberg, 1881-1970: Pioneer of Information Science*, May 1992 [web].

According to the present report, the Rapid Selector

scans the film at the rate of more than 10,000 frames per minute which may correspond to as many as 60,000 subjects per minute. It selects all abstracts which are associated with an interest category specified by the operator, and recopies the selected items on a separate roll of 35mm film by the use of high-speed photoflash techniques. (p. ii)

After its completion the Rapid Selector was shipped to the U.S. Department of Agriculture in Washington DC, where it remained in operation as late as 1958—a Congressional report on the "Science and Technology Act of 1958," published in June of that year, includes a detailed note on the Rapid Selector (p. 430) which states that "the machine is now being remodeled in cooperation with the National Bureau of Standards to simplify and improve it on the basis of operating experience." Father Roberto Busa (1913-2011), a pioneer in the use of computers for linguistic and literary analysis, observed the Rapid Selector in action in November 1949, noting that "its principal feature is the whirlwind speed with which it explores the reels of microfilm—10,000 photograms per minute—and instantaneously rephotographs on another microfilm strip all and only those photograms which bear a determined item" (Busa, *Varia specimina concordantiarum* [1951], p. 22). Another account of the Rapid Selector, published in Ridenour, Shaw and Hill's *Bibliography in an Age of Science* (1951), mentioned that the machine stored 72,000 frames of information on a 2000-foot reel of film and could search through data at the rate of 78,000 codes per minute. Not in *Origins of Cyberspace.* 44858





Extremely Rare Pre-Publication Dittoed Version of the First Textbook on Software

9. Wilkes, Maurice (1913-2010) *et al.* Report on the preparation of programmes for the EDSAC and the use of the library of subroutines. Dittoed document in two colors. [3], 40 [2], 26, 39, xi ff. 323 x 201 mm. N.p., September 1950. Original tan printed wrappers, cloth spine. Fine. Stamp of John Todd (1911-2007) on the front wrapper. $25,000

Extremely Rare First Edition issued for private circulation. OCLC cites copies in only two libraries: Harvard and the University of Toronto.

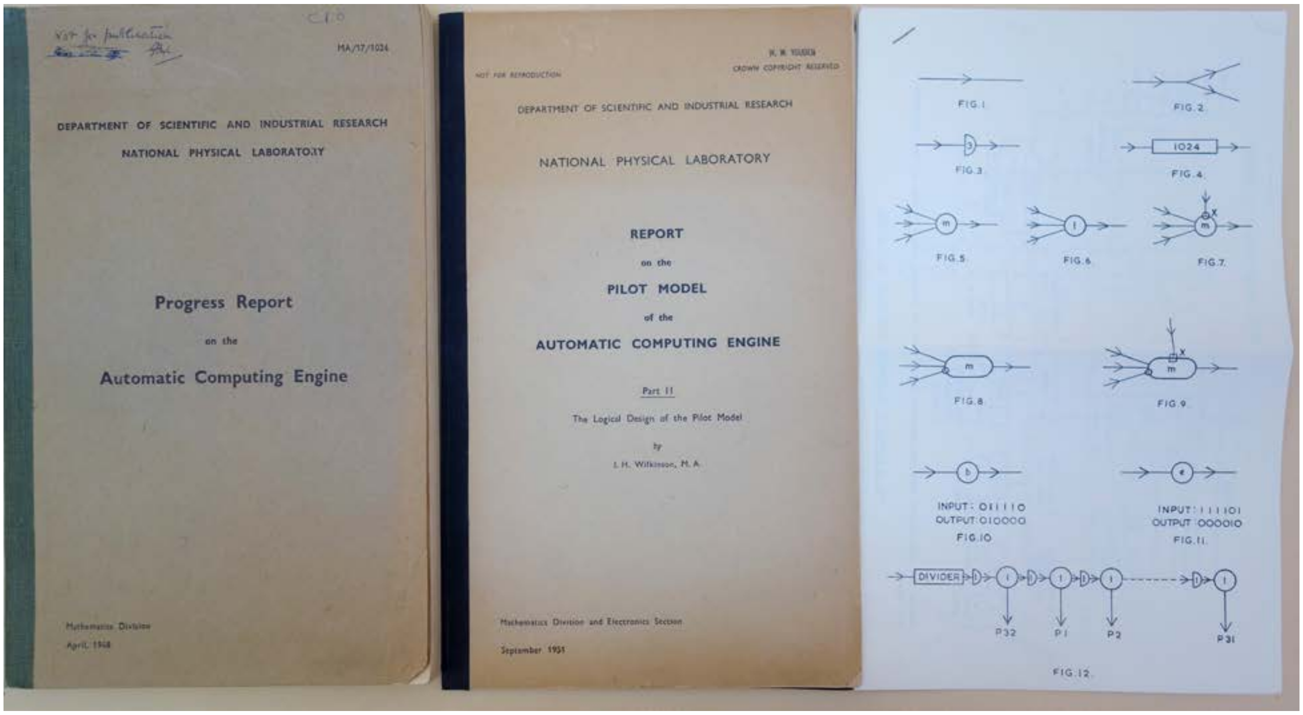
Wilkes's *Report* was the first treatise on how to program an operational stored-program computer. The text explained how to program Cambridge University's EDSAC, the world's second stored-program computer and the first electronic computer truly usable for large-scale operations. The machine was constructed at the University's Mathematical Laboratory (now the Computer Laboratory) by Maurice Wilkes, who was inspired and informed by attending the lectures on the *Theory and Techniques for Design of Electronic Digital Computers*, later known as the *Moore School Lectures,* held at the University of Pennsylvania in July and August 1946. The EDSAC ran its first program on 6 May 1949.

