Working on ENIAC:
The Lost Labors of the Information Age

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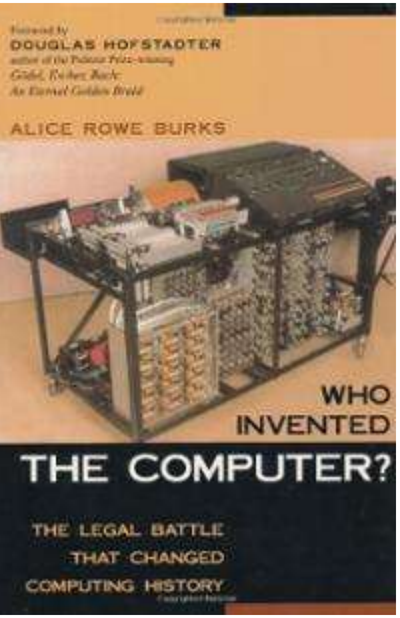
This Research Is Sponsored By

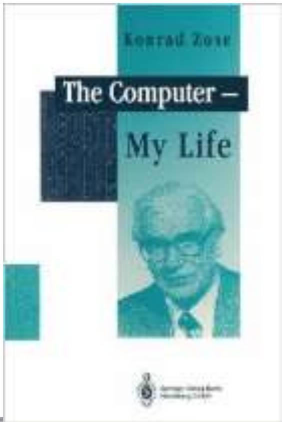
- Mrs L.D. Rope’s Second Charitable Trust
- Mrs L.D. Rope’s Third Charitable Trust

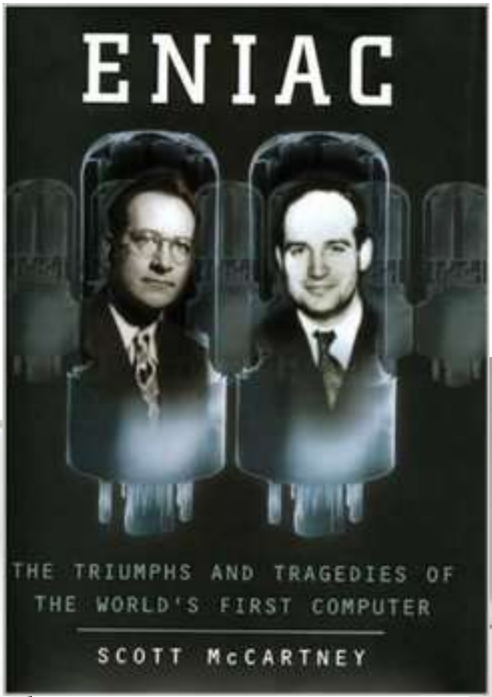
Thanks for contributions by my coauthors Mark Priestley & Crispin Rope. And to assistance from others including Ann Graf, Peter Sachs Collopy, and Stephanie Dick.

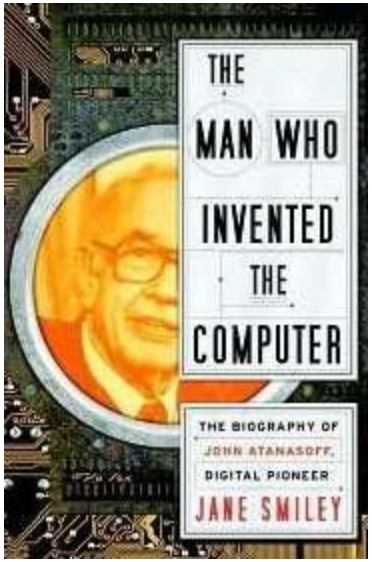
CONVENTIONAL HISTORY OF COMPUTING

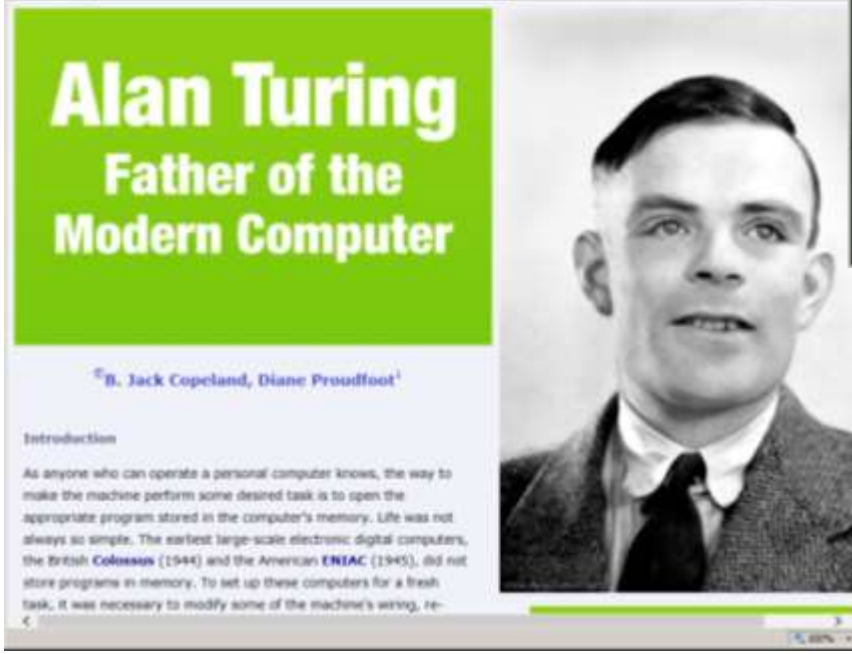
The Battle for "Firsts"









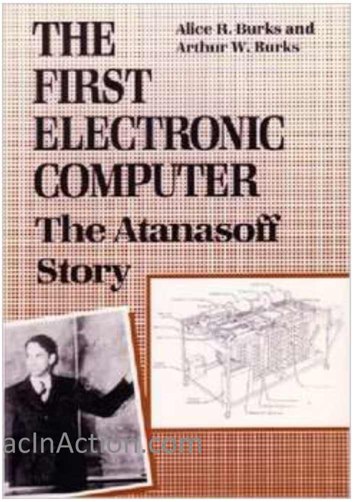


Alan Turing
Father of the Modern Computer

B. Jack Copeland, Diane Proudfoot[1]

Introduction

As anyone who can operate a personal computer knows, the way to make the machine perform some desired task is to open the appropriate program stored in the computer's memory. Life was not always so simple. The earliest large-scale electronic digital computers, the British **Colossus** (1944) and the American **ENIAC** (1945), did not store programs in memory. To set up these computers for a fresh task, it was necessary to modify some of the machine's wiring, re-

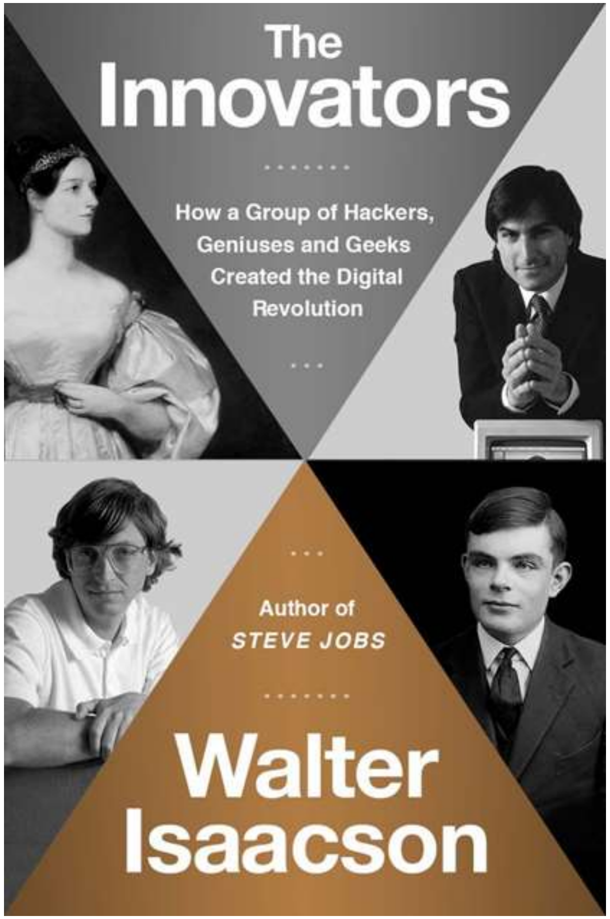


Example: Alan Turing

- A lone genius, according to *The Imitation Game*
  - *"I don't have time to explain myself as I go along, and I'm afraid these men will only slow me down"*
- Hand building "Christopher"
  - In reality hundreds of "bombes" manufactured

Isaacson's "The Innovators"

- Many admirable features
  - Stress on teamwork
  - Lively writing
  - References to scholarly history
  - Goes back beyond 1970s
  - Stresses role of liberal arts in tech innovation
- But going to disagree with some basic assumptions
  - Like the subtitle!



Amazon

- Isaacson has 7 of the top 10 in "Computer Industry History"
    - – 4 Jobs
    - – 3 Innovators

Best Sellers in Computing Industry History

1. Steve Jobs
by Walter Isaacson
(4,865)
Audible Audio Edition
$26.95
2 new from $26.95

2. Steve Jobs
by Walter Isaacson
(4,865)
Kindle Edition
$12.99

3. Steve Jobs
by Walter Isaacson
(4,865)
Paperback
$11.06
67 used & new from $2.60

4. The Innovators: How a Group of Hacker...
by Walter Isaacson
(861)
Audible Audio Edition
$29.95

5. Steve Jobs
by Walter Isaacson
(4,865)
Hardcover
$20.83
1154 used & new from $0.01

6. Alan Turing: The Enigma: The Book Tha...
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$10.49
154 used & new from $5.40

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8. Hackers: Heroes of the Computer Revol...
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Audible Audio Edition
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10. Alan Turing: The Enigma: The

11. Countdown to Zero Day:

12. Countdown to Zero Day:

Electronic Dreams: How 1980...
Audible Audio Edition
$21.83

Commodore: The Amiga Years
Hardcover
$21.29

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Hardcover
$24.43

Most Wished For › See Top 100

Steve Jobs
Paperback
$11.06

Alan Turing: The Enigma: Th...
Paperback
$10.49

TheInnovators: How a Group...
Kindle Edition
$15.99

Gift Ideas › See Top 100

Steve Jobs
Hardcover
$20.83

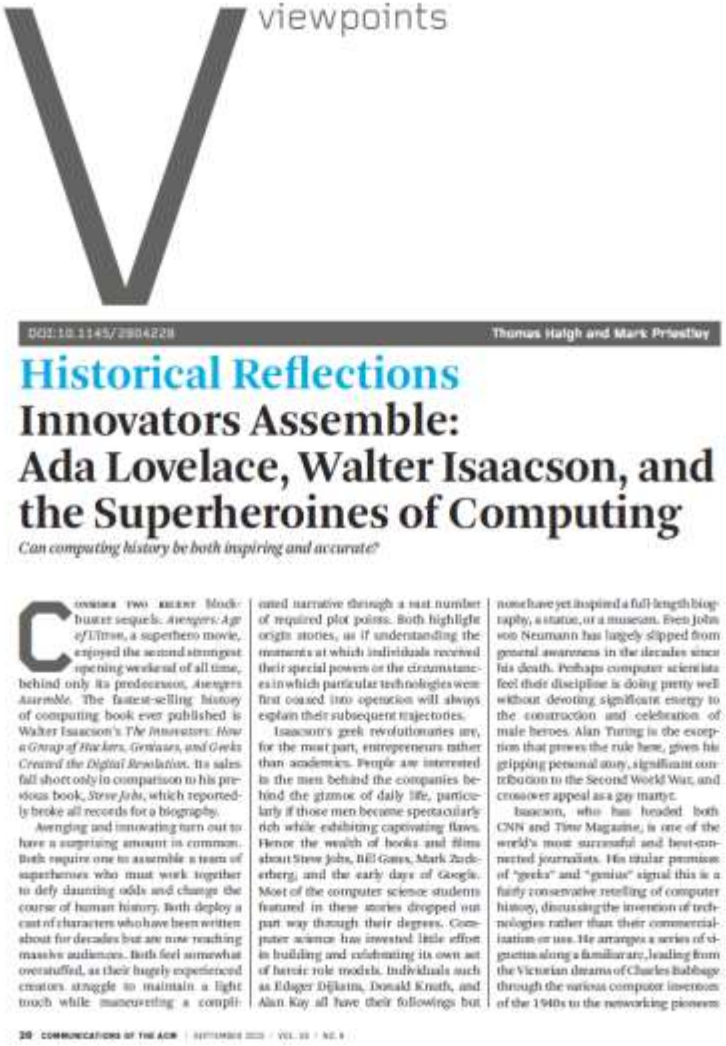
Steve Jobs
Paperback
$11.06

The Innovators: How a Group...
Paperback
$12.88

Groundbreaking for “Pennovation Center” Oct, 2014

“Six women Ph.D. students were tasked with programming the machine, but when the computer was unveiled to the public on Valentine’s Day of 1946, Isaacson said, the women programmers were not invited to the black tie event after the announcement.”

Teams of Superheroes



DOI:10.1145/2804228

Thomas Haigh and Mark Priestley

Historical Reflections

Innovators Assemble: Ada Lovelace, Walter Isaacson, and the Superheroines of Computing

Can computing history be both inspiring and accurate?

Consider two recent blockbuster sequels. *Avengers: Age of Ultron*, a superhero movie, enjoyed the second strongest opening weekend of all time, behind only its predecessor, *Avengers Assemble*. The fastest-selling history of computing book ever published is Walter Isaacson's *The Innovators: How a Group of Hackers, Geniuses, and Geeks Created the Digital Revolution*. Its sales fall short only in comparison to his previous book, *Steve Jobs*, which reportedly broke all records for a biography.

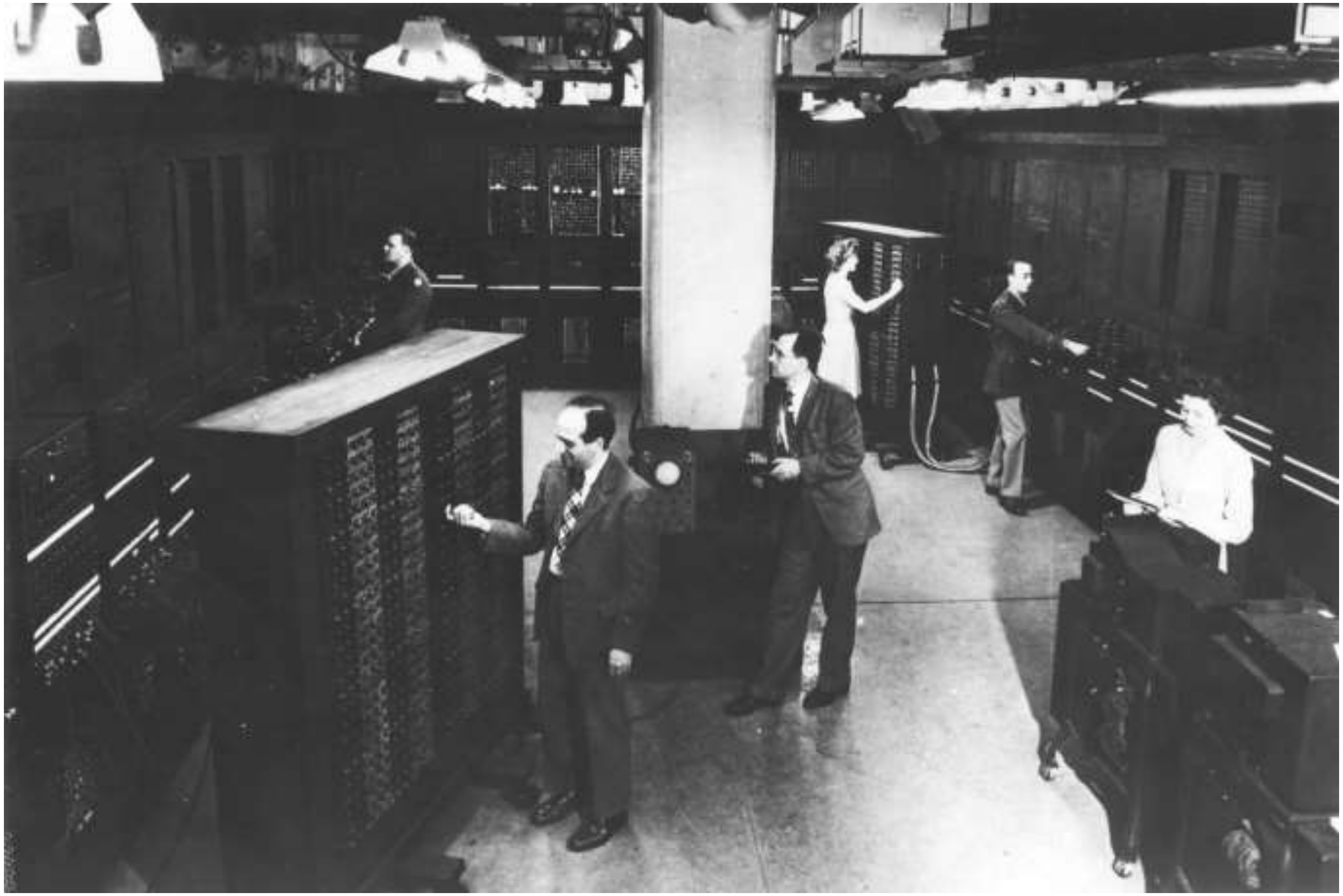
Avenging and innovating turn out to have a surprising amount in common. Both require one to assemble a team of superheroes who must work together to defy daunting odds and change the course of human history. Both deploy a cast of characters who have been written about for decades but are now reaching massive audiences. Both feel somewhat overstuffed, as their hugely experienced creators struggle to maintain a light touch while maneuvering a complicated narrative through a vast number of required plot points. Both highlight origin stories, as if understanding the moments at which individuals received their special powers or the circumstances in which particular technologies were first coaxed into operation will always explain their subsequent trajectories.

Isaacson's geek revolutionaries are, for the most part, entrepreneurs rather than academics. People are interested in the men behind the companies behind the gizmos of daily life, particularly if those men became spectacularly rich while exhibiting captivating flaws. Hence the wealth of books and films about Steve Jobs, Bill Gates, Mark Zuckerberg, and the early days of Google. Most of the computer science students featured in these stories dropped out part way through their degrees. Computer science has invested little effort in building and celebrating its own set of heroic role models. Individuals such as Edsger Dijkstra, Donald Knuth, and Alan Kay all have their followings but none have yet inspired a full-length biography, a statue, or a museum. Even John von Neumann has largely slipped from general awareness in the decades since his death. Perhaps computer scientists feel their discipline is doing pretty well without devoting significant energy to the construction and celebration of male heroes. Alan Turing is the exception that proves the rule here, given his gripping personal story, significant contribution to the Second World War, and crossover appeal as a gay martyr.

Isaacson, who has headed both CNN and Time Magazine, is one of the world's most successful and best-connected journalists. His titular promises of "geeks" and "genius" signal this is a fairly conservative retelling of computer history, discussing the invention of technologies rather than their commercialization or use. He arranges a series of vignettes along a familiar arc, leading from the Victorian dreams of Charles Babbage through the various computer inventors of the 1940s to the networking pioneers

20 COMMUNICATIONS OF THE ACM | [illegible] | VOL. [illegible] | NO. [illegible]

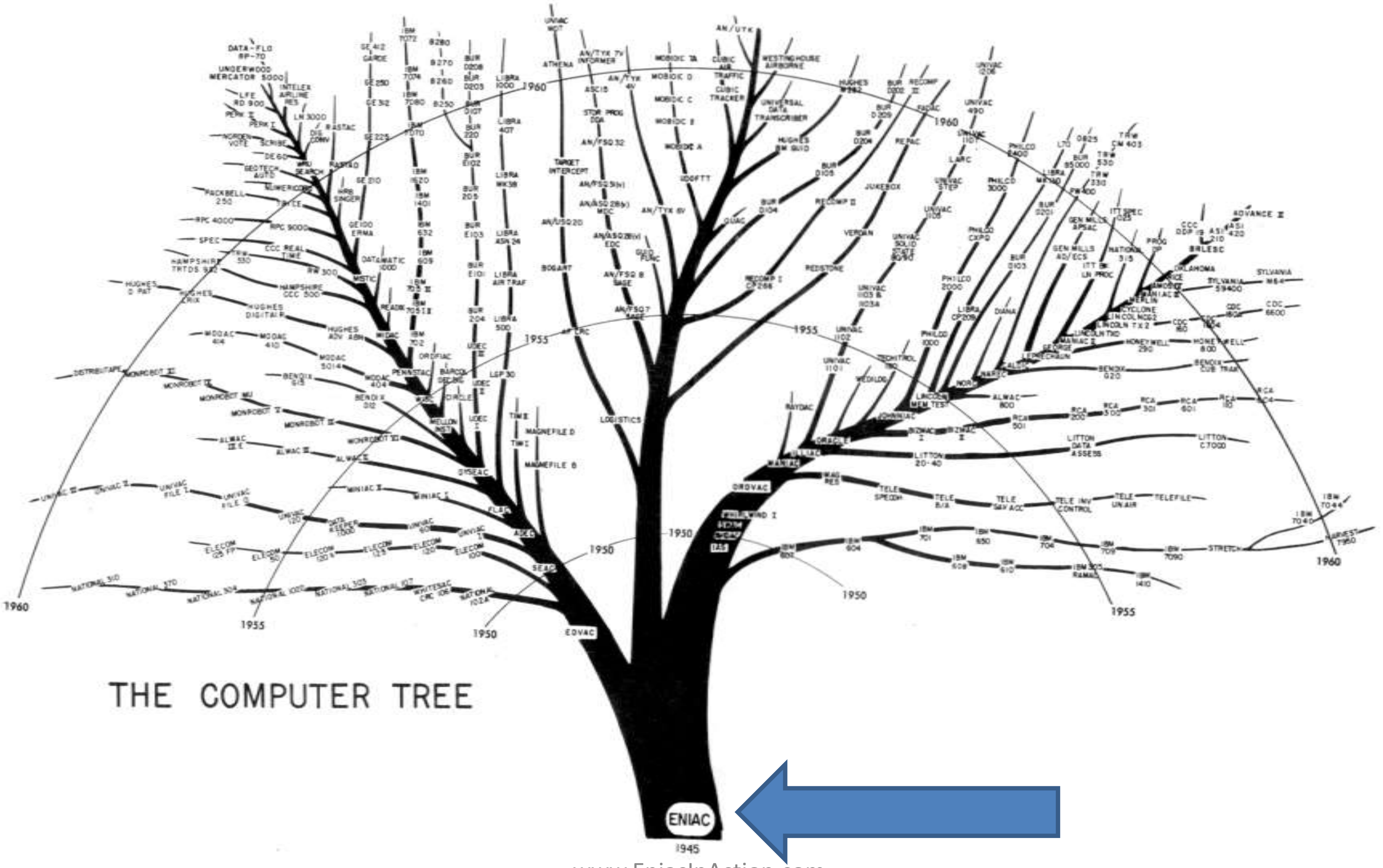
ENIAC as one of the "Great Machines"



ENIAC Life Story

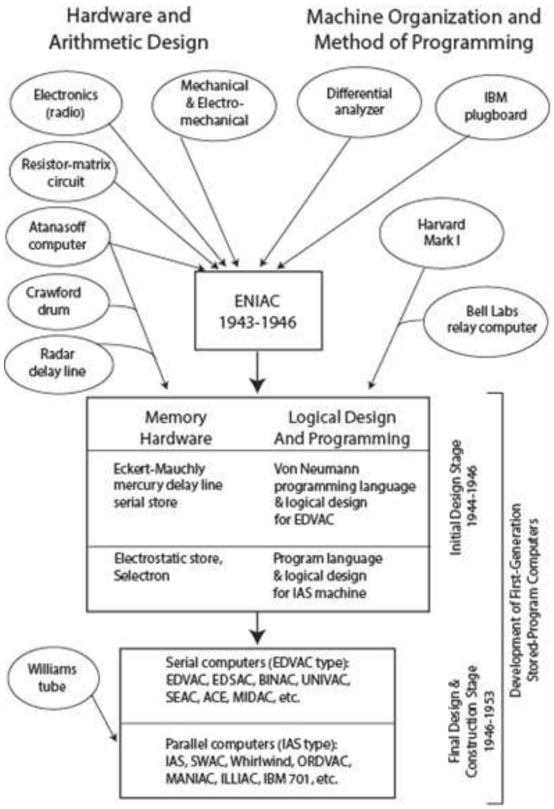
- 1943: Proposed and approved. Design work.
- 1944: Details plans and prototyping work
- 1945: Main construction & debugging.
- 1946: Experimental use at Moore School.
- 1947: Reassembled and tested at the Ballistics Research Laboratory
- 1948-1954. Intensive use at BRL
- 1955: Decommissioned

The "Computer Tree"



ENIAC in Computer History

- Often called the first
  - “electronic, digital, general-purpose computer”
- A step on the path to the “first stored-program computer”

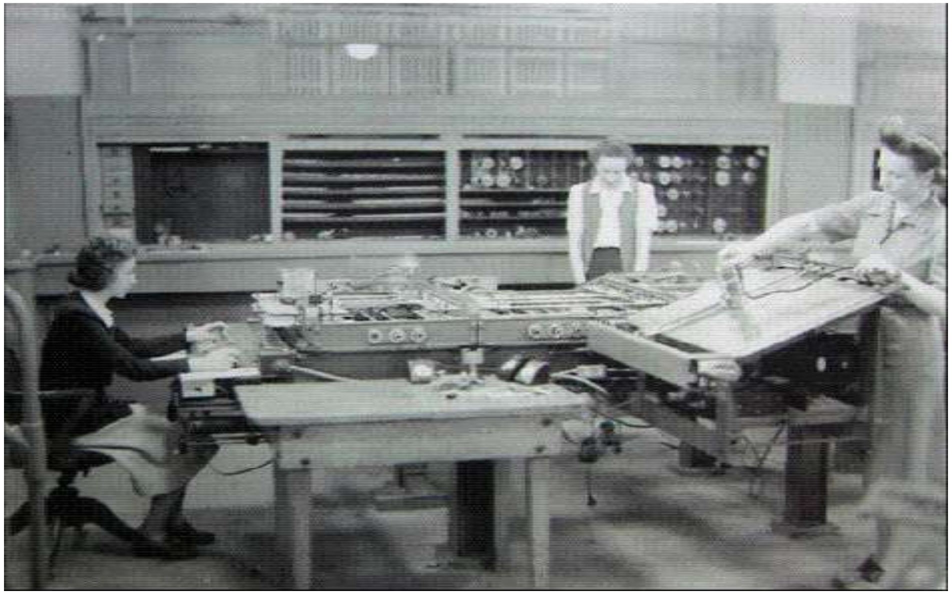


Conventional Computer History

- Traditional focus
  - Obsessed with “firsts”
  - Reduces each computer to a single date of first operation
  - Considers only architectural innovations
  - Doesn’t care about what computers were used for
- This leaves out a great deal…
- Hence: *ENIAC in Action*

