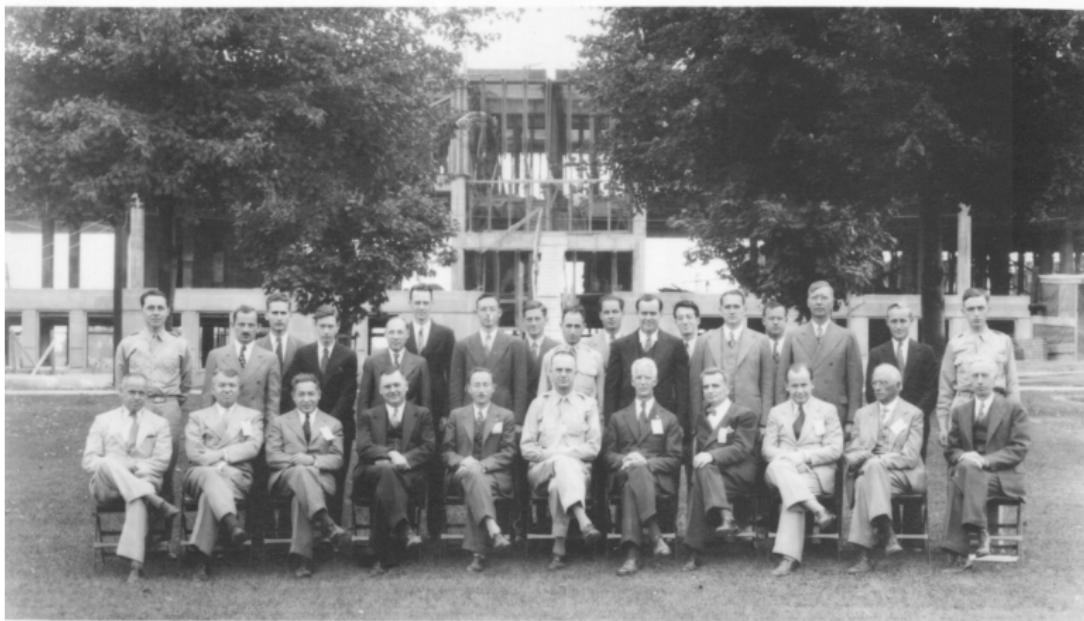


Hidden Pioneers: Programmers of the ENIAC and the Birth of Modern Computing

Nelson Jovel • Education Commonwealth Project •
joveln@gmail.com

FIRST MEETING OF THE SCIENTIFIC ADVISORY COMMITTEE
BALLISTIC RESEARCH LABORATORY SEPTEMBER 1940



Lt. Gillon	Mr. Moerman	Mr. Dickinson	Mr. Carr	Mr. McNeilly	Mr. Shanks	Mr. Leeder	Lt. Steele			
Mr. Lane	Mr. Reno	Mr. Hitchcock	Dr. Charters	Capt. Simon	Dr. Hodge	Mr. Beeman	Mr. Toich	Mr. Gay		
Mr. Kent	Prof. Urey	Prof. Rabi	Dr. Dryden	Dr. Lewis	Col. Zornig	Dr. Hull	Prof. von Karman	Prof. von Neumann	Prof. Russell	Dr. Dederick

Howitzer

Example Artillary

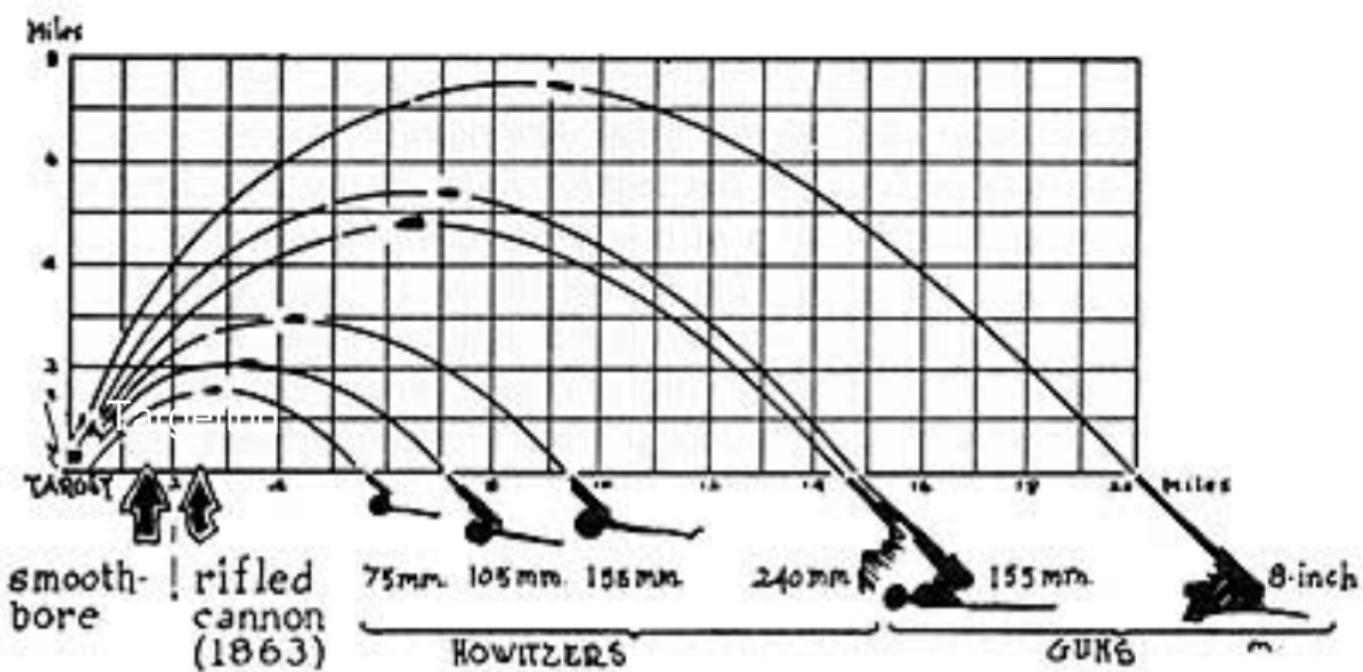


Tank



Anti-Aircraft





600	30.6	1.9	1.06	19	1	1.9	0.3	0.03
700	35.8	2.2	0.91	19	1	2.3	0.4	0.03
800	41.1	2.5	0.79	19	1	2.6	0.5	0.04
900	46.4	2.8	0.71	19	1	2.9	0.6	0.04
1000	51.7	3.2	0.63	19	1	3.2	0.7	0.04
1100	57.1	3.5	0.57	19	1	3.6	0.8	0.05
1200	62.5	3.8	0.53	18	1	3.9	0.8	0.05
1300	67.9	4.2	0.48	18	1	4.3	0.9	0.05
1400	73.4	4.5	0.45	18	1	4.6	1.0	0.06
1500	78.9	4.9	0.42	18	1	4.9	1.1	0.06
1600	84.4	5.2	0.39	18	2	5.3	1.2	0.07
1700	90.0	5.5	0.37	18	2	5.8	1.3	0.07
1800	95.6	5.9	0.35	18	2	6.0	1.4	0.07
1900	101.3	6.2	0.33	18	2	6.3	1.6	0.08
2000	107.0	6.6	0.31	17	2	6.7	1.7	0.08
2100	112.8	6.9	0.30	17	2	7.0	1.8	0.08
2200	118.5	7.3	0.28	17	2	7.4	1.9	0.09
2300	124.4	7.6	0.27	17	2	7.7	2.0	0.09
2400	130.3	8.0	0.26	17	2	8.1	2.1	0.09
2500	136.2	8.3	0.25	17	2	8.4	2.2	0.10
2600	142.2	8.7	0.24	17	2	8.8	2.3	0.10
2700	148.2	9.1	0.23	17	2	9.2	2.5	0.10
2800	154.3	9.4	0.22	16	2	9.5	2.6	0.11
2900	160.4	9.8	0.21	16	3	9.9	2.7	0.11
3000	166.6	10.2	0.20	16	3	10.3	2.9	0.12
mean	172.8	10.6	0.20	16	3	10.6	3.0	0.12

FT 155-AM-2

TABLE H

CHARGE
4GPROJ, HE, M107
FUZE, PD, M577

ROTATION - RANGE

CORRECTIONS TO RANGE, IN METERS, TO COMPENSATE
FOR THE ROTATION OF THE EARTH

RANGE METERS	AZIMUTH OF TARGET - MILS									
	0 3200	200 3000	400 2800	600 2600	800 2400	1000 2200	1200 2000	1400 1800	1600 1600	
500	0	0	-1+	-1+	-2+	-2+	-2+	-2+	-2+	
1000	0	-1+	-2+	-2+	-3+	-4+	-4+	-4+	-4+	
1500	0	-1+	-3+	-4+	-5+	-5+	-6+	-6+	-7+	
2000	0	-2+	-3+	-5+	-6+	-7+	-8+	-8+	-9+	
2500	0	-2+	-4+	-6+	-7+	-9+	-10+	-10+	-10+	
3000	0	-2+	-5+	-7+	-9+	-10+	-11+	-12+	-12+	
3500	0	-3+	-5+	-8+	-10+	-12+	-13+	-14+	-14+	
4000	0	-3+	-6+	-9+	-11+	-13+	-14+	-15+	-15+	
4500	0	-3+	-8+	-9+	-12+	-14+	-16+	-16+	-17+	
5000	0	-4+	-7+	-10+	-13+	-15+	-17+	-18+	-18+	
5500	0	-4+	-7+	-11+	-14+	-16+	-18+	-19+	-19+	
6000	0	-4+	-8+	-11+	-14+	-17+	-18+	-20+	-20+	
6500	0	-4+	-8+	-11+	-14+	-17+	-19+	-20+	-20+	
7000	0	-4+	-8+	-11+	-15+	-17+	-19+	-20+	-21+	
7500	0	-4+	-8+	-11+	-14+	-17+	-18+	-20+	-20+	
8000	0	-3+	-7+	-10+	-13+	-15+	-16+	-17+	-18+	

COMPUTING
DIVISION
COMPUTING
SECTION

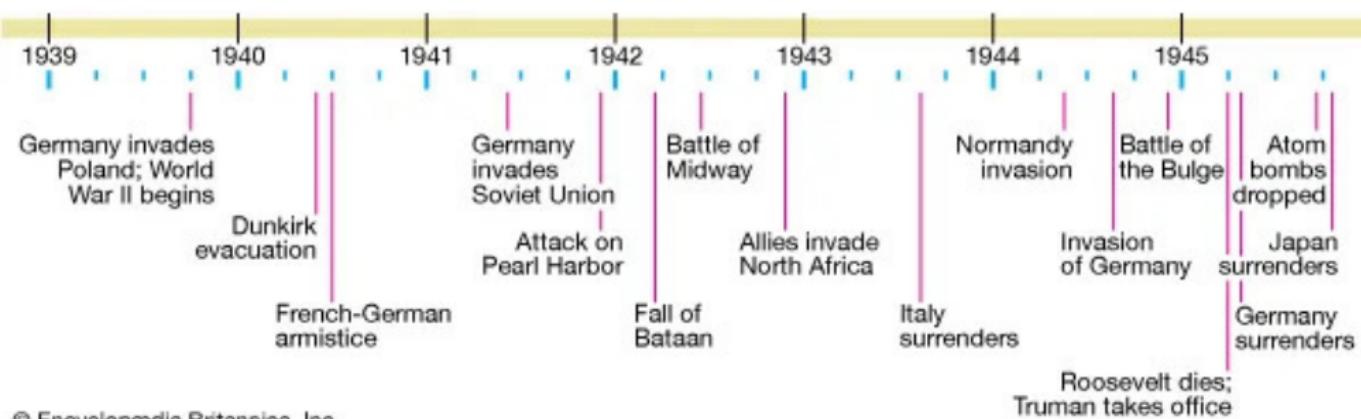


DIFFERENTIAL ANALYZER





Chief Events of World War II, 1939–45



© Encyclopædia Britannica, Inc.