The *Report on the Preparation of Programmes for the EDSAC* was prepared by Wilkes and his fifteen-man team of researchers at the Mathematical Laboratory, and distributed to no more than one hundred people—"everyone we thought would be interested, both in the United Kingdom and abroad" (Wilkes, *Memoirs of a Computer Pioneer,* p. 149). The material in this dittoed report was formally published as a textbook the following year, with very few changes, in Wilkes, Wheeler, and Gill's *Preparation of Programs for an Electronic Digital Computer* (1951). The 1951 edition initiated the software textbook publishing industry.

When Jeremy visited Maurice Wilkes around the year 2000 Wilkes pointed out that no English publisher was interested in publishing the book, and when the American firm Addison-Wesley undertook publication in

1951 they were taking a considerable risk, since no one knew at the time whether there was any demand at all for a textbook on software. At the time demand was minimal; it took six years to sell out the first edition.

This copy bears the ownership stamp of mathematician John Todd, professor of mathematics at Caltech and pioneer of numerical analysis and high-speed computer programming. *Origins of Cyberspace* 1027. 44861

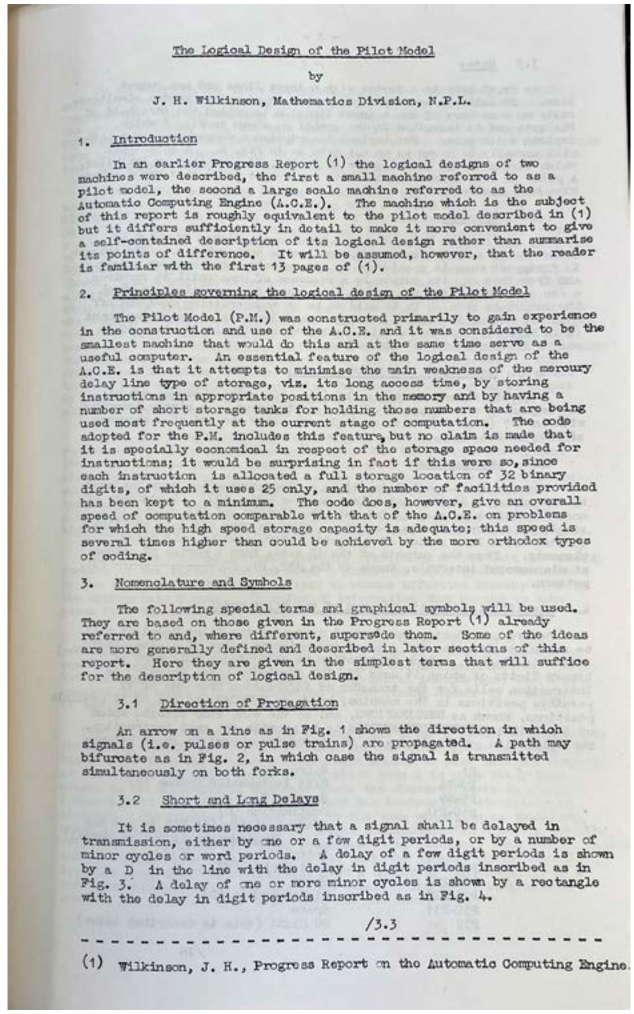


Two Rare Early Reports on Alan Turing's ACE and Pilot ACE Computers, Including Some of Turing's Earliest Published Programs