BUILDING ENIAC

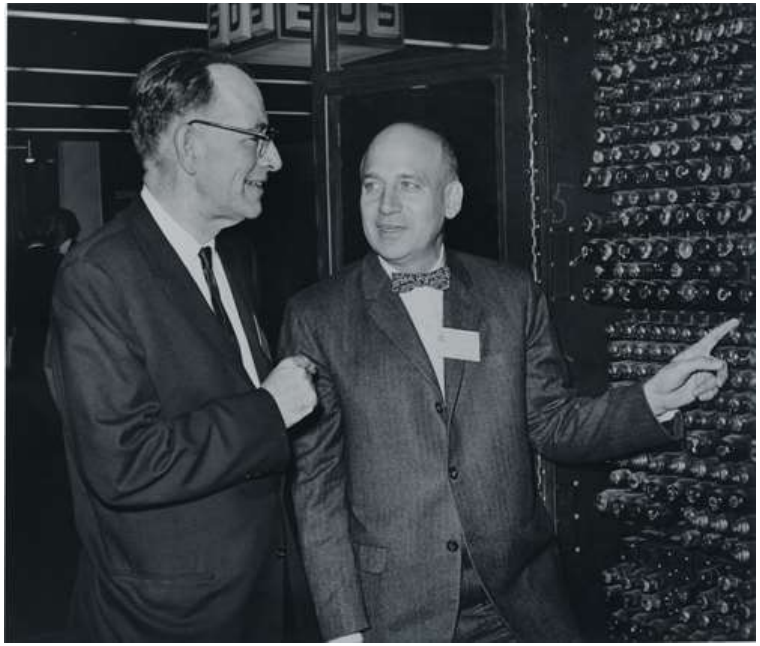
Built by the University of Pennsylvania



- Moore School of Electrical Engineering
  - Founded 1923
  - Strong ties to local electronics industry
  - Had already partnered with BRL to build “differential analyzer” and carry out hand computations
  - Fairly small

Project Initiators

- John W. Mauchly
  - Ph.D. physicist, now teaching at the Moore School after taking a summer course in electronics
- J. Presper Eckert
  - Star electrical engineering student, recently recruited to the laboratory staff for war projects



Sponsor: Ordnance Department

- Ballistics Research Laboratory
  - Part of Aberdeen Proving Ground, which was part of the Ordnance Department

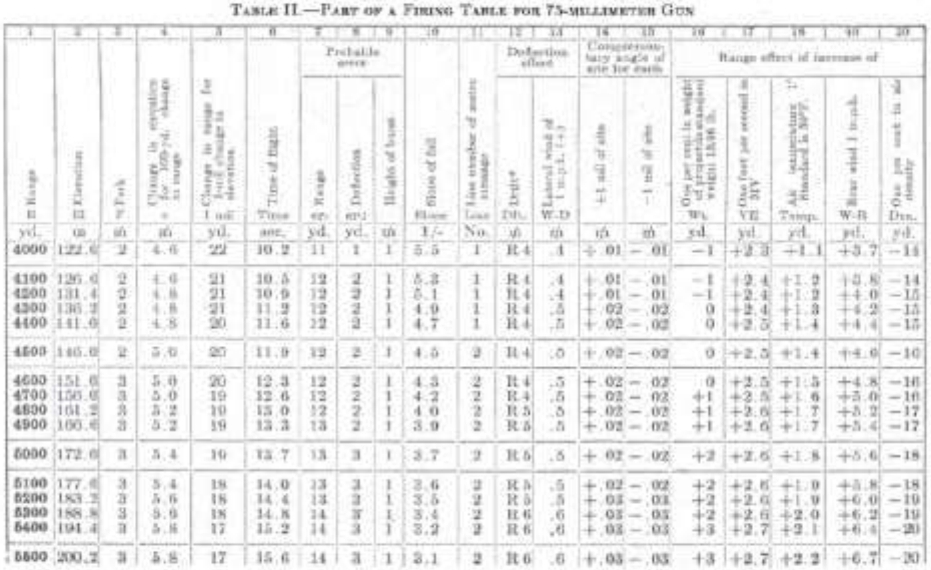
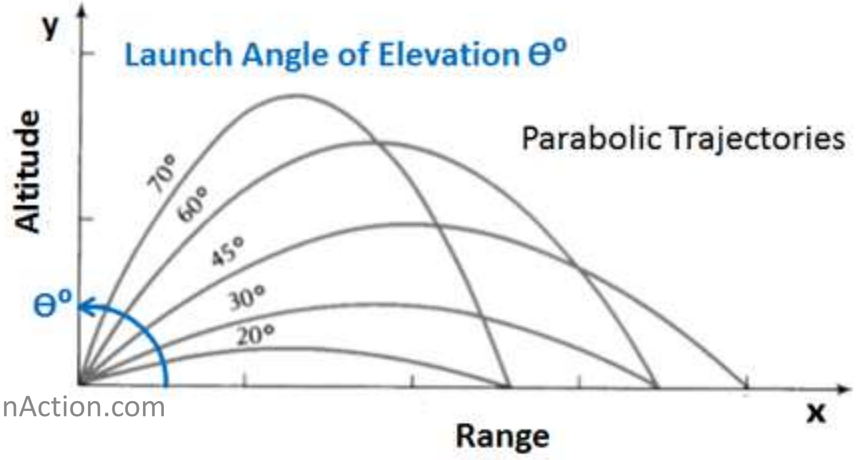


TABLE II.—PART OF A FIRING TABLE FOR 75-MILLIMETER GUN

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
						Probable errors					Deflection effect		Complementary angle of site for each		Range effect of increase of				
Range	Elevation	Fork	Change in elevation for 100 yd. change in range	Change in range for 1 mil change in elevation	Time of flight	Range	Deflection	Height of burst	Slope of fall	Line number of metro message	Drift	Lateral wind of 1 m.p.h. (+)	+1 mil of site	−1 mil of site	One per cent in weight of projectile (standard weight 13.86 lb.)	One foot per second in MV	Air temperature 1° (standard is 59°F)	Rear wind 1 m.p.h.	One per cent in air density
		F		1 mil	Time	ep	ep1		Slope	Line	Dft.	W-D			Wt	VE	Temp.	W-R	Den.
yd.	m	m	m	yd.	sec.	yd.	yd.	m	1/-	No.	m	m	m	m	yd.	yd.	yd.	yd.	yd.
4000	122.6	2	4.6	22	10.2	11	1	1	5.5	1	R4	.4	+.01	−.01	−1	+2.3	+1.1	+3.7	−14
4100	126.6	2	4.6	21	10.5	12	2	1	5.3	1	R4	.4	+.01	−.01	−1	+2.4	+1.2	+3.8	−14
4200	131.4	2	4.8	21	10.9	12	2	1	5.1	1	R4	.4	+.01	−.01	−1	+2.4	+1.2	+4.0	−15
4300	136.2	2	4.8	21	11.2	12	2	1	4.9	1	R4	.5	+.02	−.02	0	+2.4	+1.3	+4.2	−15
4400	141.0	2	4.8	20	11.6	12	2	1	4.7	1	R4	.5	+.02	−.02	0	+2.5	+1.4	+4.4	−15
4500	146.0	2	5.0	20	11.9	12	2	1	4.5	2	R4	.5	+.02	−.02	0	+2.5	+1.4	+4.6	−16
4600	151.0	3	5.0	20	12.3	12	2	1	4.3	2	R4	.5	+.02	−.02	0	+2.5	+1.5	+4.8	−16
4700	156.0	3	5.0	19	12.6	12	2	1	4.2	2	R4	.5	+.02	−.02	+1	+2.5	+1.6	+5.0	−16
4800	161.2	3	5.2	19	13.0	12	2	1	4.0	2	R5	.5	+.02	−.02	+1	+2.6	+1.7	+5.2	−17
4900	166.6	3	5.2	19	13.3	13	2	1	3.9	2	R5	.5	+.02	−.02	+1	+2.6	+1.7	+5.4	−17
5000	172.0	3	5.4	19	13.7	13	3	1	3.7	2	R5	.5	+.02	−.02	+2	+2.6	+1.8	+5.6	−18
5100	177.6	3	5.4	18	14.0	13	3	1	3.6	2	R5	.5	+.02	−.02	+2	+2.6	+1.9	+5.8	−18
5200	183.2	3	5.6	18	14.4	13	3	1	3.5	2	R5	.5	+.03	−.03	+2	+2.6	+1.9	+6.0	−19
5300	188.8	3	5.6	18	14.8	14	3	1	3.4	2	R6	.6	+.03	−.03	+2	+2.6	+2.0	+6.2	−19
5400	194.4	3	5.8	17	15.2	14	3	1	3.2	2	R6	.6	+.03	−.03	+3	+2.7	+2.1	+6.4	−20
5500	200.2	3	5.8	17	15.6	14	3	1	3.1	2	R6	.6	+.03	−.03	+3	+2.7	+2.2	+6.7	−20

Range R vs Launch Angle Θ for a Given Initial Velocity V_0



Engineering Team

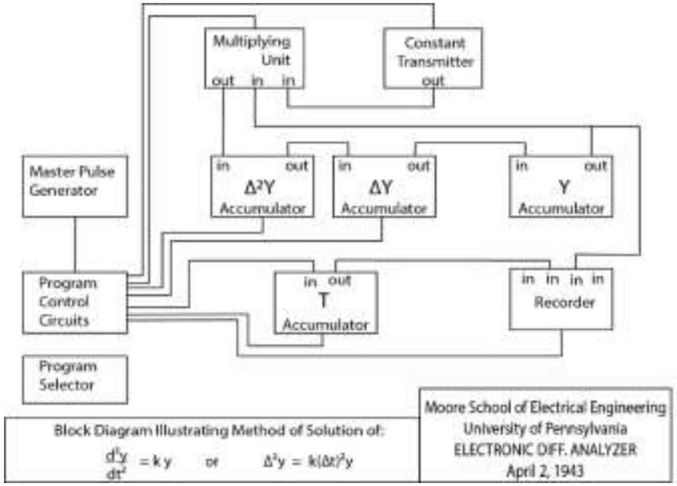
- T. Kite Sharpless
- Arthur Burks
- Robert Shaw
- Joseph Chedaker
- Chuan Chu
- Frank Mural
- And others…

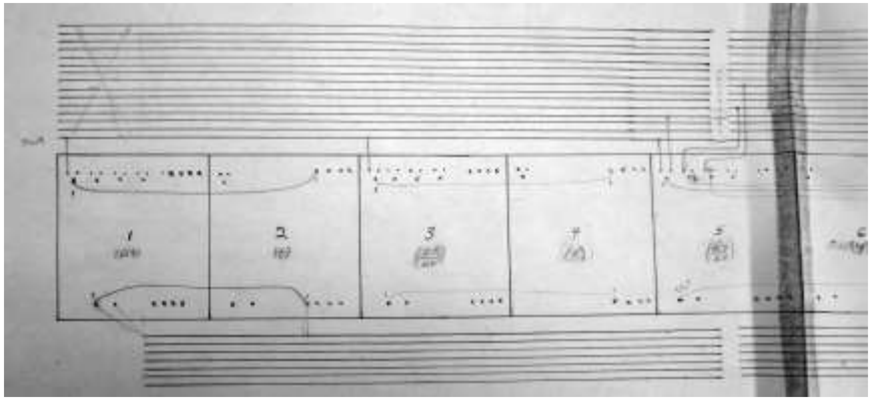
Other Longtime Roles

- Moore School:
  - Harold Pender, Dean
  - John Grist Brainerd, Project Director
  - Isabelle Jay, Secretary
  - Marjorie Santa Maria, Draughtswoman
- Penn:
  - Hans Rademacher, Numerical Methods Expert
- BRL:
  - Herman Goldstine, oversaw BRL work at Moore School
  - Paul Gillon, Goldstine's boss
  - Leland Cunningham, head of machine computation group
  - Derek Lehmer & Haskell Curry, mathematical would-be users

Structured from Mathematical Analysis

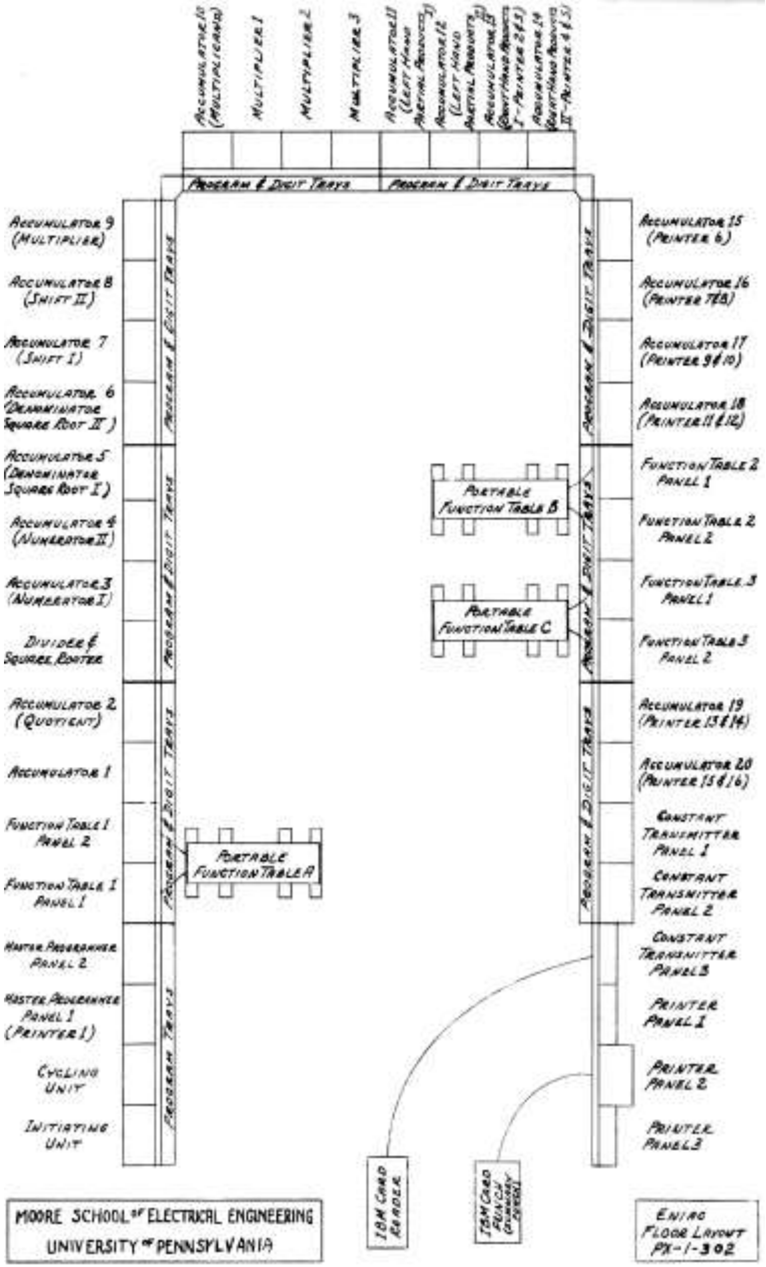
- Detailed analysis of the firing tables problem in 1943 guided ENIAC's fundamental design
- But it could tackle many other kinds of problem





Unique Architecture

- Wires route control pulses from one unit to another
- Switches determine what happens when a pulse arrives
- Data flows on ad-hoc busses

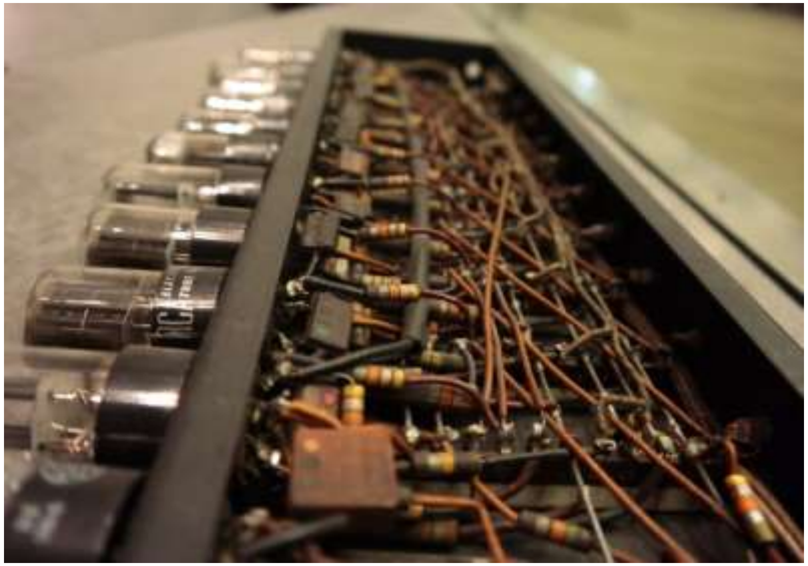


Technical Specifications

- Cost: Circa $500,000 excluding delivery
  - Up from initial budget of $150,000
- Size: About 2,000 square feet
- Weight: About 30 tons
- Power consumption: 150KW
- Memory (RAM): 200 decimal digits
- Memory (ROM): 4000 decimal digits
- Multiplications per second: approx 300

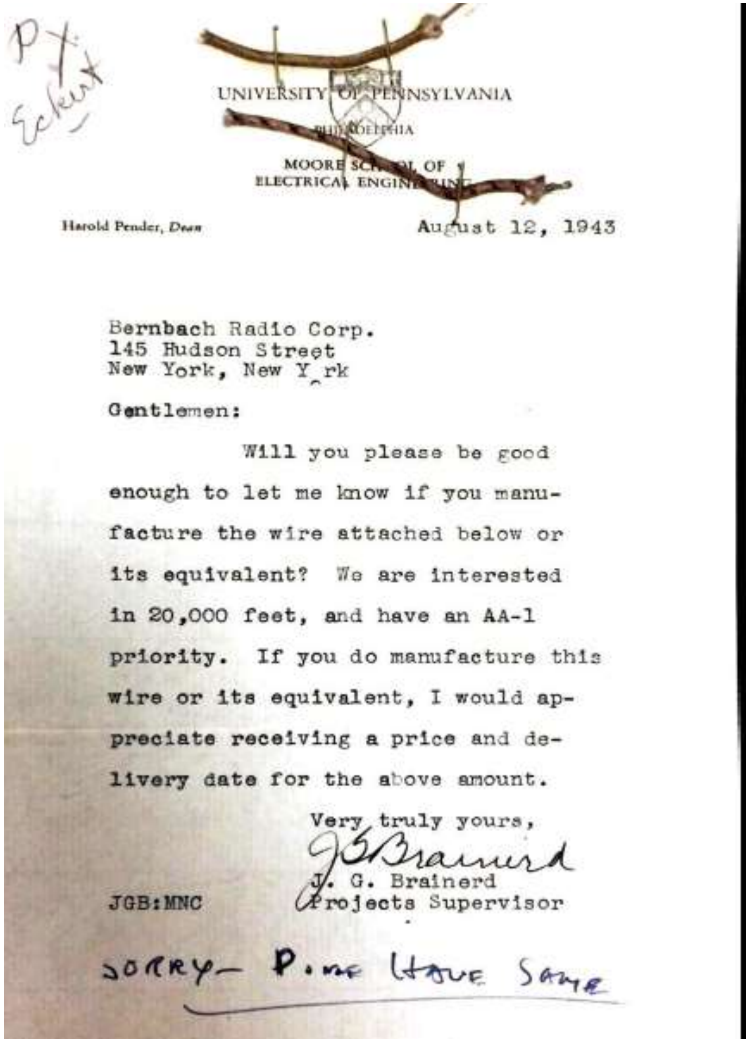
ENIAC Storage

- Each decimal digit was a “plug-in” module with 23 vacuum tubes



Procurement Challenges

- Challenging to source large quantities of high performance components in war economy
    - Vacuum tubes
    - Precision resistors
    - Custom power supplies
        - 78 voltage levels from 28 different power supplies
    - Even wire!



P.

Eckert

UNIVERSITY OF PENNSYLVANIA
PHILADELPHIA

MOORE SCHOOL OF
ELECTRICAL ENGINEERING

Harold Pender, *Dean*

August 12, 1943

Bernbach Radio Corp.
145 Hudson Street
New York, New York

Gentlemen:

Will you please be good enough to let me know if you manufacture the wire attached below or its equivalent? We are interested in 20,000 feet, and have an AA-1 priority. If you do manufacture this wire or its equivalent, I would appreciate receiving a price and delivery date for the above amount.

Very truly yours,

JGBrainerd
J. G. Brainerd
Projects Supervisor

JGB:MNC

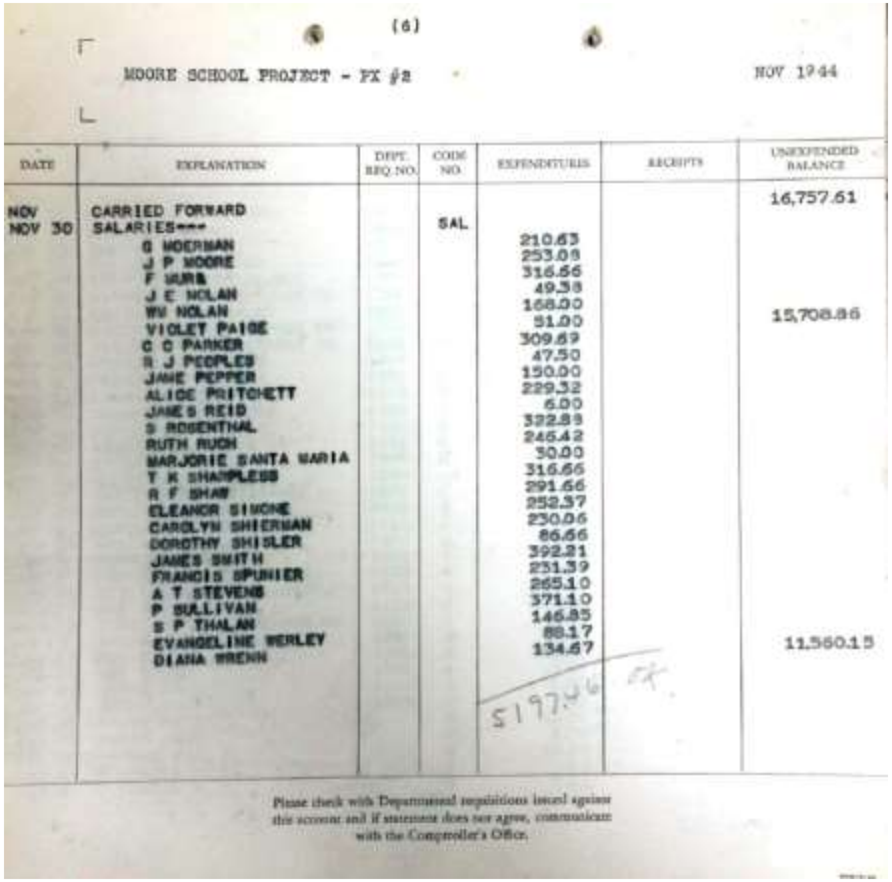
SORRY— DONT HAVE SAME

Physical Construction

- Project staff size increased rapidly in 1944 as production work began
- Split into separate groups for
  - Engineering & Test (7 design engineers)
  - Mechanical Design & Drafting (3 people)
  - Model Making Team (3 people)
  - Production team (34 FTE workers by end of 1944)
- Formal approval process needed to move designs from one group to another

Some Truly Forgotten Women

- Accounting & personnel records show
  - "Wiremen"
  - "Technicians"
  - "Assemblers"



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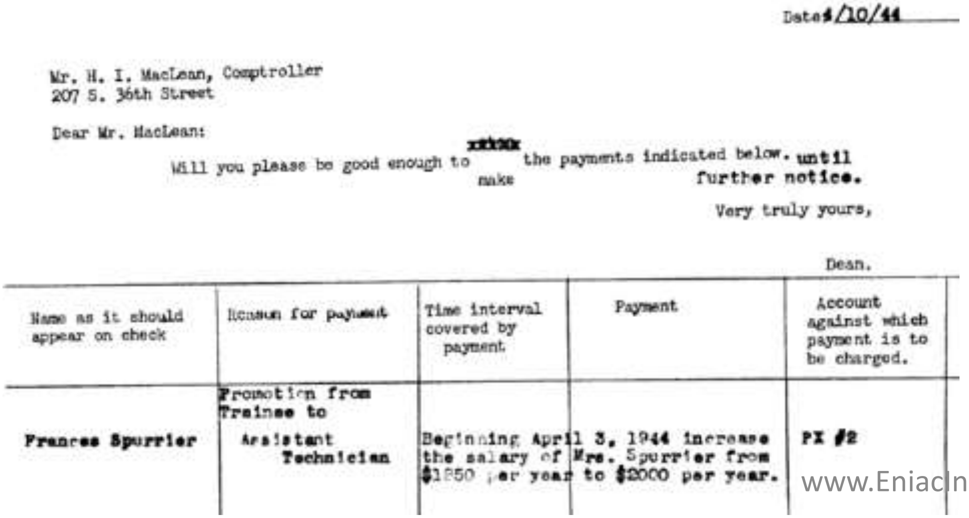
MOORE SCHOOL PROJECT - PX #2

NOV 1944

DATE	EXPLANATION	DEPT. REQ. NO.	CODE NO.	EXPENDITURES	RECEIPTS	UNEXPENDED BALANCE
NOV	CARRIED FORWARD					16,757.61
NOV 30	SALARIES---		SAL			
	G HOERMAN			210.63		
	J P MOORE			253.08		
	F WARE			316.66		
	J E NOLAN			49.38		
	WV NOLAN			168.00		15,708.86
	VIOLET PAIGE			51.00		
	C C PARKER			309.69		
	R J PEOPLES			47.50		
	JANE PEPPER			150.00		
	ALICE PRITCHETT			229.32		
	JAMES REID			6.00		
	S ROSENTHAL			322.83		
	RUTH RUSH			246.42		
	MARJORIE SANTA MARIA			30.00		
	T K SHARPLESS			316.66		
	R F SHAW			291.66		
	ELEANOR SIMONE			252.37		
	CAROLYN SHIERMAN			230.06		
	DOROTHY SHISLER			86.66		
	JAMES SMITH			392.21		
	FRANCIS SPUNIER			231.39		
	A T STEVENS			265.10		
	P SULLIVAN			371.10		
	S P THALAN			146.85		
	EVANGELINE WERLEY			88.17		11,560.15
	DIANA WRENN			134.67		
				5197.46 ck.		

Please check with Departmental requisitions issued against this account and if statement does not agree, communicate with the Comptroller's Office.