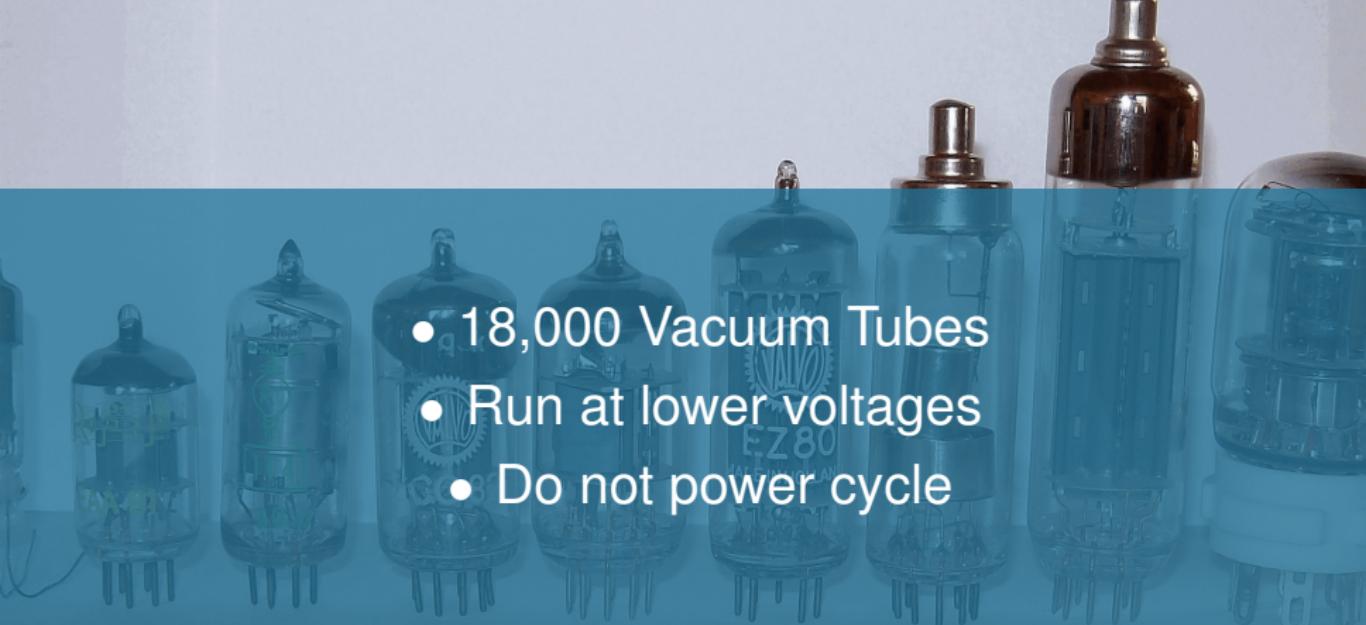


- Designers: John Mauchley and J. Presper Eckert

- The Use of High Speed Vacuum Tube Devices for Calculating
- 1000 times faster than the differential analyzer
 - General Purpose computer



- Projected Cost: 61,000
- Actual Cost: 500,000
- Today: 9,000,000+

- 
- 18,000 Vacuum Tubes
 - Run at lower voltages
 - Do not power cycle





• ENIAC



• ENIAC
• BINAC

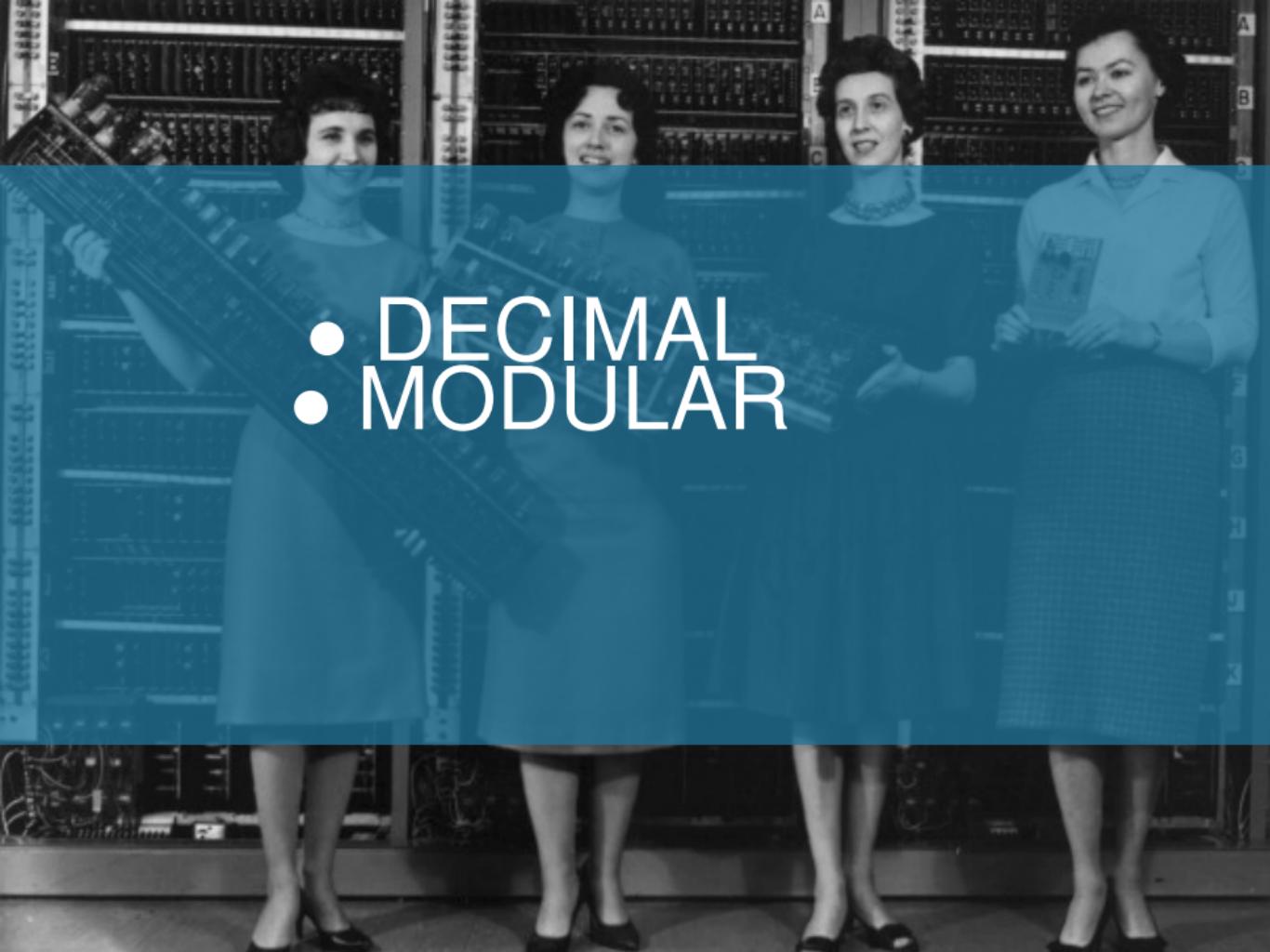
- 
- ENIAC
 - BINAC
 - EDVAC

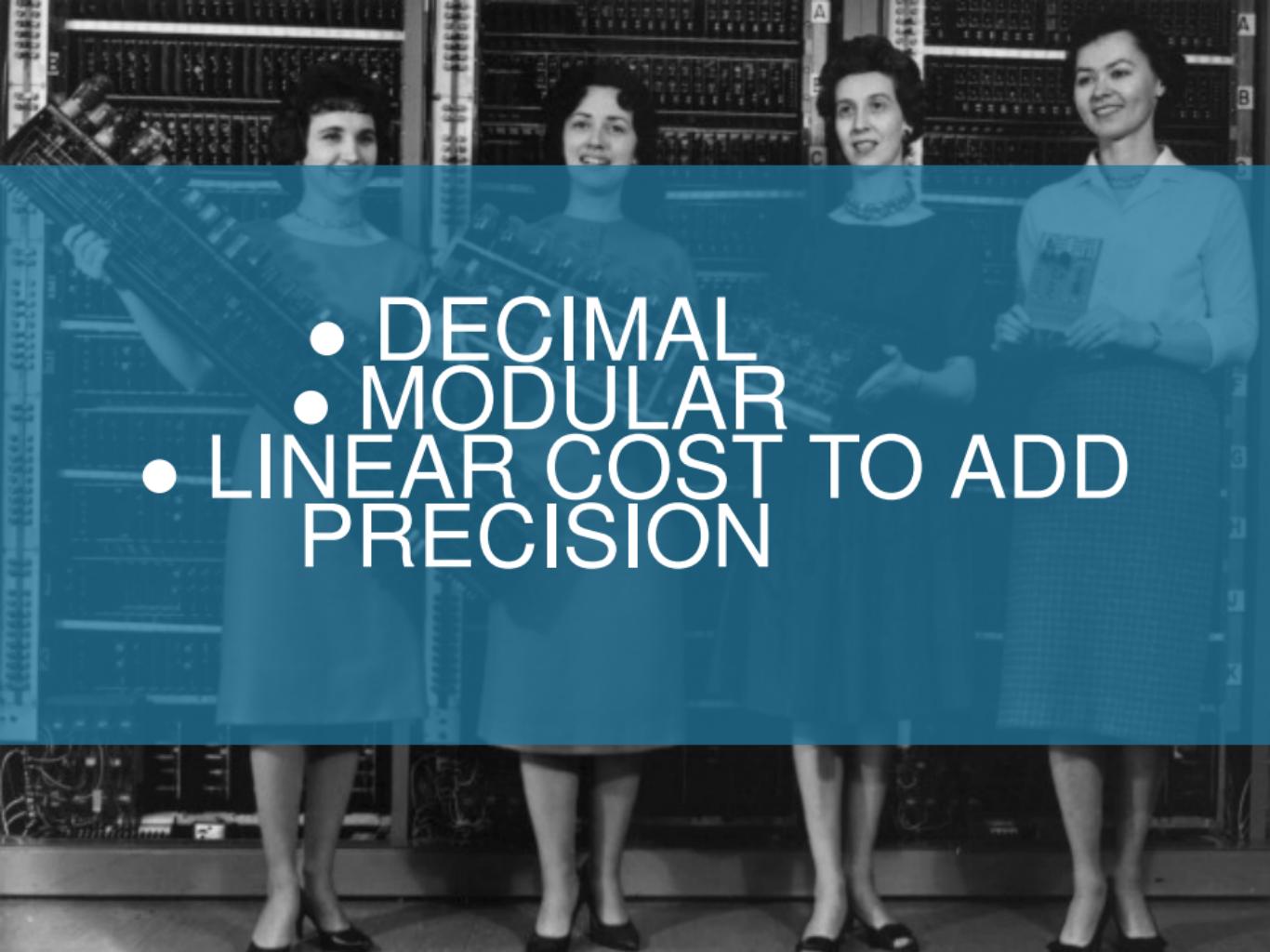
- ENIAC
- BINAC
- EDVAC
- UNIVAC





• DECIMAL

- 
- DECIMAL
 - MODULAR

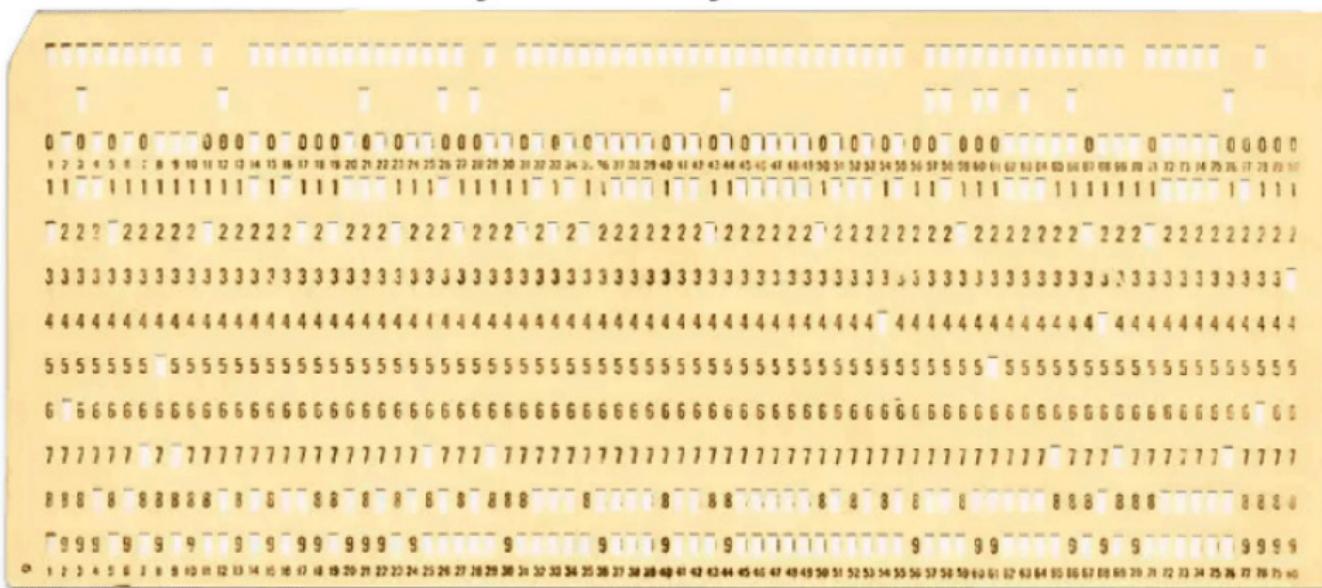
- 
- DECIMAL
 - MODULAR
 - LINEAR COST TO ADD
PRECISION