10. Wilkinson, James Hardy (1919-1986). (1) Confidential. Progress report on the Automatic Computing Engine. Mimeograph typescript. [1], 127ff. 12 plates. N.p.: National Physical Laboratory, April 1948. 324 x 202 mm. Original tan printed wrappers, green cloth spine, small tear in upper portion of backstrip, corners a bit worn, back wrapper a bit creased. The word "Confidential" crossed out on both front wrapper and title, "Not for publication" and illegible initials inscribed on front wrapper. (2) Report on the pilot model of the Automatic Computing Engine. Part II. The logical design of the pilot model. Mimeograph typescript. [4], 18pp. 6 diagrams (stapled together) in pocket of back wrapper. N.p.: National Physical Laboratory, September 1951. 331 x 203 mm. Original printed wrappers, cloth backstrip. Very good. Ownership stamp of William Wallace Youden (1925-68), bibliographer of computer literature, on front wrapper. Together two items. Bookplate of Erwin Tomash in each part. $25,000

First Editions of Both Parts, and Extremely Rare, with OCLC recording only six copies of the first part and *only one copy* of the second describing the Pilot ACE, a simplified version of the machine that was the first to become operational.

Wilkinson's 1948 report (no. [1]) is one of the earliest published documents on the ACE and contains probably the most detailed description of the work done to date in building the test assembly. The numerous programs published in this report include **some of the earliest published examples of Turing's programming for the ACE**. **These are among the earliest published programs by Turing that have ever appeared on the market.**



The Logical Design of the Pilot Model

by

J. H. Wilkinson, Mathematics Division, N.P.L.

1. Introduction

In an earlier Progress Report (1) the logical designs of two machines were described, the first a small machine referred to as a pilot model, the second a large scale machine referred to as the Automatic Computing Engine (A.C.E.). The machine which is the subject of this report is roughly equivalent to the pilot model described in (1) but it differs sufficiently in detail to make it more convenient to give a self-contained description of its logical design rather than summarise its points of difference. It will be assumed, however, that the reader is familiar with the first 13 pages of (1).

2. Principles governing the logical design of the Pilot Model

The Pilot Model (P.M.) was constructed primarily to gain experience in the construction and use of the A.C.E. and it was considered to be the smallest machine that would do this and at the same time serve as a useful computer. An essential feature of the logical design of the A.C.E. is that it attempts to minimise the main weakness of the mercury delay line type of storage, viz. its long access time, by storing instructions in appropriate positions in the memory and by having a number of short storage tanks for holding those numbers that are being used most frequently at the current stage of computation. The code adopted for the P.M. includes this feature, but no claim is made that it is specially economical in respect of the storage space needed for instructions; it would be surprising in fact if this were so, since each instruction is allocated a full storage location of 32 binary digits, of which it uses 25 only, and the number of facilities provided has been kept to a minimum. The code does, however, give an overall speed of computation comparable with that of the A.C.E. on problems for which the high speed storage capacity is adequate; this speed is several times higher than could be achieved by the more orthodox types of coding.

3. Nomenclature and Symbols

The following special terms and graphical symbols will be used. They are based on those given in the Progress Report (1) already referred to and, where different, supersede them. Some of the ideas are more generally defined and described in later sections of this report. Here they are given in the simplest terms that will suffice for the description of logical design.

3.1 Direction of Propagation

An arrow on a line as in Fig. 1 shows the direction in which signals (i.e. pulses or pulse trains) are propagated. A path may bifurcate as in Fig. 2, in which case the signal is transmitted simultaneously on both forks.

3.2 Short and Long Delays

It is sometimes necessary that a signal shall be delayed in transmission, either by one or a few digit periods, or by a number of minor cycles or word periods. A delay of a few digit periods is shown by a D in the line with the delay in digit periods inscribed as in Fig. 3. A delay of one or more minor cycles is shown by a rectangle with the delay in digit periods inscribed as in Fig. 4.