Date 4/10/44

Mr. H. I. MacLean, Comptroller
207 S. 36th Street

Dear Mr. MacLean:

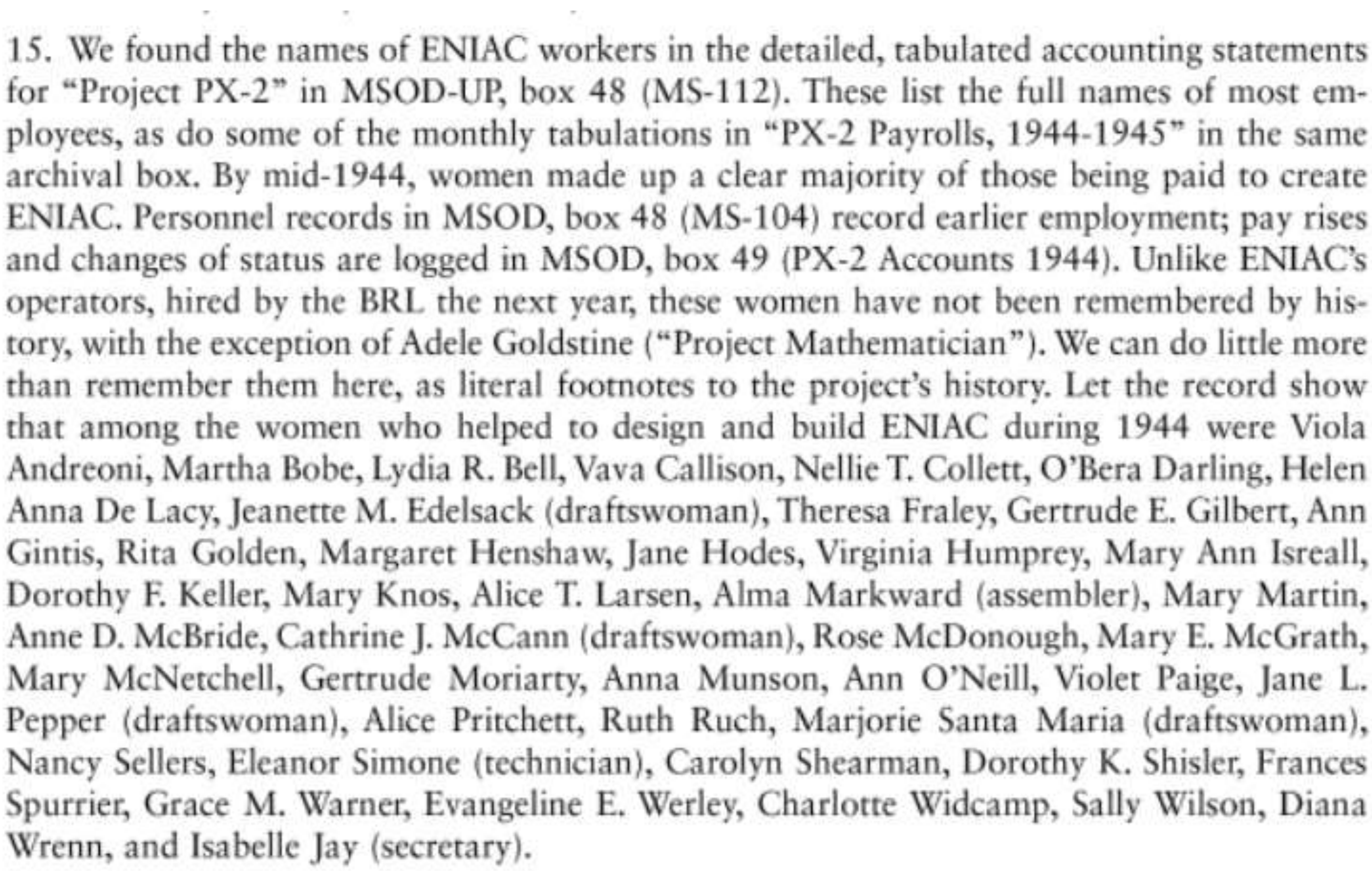
Will you please be good enough to make the payments indicated below. until further notice.

Very truly yours,

Dean.

Name as it should appear on check	Reason for payment	Time interval covered by payment	Payment	Account against which payment is to be charged.
Frances Spurrier	Promotion from Trainee to Assistant Technician	Beginning April 3, 1944 increase the salary of Mrs. Spurrier from $1850 per year to $2000 per year.		PX #2

Almost 50 confirmed “ENIAC Women” In 1944 Alone



15. We found the names of ENIAC workers in the detailed, tabulated accounting statements for “Project PX-2” in MSOD-UP, box 48 (MS-112). These list the full names of most employees, as do some of the monthly tabulations in “PX-2 Payrolls, 1944-1945” in the same archival box. By mid-1944, women made up a clear majority of those being paid to create ENIAC. Personnel records in MSOD, box 48 (MS-104) record earlier employment; pay rises and changes of status are logged in MSOD, box 49 (PX-2 Accounts 1944). Unlike ENIAC’s operators, hired by the BRL the next year, these women have not been remembered by history, with the exception of Adele Goldstine (“Project Mathematician”). We can do little more than remember them here, as literal footnotes to the project’s history. Let the record show that among the women who helped to design and build ENIAC during 1944 were Viola Andreoni, Martha Bobe, Lydia R. Bell, Vava Callison, Nellie T. Collett, O’Bera Darling, Helen Anna De Lacy, Jeanette M. Edelsack (draftswoman), Theresa Fraley, Gertrude E. Gilbert, Ann Gintis, Rita Golden, Margaret Henshaw, Jane Hodes, Virginia Humprey, Mary Ann Isreall, Dorothy F. Keller, Mary Knos, Alice T. Larsen, Alma Markward (assembler), Mary Martin, Anne D. McBride, Cathrine J. McCann (draftswoman), Rose McDonough, Mary E. McGrath, Mary McNetchell, Gertrude Moriarty, Anna Munson, Ann O’Neill, Violet Paige, Jane L. Pepper (draftswoman), Alice Pritchett, Ruth Ruch, Marjorie Santa Maria (draftswoman), Nancy Sellers, Eleanor Simone (technician), Carolyn Shearman, Dorothy K. Shisler, Frances Spurrier, Grace M. Warner, Evangeline E. Werley, Charlotte Widcamp, Sally Wilson, Diana Wrenn, and Isabelle Jay (secretary).

Spinning Progress to Sponsors

- By 1944 the end of the war is clearly approaching
  - May 26, 1944: Goldstine promises completion “by October 1”
  - August 1944, will be “virtually completed” by the end of 1944
  - Sept 1944, work is “on the fairways”
  - December 1944, “in the throes of completing the production of the ENIAC… within the next two months”
  - May 1945, “on the home stretch” with testing starting “about 2 weeks from now.”

Launch Day: 15 February, 1946

PROGRAM

Speakers

The President of the University of Pennsylvania
Dr. George Wm. McClelland

The President of the National Academy of Sciences
Dr. Frank B. Jewett

The Chief of the Research and Development Service, Ordnance Department, United States Army
Major General Gladeon M. Barnes

The Dedication of the ENIAC (Information confidential until released)

The Electronic Numerical Integrator and Computer — the ENIAC — is the fastest computing machine ever developed. It will perform more than one million additions or subtractions of ten-figure numbers in five minutes, more than a million multiplications in an hour. It can be used in the solution of mathematical problems from the simplest to the most abstruse and of many problems previously not capable of solution.

Under the direction of the Ordnance Department, United States Army, the ENIAC was developed by the Moore School of Electrical Engineering of the University of Pennsylvania. The dedication of this pioneering scientific achievement will mark the initial release of information to the public and the first viewing of the ENIAC.

MENU

Bisque of Lobster

Filet Mignon Au Jus
or
Broiled Salmon Steak

Fresh String Beans · **Au Gratin Potatoes**

Hearts of Lettuce, French Dressing

Cheese **Crackers**

Ice Cream **Fancy Cakes**

Cafe

NY Times 15 Feb, 1946

- Based on earlier, Feb 1 1946 demo for journalists

Electronic Computer Flashes Answers, May Speed Engineering

By T. R. KENNEDY Jr.

Special to THE NEW YORK TIMES.

PHILADELPHIA, Feb. 14—One of the war's top secrets, an amazing machine which applies electronic speeds for the first time to mathematical tasks hitherto too difficult and cumbersome for solution, was announced here tonight by the War Department. Leaders who saw the device in action for the first time heralded it as a tool with which to begin to rebuild scientific affairs on new foundations.

Such instruments, it was said, could revolutionize modern engineering, bring on a new epoch of industrial design, and eventually eliminate much slow and costly trial-and-error development work now deemed necessary in the fashioning of intricate machines. Heretofore, sheer mathematical difficulties have often forced designers to accept inferior solutions of their problems, with higher costs and slower progress.

The "Eniac," as the new electronic speed marvel is known, virtually eliminates time in doing such jobs. Its inventors say it computes a mathematical problem 1,000 times faster than it has ever been done before.

The machine is being used on a problem in nuclear physics.

The Eniac, known more formally as "the electronic numerical integrator and computer," has not a single moving mechanical part. Nothing inside its 18,000 vacuum tubes and several miles of wiring moves except the tiniest elements of matter-electrons. There are, however, mechanical devices associated with it which translate or "interpret" the mathematical language of man to terms understood by the Eniac, and vice versa.

Ceremonies dedicating the machine will be held tomorrow night at a dinner given a group of Government and scientific men at the University of Pennsylvania, after

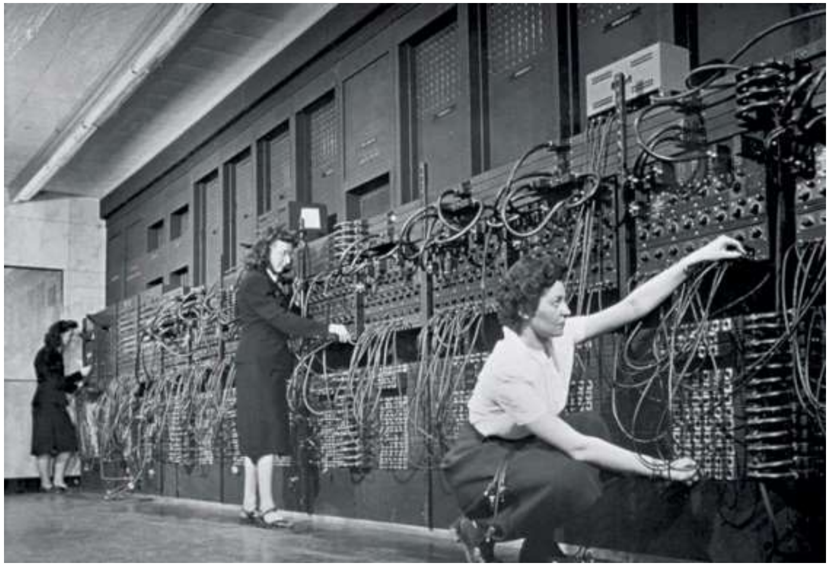
Column 3

NEW ALL-ELECTRONIC COMPUTER AND ITS INVENTORS

OPERATING ENIAC

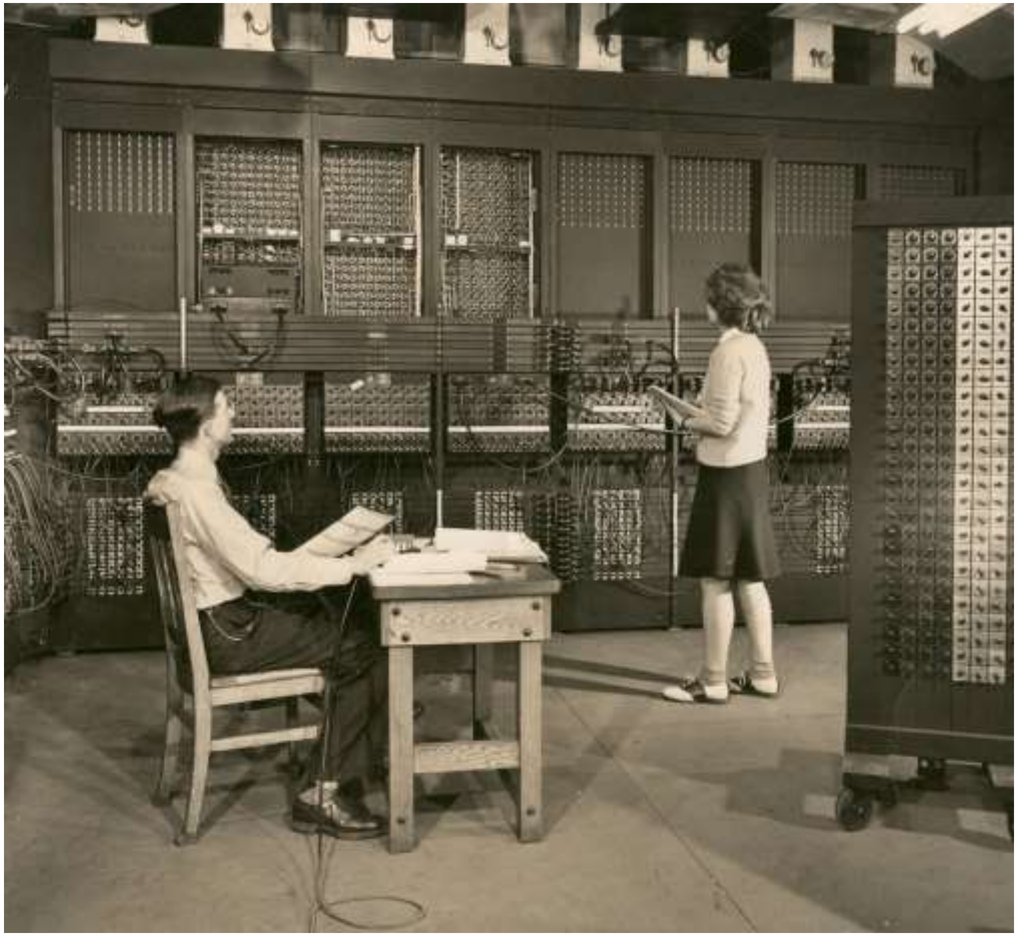
The Operators

- Six women selected summer 1945
  - Had previously been computing trajectories manually
- Operated ENIAC at the Moore School
  - Some transitioned back to Aberdeen
- Duties included
  - Configuring and wiring units from paper plans
  - Helping to diagnose and correct problems
  - Feeding cards in and out of ENIAC
  - Working the auxiliary punched card equipment
  - Working with scientific users to design ENIAC setups



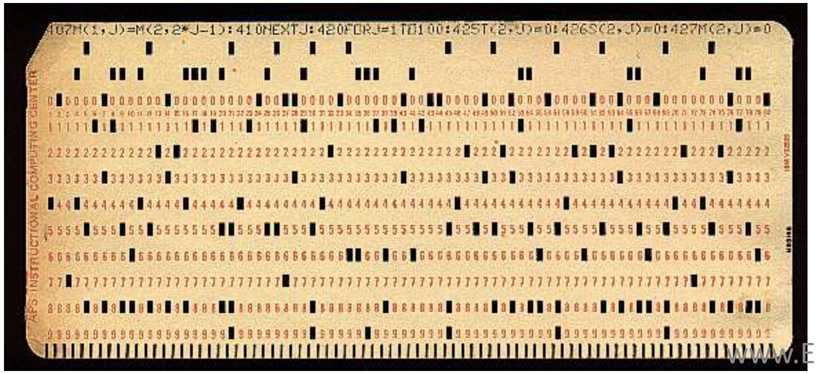
ENIAC Operation

- A hand held unit started/stopped
- Single step mode
- Adjustable clock speed

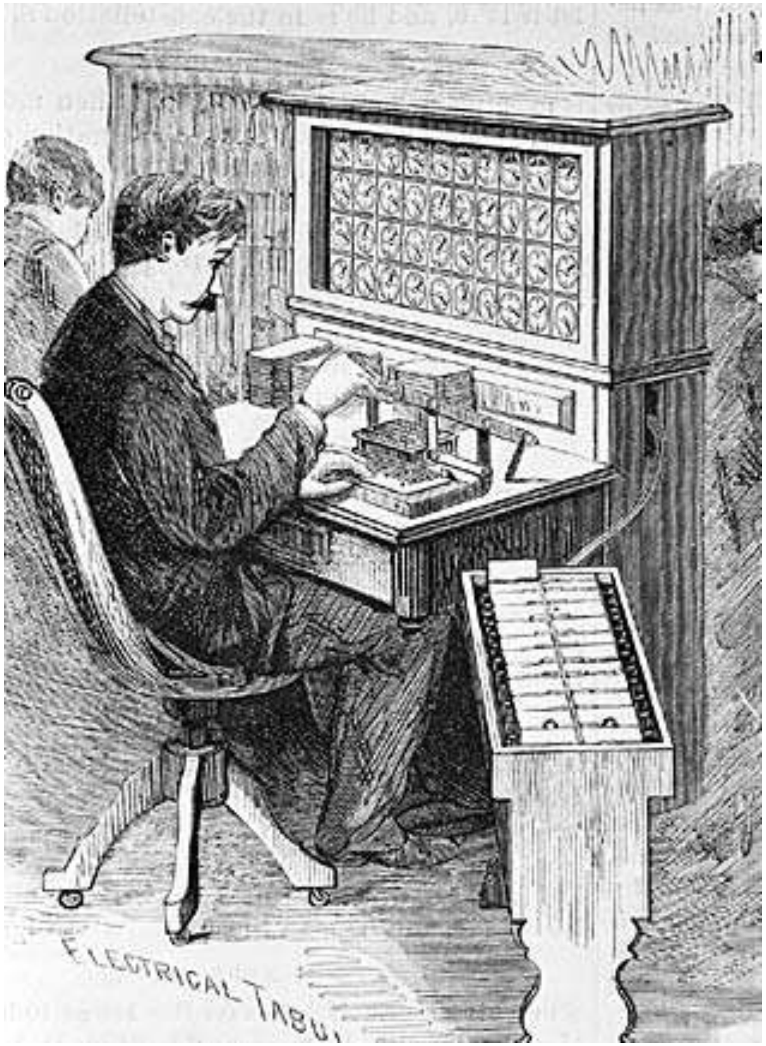


Punched Card Machines

- Specialized units
  - Sorter
  - Collator
  - Punch
  - Tabulator
- Human operators reconfigure machines and move cards between them

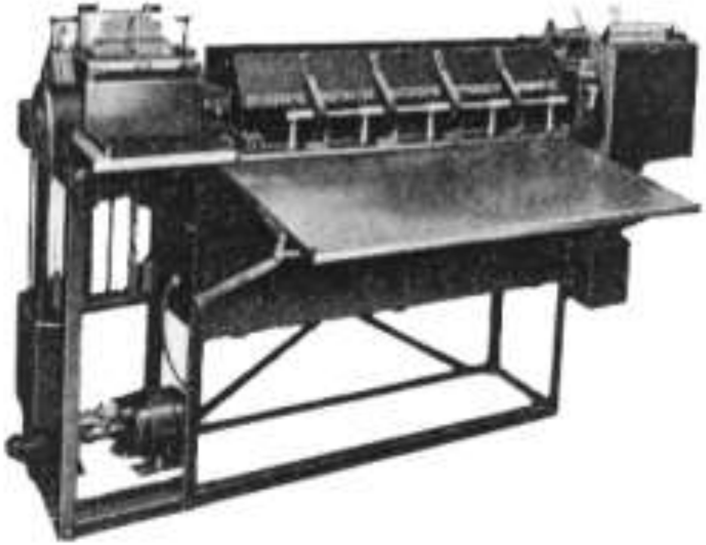


Punch Card Machines

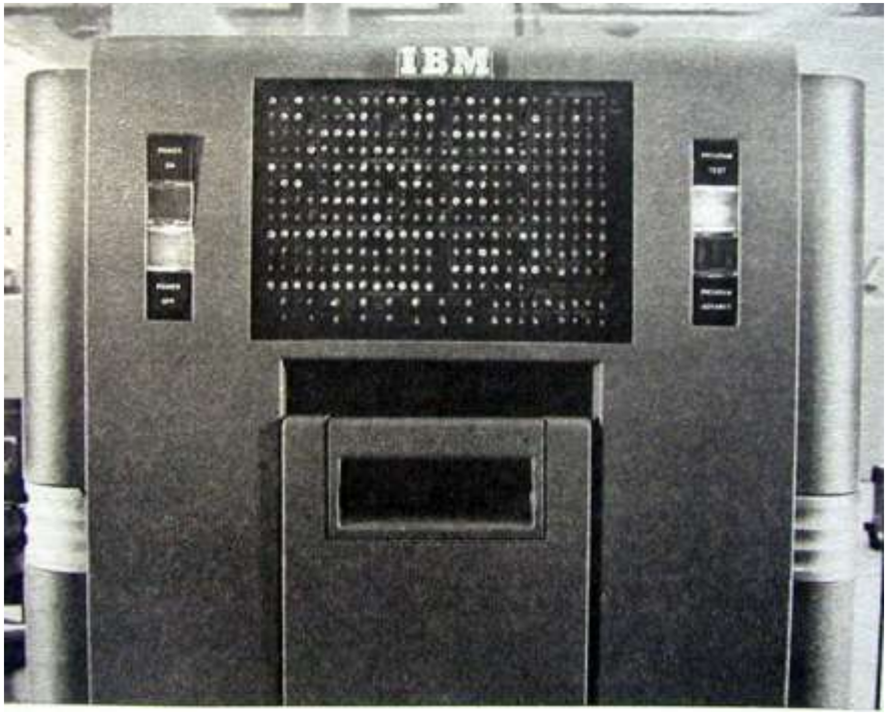


- Invented by Herman Hollerith
- Original use for 1880 Census
- His company eventually becomes IBM

Punch Card Machines Evolve

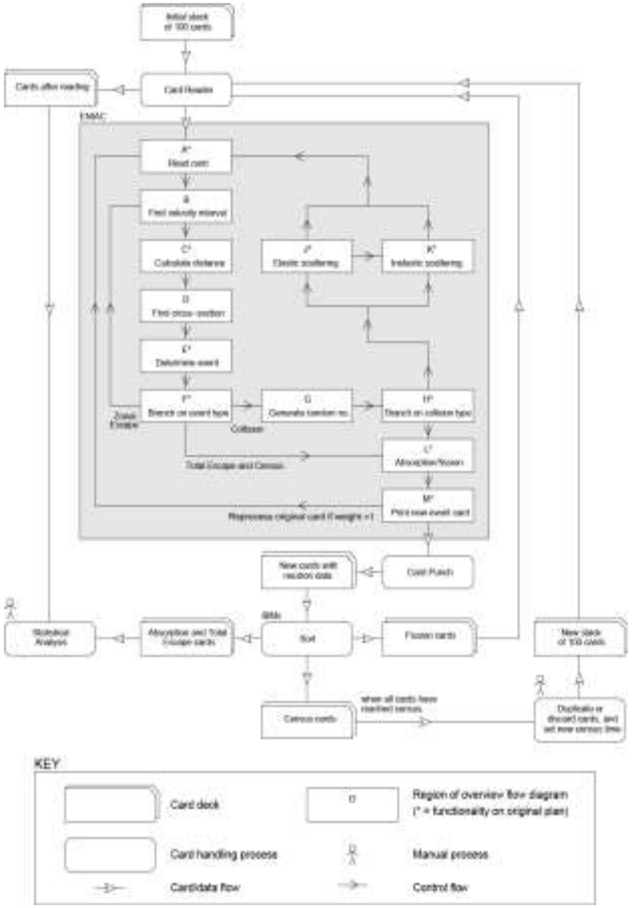


1920s

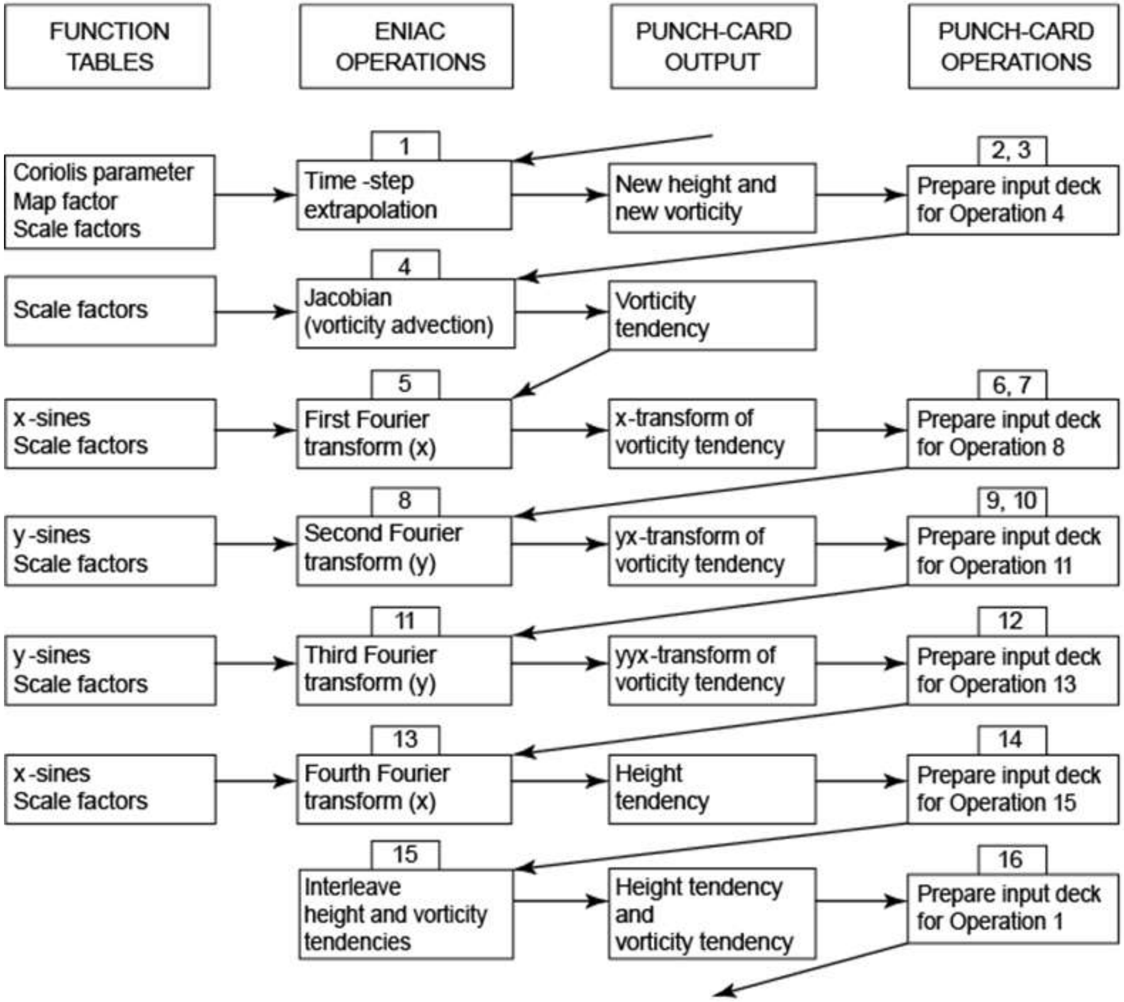


Late 1940s

ENIAC as Part of a Bigger System



Weather Prediction Application (1950)