IBM CARD PUNCH



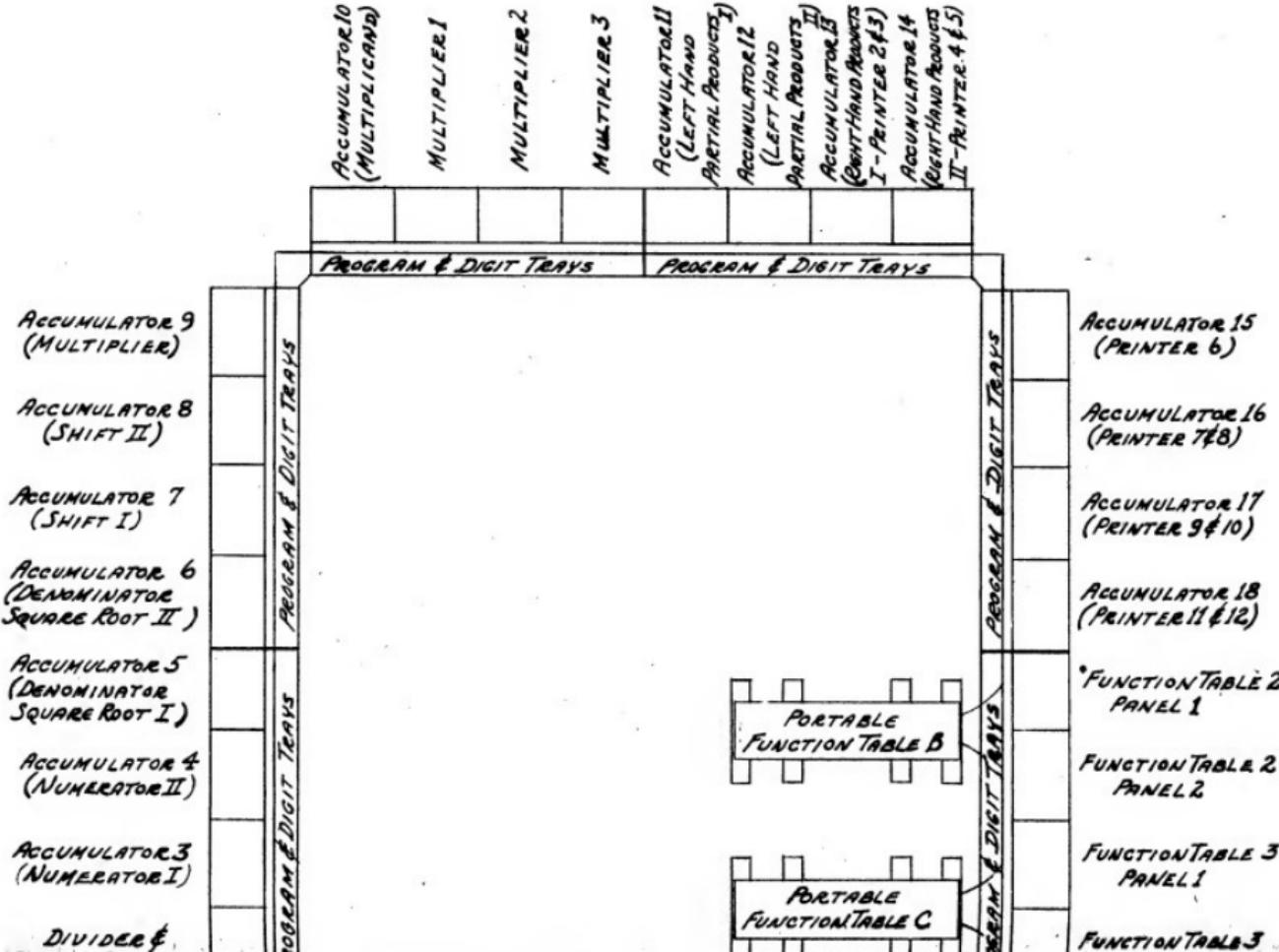
Example of a punch card



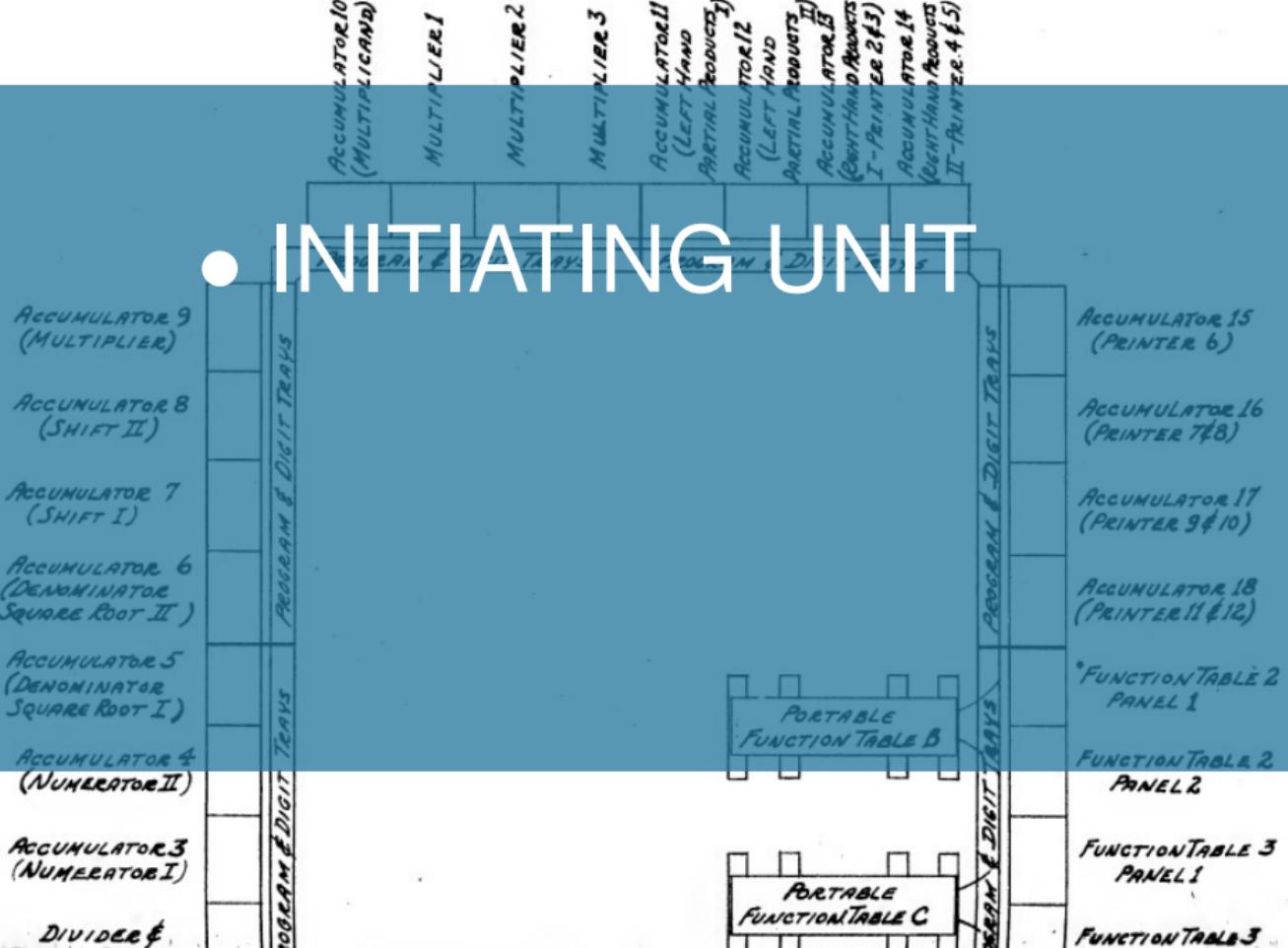


A black and white photograph of a woman from the mid-20th century. She has dark, curly hair and is wearing a dark, long-sleeved dress with a row of buttons down the front. A pearl necklace is visible around her neck. She is standing behind a massive, sprawling stack of paper, which appears to be several thousand pages thick. In the background, there's a filing cabinet and some office equipment. The entire scene is overlaid with a solid blue rectangular shape.

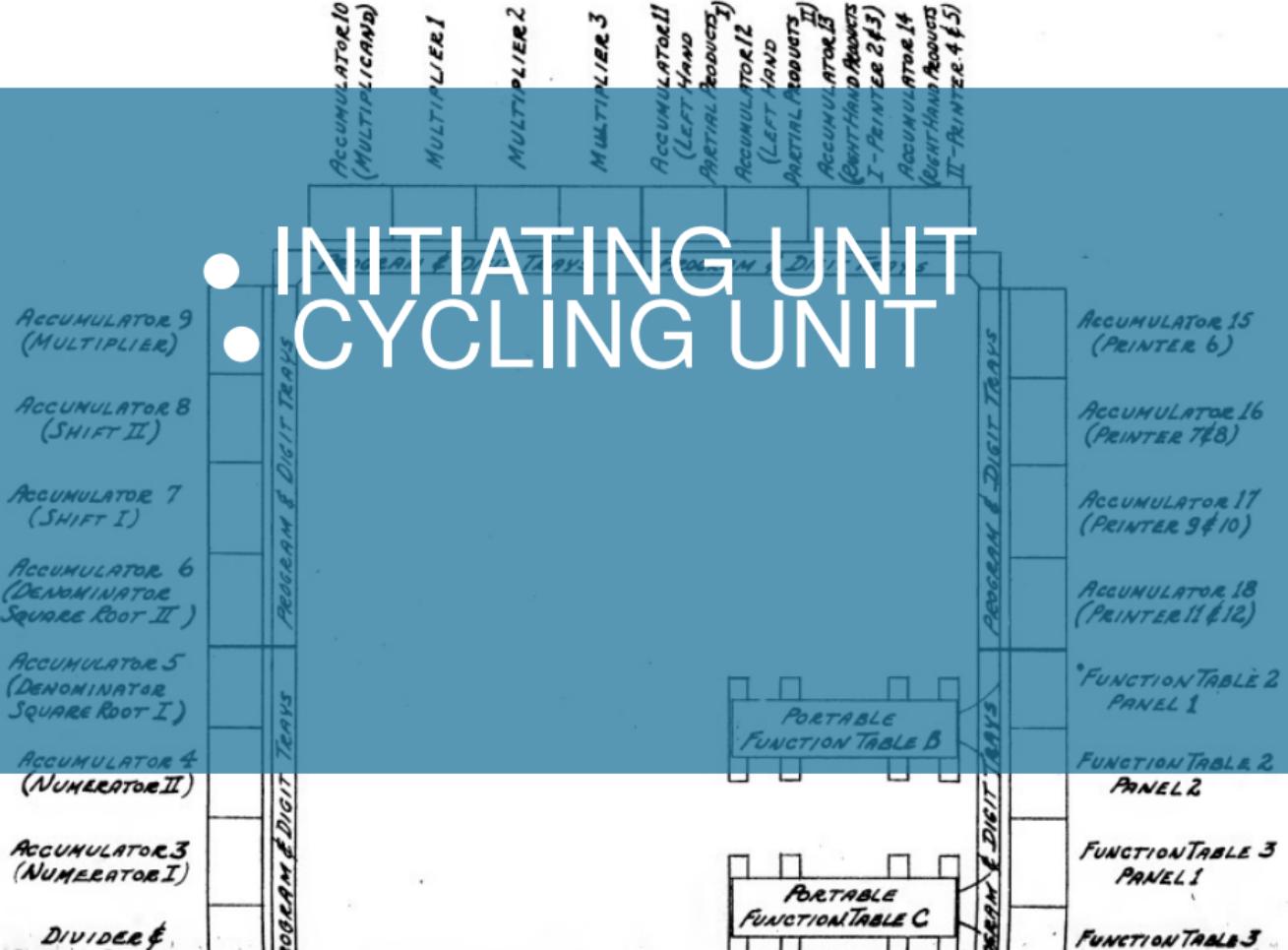
5MB OF DATA



• INITIATING UNIT



• INITIATING UNIT • CYCLING UNIT



• INITIATING UNIT • CYCLING UNIT • MASTER PROGRAMMER

ACCUMULATOR 9
(MULTIPLIER)

ACCUMULATOR 8
(SHIFT II)

ACCUMULATOR 7
(SHIFT I)

ACCUMULATOR 6
(DENOMINATOR
SQUARE ROOT II)

ACCUMULATOR 5
(DENOMINATOR
SQUARE ROOT I)

ACCUMULATOR 4
(NUMERATOR II)

ACCUMULATOR 3
(NUMERATOR I)

DIVIDER 4



ACCUMULATOR 15
(PRINTER 6)

ACCUMULATOR 16
(PRINTER 7&8)

ACCUMULATOR 17
(PRINTER 9&10)

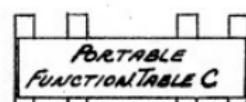
ACCUMULATOR 18
(PRINTER 11&12)