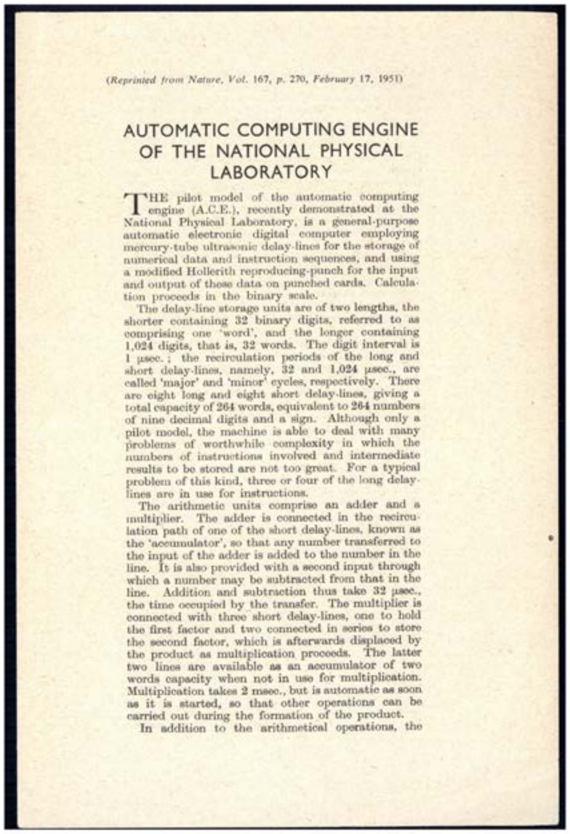
/3.3

(1) Wilkinson, J. H., Progress Report on the Automatic Computing Engine.

The National Physical Laboratory's ACE (Automatic Computing Engine) was designed by Alan Turing, who began working on the project a few months before he joined the NPL's mathematics division on October 1, 1945. Construction of the ACE began with a "test assembly" to try out Turing's ideas of computer design. Although Turing's design was workable, the effect of the Official Secrets Act surrounding the wartime work at Bletchley Park made it impossible for Turing to explain the basis of his analysis of how a computer installation involving human operators would work. This led to delays in starting the project, and Turing became disillusioned, leaving the NPL in September 1947 to take a sabbatical year at Cambridge University.

After Turing's departure from the NPL, the ACE project was taken over by his assistants, James H. Wilkinson and Michael Woodger. In early 1949 the original ACE test assembly was abandoned and a new version, redesigned to make the electronics as simple as possible, began construction in early 1949. In the design of this simplified machine Wilkinson collaborated with Donald Davies, Harry Huskey and Mike Woodger. The simplified machine, completed in 1950, came to be known as the "Pilot ACE." Wilkinson's 1951 report (no. [2]) was published during the first year the Pilot ACE was in operation. The report sets out the machine's logical design and mode of operation; "it includes definitions of the special terms and graphical symbols used, and functional descriptions and schematic diagrams of the circuits used for logical control and for computation" (p. [iii]).

The Pilot ACE, although intended as a prototype, was immediately pressed into service, as it was then the only computer in a British government department. A commercial version of the machine, called the DEUCE was marketed by English Electric from 1955. In addition, one of the designers of the Pilot Ace, Harry Huskey, applied the design to the 966-pound refrigerator-sized American Bendix G-15 computer, marketed in the U.S. as a "personal" computer between 1956 and 1963. *Origins of Cyberspace* 933 (1948 report only). Yates, *Turing's Legacy: A History of Computing at the National Physical Laboratory 1945–1995*, 337, no. 138. 44770


(Reprinted from Nature, Vol. 167, p. 270, February 17, 1951)

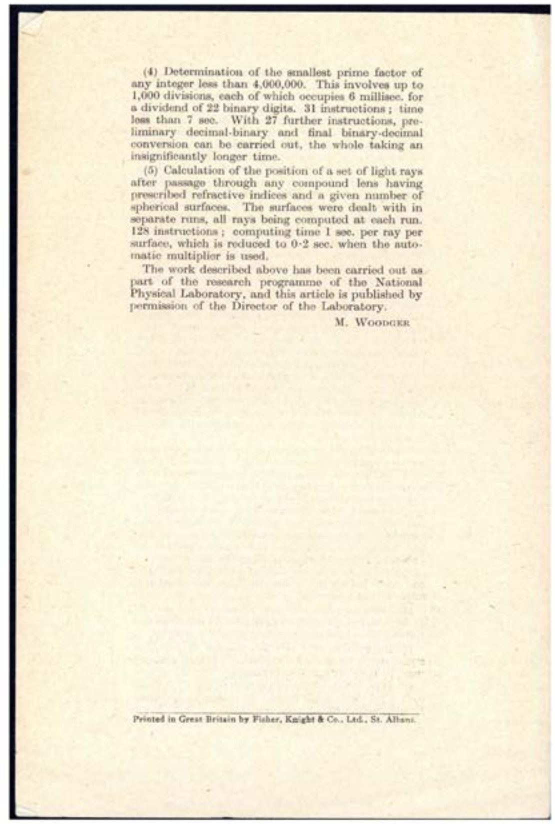
AUTOMATIC COMPUTING ENGINE OF THE NATIONAL PHYSICAL LABORATORY

THE pilot model of the automatic computing engine (A.C.E.), recently demonstrated at the National Physical Laboratory, is a general-purpose automatic electronic digital computer employing mercury-tube ultrasonic delay-lines for the storage of numerical data and instruction sequences, and using a modified Hollerith reproducing-punch for the input and output of these data on punched cards. Calculation proceeds in the binary scale.