FUNCTION TABLES

ENIAC OPERATIONS

PUNCH-CARD OUTPUT

PUNCH-CARD OPERATIONS

Coriolis parameter
Map factor
Scale factors

1

Time -step extrapolation

New height and new vorticity

2, 3

Prepare input deck for Operation 4

Scale factors

4

Jacobian (vorticity advection)

Vorticity tendency

x-sines
Scale factors

5

First Fourier transform (x)

x-transform of vorticity tendency

6, 7

Prepare input deck for Operation 8

y-sines
Scale factors

8

Second Fourier transform (y)

yx-transform of vorticity tendency

9, 10

Prepare input deck for Operation 11

y-sines
Scale factors

11

Third Fourier transform (y)

yyx-transform of vorticity tendency

12

Prepare input deck for Operation 13

x-sines
Scale factors

13

Fourth Fourier transform (x)

Height tendency

14

Prepare input deck for Operation 15

15

Interleave height and vorticity tendencies

Height tendency and vorticity tendency

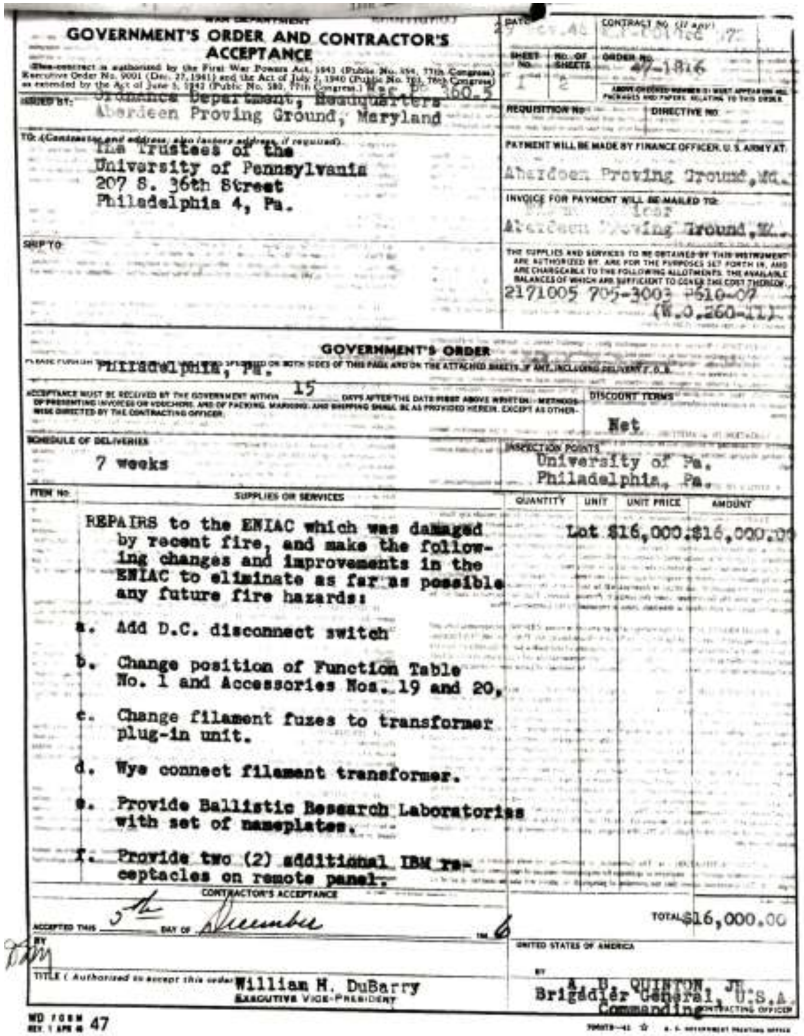
16

Prepare input deck for Operation 1

ENIAC AS A MATERIAL SPACE

Poor Conditions at Moore School

- Floods in October & December 1945
  - December 25 flood from snow melt, Mauchly went home at 3am leaving “about five men still working, mopping up water and emptying buckets which catch drips.”
- Fire on October 26, 1945
  - Shutdown circuits on blowers prevent spread to other panels



WAR DEPARTMENT

GOVERNMENT'S ORDER AND CONTRACTOR'S ACCEPTANCE

~~This contract~~ is authorized by the First War Powers Act, 1941 (Public No. 354, 77th Congress) Executive Order No. 9001 (Dec. 27, 1941) and the Act of July 2, 1940 (Public No. 703, 76th Congress) as extended by the Act of June 5, 1942 (Public No. 580, 77th Congress.) [illegible] 360.5

DATE 2[illegible] Nov.46

CONTRACT NO. (if any) [illegible]

SHEET NO. 1 NO. OF SHEETS 2

ORDER NO. 47-1816

ABOVE ORDER NUMBER(S) MUST APPEAR ON ALL PACKAGES AND PAPERS RELATING TO THIS ORDER

ISSUED BY: Ordnance Department, Headquarters
Aberdeen Proving Ground, Maryland

REQUISITION NO.

DIRECTIVE NO.

TO: (Contractor and address; also factory address, if required)
The Trustees of the
University of Pennsylvania
207 S. 36th Street
Philadelphia 4, Pa.

PAYMENT WILL BE MADE BY FINANCE OFFICER, U. S. ARMY AT:
Aberdeen Proving Ground, Md.

INVOICE FOR PAYMENT WILL BE MAILED TO:
[illegible] Officer
Aberdeen Proving Ground, Md.

SHIP TO:

THE SUPPLIES AND SERVICES TO BE OBTAINED BY THIS INSTRUMENT ARE AUTHORIZED BY, ARE FOR THE PURPOSES SET FORTH IN, AND ARE CHARGEABLE TO THE FOLLOWING ALLOTMENTS, THE AVAILABLE BALANCES OF WHICH ARE SUFFICIENT TO COVER THE COST THEREOF.
2171005 705-3003 P610-07
(W.O.260-11)

GOVERNMENT'S ORDER

PLEASE FURNISH THE SUPPLIES OR SERVICES SPECIFIED ON BOTH SIDES OF THIS PAGE AND ON THE ATTACHED SHEETS, IF ANY, INCLUDING DELIVERY F.O.B. Philadelphia, Pa.

ACCEPTANCE MUST BE RECEIVED BY THE GOVERNMENT WITHIN 15 DAYS AFTER THE DATE FIRST ABOVE WRITTEN. METHODS OF PRESENTING INVOICES OR VOUCHERS, AND OF PACKING, MARKING, AND SHIPPING SHALL BE AS PROVIDED HEREIN, EXCEPT AS OTHERWISE DIRECTED BY THE CONTRACTING OFFICER.

DISCOUNT TERMS Net

SCHEDULE OF DELIVERIES 7 weeks

INSPECTION POINTS University of Pa.
Philadelphia, Pa.

ITEM NO.	SUPPLIES OR SERVICES	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	REPAIRS to the ENIAC which was damaged by recent fire, and make the following changes and improvements in the ENIAC to eliminate as far as possible any future fire hazards:		Lot	$16,000.	$16,000.00
a.	Add D.C. disconnect switch				
b.	Change position of Function Table No. 1 and Accessories Nos. 19 and 20,				
c.	Change filament fuzes to transformer plug-in unit.				
d.	Wye connect filament transformer.				
e.	Provide Ballistic Research Laboratories with set of nameplates.				
f.	Provide two (2) additional IBM receptacles on remote panel.				

CONTRACTOR'S ACCEPTANCE

ACCEPTED THIS 5th DAY OF December 1946

TOTAL $16,000.00

BY

TITLE (Authorized to accept this order) William H. DuBarry
EXECUTIVE VICE-PRESIDENT

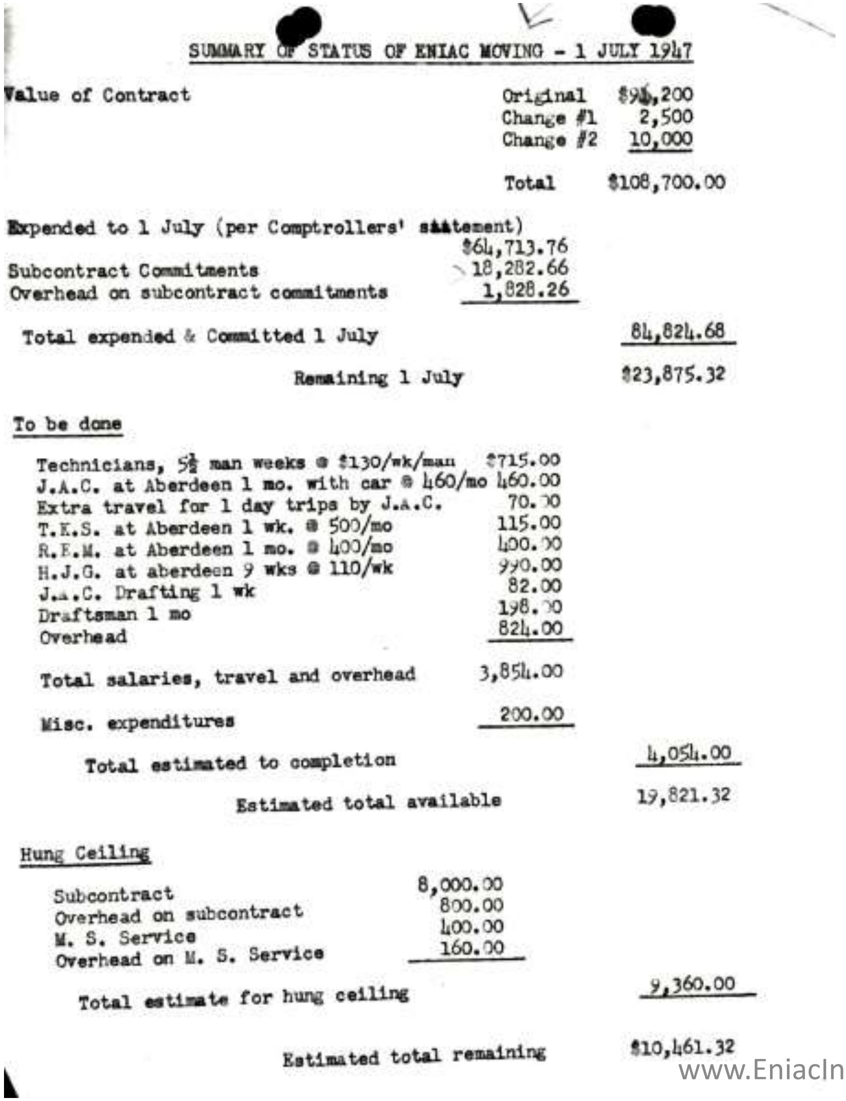
UNITED STATES OF AMERICA

BY A. B. QUINTON, JR.
Brigadier General, U.S.A.
Commanding
CONTRACTING OFFICER

WD FORM 47
REV. 1 APR 44

[illegible] U. S. GOVERNMENT PRINTING OFFICE

The Move to Aberdeen



SUMMARY OF STATUS OF ENIAC MOVING - 1 JULY 1947

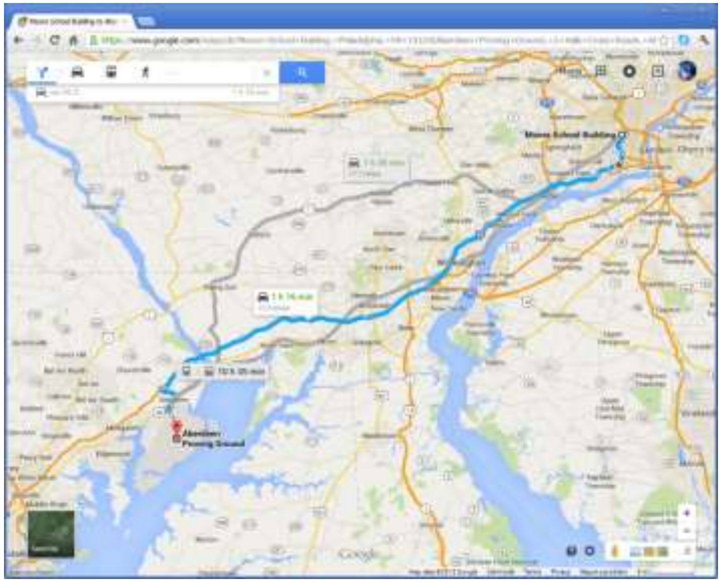
Value of Contract	Original		$94,200
	Change #1		2,500
	Change #2		10,000
	Total		$108,700.00
Expended to 1 July (per Comptrollers' statement)		$64,713.76	
Subcontract Commitments		18,282.66	
Overhead on subcontract commitments		1,828.26	
Total expended & Committed 1 July			84,824.68
Remaining 1 July			$23,875.32

To be done

Technicians, 5½ man weeks @ $130/wk/man	$715.00	
J.A.C. at Aberdeen 1 mo. with car @ 460/mo	460.00	
Extra travel for 1 day trips by J.A.C.	70.00	
T.K.S. at Aberdeen 1 wk. @ 500/mo	115.00	
R.E.M. at Aberdeen 1 mo. @ 400/mo	400.00	
H.J.G. at aberdeen 9 wks @ 110/wk	990.00	
J.A.C. Drafting 1 wk	82.00	
Draftsman 1 mo	198.00	
Overhead	824.00	
Total salaries, travel and overhead	3,854.00	
Misc. expenditures	200.00	
Total estimated to completion		4,054.00
Estimated total available		19,821.32

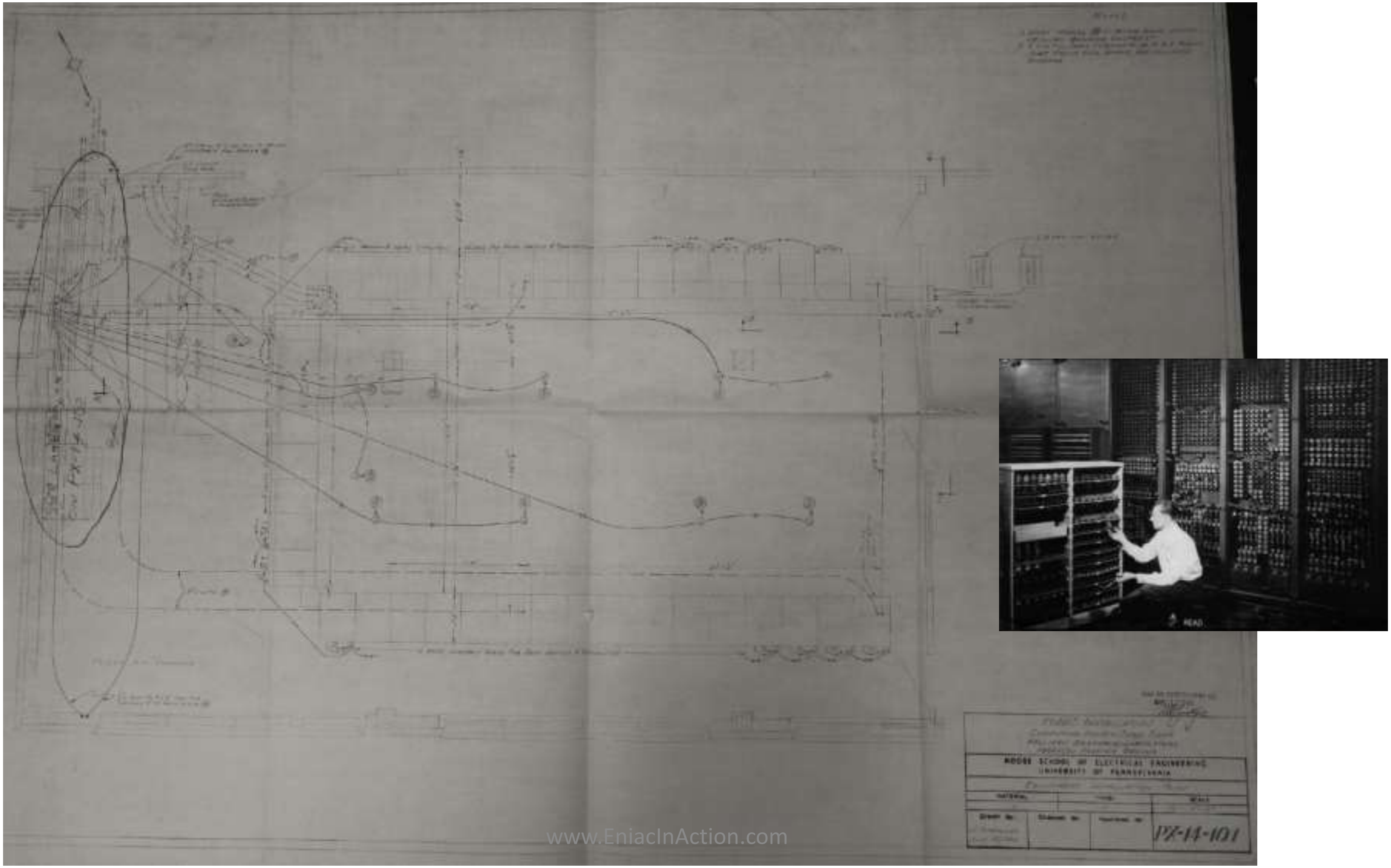
Hung Ceiling

Subcontract	8,000.00	
Overhead on subcontract	800.00	
M. S. Service	400.00	
Overhead on M. S. Service	160.00	
Total estimate for hung ceiling		9,360.00
Estimated total remaining		$10,461.32

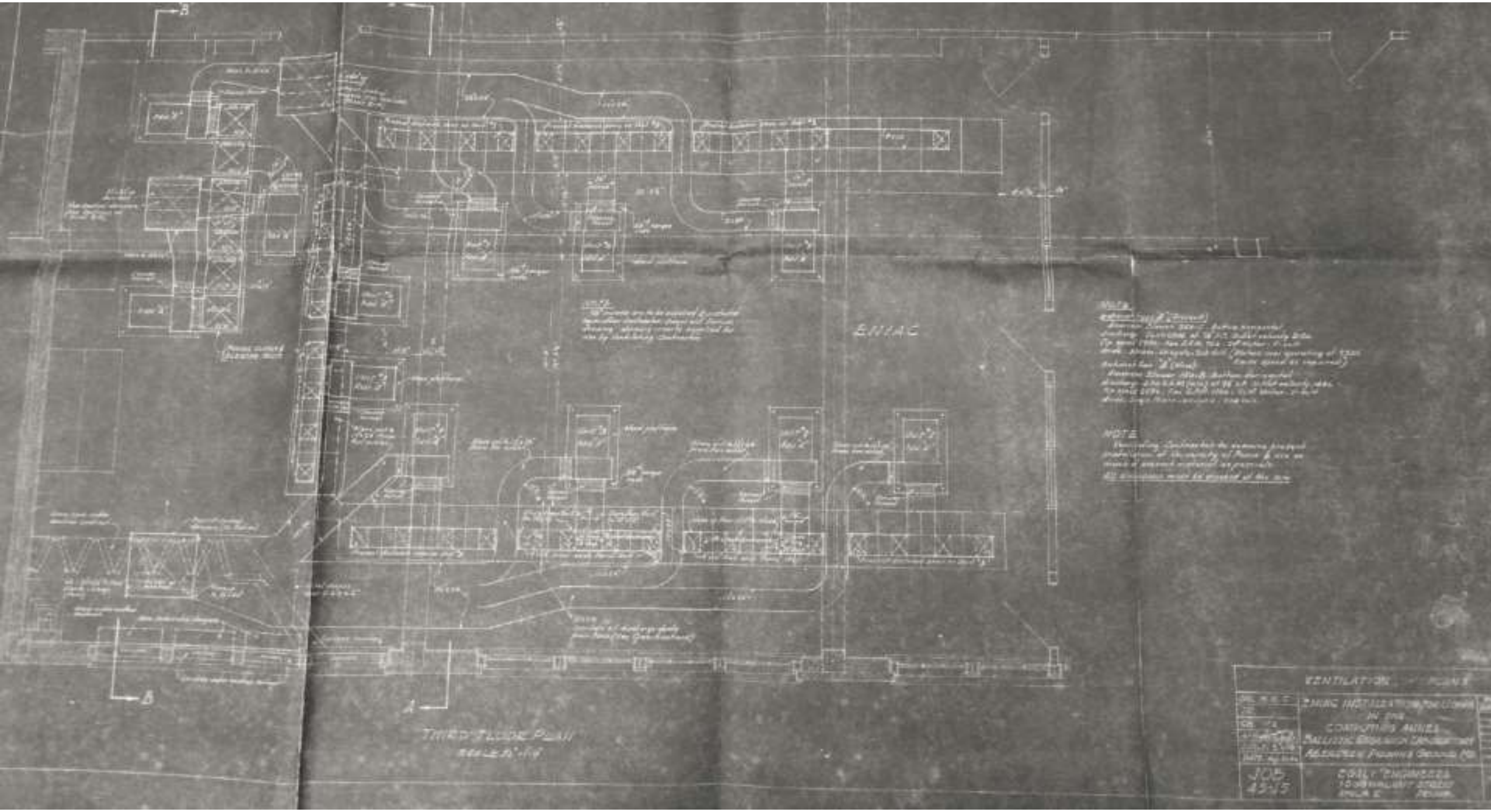


- Contracted to local moving company
- Panels winched through a hole in the outer wall.