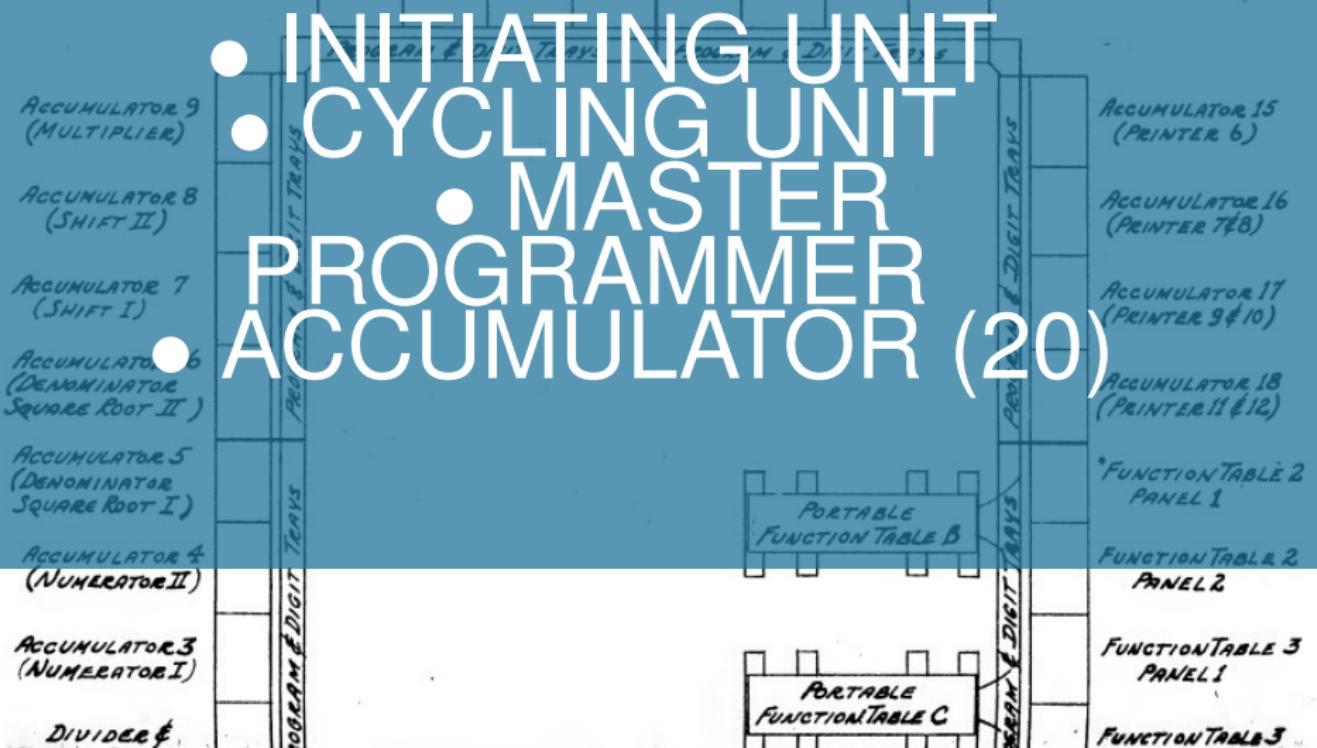
*FUNCTION TABLE 2
PANEL 1

FUNCTION TABLE 2
PANEL 2

FUNCTION TABLE 3
PANEL 1

FUNCTION TABLE 3
PANEL 2





• INITIATING UNIT • CYCLING UNIT • MASTER PROGRAMMER ACCUMULATOR (20)

• DIVIDER/SQUARE ROOTER - 35 PER SECOND

ACCUMULATOR 9
(MULTIPLIER)

ACCUMULATOR 8
(SHIFT II)

ACCUMULATOR 7
(SHIFT I)

ACCUMULATOR 6
(DENOMINATOR
SQUARE ROOT II)

ACCUMULATOR 5
(DENOMINATOR
SQUARE ROOT I)

ACCUMULATOR 4
(NUMERATOR II)

ACCUMULATOR 3
(NUMERATOR I)

DIVIDER

PROGRAM 5-DIGIT TRAYS

ACCUMULATOR 10
(MULTIPLICAND)

MULTIPLIER 1

MULTIPLIER 2

MULTIPLIER 3

ACCUMULATOR 11
(LEFT HAND
MULTIPLYING PRODUCTS)

ACCUMULATOR 12
(RIGHT HAND
MULTIPLYING PRODUCTS)

ACCUMULATOR 13
(LEFT HAND
DIVIDERS
INTER 2 & 3)

ACCUMULATOR 14
(RIGHT HAND
DIVIDERS
INTER 4 & 5)

ACCUMULATOR 15
(PRINTER 6)

ACCUMULATOR 16
(PRINTER 7&8)

ACCUMULATOR 17
(PRINTER 9&10)

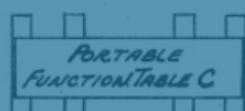
ACCUMULATOR 18
(PRINTER 11&12)

*FUNCTION TABLE 2
PANEL 1

FUNCTION TABLE 2
PANEL 2

FUNCTION TABLE 3
PANEL 1

FUNCTION TABLE 3
PANEL 2



• DIVIDER/SQUARE ROOTER - 35 PER SECOND • MULTIPLIER - 357 MULTIPLICATIONS PER SECOND

ACCUMULATOR 9
(MULTIPLIER)

ACCUMULATOR 8
(SHIFT II)

ACCUMULATOR 7
(SHIFT I)

ACCUMULATOR 6
(DENOMINATOR
SQUARE ROOT II)

ACCUMULATOR 5
(DENOMINATOR
SQUARE ROOT I)

ACCUMULATOR 4
(NUMERATOR II)

ACCUMULATOR 3
(NUMERATOR I)

DIVIDER

ACCUMULATOR 10
(MULTIPLICAND)
MULTIPLIER 1
MULTIPLIER 2
MULTIPLIER 3

ACCUMULATOR 11
(LEFT HAND
MULTIPLYER PRODUCTS)
MULTIPLIER 12
(RIGHT HAND
MULTIPLYER PRODUCTS)
ACCUMULATOR 13
(RIGHT HAND
PRODUCTS)
ACCUMULATOR 14
(RIGHT HAND
PRODUCTS)
ACCUMULATOR 15
(RIGHT HAND
PRODUCTS)

ACCUMULATOR 15
(PRINTER 6)

ACCUMULATOR 16
(PRINTER 7&8)

ACCUMULATOR 17
(PRINTER 9&10)

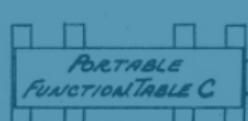
ACCUMULATOR 18
(PRINTER 11&12)

*FUNCTION TABLE 2
PANEL 1

FUNCTION TABLE 2
PANEL 2

FUNCTION TABLE 3
PANEL 1

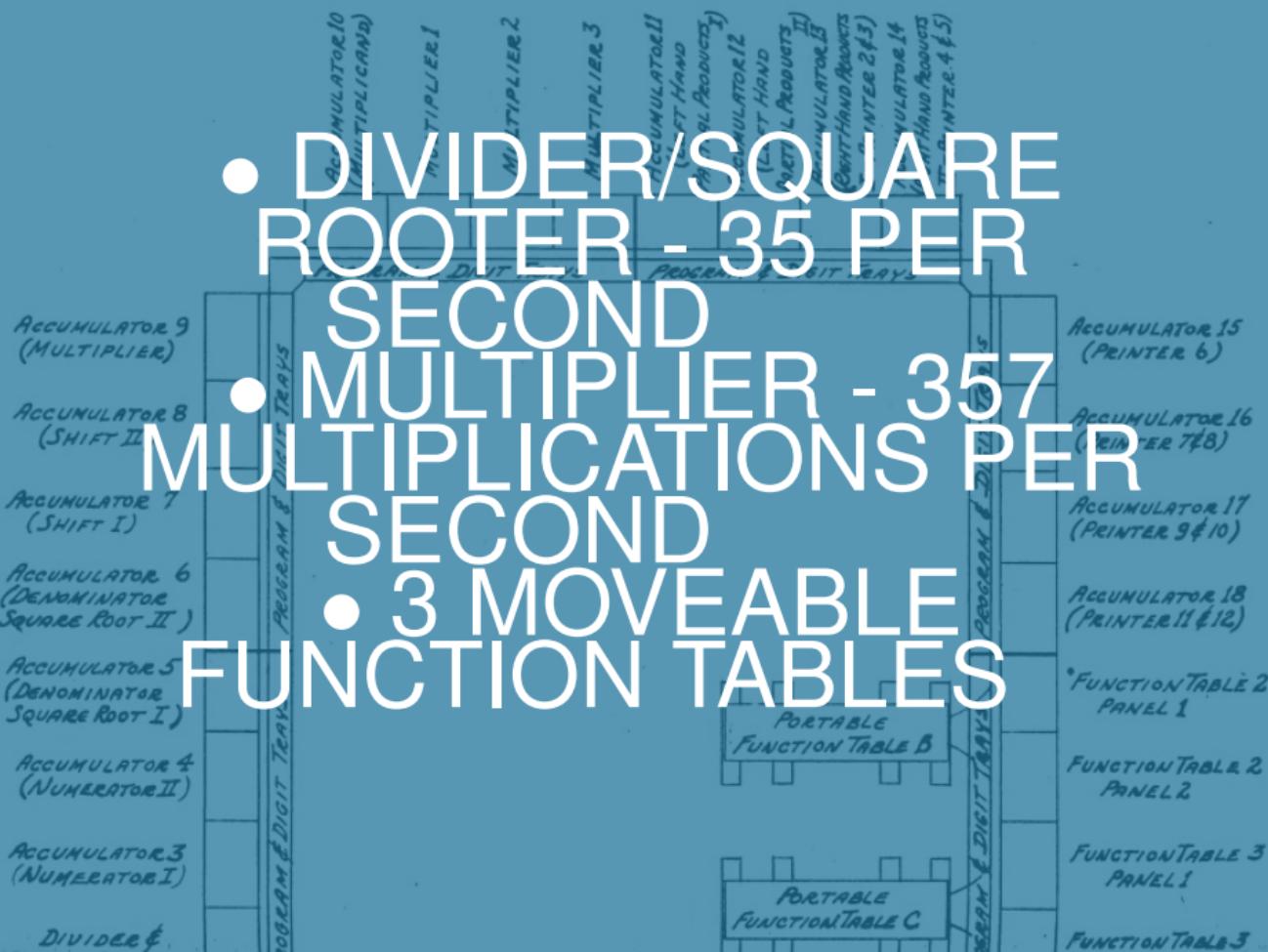
FUNCTION TABLE 3
PANEL 2



• DIVIDER/SQUARE ROOTER - 35 PER SECOND

• MULTIPLIER - 357 MULTIPLICATIONS PER SECOND

• 3 MOVEABLE FUNCTION TABLES



• DIVIDER/SQUARE ROOTER - 35 PER SECOND

• MULTIPLIER - 357 MULTIPLICATIONS PER SECOND

• 3 MOVEABLE FUNCTION TABLES

• CARD READER

ACCUMULATOR 9
(MULTIPLIER)

ACCUMULATOR 8
(SHIFT II)

ACCUMULATOR 7
(SHIFT I)

ACCUMULATOR 6
(DENOMINATOR
SQUARE ROOT II)

ACCUMULATOR 5
(DENOMINATOR
SQUARE ROOT I)

ACCUMULATOR 4
(NUMERATOR II)

ACCUMULATOR 3
(NUMERATOR I)

DIVIDER

ACCUMULATOR 10
(MULTIPLIER)

MULTIPLIER 1

MULTIPLIER 2

MULTIPLIER 3

ACCUMULATOR 11
(LEFT HAND
MULTIPLYER PRODUCTS)

ACCUMULATOR 12
(RIGHT HAND
MULTIPLYER PRODUCTS)

ACCUMULATOR 13
(LEFT HAND
DIVIDERS INTEG 2 & 3)

ACCUMULATOR 14
(RIGHT HAND
DIVIDERS INTEG 4 & 5)

ACCUMULATOR 15
(PRINTER 6)

ACCUMULATOR 16
(PRINTER 7&8)

ACCUMULATOR 17
(PRINTER 9&10)

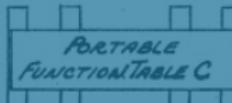
ACCUMULATOR 18
(PRINTER 11&12)

*FUNCTION TABLE 2
PANEL 1

FUNCTION TABLE 2
PANEL 2

FUNCTION TABLE 3
PANEL 1

FUNCTION TABLE 3
PANEL 2



- DIVIDER/SQUARE ROOTER - 35 PER SECOND
- MULTIPLIER - 357 MULTIPLICATIONS PER SECOND
- 3 MOVEABLE FUNCTION TABLES
- CARD READER
- CARD PUNCH

ACCUMULATOR 9
(MULTIPLIER)

ACCUMULATOR 8
(SHIFT II)

ACCUMULATOR 7
(SHIFT I)

ACCUMULATOR 6
(DENOMINATOR
SQUARE ROOT II)

ACCUMULATOR 5
(DENOMINATOR
SQUARE ROOT I)

ACCUMULATOR 4
(NUMERATOR II)

ACCUMULATOR 3
(NUMERATOR I)

DIVIDER &

ACCUMULATOR 10
(MULTIPLIER)