The delay-line storage units are of two lengths, the shorter containing 32 binary digits, referred to as comprising one 'word', and the longer containing 1,024 digits, that is, 32 words. The digit interval is 1 µsec.; the recirculation periods of the long and short delay-lines, namely, 32 and 1,024 µsec., are called 'major' and 'minor' cycles, respectively. There are eight long and eight short delay-lines, giving a total capacity of 264 words, equivalent to 264 numbers of nine decimal digits and a sign. Although only a pilot model, the machine is able to deal with many problems of worthwhile complexity in which the numbers of instructions involved and intermediate results to be stored are not too great. For a typical problem of this kind, three or four of the long delay-lines are in use for instructions.

The arithmetic units comprise an adder and a multiplier. The adder is connected in the recirculation path of one of the short delay-lines, known as the 'accumulator', so that any number transferred to the input of the adder is added to the number in the line. It is also provided with a second input through which a number may be subtracted from that in the line. Addition and subtraction thus take 32 µsec., the time occupied by the transfer. The multiplier is connected with three short delay-lines, one to hold the first factor and two connected in series to store the second factor, which is afterwards displaced by the product as multiplication proceeds. The latter two lines are available as an accumulator of two words capacity when not in use for multiplication. Multiplication takes 2 msec., but is automatic as soon as it is started, so that other operations can be carried out during the formation of the product.

In addition to the arithmetical operations, the


(4) Determination of the smallest prime factor of any integer less than 4,000,000. This involves up to 1,000 divisions, each of which occupies 6 millisec. for a dividend of 22 binary digits. 31 instructions; time less than 7 sec. With 27 further instructions, preliminary decimal-binary and final binary-decimal conversion can be carried out, the whole taking an insignificantly longer time.

(5) Calculation of the position of a set of light rays after passage through any compound lens having prescribed refractive indices and a given number of spherical surfaces. The surfaces were dealt with in separate runs, all rays being computed at each run. 128 instructions; computing time 1 sec. per ray per surface, which is reduced to 0·2 sec. when the automatic multiplier is used.

The work described above has been carried out as part of the research programme of the National Physical Laboratory, and this article is published by permission of the Director of the Laboratory.