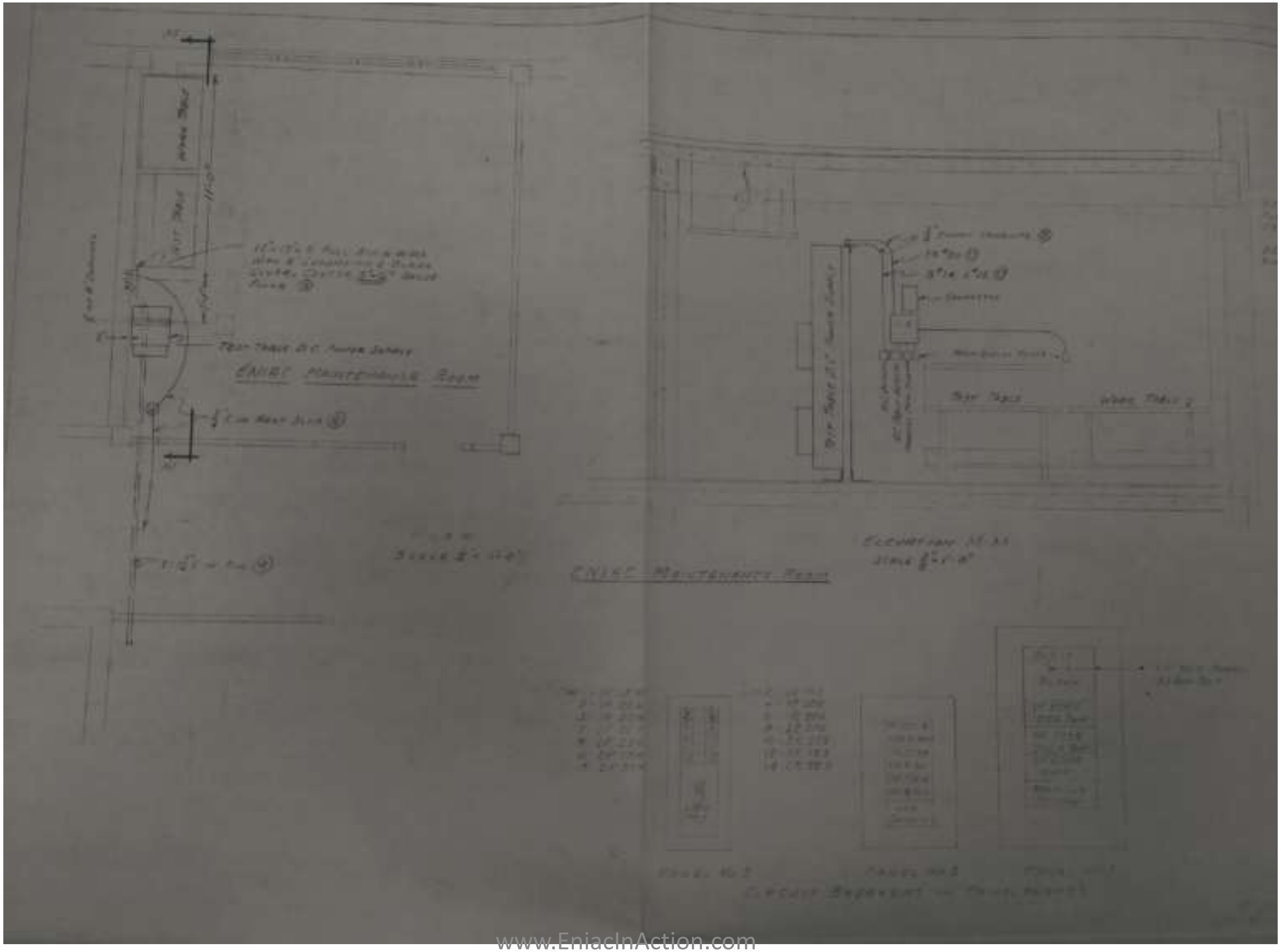
Equipment Installation Plan



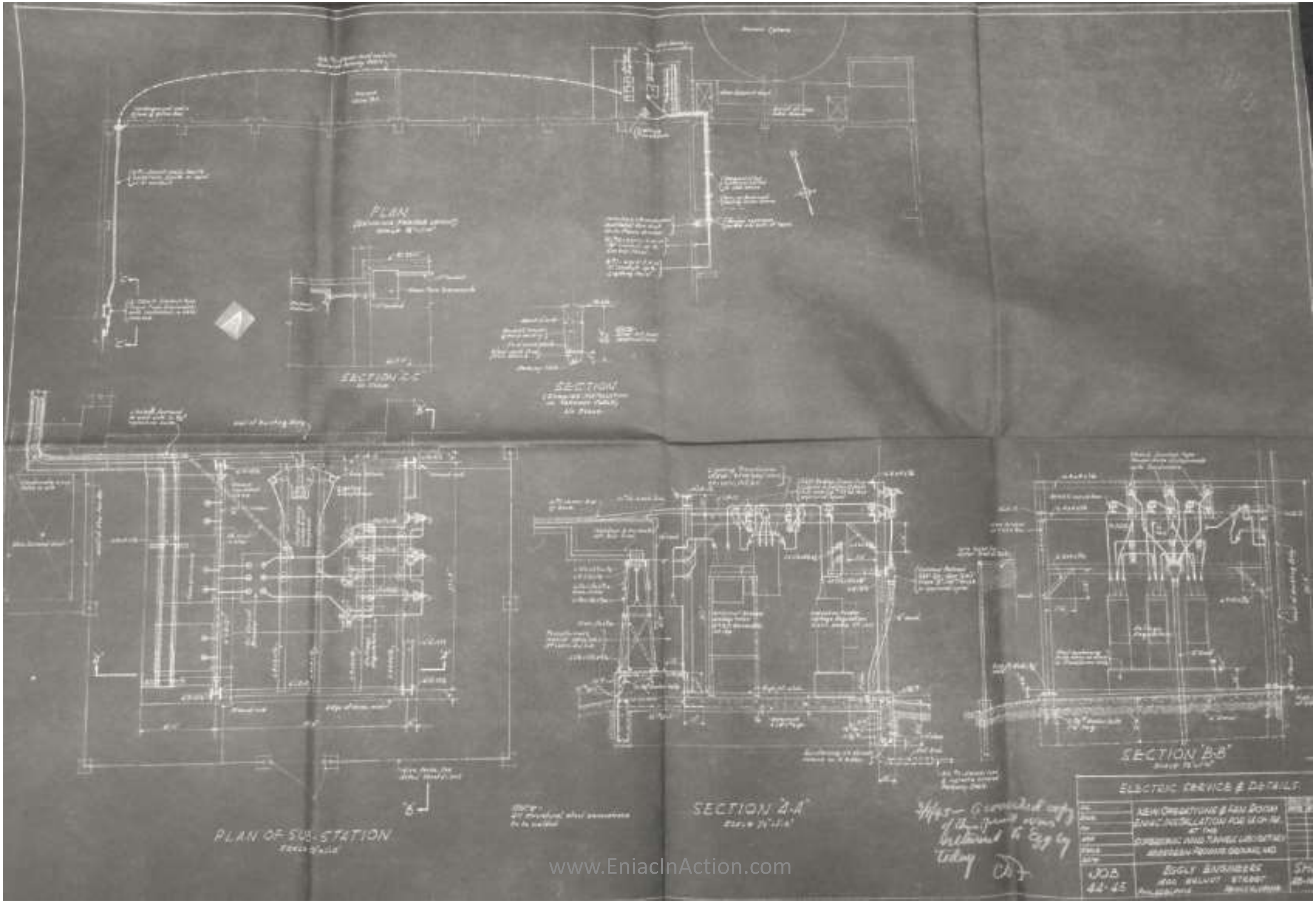
Ventilation Plans



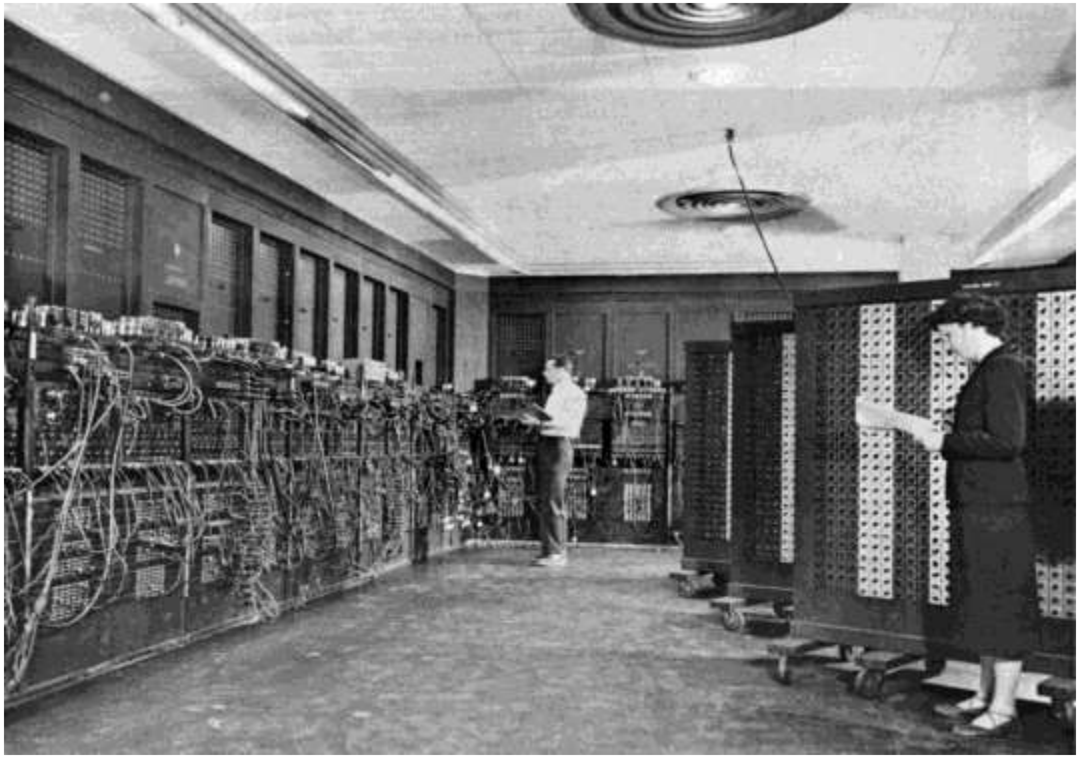
Test Room Plans



Electric Service Plan



The Suspended Ceiling



- Proposed in early planning, but seen as luxury
- Approved by the Army only in June, 1947
  - Installed 1948

ENIAC as a Showpiece

- Even before ENIAC was finished, there were enough visitors to trigger a ban
- In 1948, regular visits by delegations for demonstrations

In December 1947

- Running on production work 2 hours a week!
- 17% of time setting up and testing configurations
- 49% checking, diagnosing, and fixing hardware

MECHANICAL 'BRAIN' HAS ITS TROUBLES

Automatic Computers Go Awry at Times, but Eniac, Fastest, Outspeeds Man 5,000 to One

By WILL LISSNER

Special to THE NEW YORK TIMES.

ABERDEEN, Md., Dec. 13—The fastest automatic computer or "mathematical brain" in use works only a two-hour week, mathematicians on the staff of the ballistic research laboratories at Aberdeen Proving Ground reported today.

Data on the comparative performance of three types of automatic computing machines with a desk machine operated by human computer were made public as 300 specialists in the machines, attending a meeting of the Eastern Association for Computing Machinery, closed a three-day demonstration of high-speed computing devices.

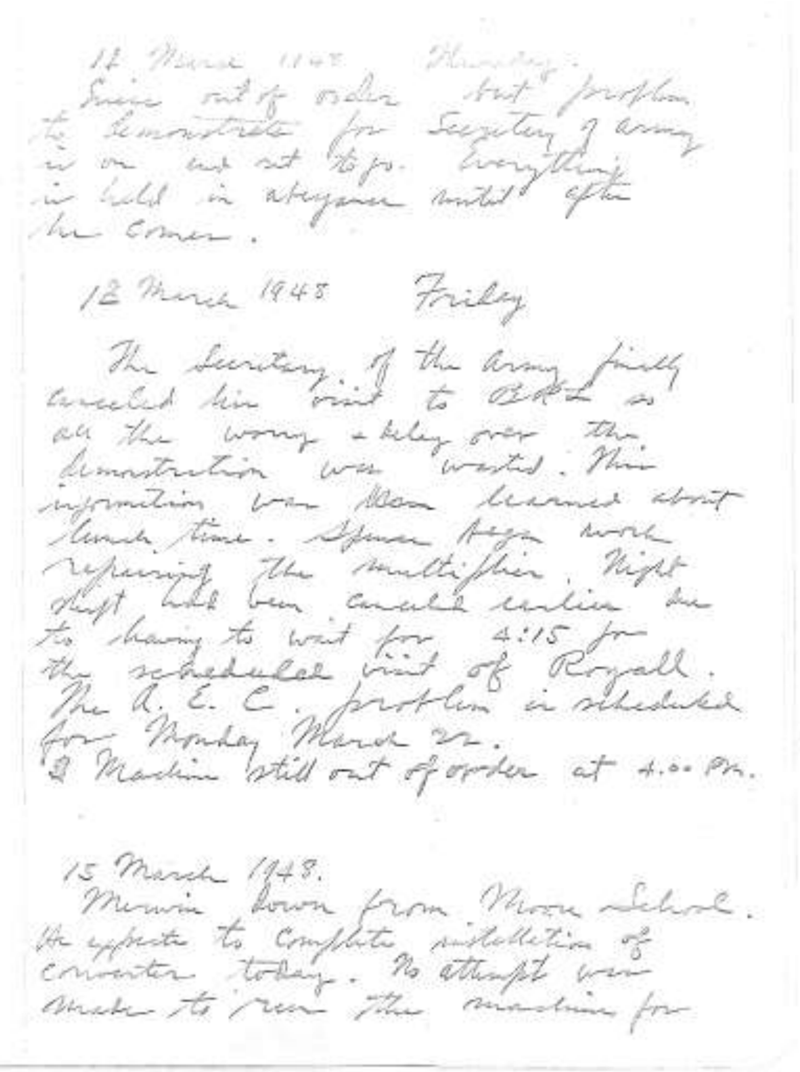
The performance records showed that in its two-hour week, the fastest of the high-speed devices, the

Struggling for Reliability

- Frank E. Grubbs, Ph.D. student turned mathematical analyst for BRL
  - Pioneered statistical tests for outliers
- Three weeks of computer time before first useful output produced
  - Intermittents
  - Power supplies "dumping"
  - Error in mathematical treatment
  - Time lost to hardware upgrades
  - Unreproducible results
  - Preparations for inspection by Secretary of Army

ENIAC Operations Log

- Preserved, but never used by historians previously



11 March 1948 Thursday.
Eniac out of order but problem
to demonstrate for Secretary of Army
is on and set to go. Everything
is held in abeyance until after
he comes.

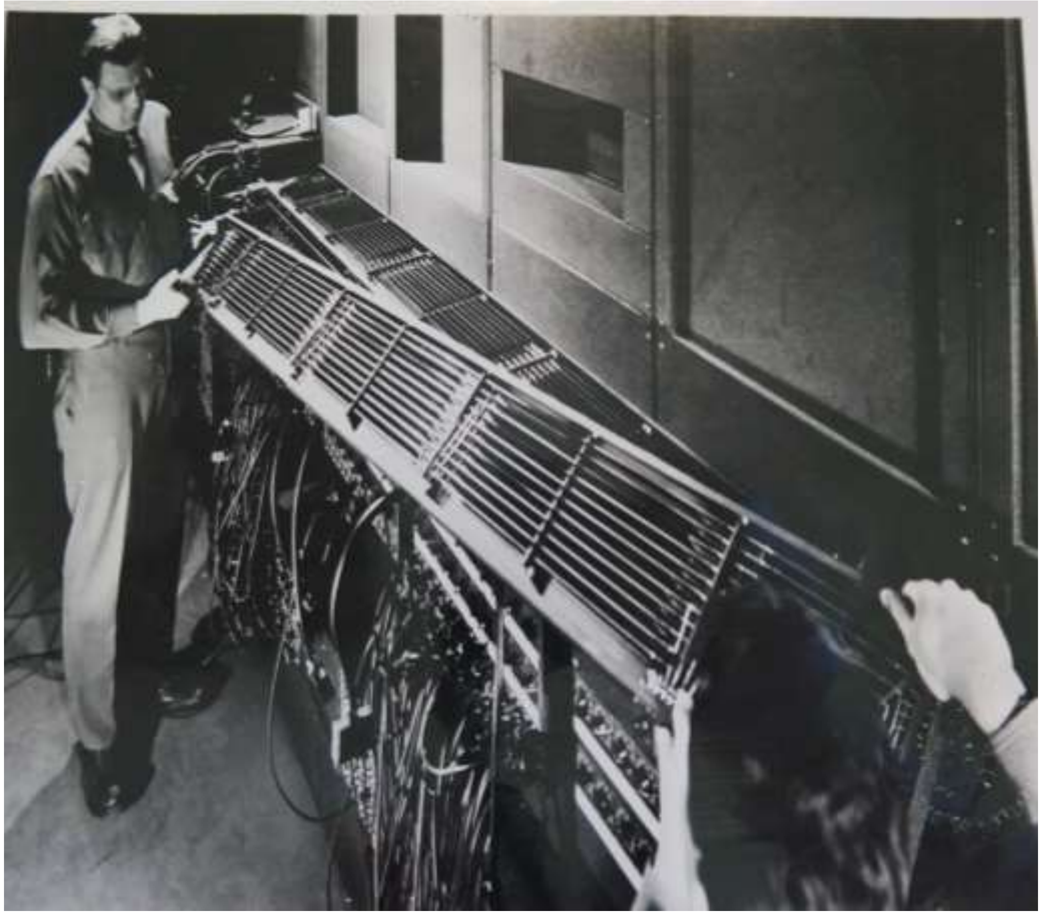
12 March 1948 Friday

The Secretary of the Army finally
canceled his visit to BRL so
all the worry & delay over the
demonstration was wasted. This
information was [illegible] learned about
lunch time. Spence Hege were
repairing the multiplier. Night
shift had been canceled earlier due
to having to wait for 4:15 for
the scheduled visit of Royall.
The A. E. C. problem is scheduled
for Monday March 22.
Machine still out of order at 4.00 PM.

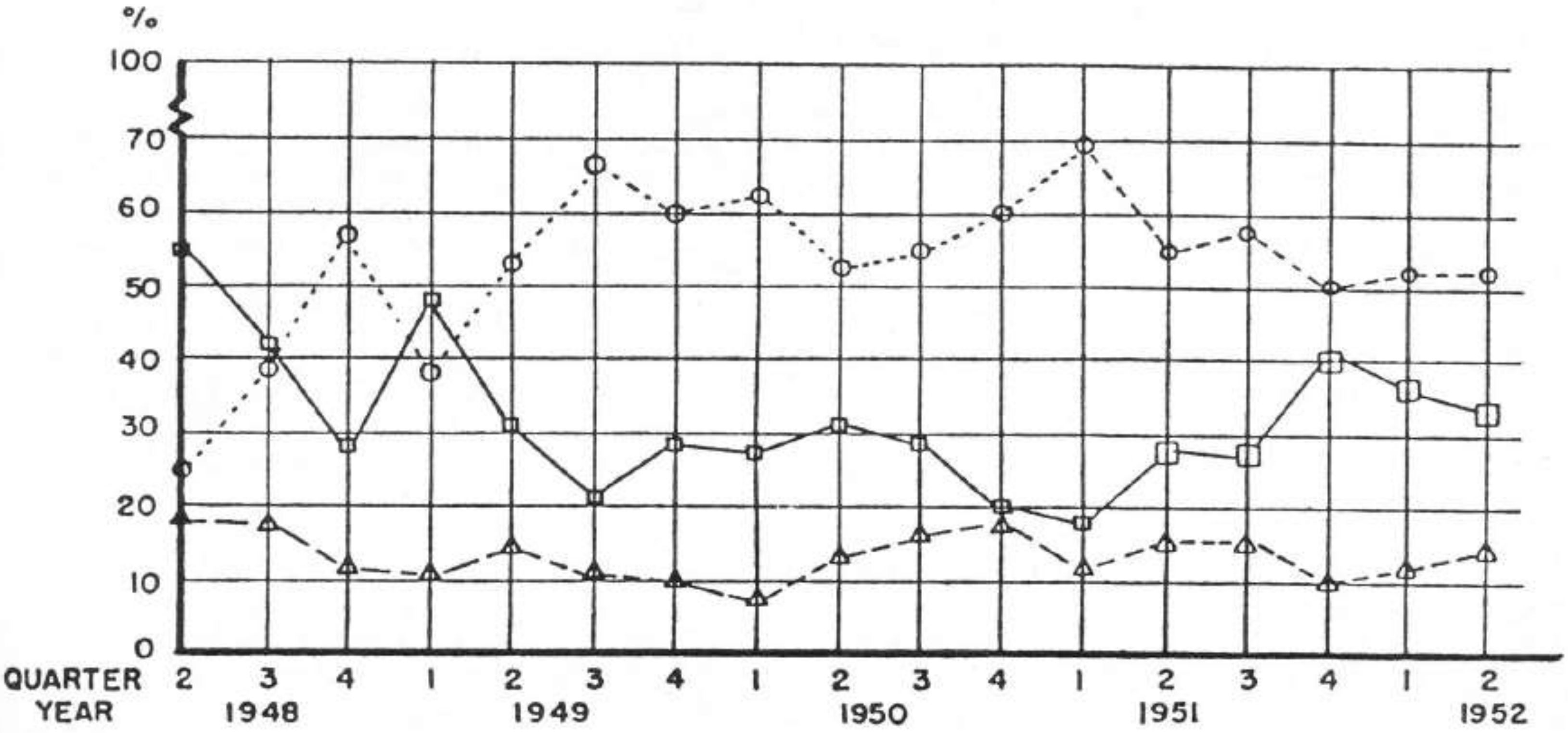
15 March 1948.
Merwin down from Moore School.
He expects to complete installation of
converter today. No attempt was
made to run the machine for

Homer Spence

- Original an army technical assigned to ENIAC
- Returned to BRL as civilian employee
- Spence “detected so many cold solder joints that he simply went through and resoldered every joint on the machine.”



Usable Machine Time

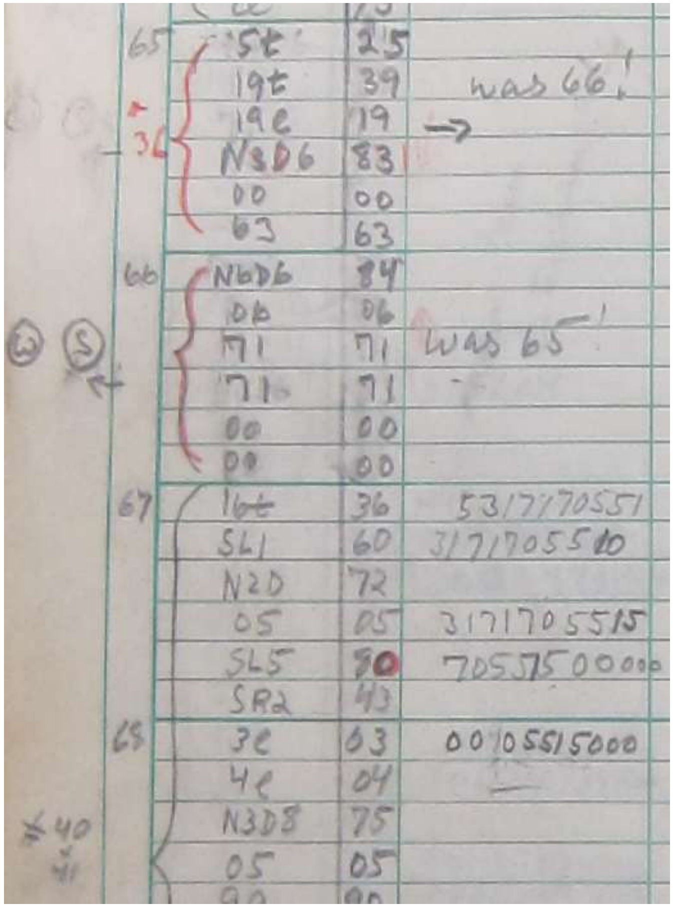


1. ○----○ CORRECTLY OPERATING ON THE SOLUTION OF REGULAR PROBLEMS.
2. □——□ LOCATING AND CORRECTING MACHINE TROUBLE IN THE ENIAC, NON DUPLICATION TIME, AND DOWN TIME ON SPECIAL PREVENTIVE MAINTENANCE.
3. △----△ PLACING NEW PROBLEMS ON THE ENIAC, CHECKING PROGRAMMING, DATA ANALYSIS, AND DOWN TIME DUE TO HUMAN OPERATING ERROR.

UPGRADES TO ENIAC

New Programming System

- From March 1948 ENIAC control switches and wires no longer moved
- Programs were written as numerical codes read and executed from addressable memory
- First modern computer program ever run!



65	5t	25	
	19t	39	was 66!
	19e	19	→
36	N3D6	83	
	00	00	
	63	63	
66	N6D6	84	
	06	06	
	71	71	was 65!
	71	71	
	00	00	
	00	00	
67	16t	36	5317170551
	SL1	60	3171705510
	N2D	72	
	05	05	3171705515
	SL5	80	70557500000
	SR2	43	
68	3e	03	0010551500
	4e	04	
≠40	N3D8	75	
41	05	05	

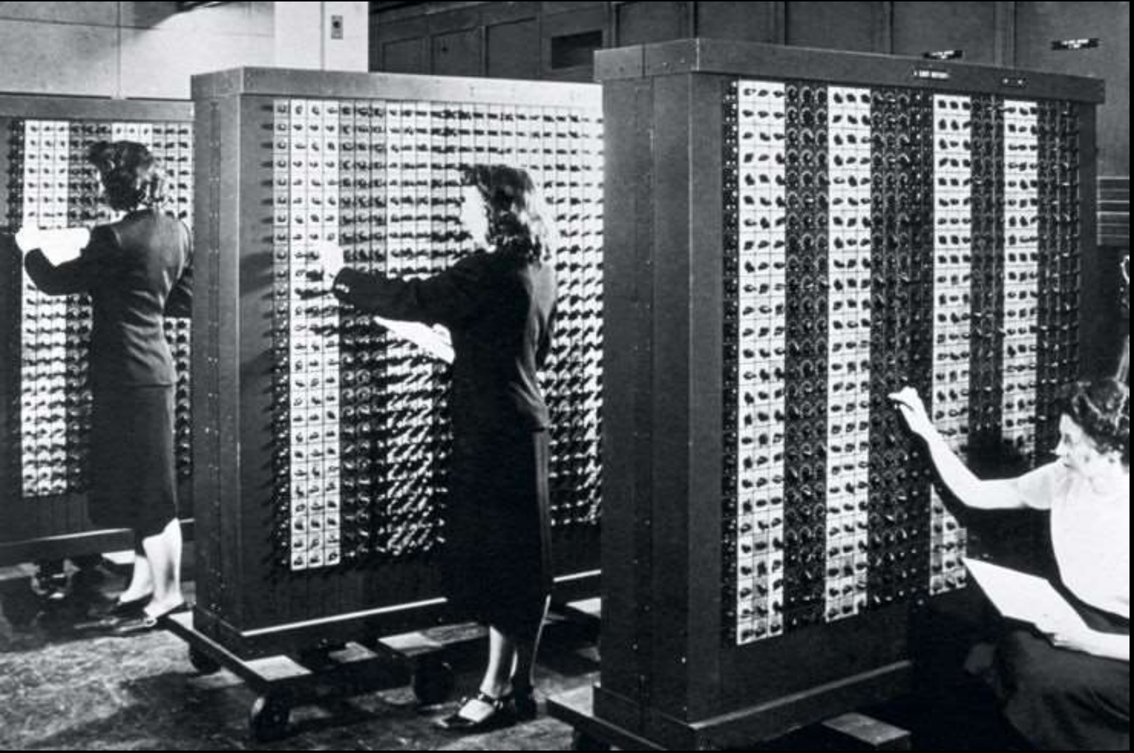
171	ce	15				ce
	16t	36				16t
	S'R1	38				S'R1
	12t	62		/		12t
	S'L5	86			$10^{-5}\xi_0 \to [12]_R$	S'L5
	11e	11			$(10^5\xi_1)_L$ com	11e
172	L12t	62		$(10^{-2}\xi_0)_R$		12t
	10e	10	67900 98765		$10^{-5}\xi_0 \to [10]_R$	10e
	ce	15				12t
	1ce	15	567900 98576			
	ce	15	09876	567900	⑫	
	le	15				
173	12t	62		567900 $10^{-2}\xi_0$		
	SL5	80		ξ_0		
	X	57	0560858040	$\xi_0(10^5\xi_1)$		
	7e	07			$(\xi_0(10^5\xi_1) \to [7]$ 0560858040	
	11t	31				
	X	57	0097535376	$(10^5\xi_0)^2$		
174	SRS	52	00975	$10^{-5}\xi_1^2$		
	7t	27	0560859015			
	7t	27	1121717055		$[10^{-4}\xi_1^2 + 2\xi_0(10^5\xi_1)$	
	7e	07			1121717055	
	12t 10e	62 10				
	SL5	80		ξ_0		
175	11e	11				
	11t	31				
	X	57	3225104100	ξ_0^2		
	SL5	80	04100	ξ_0^2		
	7t	27		ξ'		
	DS	46	1531717055			
176	S'--	○	5317170550			
	12t	62	5317170551			
	16e	16				
	Count					
	CT	69				