MULTIPLIER 1

MULTIPLIER 2

MULTIPLIER 3

ACCUMULATOR 11
(LEFT HAND
MULTIPLYER PRODUCTS)

ACCUMULATOR 12
(RIGHT HAND
MULTIPLYER PRODUCTS)

ACCUMULATOR 13
(LEFT HAND
DIVIDERS INTEG 2 & 3)

ACCUMULATOR 14
(RIGHT HAND
DIVIDERS INTEG 4 & 5)

ACCUMULATOR 15
(PRINTER 6)

ACCUMULATOR 16
(PRINTER 7&8)

ACCUMULATOR 17
(PRINTER 9&10)

ACCUMULATOR 18
(PRINTER 11&12)

*FUNCTION TABLE 2
PANEL 1

FUNCTION TABLE 2
PANEL 2

FUNCTION TABLE 3
PANEL 1

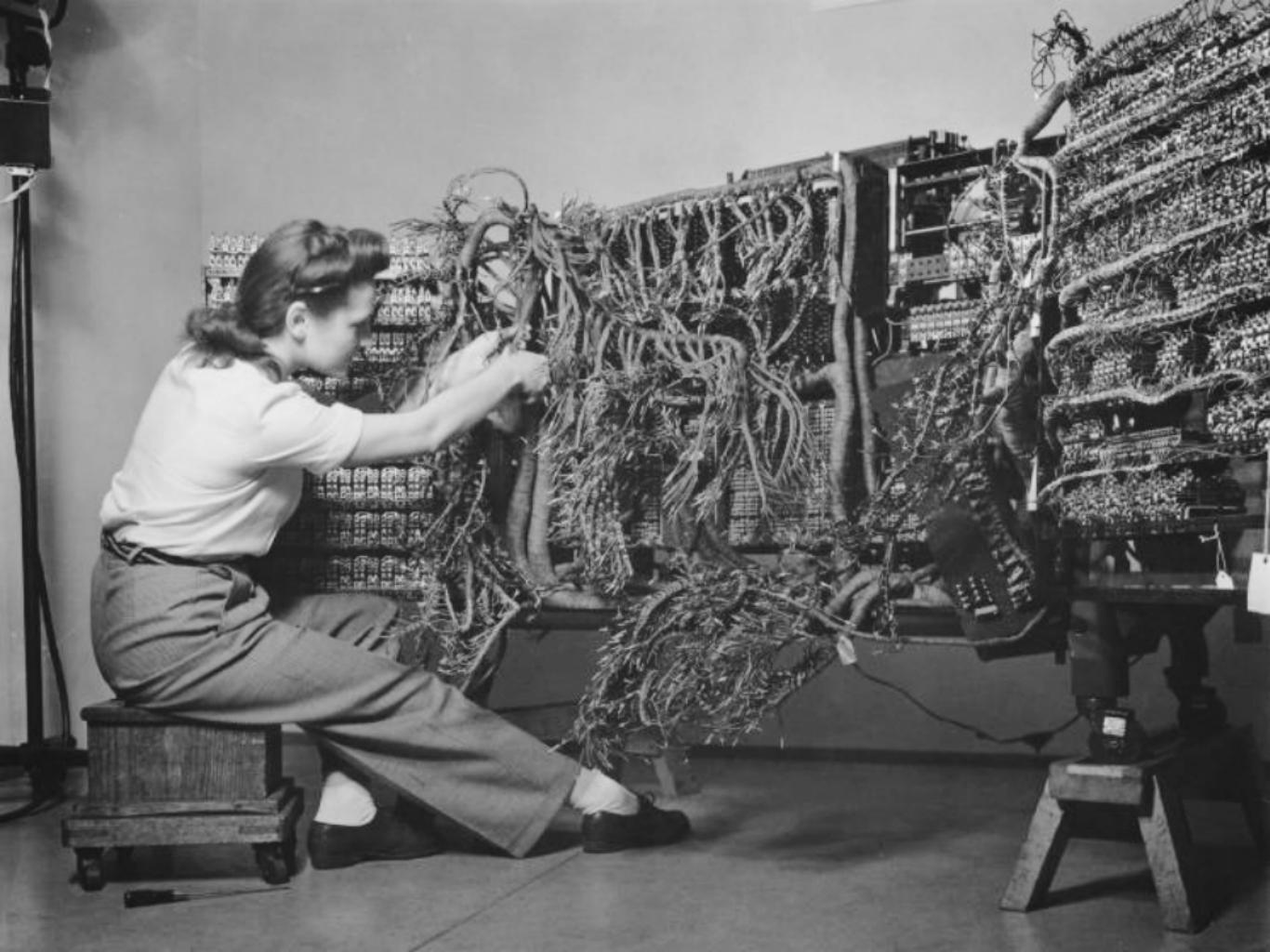
FUNCTION TABLE 3
PANEL 2

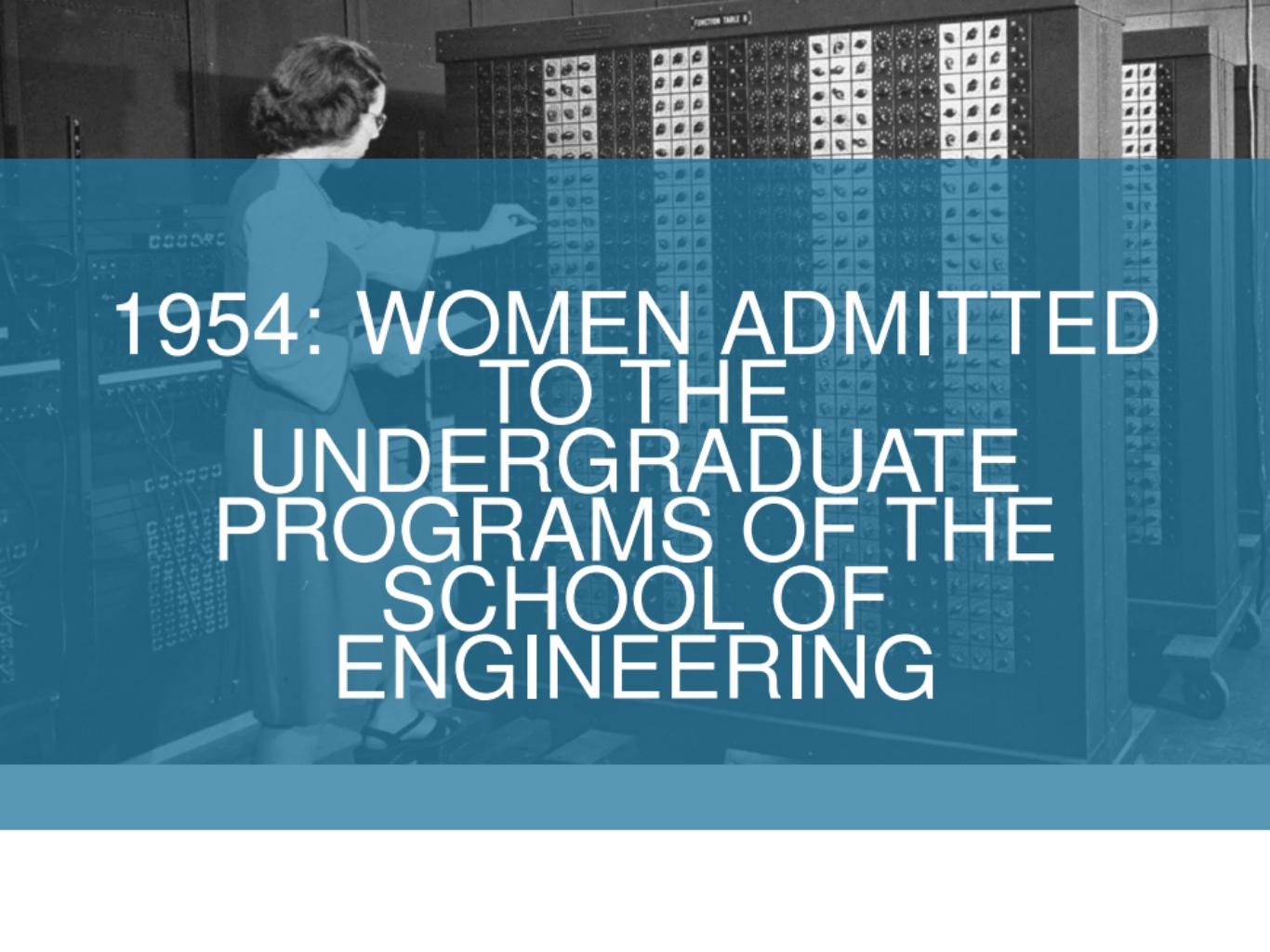
PORTABLE
FUNCTION TABLE C

- 
- Robert F. Shaw (function tables)
 - Jeffrey Chuan Chu (divider/square-rooter)
 - Thomas Kite Sharpless (master programmer)
 - Frank Mural (master programmer)
 - Arthur Burks (multiplier)
 - Harry Huskey (reader/printer)
 - Jack Davis (accumulators)



WIREMEN



A black and white photograph showing a woman from the side, wearing a light-colored dress, operating a large-scale control panel. The panel is filled with a grid of numerous knobs and switches. The words "FUNCTION TABLE" are visible at the top of the panel. The background shows more of the complex machinery of the computer.