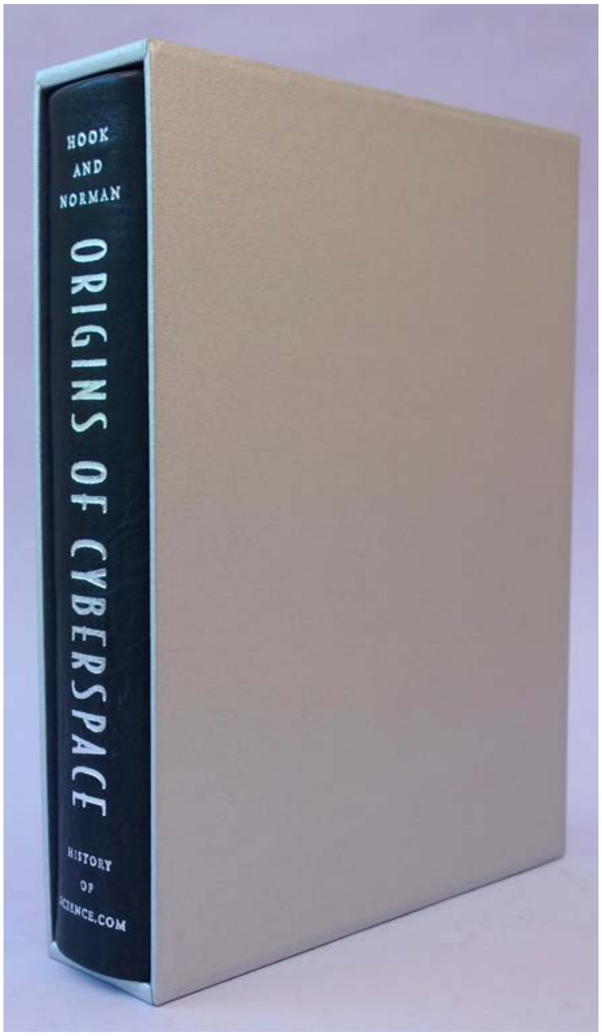
M. WOODGER

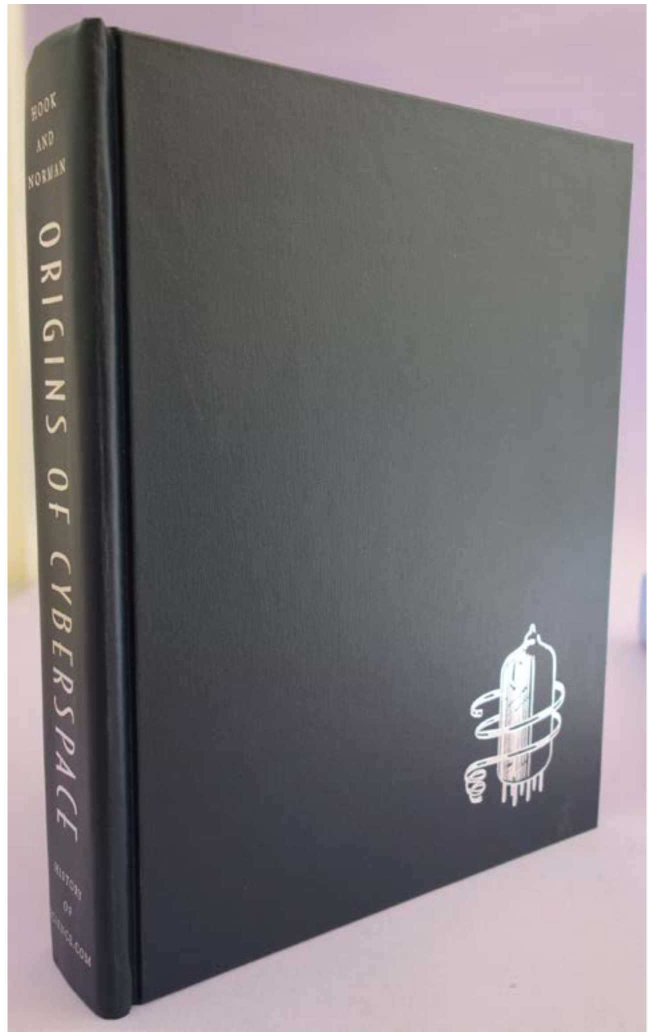
Printed in Great Britain by Fisher, Knight & Co., Ltd., St. Albans.

First Published Description of the Completed Pilot ACE Computer

11. Woodger, Michael (1923-). Automatic Computing Engine of the National Physical Laboratory. Offprint from Nature 167 (1951). [4]pp. 211 x 140 mm. Without wrappers; in later paper sleeve with printed label. Slight creasing, a few tiny marginal tears but very good. $1500

First Edition, Offprint Issue of *the first published description of the completed Pilot ACE computer.* "The pilot model of the automatic computing machine (A.C.E.), recently demonstrated at the National Physical Laboratory, is a general-purpose automatic electronic digital computer employing mercury-tube ultrasonic delay lines for the storage of numerical data and instruction sequences, and using a modified Hollerith reproducing-punch for the input and output of these data on punched cards. Calculation proceeds in the binary scale . . ." (p. [1]). Woodger's report includes a description of five test computations run on the ACE. Not in *Origins of Cyberspace.* 50673





Left: Deluxe leather-bound edition in slipcase. Right: Regular cloth-bound edition.

12. Hook, Diana and **Jeremy M. Norman.** Origins of cyberspace: A library on the history of computing, networking and telecommunications. With contributions by Michael R. Williams. x, 670pp. 284 illustrations. Printed in two colors throughout on Fortune Matte 80-pound acid-free paper. Novato: Historyofscience.com, 2002. Deluxe edition, one of 15 copies numbered in binary and signed by the authors, designer and binder; bound in full leather, all edges gilt, in cloth slipcase. *Only two copies remaining!* $2000

Origins of Cyberspace describes the Jeremy Norman library of technical reports, books, pamphlets, blueprints, typescripts, manuscripts, photographs, and ephemera on the history of computing and computer-related aspects of telecommunications, from the early seventeenth century to about 1969; it includes 1411 annotated entries. *Only two copies of the deluxe edition remaining!* 38310

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