A complex human-readable text,
written in 1948 by Klára von Neumann

Many different layers of information

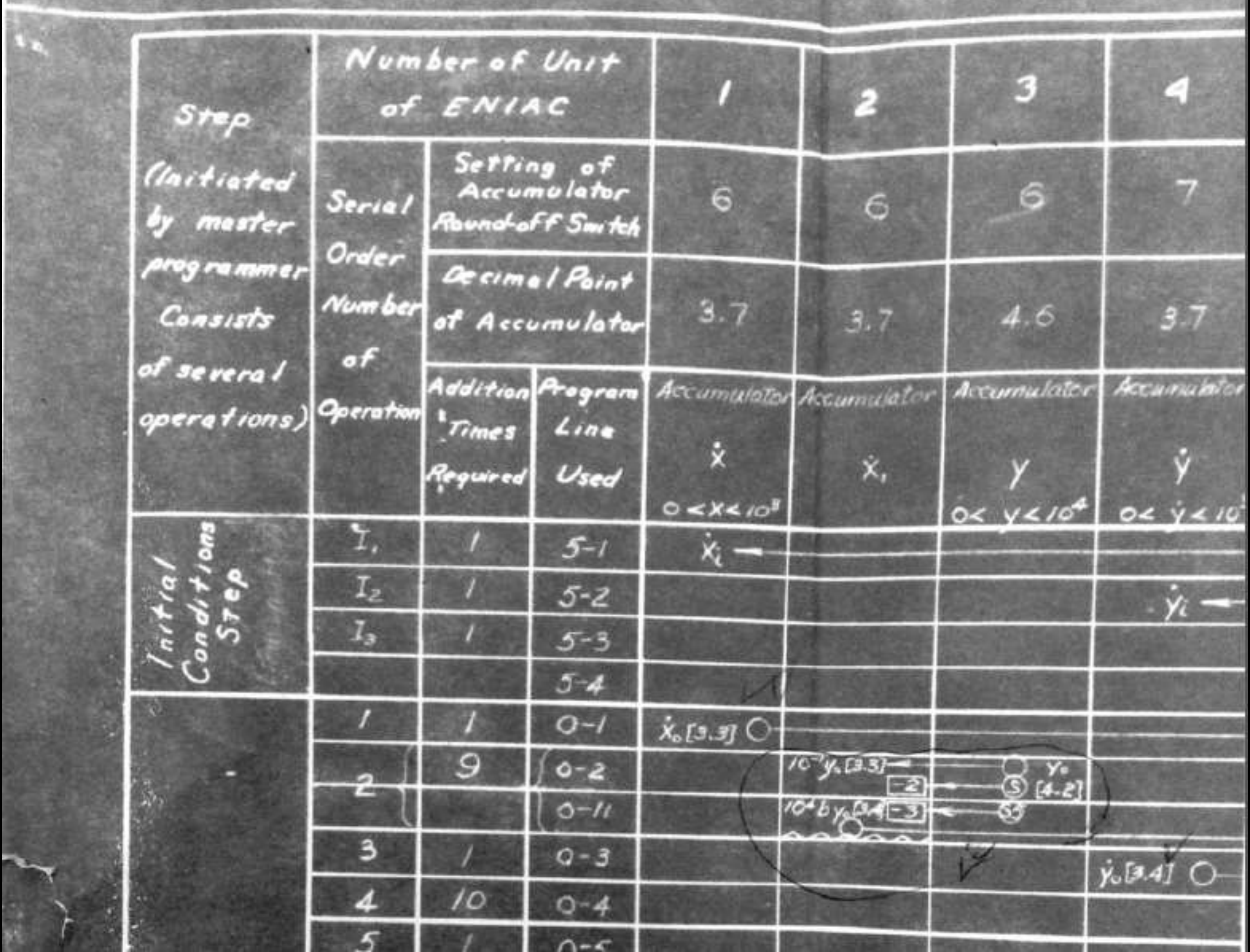
Added to and amended over time

Central repository of information about the program

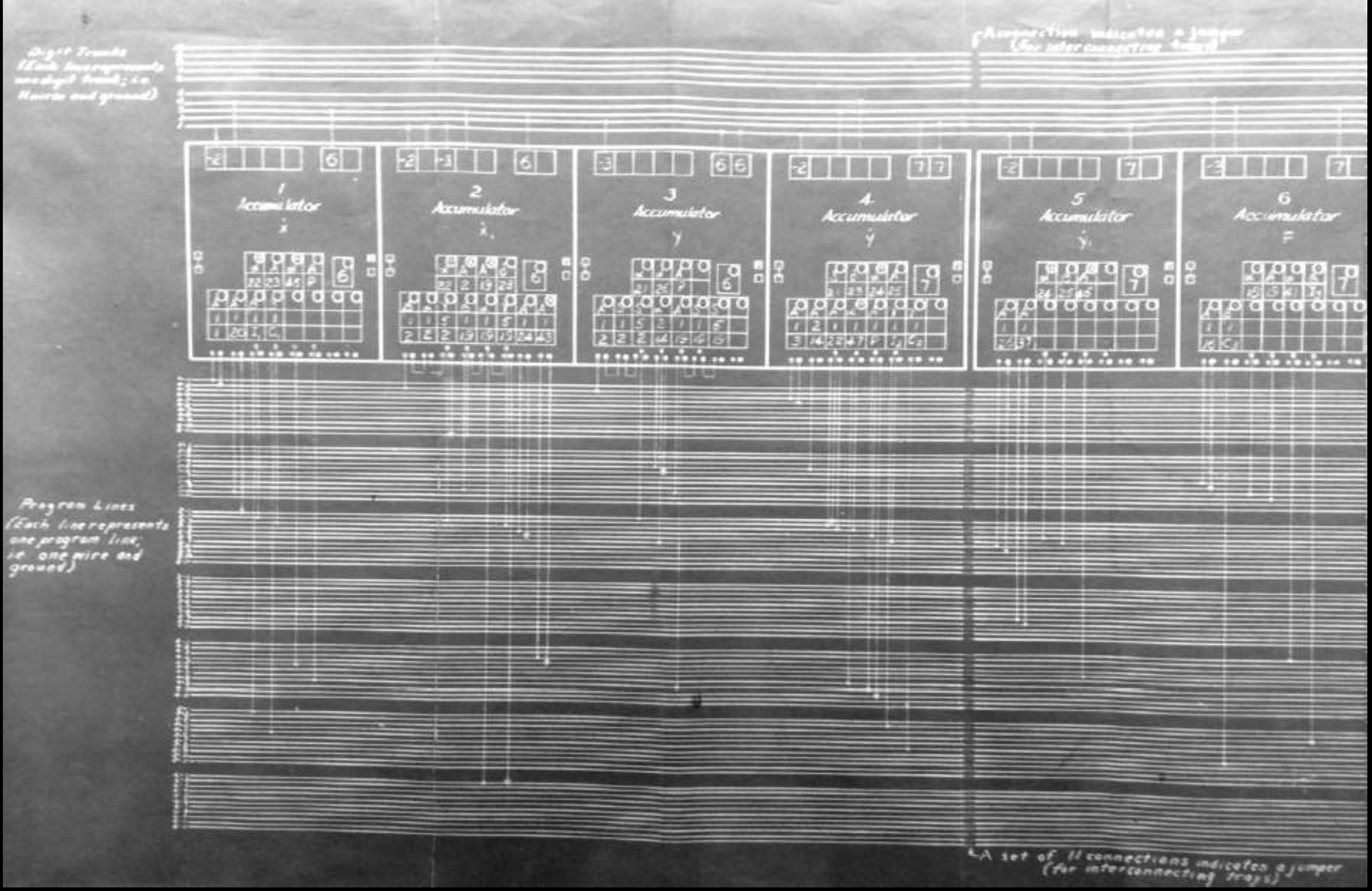


ENIAC read only the 2-digit codes, set on switches by operators

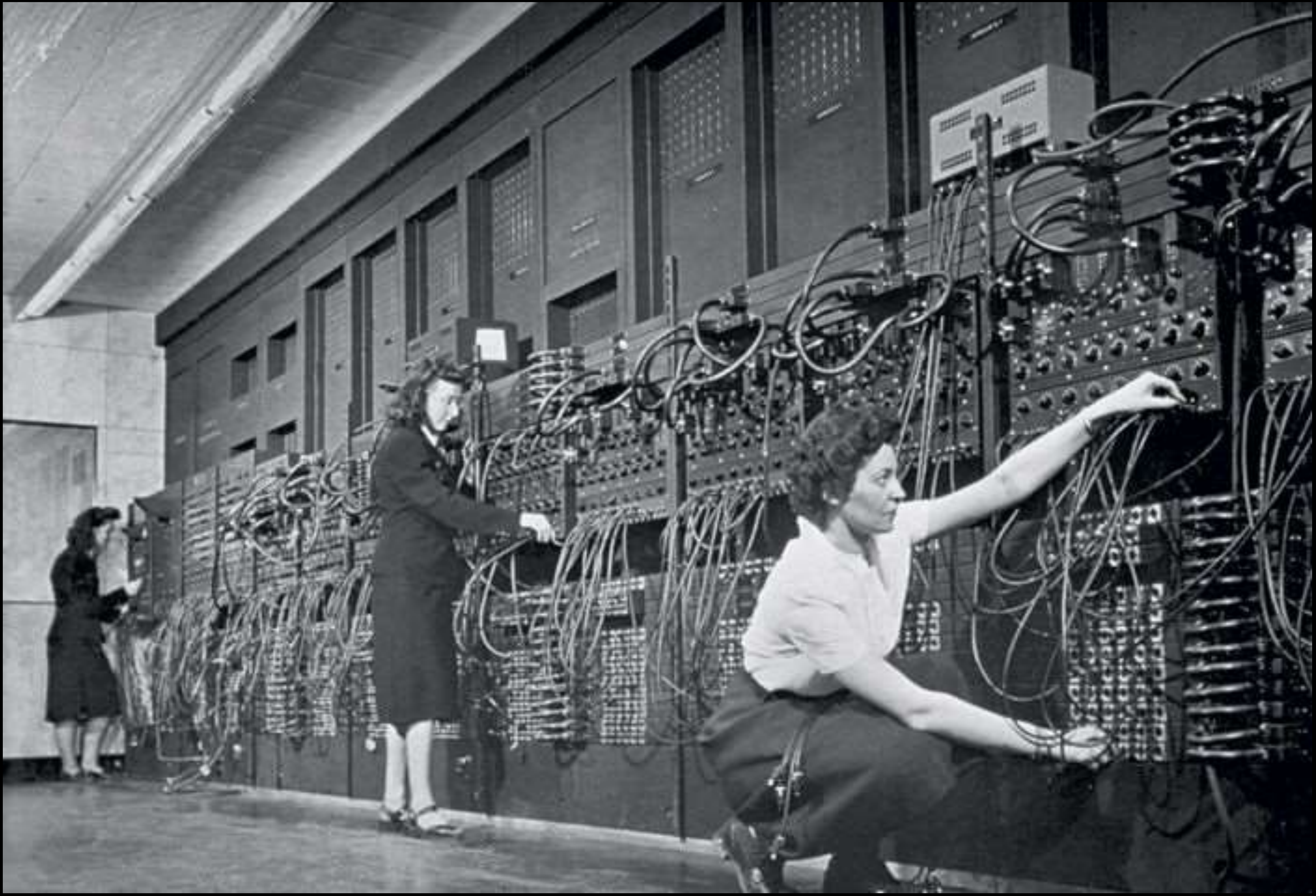
Earlier ENIAC “programs” are tables or diagrams



Step (Initiated by master programmer Consists of several operations)	Number of Unit of ENIAC			1	2	3	4
	Setting of Accumulator Round-off Switch			6	6	6	7
	Decimal Point of Accumulator			3.7	3.7	4.6	3.7
	Serial Order Number of Operation	Addition Times Required	Program Line Used	Accumulator $\dot{x}$ $0<\dot{x}<10^3$	Accumulator $\dot{x}_1$	Accumulator y $0<y<10^4$	Accumulator $\dot{y}$ $0<\dot{y}<10$
Initial Conditions Step	I_1	1	5-1	$\dot{x}_i$ ←			
	I_2	1	5-2				$\dot{y}_i$ ←
	I_3	1	5-3				
			5-4				
	1	1	0-1	$\dot{x}_0$ [3.3] ○			
	2	9	0-2		$10^{-1}y_0$ [3.3] ← −2 ←	○ y_0 Ⓢ [4-2]	
			0-11		$10^4 by_0$ [3.4] −3 ← ○	Ⓢ	
	3	1	0-3				$\dot{y}_0$ [3.4] ○
	4	10	0-4				
	5	1	0-5				


Digit Trunks (Each line represents one digit trunk; i.e. 11 wires and ground)
A connection indicates a jumper (for interconnecting trays)
1 Accumulator
2 Accumulator
3 Accumulator
4 Accumulator
5 Accumulator
6 Accumulator F
Program Lines (Each line represents one program line, i.e. one wire and ground)
A set of 11 connections indicates a jumper (for interconnecting trays)

that tell you how to set up ENIAC for a specific problem



Compressible Laminar Boundary Layer [illegible] Equations — Set-up for integration procedure

21

21

M.P.	Acc 1 H(0)	Acc 2 Quotient	Divider	Acc 3 [illegible]	Acc 4 τ(0)	Acc 5 Denom	Acc 6	Acc 7 Divider Shifter	Acc 8	Acc 9	Acc 10	MSPP	Acc 11 LHPP	Acc 12	Acc 13 RHPP	Acc 14	Acc 15 H	Acc 16 h	Acc 17 R	Acc 18 r	PTF3	Acc 19 r'	Acc 20 F	C.T.
Digit Trs, Shifter, Deleter	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]				[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
	H(0)				τ(0)						0	0	0	0	0	0	H_0	h_0	R_0	r_0		r'_0	F_0	
Pulse for [illegible] integration sequence										F_0	H_0	[illegible]					AO	α1					AO	
										H_0	H_0	[illegible]			F_0H_0		AO	α1						
										F_0	R_0	[illegible]			H_0^2	α1 H_0^2		h_0	AO				AO	
											AO1								SO	αO				
										γ0	γ01					AC								[illegible]
										r	[illegible]	[illegible]			[illegible]									
																pO5				AO				
														yO2		AC2				AO5				
																αO2					Output			
																AO1	αO2							1
	A1																				Output [illegible]			
	B1													αO1	AO1									
										W_0	W_0	[illegible]			AC									
										[illegible]	[illegible]	[illegible]			[illegible]									

No. 3880

With ENIAC’s successor, the EDVAC,

programming takes a linguistic turn

First Draft of a Report on the EDVAC

by

John von Neumann

Contract No. W-670-ORD-4926

Between the

United States Army Ordnance Department

and the

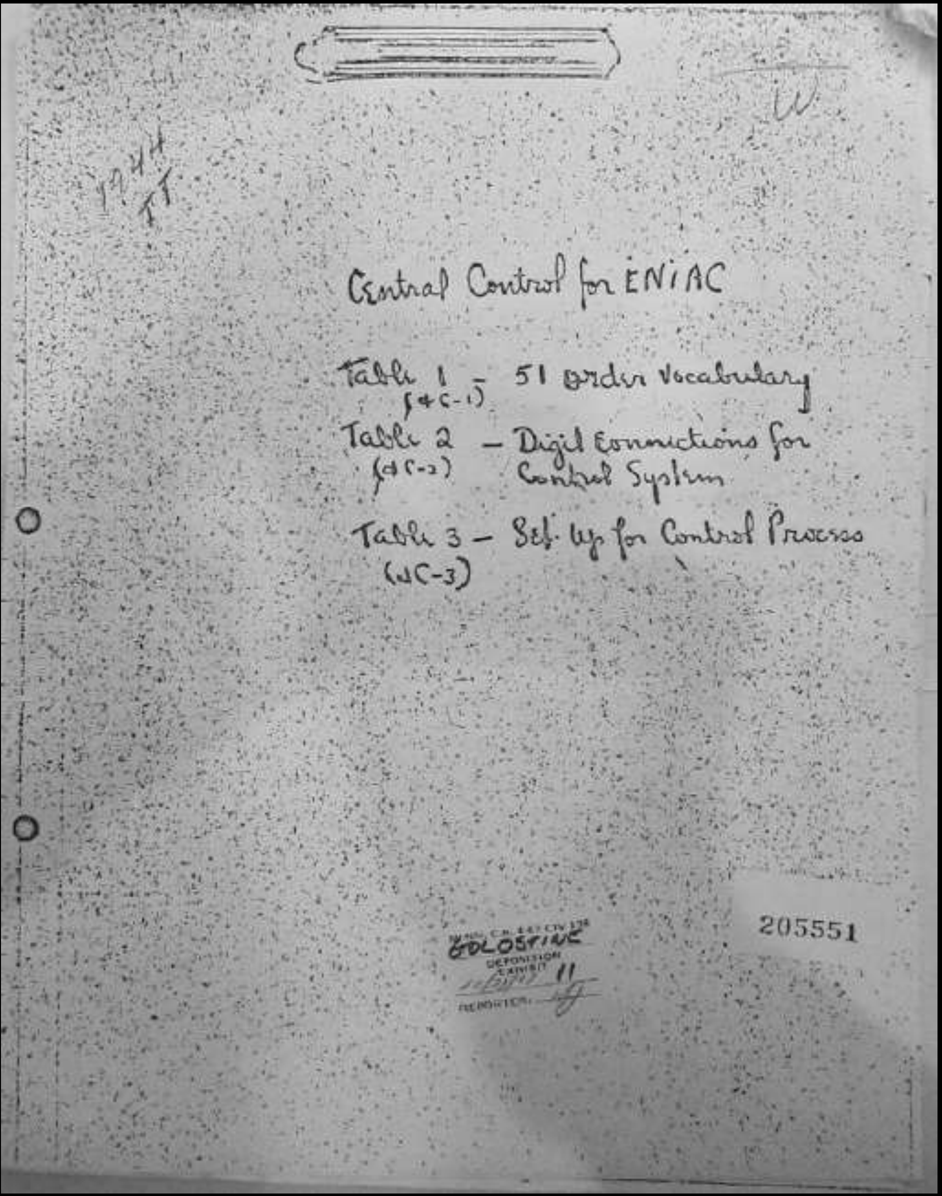
University of Pennsylvania

Moore School of Electrical Engineering
University of Pennsylvania

June 30, 1945

Table.

<table>
<tr><th>(I)
Type.</th><th>(II)
Meaning.</th><th>(III)
Short Symbol</th><th>(IV)
Code Symbol</th></tr>
<tr><td></td><td></td><td></td><td>Minor cycle $I = (i_\nu) = (i_0 i_1 i_2 --- i_{31})$</td></tr>
<tr><td>Standard number or Order (γ)</td><td>Storage for the number defined by $\xi = i_{31}$. $i_{30}\ i_{29} --- i_1 = \sum_{\nu=1}^{31} i_\nu 2^{31-\nu}$ (mod 2)$_1$ - $1 \le \xi < 1$. i_{31} is the sign: 0 for +, 1 for -. If CC is connected to this minor cycle, then it operates as an order, causing the transfer of into I_{ca}. This does not apply however if this minor cycle follows immediately upon an order w → A or wh → A.</td><td>$N\xi$</td><td>$i_0 = 0$</td></tr>
<tr><td>Order (α) +(β)</td><td rowspan="4">Order to carry out the operation w in CA and to dispose of the result. w is from the list of 11.4. These are the operations of 11.4, with their current numbers w and their symbols w:<table><tr><th>w, decimal</th><th>w, binary</th><th>w</th><th>w, decimal</th><th>w, binary</th><th>w</th></tr><tr><td>0</td><td>0000</td><td>+</td><td>5</td><td>0101</td><td>i</td></tr><tr><td>1</td><td>0001</td><td>-</td><td>6</td><td>0110</td><td>j</td></tr><tr><td>2</td><td>0010</td><td>×</td><td>7</td><td>0111</td><td>s</td></tr><tr><td>3</td><td>0011</td><td>/</td><td>8</td><td>1000</td><td>db</td></tr><tr><td>4</td><td>0100</td><td>√</td><td>9</td><td>1001</td><td>bd</td></tr></table>h means that the result is to be held in O_{ca}. →up means, that the result is to be transferred into the minor cycle ρ in the major cycle u; →f, that it is to be transferred into the minor cycle immediately following upon the order; →A, that it is to be transferred into I_{ca}; no →, that no disposal is wanted (apart from h).</td><td>w → up
or
wh → up</td><td rowspan="4">$i_1 = 1$</td></tr>
<tr><td>Order (α) +(ε)</td><td>w → f
or
wh → f</td></tr>
<tr><td>Order (α) +(δ)</td><td>w → A
or
wh → A</td></tr>
<tr><td>Order (α)</td><td>wh</td></tr>
<tr><td>Order (ζ)</td><td>Order to transfer the number in the minor cycle in the major cycle u into I_{ca}.</td><td>A ← up</td><td></td></tr>
<tr><td>Order</td><td>Order to connect CC with the minor cycle in the major cycle u.</td><td>C ← up</td><td></td></tr>
</table>



Central Control for ENIAC

Table 1 (AC-1) – 51 order Vocabulary

Table 2 (AC-2) – Digit Connections for Control System

Table 3 (AC-3) – Set up for Control Process

GOLDSTINE
DEPOSITION
EXHIBIT 11
REPORTER

205551

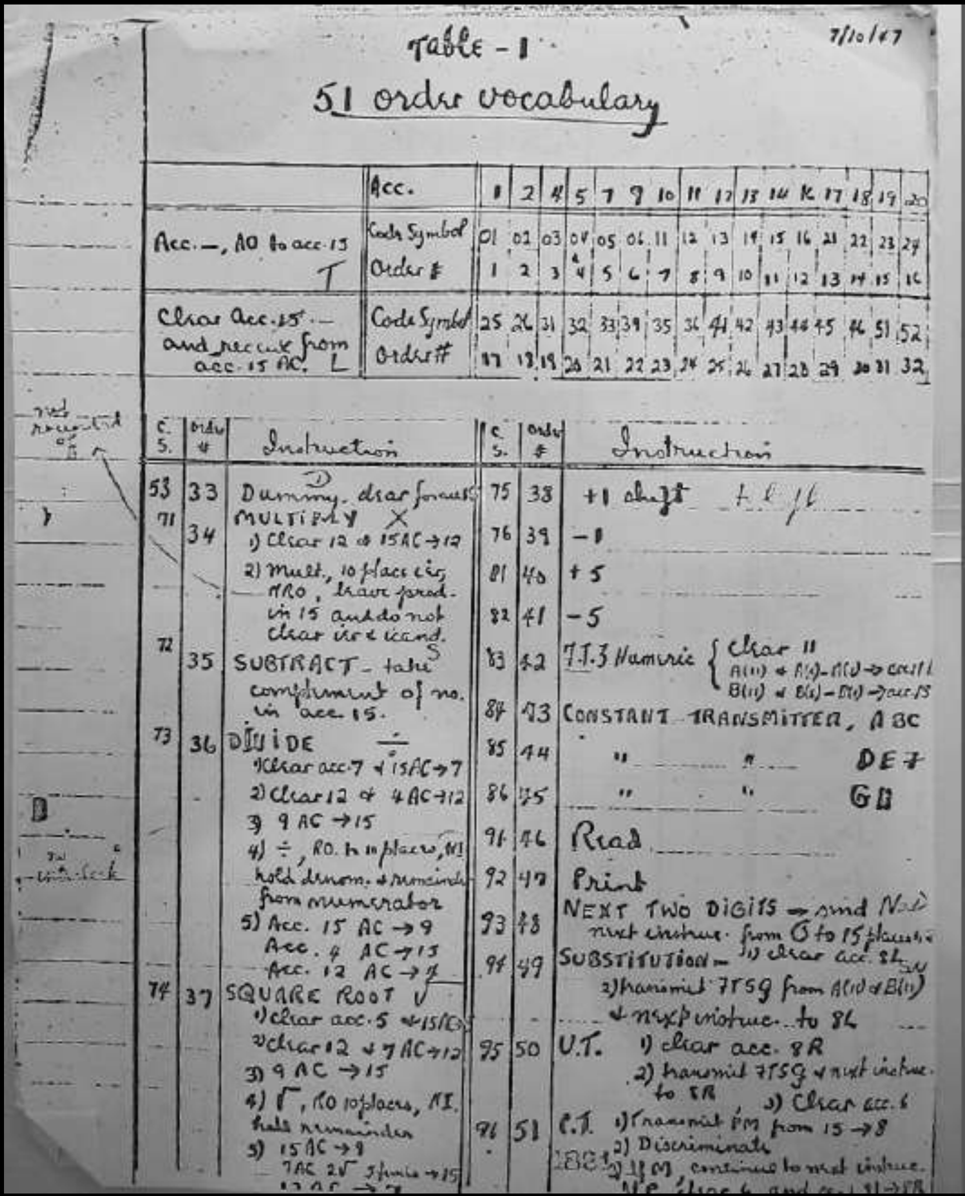


TABLE – I

7/10/47

51 order vocabulary

	Acc.	1	2	4	5	7	9	10	11	12	13	14	15	17	18	19	20
Acc. –, AO to acc. 15 T	Code Symbol	01	02	03	04	05	06	11	12	13	14	15	16	21	22	23	24
	Order #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Clear acc. 15 – and receive from acc. 15 AC. L	Code Symbol	25	26	31	32	33	34	35	36	41	42	43	44	45	46	51	52
	Order #	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32

not requested of B

C. S.	Order #	Instruction	C. S.	Order #	Instruction
53	33	Dummy. clear forces D	75	38	+1 shift
71	34	MULTIPLY × 1) Clear 12 & 15AC→12 2) Mult., 10 places cir, NRO, leave prod. in 15 and do not clear ier & icand.	76	39	–1
			81	40	+5
			82	41	–5
72	35	SUBTRACT – take complement of no. in acc 15. S	83	42	T.T.3 Numeric { Clear 11 A(11) + A(5)–A(1) → acc 11 B(11) + B(5) – B(1) → acc 15
			84	43	CONSTANT TRANSMITTER, A BC
73	36	DIVIDE ÷ 1) Clear acc. 7 & 15AC→7	85	44	" " DEF
		2) Clear 12 & 4AC→12 3) 9 AC → 15	86	45	" " GH
		4) ÷, RO. to 10 places, NI hold denom. & remainder from numerator	91	46	Read
			92	47	Print
		5) Acc. 15 AC → 9 Acc. 4 AC → 15	93	48	NEXT TWO DIGITS → send NI next instruc. from 6 to 15 places
		Acc. 12 AC → 4	94	49	SUBSTITUTION – 1) clear acc. 8L 2) transmit 7159 from A(11) & B(11) & next instruc. to 8L
74	37	SQUARE ROOT √ 1) clear acc. 5 & 15AC			
		2) clear 12 & 7 AC→12 3) 9 AC → 15	95	50	U.T. 1) clear acc. 8R 2) transmit 7159 & next instruc. to 8R 3) Clear acc. 6
		4) √, RO 10 places, NI. hold remainder 5) 15 AC → 9 7AC 2√ 5 places → 15	96	51	C.T. 1) Transmit PM from 15 → 8 2) Discriminate 3) If M, continue to next instruc.