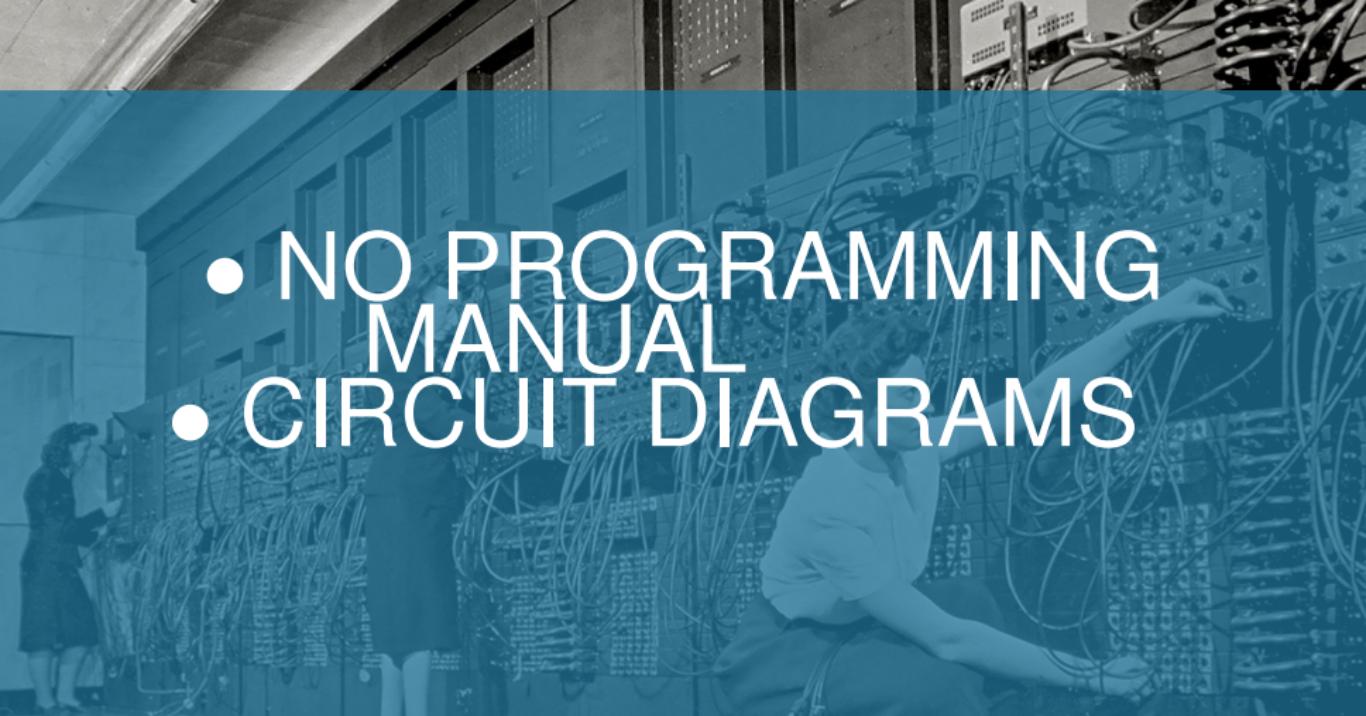
1954: WOMEN ADMITTED
TO THE
UNDERGRADUATE
PROGRAMS OF THE
SCHOOL OF
ENGINEERING



COMPUTERS



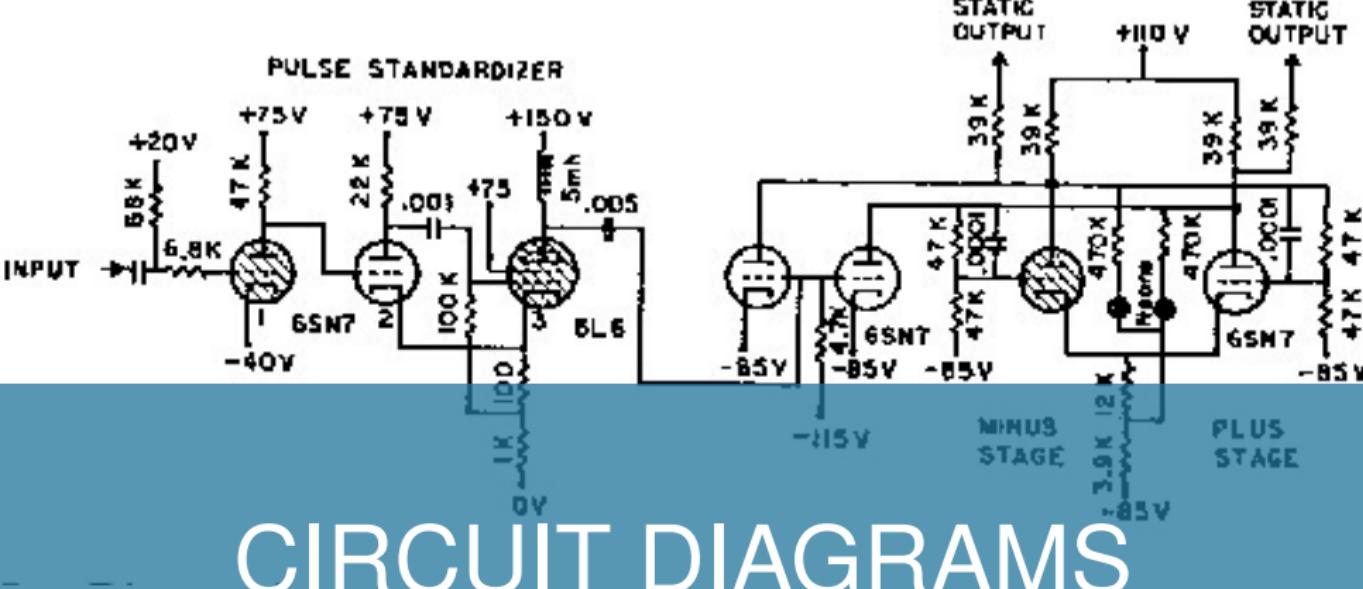
• NO PROGRAMMING
MANUAL

- 
- NO PROGRAMMING
 - MANUAL
 - CIRCUIT DIAGRAMS

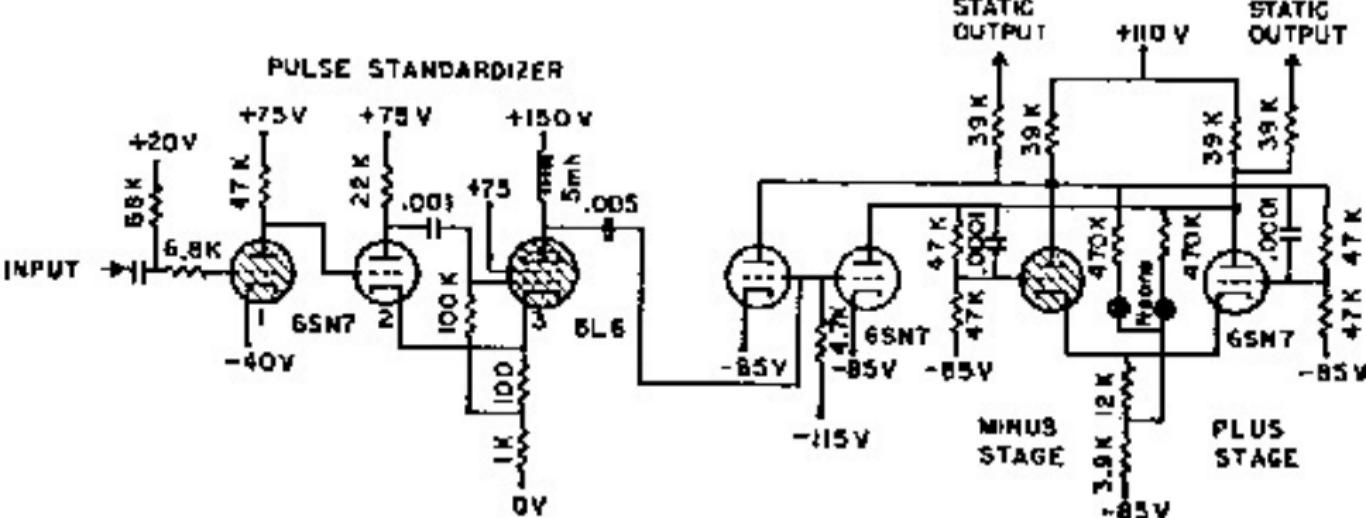
- 
- NO PROGRAMMING
MANUAL
 - CIRCUIT DIAGRAMS
 - LOGIC DIAGRAMS

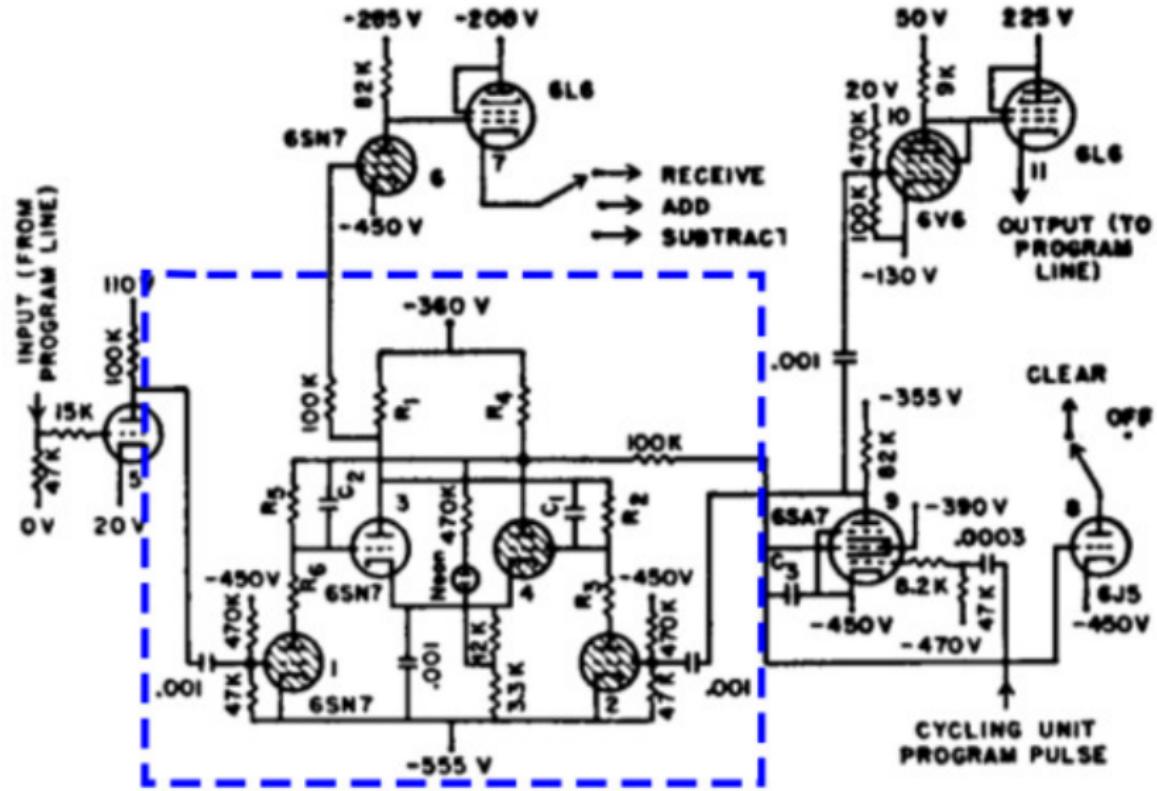
- NO PROGRAMMING
MANUAL
- CIRCUIT DIAGRAMS
- LOGIC DIAGRAMS
- FRONT PANEL
DIAGRAMS

- NO PROGRAMMING
MANUAL
- CIRCUIT DIAGRAMS
- LOGIC DIAGRAMS
 - FRONT PANEL
DIAGRAMS
- PAIRED TEACHING



CIRCUIT DIAGRAMS





MULTIPLICATION TABLE

MULTIPLIER
ACCUMULATOR
STATIC OUTPUTS:

TENS UNITS

TENS (LEFT-HAND)

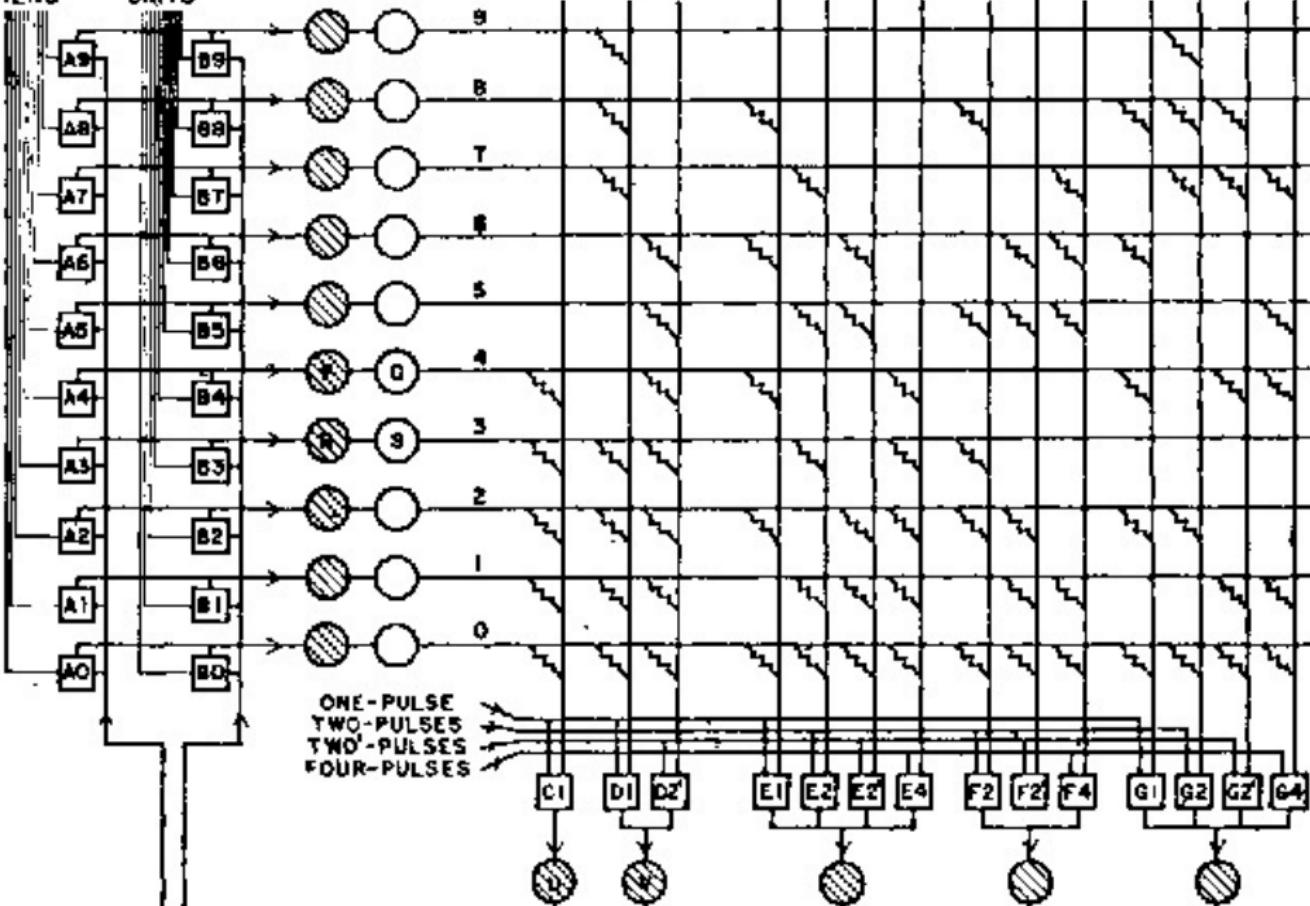
TWO THREE

UNITS (RIGHT-HAND)

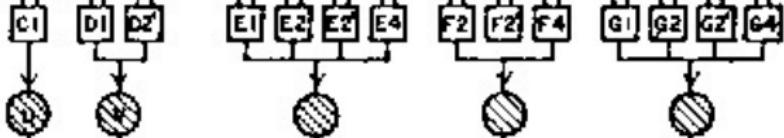
ONE

TWO

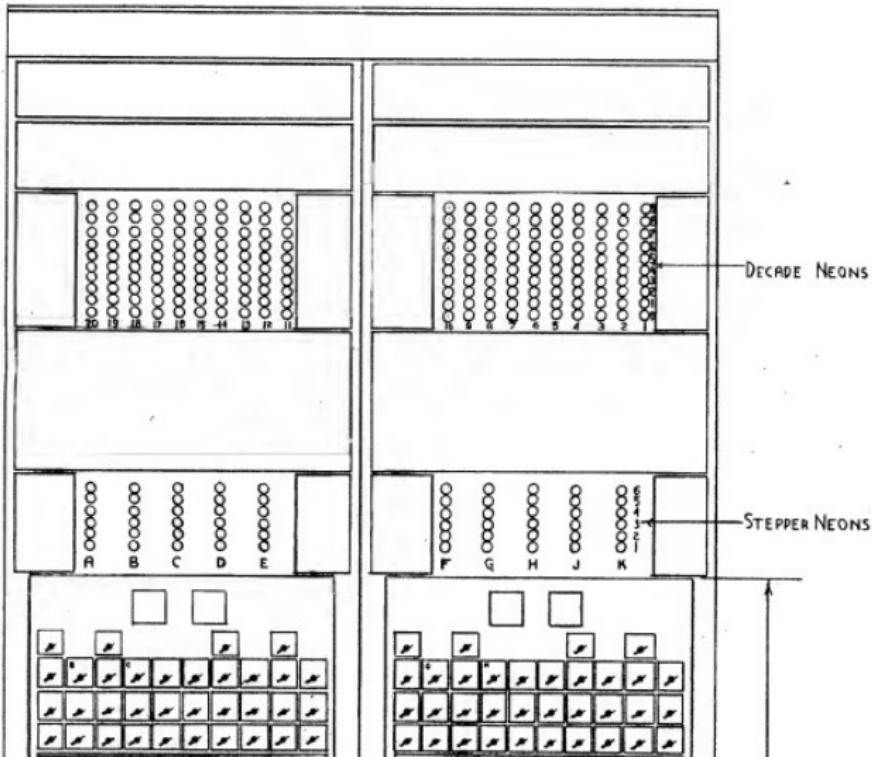
THREE



ONE-PULSE
TWO-PULSES
TWO'-PULSES
FOUR-PULSES



144



● PROGRAMMED WITH WIRES AND SWITCHES

ACCUMULATOR 9
(MULTIPLIER)

ACCUMULATOR 8
(SHIFT II)

ACCUMULATOR 7
(SHIFT I)

ACCUMULATOR 6
(DENOMINATOR
SQUARE ROOT II)

ACCUMULATOR 5
(DENOMINATOR
SQUARE ROOT I)

ACCUMULATOR 4
(NUMERATOR II)

ACCUMULATOR 3
(NUMERATOR I)

DIVIDER 4

PROGRAM 6-DIGIT TRAPS

ACCUMULATOR 10
(MULTIPLIER AND)

MULTIPLIER 1

MULTIPLIER 2

MULTIPLIER 3

ACCUMULATOR 11
LEFT HAND
MULTIPLY PRODUCTS

ACCUMULATOR 12
LEFT HAND
MULTIPLY PRODUCTS

ACCUMULATOR 13
RIGHT HAND
MULTIPLY PRODUCTS

ACCUMULATOR 14
RIGHT HAND
MULTIPLY PRODUCTS

ACCUMULATOR 15
RIGHT HAND
MULTIPLY PRODUCTS

ACCUMULATOR 15
(PRINTER 6)

ACCUMULATOR 16
(PRINTER 7&8)

ACCUMULATOR 17
(PRINTER 9&10)

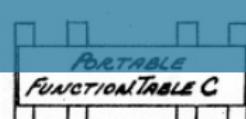
ACCUMULATOR 18
(PRINTER 11&12)

*FUNCTION TABLE 2
PANEL 1

FUNCTION TABLE 2
PANEL 2

FUNCTION TABLE 3
PANEL 1

FUNCTION TABLE 3



• PROGRAMMED WITH WIRES AND SWITCHES • ACCUMULATORS ARE THE ONLY MEMORY

ACCUMULATOR 9
(MULTIPLIER I)

ACCUMULATOR 8
(SHIFT II)

ACCUMULATOR 7
(SHIFT I)

ACCUMULATOR 6
(DENOMINATOR
SQUARE ROOT II)

ACCUMULATOR 5
(DENOMINATOR
SQUARE ROOT I)

ACCUMULATOR 4
(NUMERATOR II)

ACCUMULATOR 3
(NUMERATOR I)

DIVIDER 4

ACCUMULATOR 10
(MULTIPLIER II)

MULTIPLIER 1

MULTIPLIER 2

MULTIPLIER 3

ACCUMULATOR 11
LEFT HAND
TOTAL PRODUCTS I

ACCUMULATOR 12
LEFT HAND
TOTAL PRODUCTS II

ACCUMULATOR 13
RIGHT HAND
TOTAL PRODUCTS III

ACCUMULATOR 14
RIGHT HAND
TOTAL Products IV

ACCUMULATOR 15
RIGHT HAND
TOTAL Products V

ACCUMULATOR 16
RIGHT HAND
TOTAL Products VI

ACCUMULATOR 17
RIGHT HAND
TOTAL Products VII

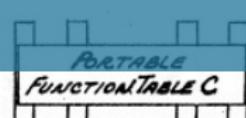
ACCUMULATOR 18
RIGHT HAND
TOTAL Products VIII

ACCUMULATOR 19
RIGHT HAND
TOTAL Products IX

ACCUMULATOR 20
RIGHT HAND
TOTAL Products X

PROGRAM 3-DIGIT TEAMS

PROGRAM 4-DIGIT TEAMS



ACCUMULATOR 15
(QUOTIENT 6)

ACCUMULATOR 16
(PRINTER 7&8)

ACCUMULATOR 17
(PRINTER 9&10)

ACCUMULATOR 18
(PRINTER 11&12)

*FUNCTION TABLE 2
PANEL 1

FUNCTION TABLE 2
PANEL 2

FUNCTION TABLE 3
PANEL 1

FUNCTION TABLE 3
PANEL 2

● PROGRAMMED WITH WIRES AND SWITCHES
● ACCUMULATORS ARE THE ONLY MEMORY
● NO SEPARATION BETWEEN STORAGE AND COMPUTATION

ACCUMULATOR 9
(MULTIPLIER I)

ACCUMULATOR 8
(SHIFT II)

ACCUMULATOR 7
(SHIFT I)

ACCUMULATOR 6
(DENOMINATOR
SQUARE ROOT II)

ACCUMULATOR 5
(DENOMINATOR
SQUARE ROOT I)

ACCUMULATOR 4
(NUMERATOR II)

ACCUMULATOR 3
(NUMERATOR I)

DIVIDER \$

ACCUMULATOR 10
(MULTIPLIER II)

MULTIPLIER 1

MULTIPLIER 2

MULTIPLIER 3

ACCUMULATOR 11
LEFT HAND
TOTAL PRODUCTS I)

ACCUMULATOR 12
LEFT HAND
TOTAL PRODUCTS II)

ACCUMULATOR 13
RIGHT HAND
TOTAL PRODUCTS III)

ACCUMULATOR 14
RIGHT HAND
TOTAL PRODUCTS IV)

ACCUMULATOR 15
RIGHT HAND
TOTAL PRODUCTS V)

ACCUMULATOR 16
RIGHT HAND
TOTAL PRODUCTS VI)

ACCUMULATOR 17
RIGHT HAND
TOTAL PRODUCTS VII)

ACCUMULATOR 18
RIGHT HAND
TOTAL PRODUCTS VIII)

ACCUMULATOR 15
(PRINTER 6)

ACCUMULATOR 16
(PRINTER 7&8)

ACCUMULATOR 17
(PRINTER 9&10)

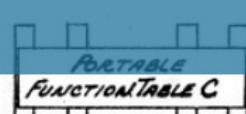
ACCUMULATOR 18
(PRINTER 11&12)

*FUNCTION TABLE 2
PANEL 1

FUNCTION TABLE 2
PANEL 2

FUNCTION TABLE 3
PANEL 1

FUNCTION TABLE 3
PANEL 2



- PROGRAMMED WITH WIRES AND SWITCHES
- ACCUMULATORS ARE THE ONLY MEMORY
- NO SEPARATION BETWEEN STORAGE AND COMPUTATION
- PARALLEL

ACCUMULATOR 9
(MULTIPLIER I)

ACCUMULATOR 8
(SHIFT II)

ACCUMULATOR 7
(SHIFT I)

ACCUMULATOR 6
(DENOMINATOR
SQUARE ROOT II)

ACCUMULATOR 5
(DENOMINATOR
SQUARE ROOT I)

ACCUMULATOR 4
(NUMERATOR II)

ACCUMULATOR 3
(NUMERATOR I)

DIVIDER 4

ACCUMULATOR 10
(MULTIPLIER II)

MULTIPLIER 1

MULTIPLIER 2

MULTIPLIER 3

ACCUMULATOR 11
LEFT HAND
MULTIPLYER PRODUCTS I)

ACCUMULATOR 12
LEFT HAND
MULTIPLYER PRODUCTS II)

ACCUMULATOR 13
RIGHT HAND
MULTIPLYER PRODUCTS III)

ACCUMULATOR 14
RIGHT HAND
MULTIPLYER PRODUCTS IV)

ACCUMULATOR 15
RIGHT HAND
MULTIPLYER PRODUCTS V)

ACCUMULATOR 16
(PRINTER 6)

ACCUMULATOR 16
(PRINTER 7&8)

ACCUMULATOR 17
(PRINTER 9&10)

ACCUMULATOR 18
(PRINTER 11&12)

*FUNCTION TABLE 2
PANEL 1

FUNCTION TABLE 2
PANEL 2

FUNCTION TABLE 3
PANEL 1

FUNCTION TABLE 3
PANEL 2



2.2. TESTING AN ACCUMULATOR

Cards should be prepared as follows:

1. P 11111 11111

2. P 00000 00001

The numbers should be so placed on a card that one group in the constant transmitter, say A_{LR} , corresponds to these numbers. Next, a master programmer stepper should be used to transmit the first number into the accumulators which are to be tested eighteen times. At this time the accumulators should read

DEBUGGING AND BREAKPOINTS

and all stages of each decade have been checked as well as the delayed carry-over circuits. Now the stepper (used above) should cause the reader to read the next card and the number to be transmitted to the accumulators twice. This should

2.2. TESTING AN ACCUMULATOR

Cards should be prepared as follows:

1. P 11111 11111

2. P 00000 00001 :

The numbers should be so placed on a card that one group in the constant transmitter, say A_{LR} , corresponds to these numbers. Next, a **master programmer** stepper should be used to transmit the first number into the accumulators which are to be tested eighteen times. At this time the accumulators should read

M 99999 99998

and all stages of each decade have been checked as well as the delayed carry-over circuits. Now the stepper (used above) should cause the reader to read the next card and the number to be transmitted to the accumulators twice. This should

2.3. TESTING THE MULTIPLIER

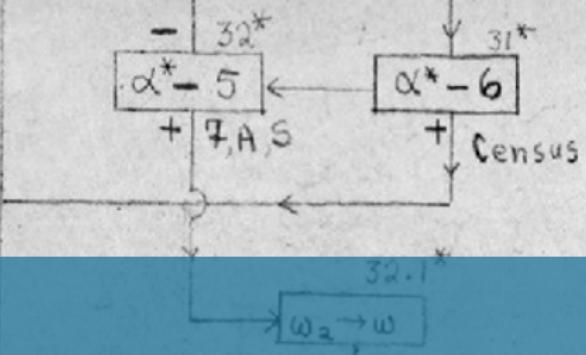
The following set of cards should be prepared.

<u>Card</u>	<u>Multiplier</u> A_{LR} (say)	<u>Multiplicand</u> B_{LR} (say)
1	P 00000 00000	P 11111 11111
2	P 11111 11111	P 11111 11111
3	P 11111 11111	P 22222 22222
.....
10	P 11111 11111	P 99999 99999
11	P 22222 22222	P 11111 11111
12	P 22222 22222	P 22222 22222
.....
82	P 99999 99999	P 99999 99999
83	F P 11111 11111	M 11111 11111
84	M 11111 11111	P 11111 11111
85	M 11111 11111	M 11111 11111

2.3. TESTING THE MULTIPLIER

The following set of cards should be prepared.