ENIAC is set up to read and interpret

an EDVAC-style numerical code

November 7, 1947 Master Sheet p. 1

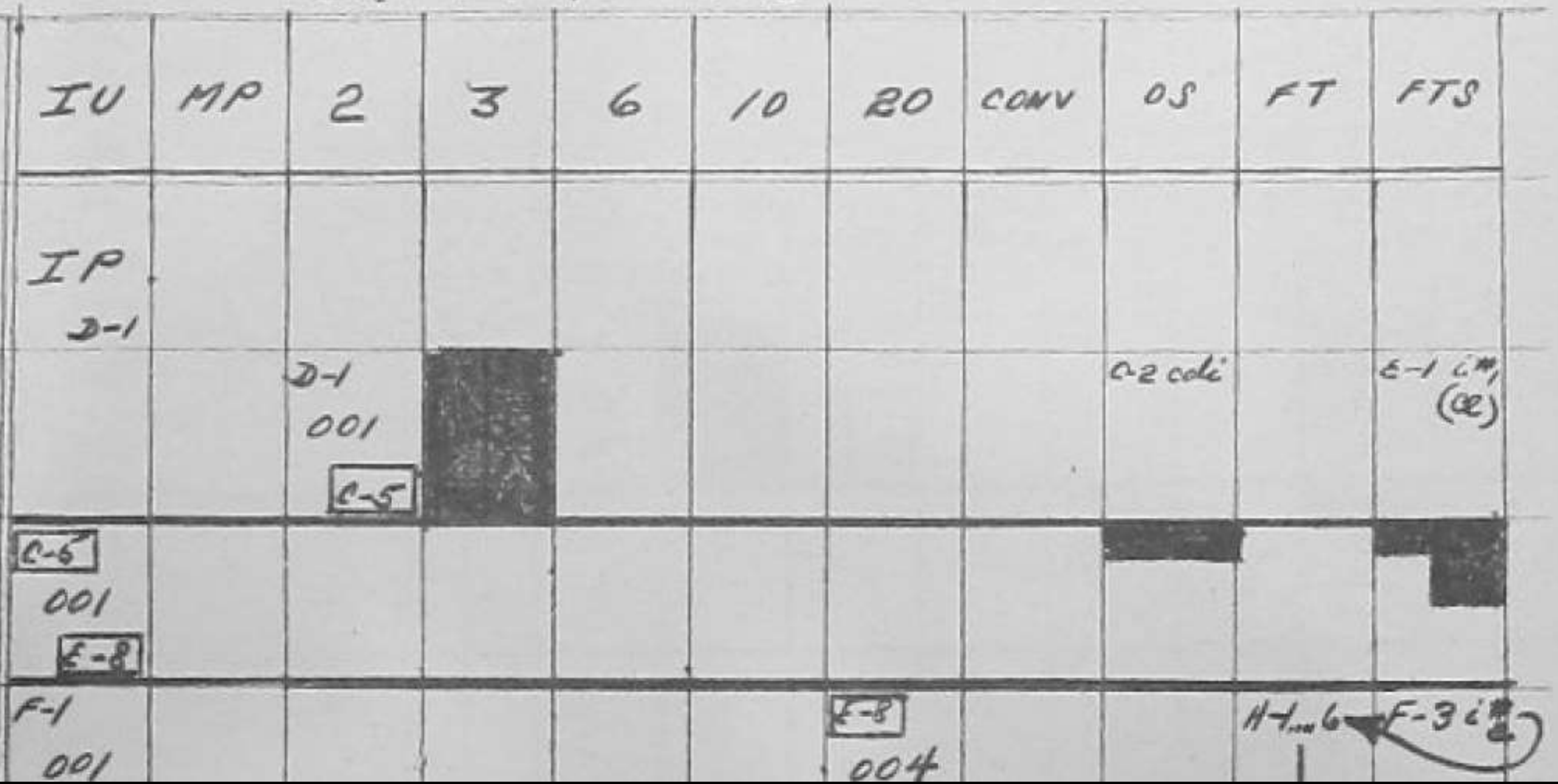
Initiating Unit		Order Selector				Master Programmer			
P_i	O-1	i	G-8	Cpp_o	F-4	Stepper A			
P_o	C-5	Cdi	G-6	O_u	~~II_2~~ → E-2	i	B-2		
R_i	O-2	Cppi	F-3	O_t	II_2 → F-6	di	E-2		
R_o	C-5	P.M. Discriminator #1				Cdi	F-5		
$Sc_i^{\#1}$	F-5	i	F-7	0 → F-9		Sl. 1	C-1	Sl. 4	S-3
$Sc_o^{\#1}$	G-8	di	F-6	9 → F-8		Sl. 2	S-1	Sl. 5	S-4
$Sc_i^{\#2}$	E-3	Cdi	G-7			Sl. 3	S-2	Sl. 6	S-5
$Sc_o^{\#2}$	U-10	P.M. Discriminator #2				Stepper B			
$Sc_i^{\#3}$	O-4	i	G-4	0 → G-5		i	B-5		
$Sc_o^{\#3}$	C-4	di	G-3	9 → C-5		di	E-2		

[redacted] BASIC SEQUENCE
[redacted] F.T. CONTROL
SHEET 1 OF 1

①

$$\begin{tikzcd}
 & C\text{-}2 \\
D\text{-}1 \arrow[ur] \arrow[r] & E\text{-}1
\end{tikzcd}$$

E-8 → F-1 → F-3



IU	MP	2	3	6	10	20	CONV	OS	FT	FTS
IP D-1										
		D-1 001 C-5	▨					C-2 cold		E-1 c m, (OL)
C-6 001 E-8								▨		▨
F-1 001						E-8 004			H-1 ... 6 ←	F-3 c

Marginal notes on the listing cross-reference

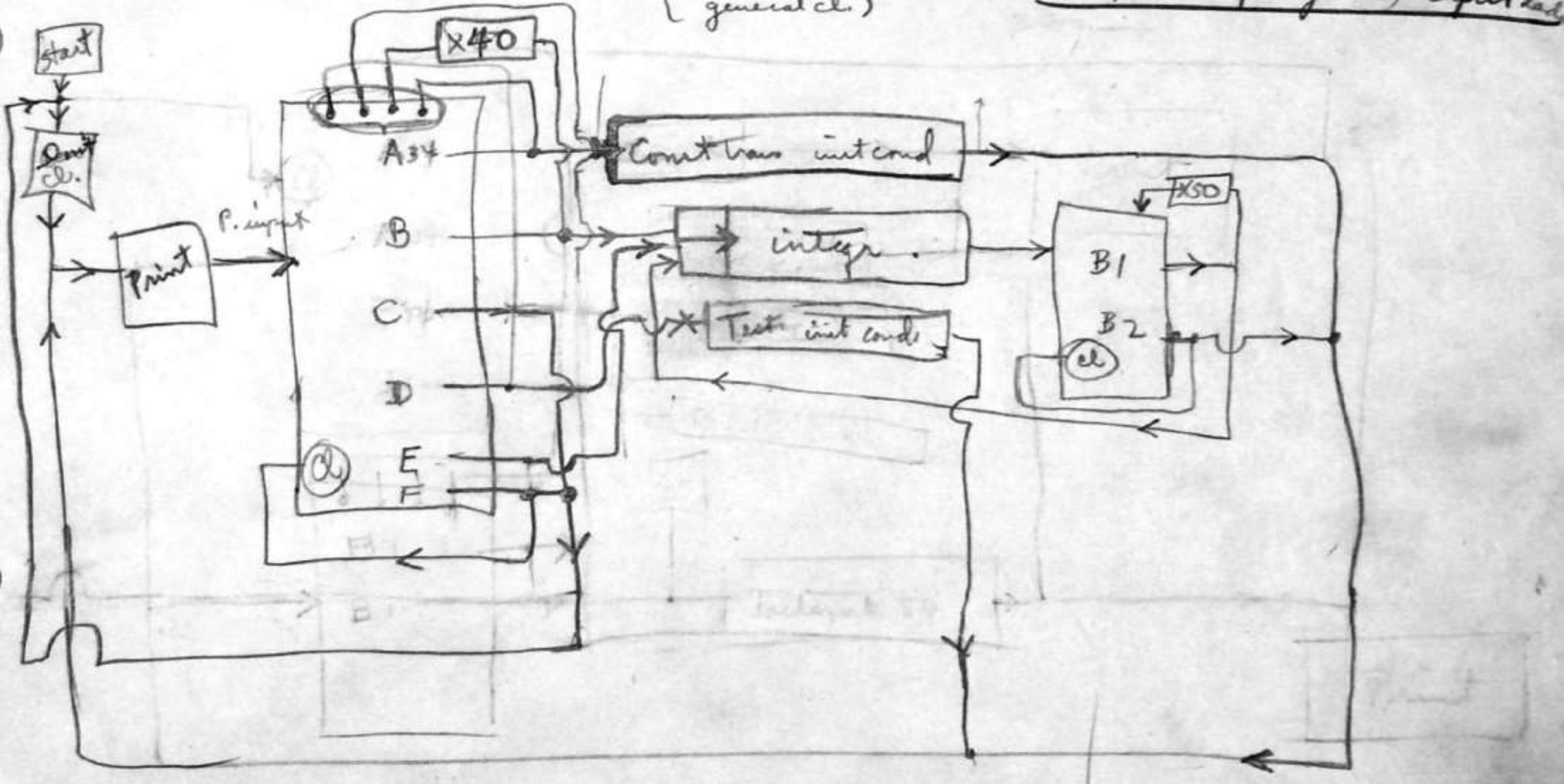
a flow-diagram used to plan the program

↓
⑨
⑥
↓

171	le	15					le
	16t	36					16t
	S'R1	38					S'R1
	12t	62		/			12t
	S'L5	56				$10^{-5}\xi_0 \to [12]_R$	S'L5
	11e	11			$(10^5\xi_1)_L$		11e
172	L12t	62		$(10^{-2}\xi_0)_R$			12t
	10e	10	67900 98765			$10^{-5}\xi_0 \to [10]_R$	10e
	le	15					12t
	le	15	567900 98576				
	le	15	09876	567900	(12)		
	le	15					
173	12t	62		567900 $10^{-2}\xi_0$			
	SL5	80		ξ_0			
	X	57	0560858040	$\xi_0(10^5\xi_1)$			
	7e	07			$(\xi_0(10^5\xi_1)) \to [7]$	560858040	
	11t	31					
	X	57	0097535376	$(10^5\xi_0)^2$			
174	SR5	52	00975	$10^{-5}\xi_1^2$			
	7t	27	0560859015				
	7t	27	1121717055		$10^{-4}\xi_1^2+2\xi_0(10^5\xi_1)$		
	7e	07				1121717055	
	12t 12e	62					
	SL5	80		ξ_0			
175	11e	11					
	11t	31					
	X	57	3225104100	ξ_0^2			
	SL5	80	04100	ξ_0^2			
	7t	27		ξ'			
	DS	46	1531717055				
176	S'-	○	5317170550				
	12t	62	5317170551				
	16e	16					
	Count						
	CT	69					

Similar diagrams were used from before the conversion

Let us assume that $\left\{\begin{array}{c}\text{printer}\\ \text{general cl.}\end{array}\right\}$ have only one program input ea



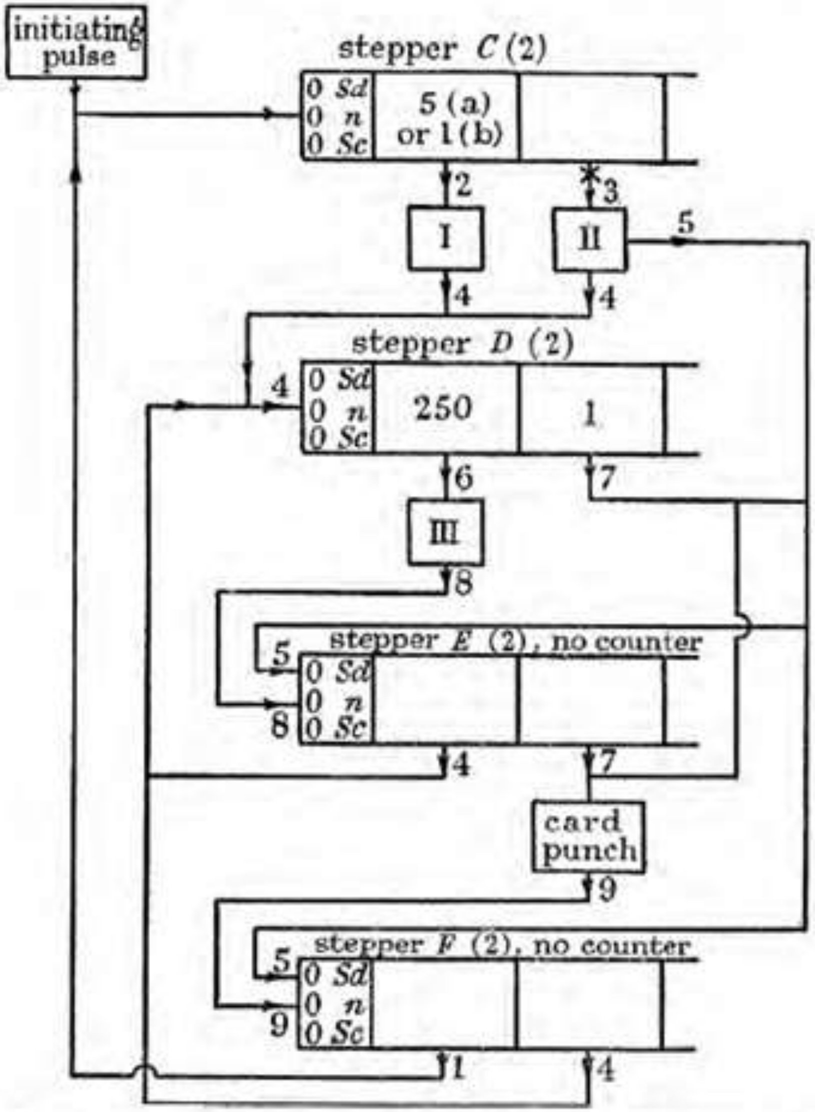
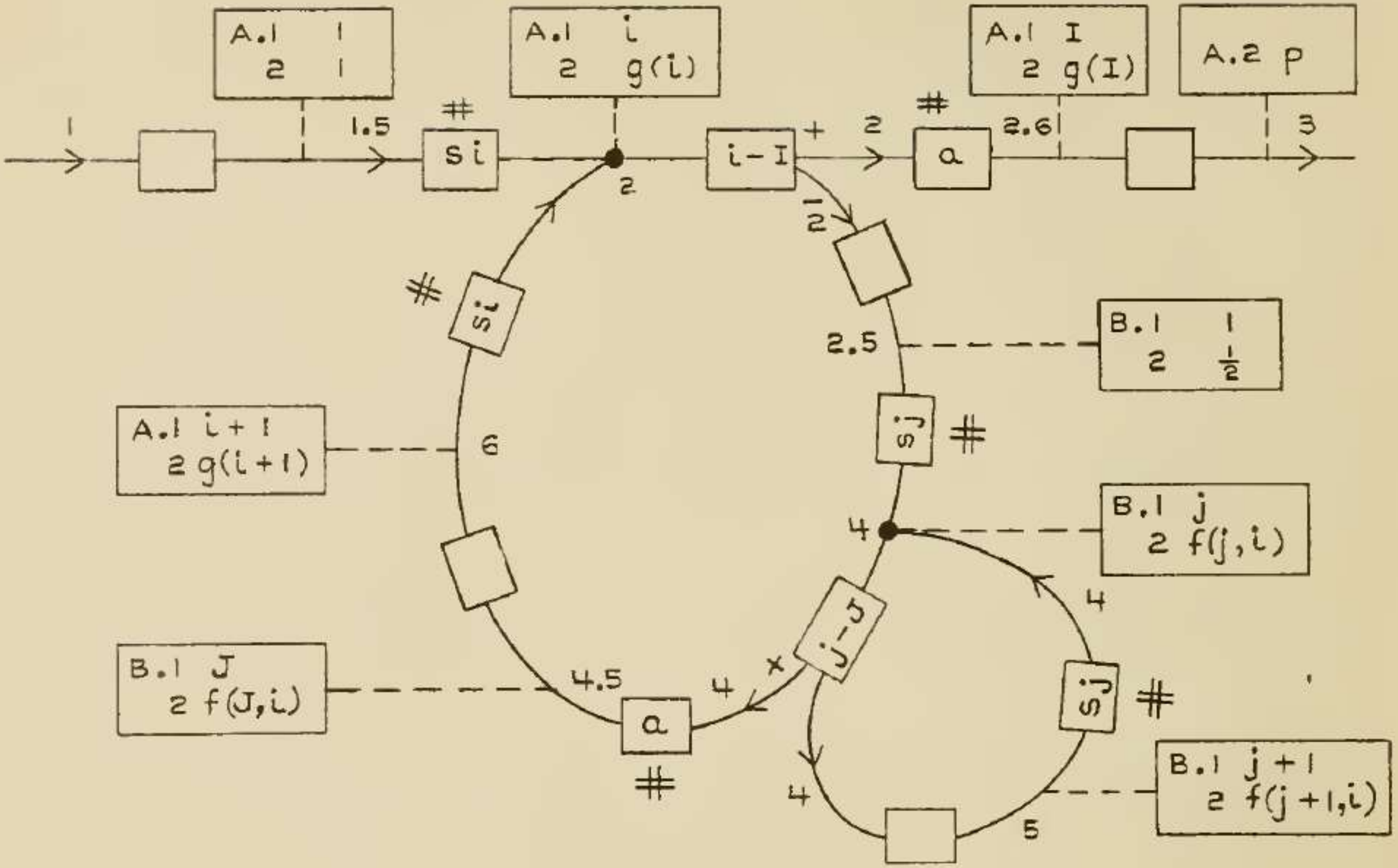
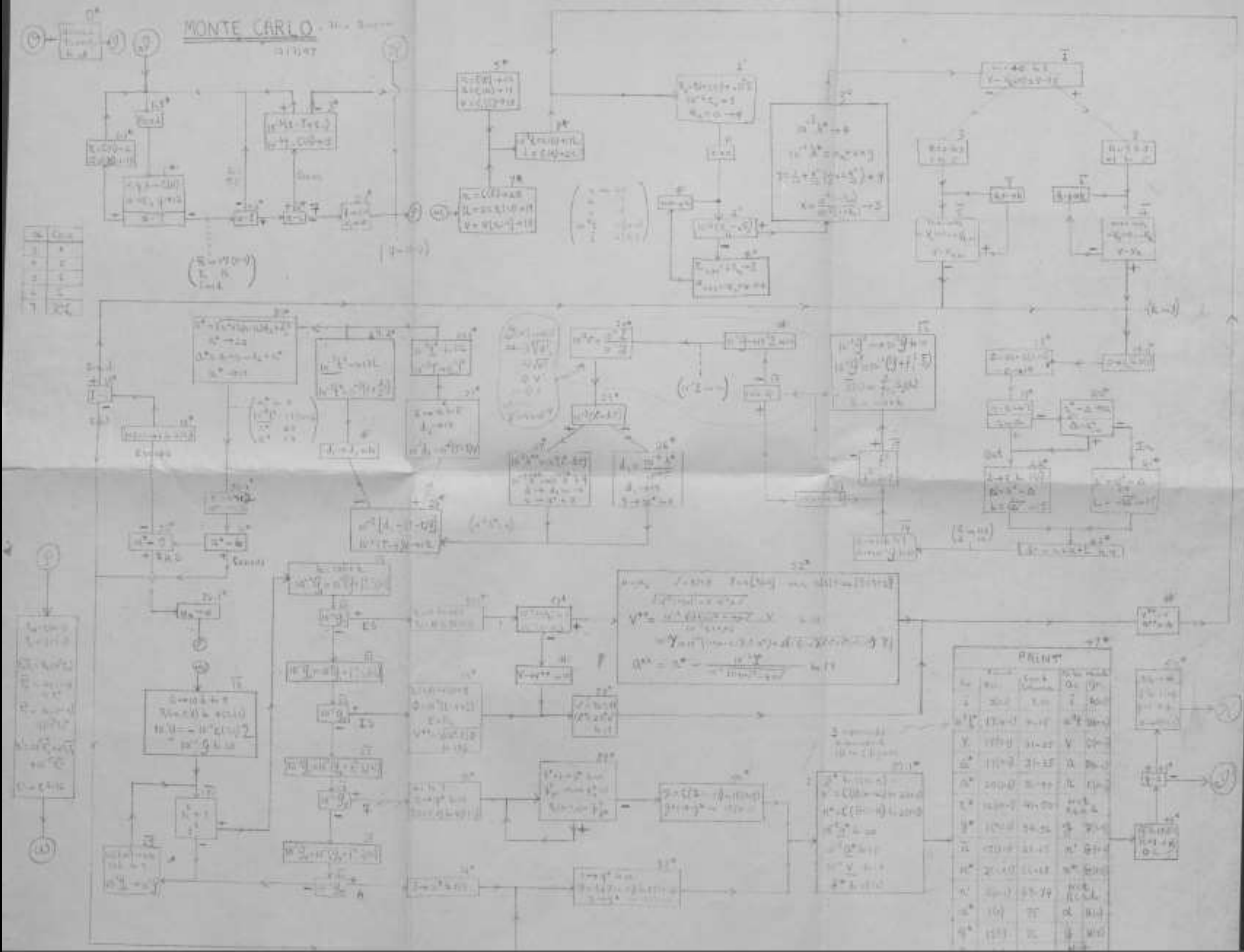
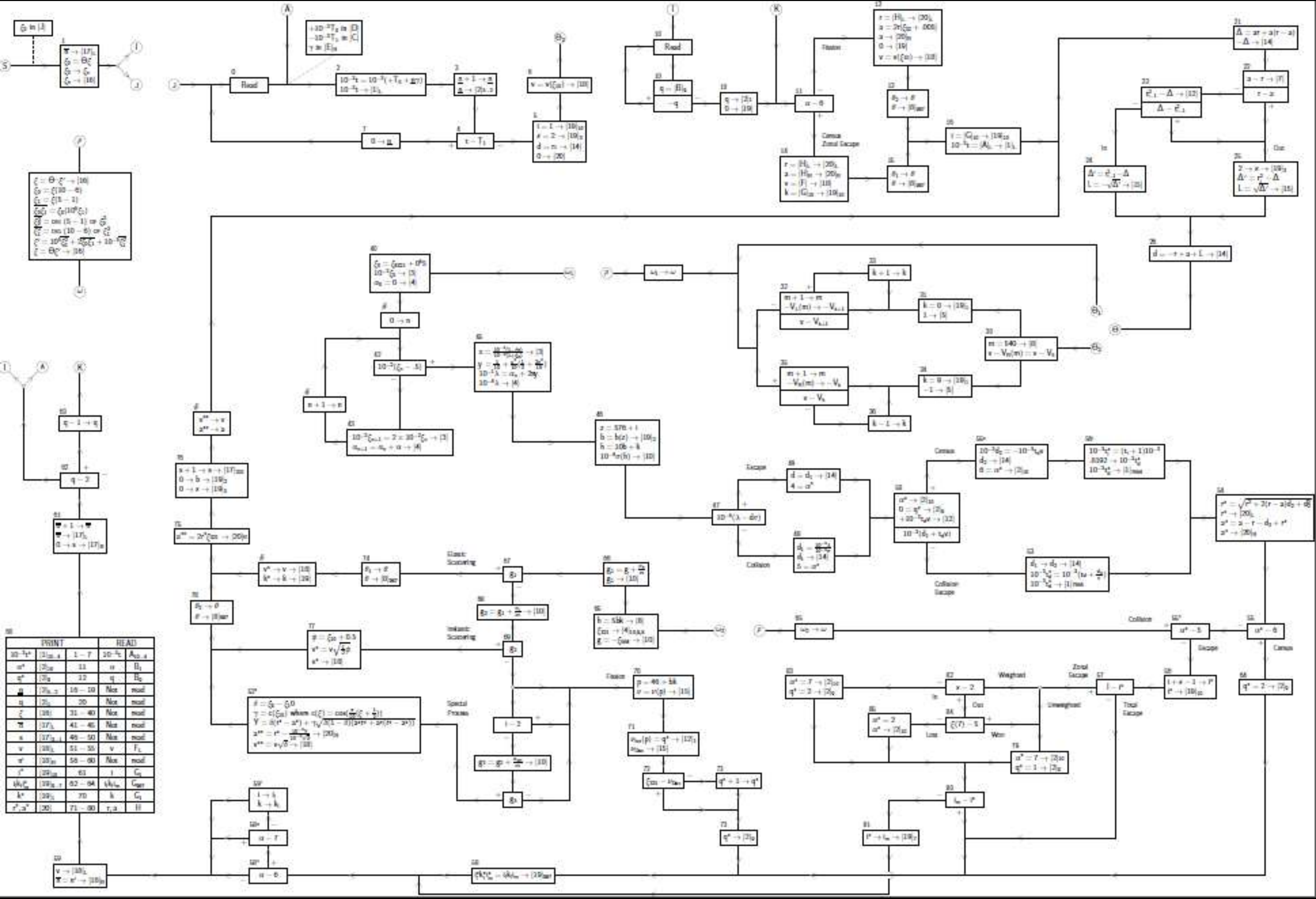


FIGURE 10. Master-programmer set-up for control of computation of null-order functions.


A.1 1
2 1
A.1 i
2 g(i)
A.1 I
2 g(I)
A.2 p
1
1.5
#
si
2
i − I
+
2
#
a
2.6
3
$\bar{2}$
B.1 1
2 $\frac{1}{2}$
2.5
#
si
sj
#
A.1 i + 1
2 g(i + 1)
6
4
B.1 j
2 f(j, i)
4
j − J
×
B.1 J
2 f(J, i)
4.5
4
a
#
sj
#
4
B.1 j + 1
2 f(j + 1, i)
5


MONTE CARLO
PRINT



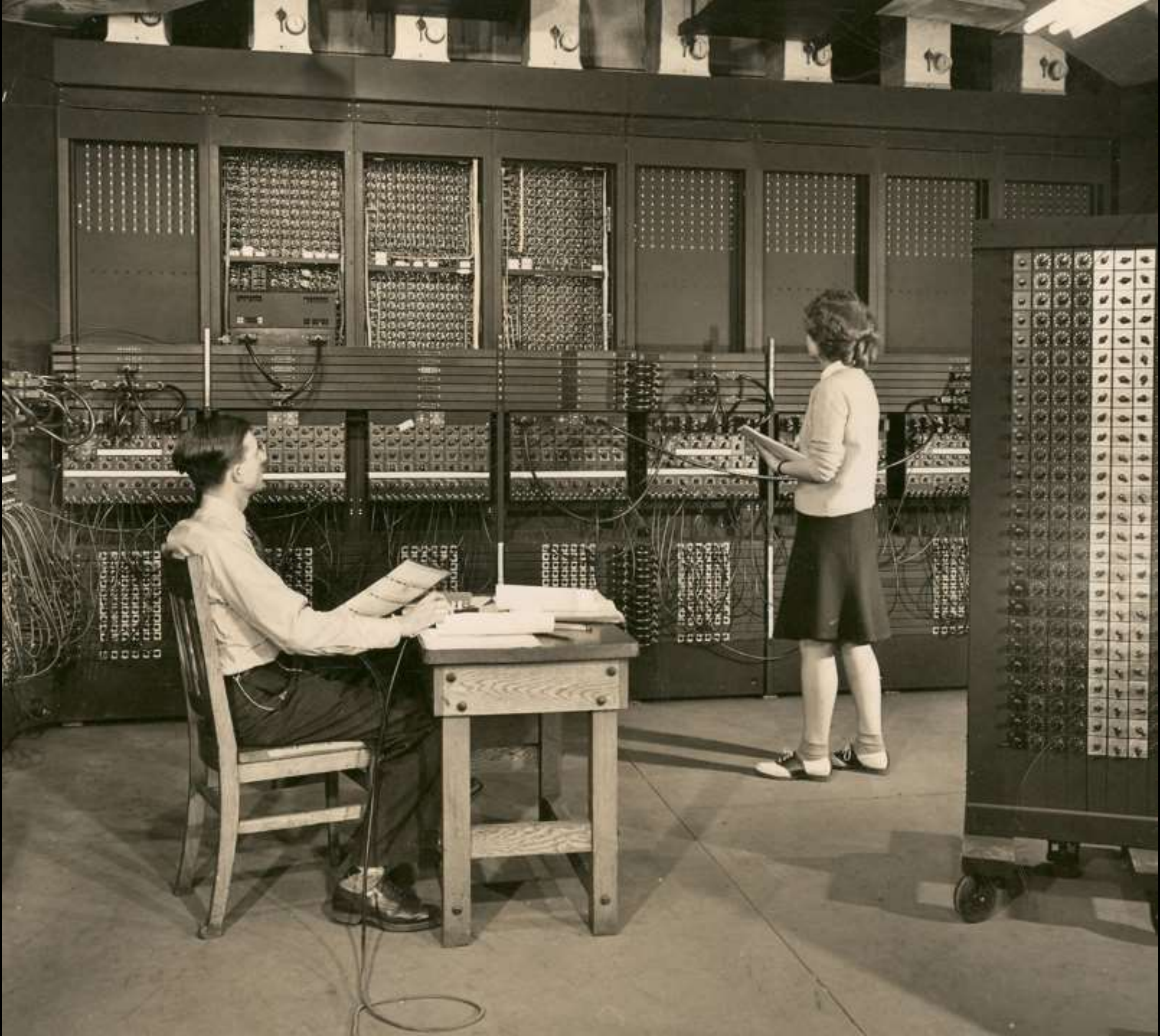
PRINT			READ	
$10^{-3}t^*$	$\|1\|_{20..4}$	1 – 7	$10^{-3}t$	$A_{10..4}$
α^*	$\|2\|_{10}$	11	α	B_1
q^*	$\|2\|_8$	12	q	B_2
n	$\|2\|_{6..2}$	16 – 19	Not	read
q	$\|2\|_1$	20	Not	read
ζ	$\|16\|$	31 – 40	Not	read
$\overline{\pi}$	$\|17\|_L$	41 – 45	Not	read
s	$\|17\|_{2..1}$	46 – 50	Not	read
v	$\|10\|_L$	51 – 55	v	F_L
π'	$\|10\|_R$	56 – 60	Not	read
i^*	$\|19\|_{10}$	61	i	G_1
$i/k_i/t^*_m$	$\|19\|_{8..7}$	62 – 64	$i/k_i/t_m$	G_{987}
k^*	$\|19\|_1$	70	k	G_1
r^*,a^*	$\|20\|$	71 – 80	r, a	H

Annotations on the listing document a

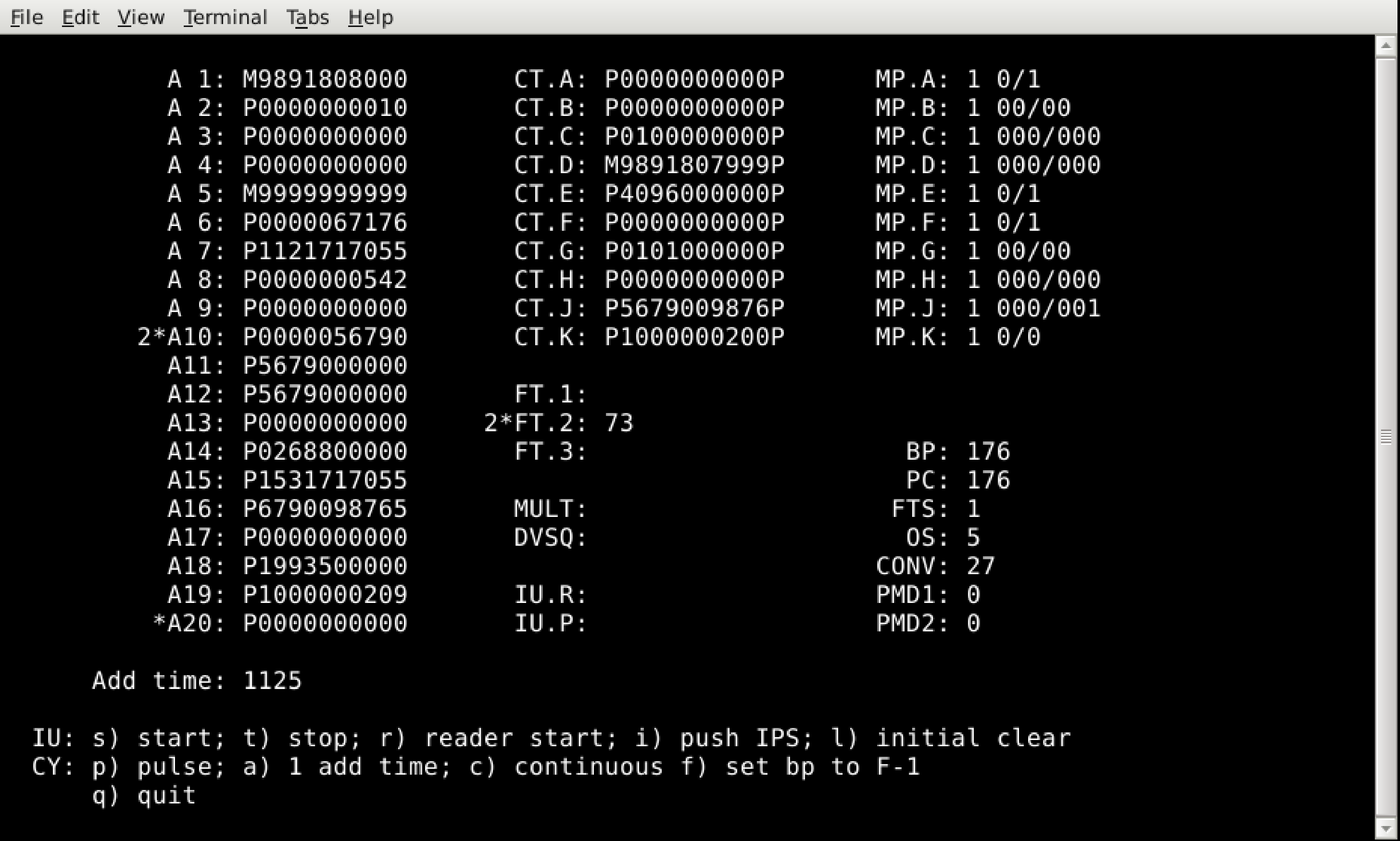
step-by-step “paper run” to check the code

↓
⑨
⑥
↓

171	ℓ	15				ℓ
	16t	36				16t
	S'R1	38				S'R1
	12t	62		/		12t
	S'L5	56			$10^{-5}\xi_0 \to [12]_R$	S'L5
	11ℓ	11			$(10^5\xi_1)_L$	11ℓ
172	L12t	62		$(10^{-2}\xi_0)_R$		12t
	10ℓ	10	67900 98765		$10^{-5}\xi_0 \to [10]_R$	10ℓ
	ℓ	15				12t
	ℓ	15	567900 98576			
	ℓ	15	09876	.567900	⑫	
	ℓ	15				
173	12t	62		567900 $10^{-2}\xi_0$		
	SL5	80		ξ_0		
	X	57	0560858040	$\xi_0(10^5\xi_1)$		
	7ℓ	07			$(\xi_0(10^5\xi_1)) \to [7]$ 560858040	
	11t	31				
	X	57	0097535376	$(10^5\xi_0)^2$		
174	SR5	52	00975	$10^5\xi_1^2$		
	7t	27	0560859015			
	7t	27	1121717055		$10^{-4}\xi_0^2 + 2\xi_0(10^5\xi_1)$	
	7ℓ	07			1121717055	
	12t 15ℓ	62 10				
	SL5	80		ξ_0		
175	11ℓ	11				
	11t	31				
	X	57	3225104100	ξ_0^2		
	SL5	80	04100	ξ_0^2		
	7t	27		ξ'		
	DS	46	1531717055			
176	S'-	0	5317170550			
	12t	62	5317170551			
	16ℓ	16				
	Count					
	CT	69				



that we can replicate on an emulator



```
       A 1: M9891808000      CT.A: P0000000000P      MP.A: 1 0/1
       A 2: P0000000010      CT.B: P0000000000P      MP.B: 1 00/00
       A 3: P0000000000      CT.C: P0100000000P      MP.C: 1 000/000
       A 4: P0000000000      CT.D: M9891807999P      MP.D: 1 000/000
       A 5: M9999999999      CT.E: P4096000000P      MP.E: 1 0/1
       A 6: P0000067176      CT.F: P0000000000P      MP.F: 1 0/1
       A 7: P1121717055      CT.G: P0101000000P      MP.G: 1 00/00
       A 8: P0000000542      CT.H: P0000000000P      MP.H: 1 000/000
       A 9: P0000000000      CT.J: P5679009876P      MP.J: 1 000/001
     2*A10: P0000056790      CT.K: P1000000200P      MP.K: 1 0/0
       A11: P5679000000
       A12: P5679000000      FT.1:
       A13: P0000000000    2*FT.2: 73
       A14: P0268800000      FT.3:                     BP: 176
       A15: P1531717055                                PC: 176
       A16: P6790098765      MULT:                    FTS: 1
       A17: P0000000000      DVSQ:                     OS: 5
       A18: P1993500000                              CONV: 27
       A19: P1000000209      IU.R:                   PMD1: 0
      *A20: P0000000000      IU.P:                   PMD2: 0

    Add time: 1125

IU: s) start; t) stop; r) reader start; i) push IPS; l) initial clear
CY: p) pulse; a) 1 add time; c) continuous f) set bp to F-1
    q) quit
```

Other dimensions of the program include

What did it do?

A Monte Carlo simulation of chain reactions in nuclear material

How did it do it?

Complex program structure (c. 800 instructions), including a subroutine to generate pseudo-random numbers

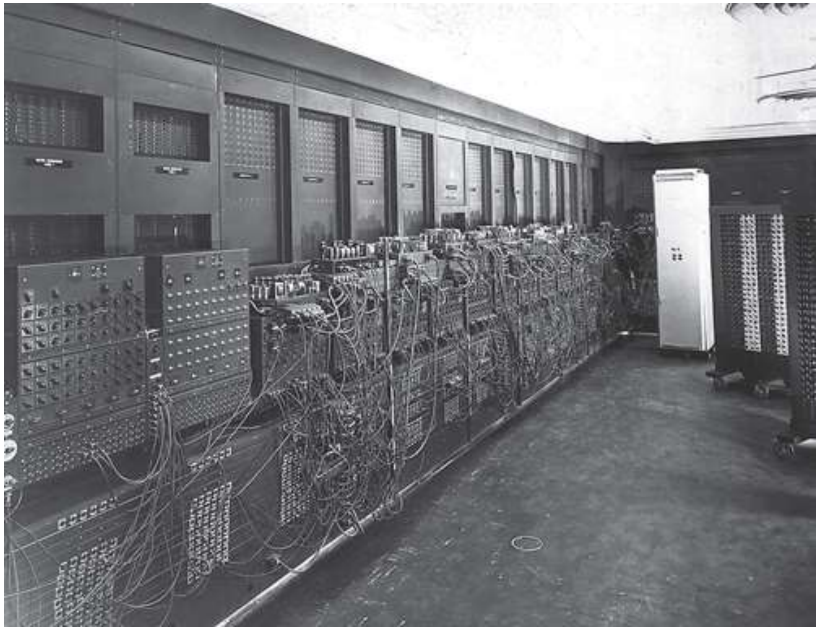
…

Moore School Programming Group

- Set up March 1947 here, under contract to BRL
  - First leader was Jean Bartik, who didn’t want to leave Philadelphia with ENIAC
  - Worked on applications and on “converter code”
  - Probably the first time anyone was hired specifically to do programming

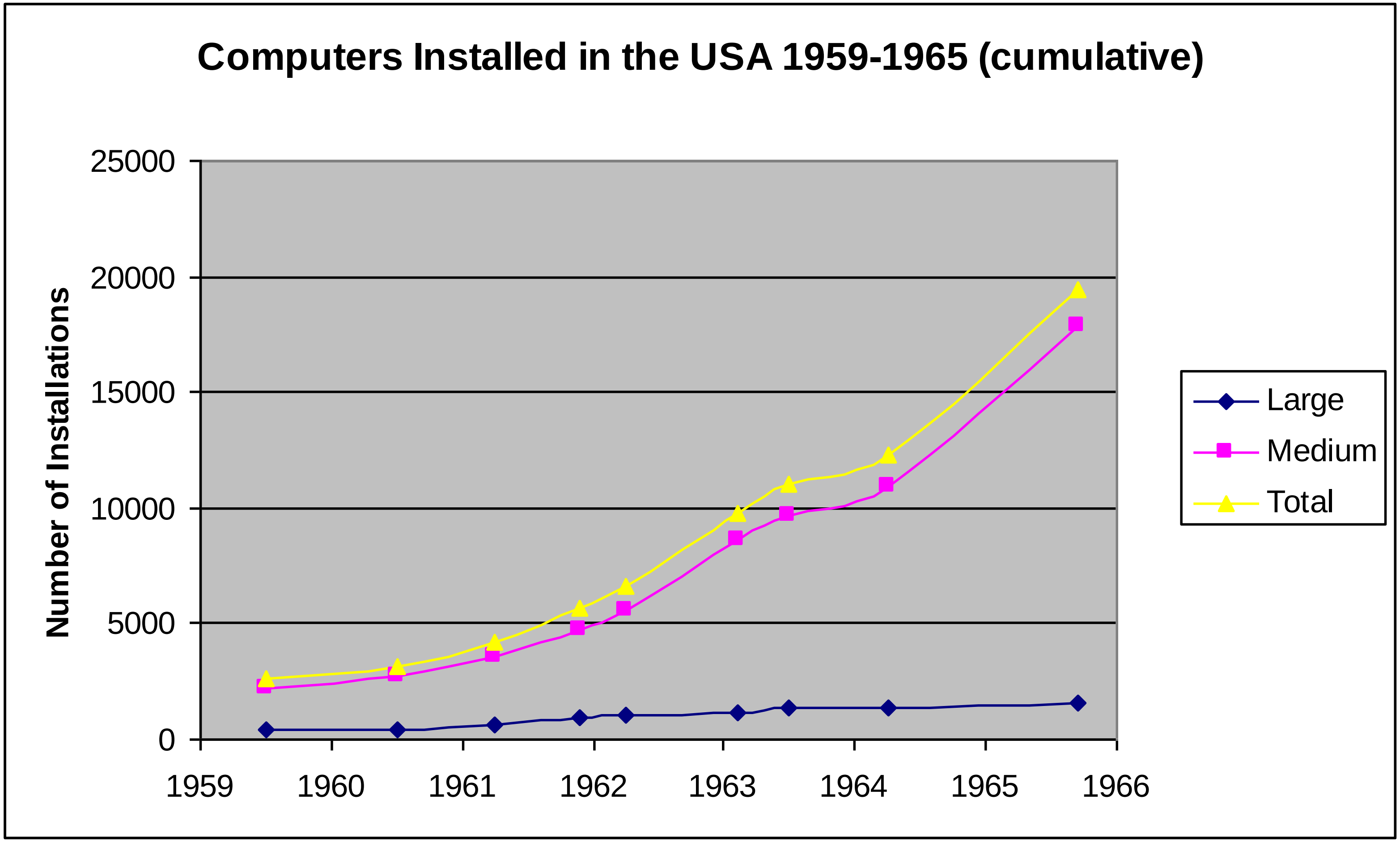
Core Memory

- ENIAC’s biggest limitation was its tiny writable electronic memory
- “Register” delay line memory ordered 1947. Delivered, but never worked.
- Random access static core memory delivered by Burroughs corporation 1953



DATA PROCESSING OPERATIONS WORK IN THE 1950S & 60S

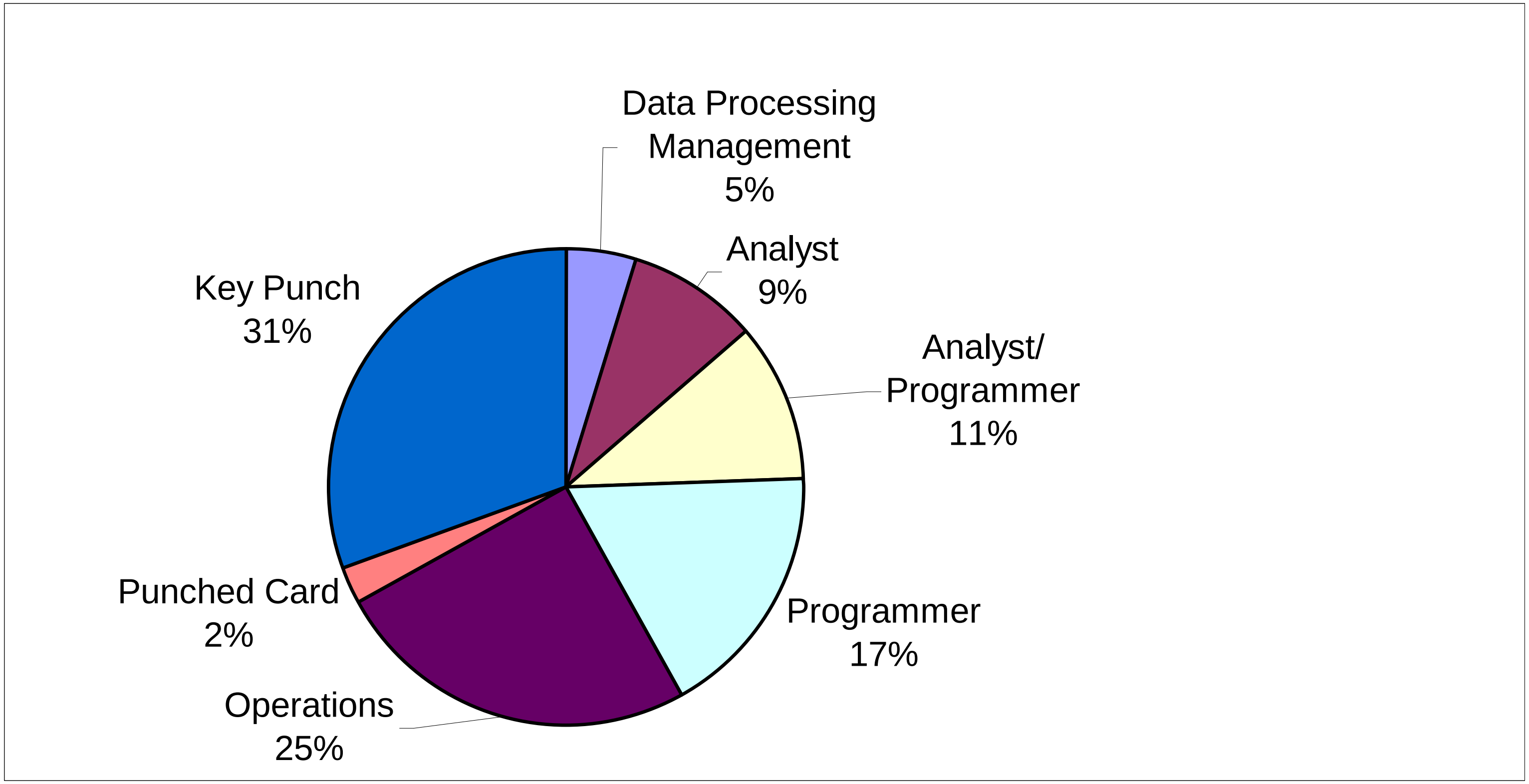
The Computer Enters Business



In 1959 there are 45,000 punched card installations.

In 1962, IBM revenue from computer products overtakes that from punched card products

Data Processing Staff, 1971



CONCLUSIONS

Female Pioneers

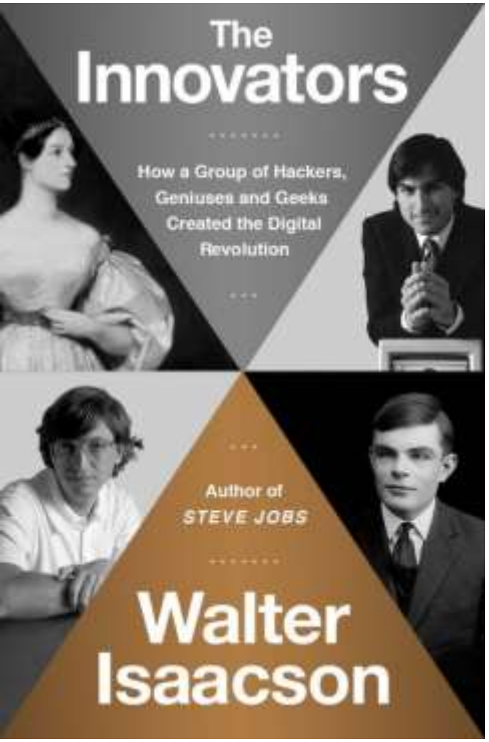
- Underrepresentation of women in IT has inspired a hunt for female role models and pioneers
- Historical figures become figureheads for events
  - Ada Lovelace (Day)
  - Grace Hopper (Celebration of Women in Computing)
- The "women of ENIAC" increasingly celebrated as "the first programmers"
  - Proof that women can program

“The Women of ENIAC”

- Title of 1996 article by W. Barkley Fritz
  - Fragments of memoirs from many women who worked on ENIAC
- Kathryn Kleiman works for years on a film, bringing more attention
  - Esp. 1996 a 1996 WSJ column by Tom Petzinger
- Jennifer S. Light 1999 paper “When Computers Were Women”

Now Applied Narrowly

- “Women of ENIAC” = the first six operators
  - Not the women who built ENIAC
  - Or Adele Goldstine who wrote the manual and trained & recruited other women
  - Or Klara von Neumann, who coded the first modern program ever run
  - Or the many later operators and programmers at BRL



Walter Isaacson

- “All the engineers who built ENIAC’s hardware were men…”
- “all the programmers who created the first general-purpose computer were women.”

The Forgotten Female Programmers Who Created Modern Tech

OCTOBER 06, 2014 3:28 AM ET

LAURA SYDELL

Jean Jennings (left) and Frances Bilas set up the ENIAC in 1946. Bilas is arranging the program settings on the Master Programmer.

Courtesy of University of Pennsylvania

If your image of a computer programmer is a young man, there's a good reason: It's true. Recently, many big tech companies revealed how few of their female employees worked in programming and technical jobs. Google had some of the highest rates: 17 percent of its technical staff is female.

It wasn't always this way. Decades ago, it was

Still forgotten?

BUSINESS DAY

Jean Bartik, Software Pioneer, Dies at 86

By STEVE LOHR APRIL 7, 2011

Jean Jennings Bartik, one of the first computer programmers and a pioneering forerunner in a technology that came to be known as software, died on March 23 at a nursing home in Poughkeepsie, N.Y. She was 86.

The cause was congestive heart disease, her son, Timothy Bartik, said.

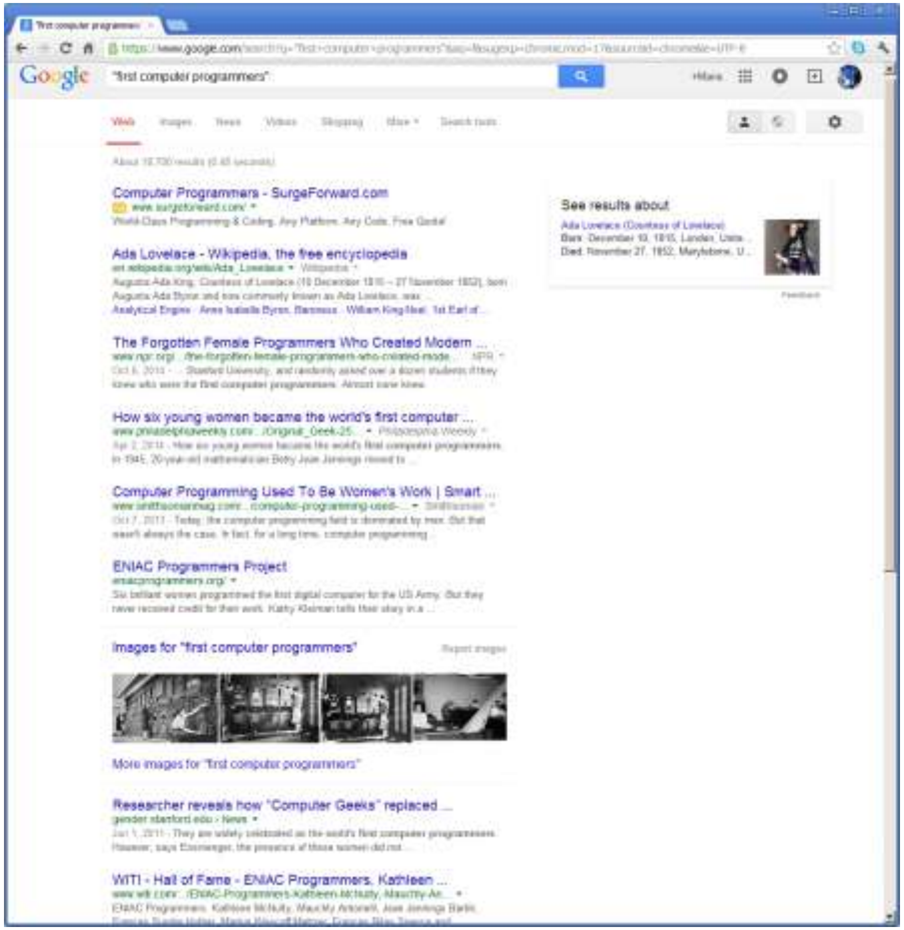
Ms. Bartik was one of the last surviving members of the group of women who programmed the Eniac, or

Welcome to our computer history museum. Once inside, click on items to explore.

Click on the door to proceed.

©2009 Northwest Missouri State University

Google “first programmers”



"first computer programmers"

Computer Programmers - SurgeForward.com

Ada Lovelace - Wikipedia, the free encyclopedia

The Forgotten Female Programmers Who Created Modern ...

How six young women became the world's first computer ...

Computer Programming Used To Be Women's Work | Smart ...

ENIAC Programmers Project

Images for "first computer programmers"

More images for "first computer programmers"

Researcher reveals how "Computer Geeks" replaced ...

WITI - Hall of Fame - ENIAC Programmers, Kathleen ...

See results about

- Top hit is Ada Lovelace
- Next six hits are the ENIAC women
- But… Nobody celebrates the “first computer operators.”

Girls Who Code vs. Women Who Operate

- We can’t fix the “Great Man” view of history by adding a few “Great Women”
    - Insistence on genius and innovative breakthroughs
- By 1950s, computer operations and keypunch work seen as almost blue collar
    - Also the computer work most likely to be done by women
- “reclaiming these women as the first programmers…glosses over the hierarchies...among operators, coders, and analysts.”
  (Wendy Hui Kyong Chun)

BEFORE GATES, ZUCKERBERG, OR JOBS, 6 WOMEN PROGRAMMED THE FIRST DIGITAL COMPUTER

The Birth of Programming

Cloud Computing

The Age of the Cloud

- "Cloud" metaphor hides from view the actual physical infrastructure and challenges of computing…
- … just as a focus on genius, conceptual breakthroughs, and programming has hidden the historical reality of early computing from view.

“Innovation” Associated With

- Science, Progress, the Future
  - Silicon Valley
  - Billionaires
- History, by definition, is about the past
- Famous Silicon Valley venture capitalist Vinhod Kholsa just wrote…

> If subjects like history and literature are focused on too early, it is easy for someone not to learn to think for themselves and not to question assumptions, conclusions, and expert philosophies. This can do a lot of damage.

One Ironic Proposal

- *The Maintainers: How a Group of Bureaucrats, Standards Engineers, and Introverts Made Digital Infrastructures That Kind of Work Most of the Time* – Andrew Russell
- “The Maintainers” conference is running at Stevens University, April 8

Closing Thoughts

- History matters, even though IT has always been focused on the future.
- There is more to history than “firsts” and lone geniuses. Don’t believe Hollywood.
- Successful IT innovation has always depended on execution, operations, logistics, and doing the little things well.

The Work of Innovation

- ENIAC is the story of
  - Smart (to very smart)
  - Hardworking (to obsessive)
  - Flawed
- men and women who came together to do many kinds of work more or less collaboratively.
- They were in the right places at the right time, supported by bigger institutions.
- They did their jobs well enough in challenging times.
- They changed the world, without superpowers.
- All of them did that, even the secretary and the draughtswomen and the wirewomen whose names are forgotten.

Find out more…

- My website www.tomandmaria.com/tom
- Project website: www.EniacInAction.com
- Book, *ENIAC in Action: Making and Remaking the Modern Computer*, MIT Press, 2016.