<u>Card</u>	<u>Multiplier</u> A_{LR} (say)	<u>Multiplicand</u> B_{LR} (say)
1	P 00000 00000	P 11111 11111
2	P 11111 11111	P 11111 11111
3	P 11111 11111	P 22222 22222
.....
10	P 11111 11111	P 99999 99999
11	P 22222 22222	P 11111 11111
12	P 22222 22222	P 22222 22222
.....
82	P 99999 99999	P 99999 99999
83	P 11111 11111	M 11111 11111
84	M 11111 11111	P 11111 11111
85	M 11111 11111	M 11111 11111



$$10^{-3} \left[d_1 - \right.$$

$$10^{-5} (T_{\text{eff}} +$$

16

$$10^{-1}Q = 10^{-1}(Q + \int_0^b S_o(h))$$

$$10^{-1}Q = 10^{-1}(Q + \int_0^h S_o(h))$$

ES

$$B = 10^4 (g_i + f_i^b S_i(h))$$

10⁻⁹ g IS

11

— 3 —

$$g_3 = 10^{-1} (g_2 + f_{\pm}^b S_3(b))$$

24

— 20 —

$$0 \rightarrow 10 \text{ b to } 9$$

$$\xi_{\beta}(10, 9, 8) \rightarrow 4(3, 2, 1)$$

$$10^{-1}g = -10^{-1}\xi_{\beta}(7, 6) \sum$$

$$10^{-1}g \rightarrow 10$$

fif

$$\begin{aligned}\xi_0 &= \xi_0(m_0 - \zeta) \\ \xi_1 &= \xi_1(m_1 - \zeta) \\ \overline{\xi_0 \xi_1} &= \xi_0(10^{-5} \overline{\xi_1}) \\ \overline{\xi_0^2} &= \text{diag } (m_1 - \zeta) \\ \overline{\xi_1^2} &= \text{diag } (10^{-5} \xi_1)^2\end{aligned}$$

x = distance down range

y = altitude

z = distance cross range in the right hand

sense

BALLISTICS PROGRAM VARIABLES

w_x = wind down range

w_z = wind across range

Ω = angular velocity of the earth

L = latitude

a = azimuth

E = $a(y)H(y)G\left(\frac{v}{a(y)}\right)$

x = distance down range

y = altitude

z = distance cross range in the right hand
sense

w_x = wind down range

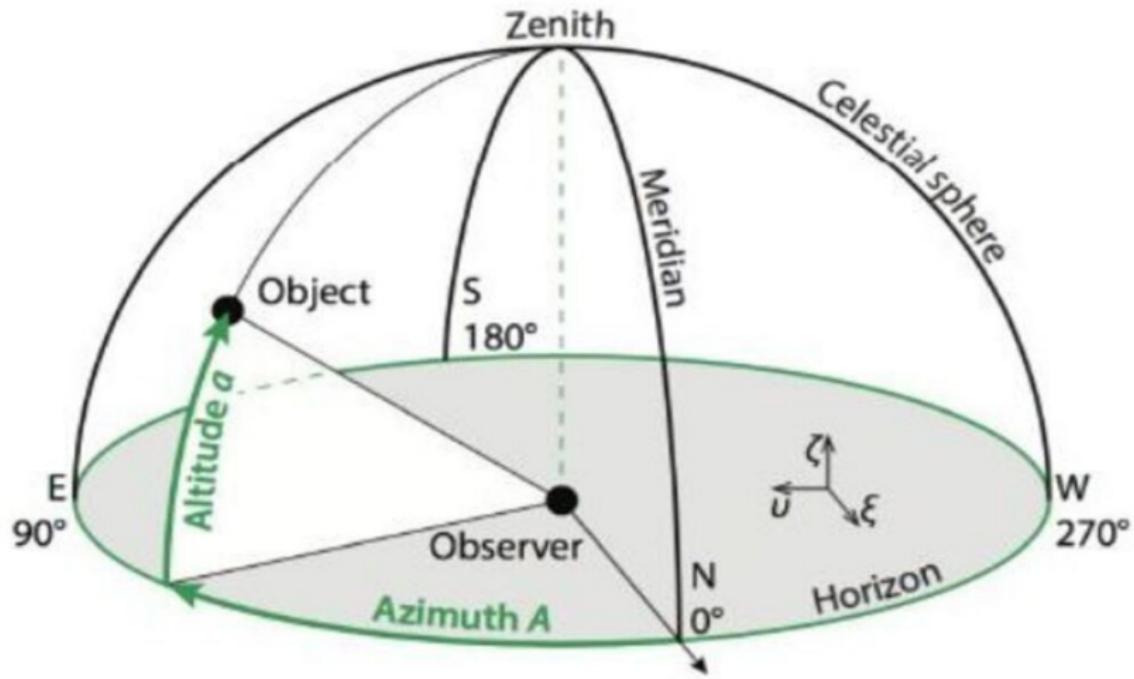
w_z = wind across range

Ω = angular velocity of the earth

L = latitude

α = azimuth

$E = a(y)H(y)G\left(-\frac{v}{a(y)}\right)$



The equations for particle trajectory theory are:

$$x' = -E(x' - w_x) + 2 \Omega \cos L \sin a y'$$

$$y' = -E y' - g - 2 \Omega \cos L \sin a x'$$

$$z' = -E(z' - w_z) + 2 \Omega \sin L x' + 2 \Omega \cos L \cos a y'$$

BALLISTICS PROGRAM

EQUATIONS

where

$$x' = \frac{dx}{dt}$$

The equations for particle trajectory theory are:

$$x' = -E(x' - w_x) + 2 \Omega \cos L \sin \alpha y'$$

$$y' = -E y' - g - 2 \Omega \cos L \sin \alpha x'$$

$$z' = -E(z' - w_z) + 2 \Omega \sin L x' + 2 \Omega \cos L \cos \alpha y'$$

where

$$x' = \frac{dx}{dt}$$

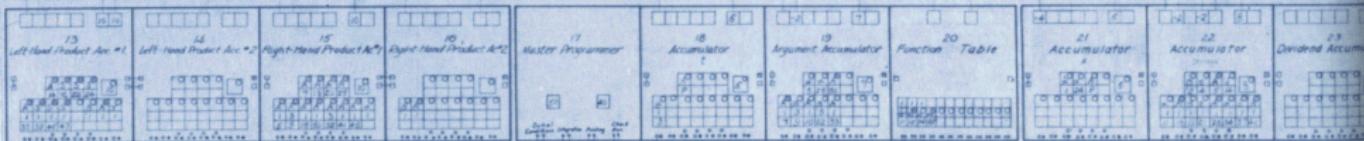




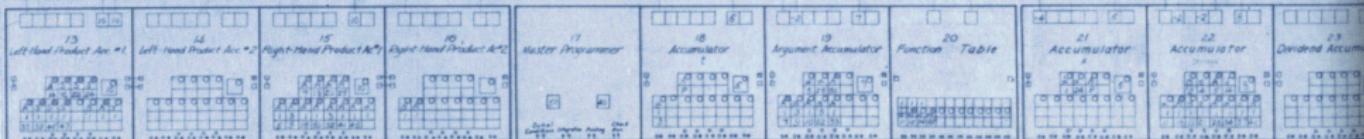
^ ^ ^ ^ ^



^ ^ ^ ^ ^



PEDALING SHEET



• NUCLEAR BOMB SIMULATION

ACCUMULATOR 9
(MULTIPLIER)

ACCUMULATOR 8
(SHIFT II)

ACCUMULATOR 7
(SHIFT I)

ACCUMULATOR 6
(DENOMINATOR
SQUARE ROOT II)

ACCUMULATOR 5
(DENOMINATOR
SQUARE ROOT I)

ACCUMULATOR 4
(NUMERATOR II)

ACCUMULATOR 3
(NUMERATOR I)

DIVIDER

PROGRAM 6-DIGIT TRAYS

PROGRAM 5-DIGIT TRAYS

PROGRAM 6-DIGIT TRAYS

ACCUMULATOR 10
(MULTIPLIER)

MULTIPLIER 1

MULTIPLIER 2

MULTIPLIER 3

MULTIPLIER 11
(LEFT HAND
MULTI PRODUCTS)

MULTIPLIER 12
(LEFT HAND
MULTI PRODUCTS)

MULTIPLIER 13
(LEFT HAND
MULTI PRODUCTS)

MULTIPLIER 14
(RIGHT HAND
PRODUCTS)

MULTIPLIER 15
(RIGHT HAND
PRODUCTS)

ACCUMULATOR 15
(PRINTER 6)

ACCUMULATOR 16
(PRINTER 7&8)

ACCUMULATOR 17
(PRINTER 9&10)

ACCUMULATOR 18
(PRINTER 11&12)

*FUNCTION TABLE 2
PANEL 1

FUNCTION TABLE 2
PANEL 2

FUNCTION TABLE 3
PANEL 1

FUNCTION TABLE 3
PANEL 2



• NUCLEAR BOMB SIMULATION

• BALLISTICS TRAJECTORY CALULATIONS

ACCUMULATOR 9
(MULTIPLIER)

ACCUMULATOR 8
(SHIFT II)

ACCUMULATOR 7
(SHIFT I)

ACCUMULATOR 6
(DENOMINATOR
SQUARE ROOT II)

ACCUMULATOR 5
(DENOMINATOR
SQUARE ROOT I)

ACCUMULATOR 4
(NUMERATOR II)

ACCUMULATOR 3
(NUMERATOR I)

DIVIDER

PROGRAM # DIGIT TRAJS

ACCUMULATOR 15
(PRINTER 6)

ACCUMULATOR 16
(PRINTER 7&8)

ACCUMULATOR 17
(PRINTER 9&10)

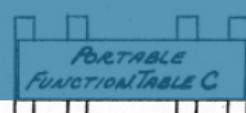
ACCUMULATOR 18
(PRINTER 11&12)

*FUNCTION TABLE 2
PANEL 1

FUNCTION TABLE 2
PANEL 2

FUNCTION TABLE 3
PANEL 1

FUNCTION TABLE 3
PANEL 2



• NUCLEAR BOMB SIMULATION

• BALLISTICS TRAJECTORY

CALULATIONS

ELECTION PREDICTION

ACCUMULATOR 9
(MULTIPLIER)

ACCUMULATOR 8
(SHIFT II)

ACCUMULATOR
(SHIFT I)

ACCUMULATOR 6
(DENOMINATOR
SQUARE ROOT II)

ACCUMULATOR 5
(DENOMINATOR
SQUARE ROOT I)

ACCUMULATOR 4
(NUMERATOR II)

ACCUMULATOR 3
(NUMERATOR I)

DIVIDER

ACCUMULATOR 10
(MULTIPLIER)

MULTIPLIER 1

MULTIPLIER 2

MULTIPLIER 3

MULTIPLIER 11
(LEFT HAND
MULTI PRODUCTS)

MULTIPLIER 12
(LEFT HAND
MULTI PRODUCTS)

MULTIPLIER 13
(LEFT HAND
MULTI PRODUCTS)

MULTIPLIER 14
(RIGHT HAND
MULTI PRODUCTS)

MULTIPLIER 15
(RIGHT HAND
MULTI PRODUCTS)

ACCUMULATOR 15
(PRINTER 6)

ACCUMULATOR 16
(PRINTER 7&8)

ACCUMULATOR 17
(PRINTER 9&10)

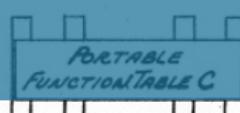
ACCUMULATOR 18
(PRINTER 11&12)

*FUNCTION TABLE 2
PANEL 1

FUNCTION TABLE 2
PANEL 2

FUNCTION TABLE 3
PANEL 1

FUNCTION TABLE 3
PANEL 2



• NUCLEAR BOMB SIMULATION

• BALLISTICS
TRAJECTORY

CALULATIONS

ELECTION PREDICTION

• WEATHER
FORCASTING

ACCUMULATOR 9
(MULTIPLIER)

ACCUMULATOR 8
(SHIFT II)

ACCUMULATOR
(SHIFT I)

ACCUMULATOR 6
(DENOMINATOR
SQUARE ROOT II)

ACCUMULATOR 5
(DENOMINATOR
SQUARE ROOT I)

ACCUMULATOR 4
(NUMERATOR II)

ACCUMULATOR 3
(NUMERATOR I)

DIVIDER

ACCUMULATOR 10
(MULTIPLIER)

MULTIPLIER 1

MULTIPLIER 2

MULTIPLIER 3

MULTIPLIER 11
(LEFT HAND
MULTI PRODUCTS)

MULTIPLIER 12
(LEFT HAND
MULTI PRODUCTS)

MULTIPLIER 13
(LEFT HAND
MULTI PRODUCTS)

MULTIPLIER 14
(RIGHT HAND
MULTI PRODUCTS)

MULTIPLIER 15
(RIGHT HAND
MULTI PRODUCTS)

ACCUMULATOR 15
(PRINTER 6)

ACCUMULATOR 16
(PRINTER 7&8)

ACCUMULATOR 17
(PRINTER 9&10)

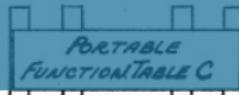
ACCUMULATOR 18
(PRINTER 11&12)

*FUNCTION TABLE 2
PANEL 1

FUNCTION TABLE 2
PANEL 2

FUNCTION TABLE 3
PANEL 1

FUNCTION TABLE 3
PANEL 2



• NUCLEAR BOMB SIMULATION

• BALLISTICS
TRAJECTORY
CALULATIONS

ELECTION PREDICTION

• WEATHER
FORCASTING

ACCUMULATOR 5
(DENOMINATOR
SQUARE ROOT I)

ACCUMULATOR 4
(NUMERATOR II)

ACCUMULATOR 3
(NUMERATOR I)

DIVIDER

ACCUMULATOR 9
(MULTIPLIER)

ACCUMULATOR 8
(SHIFT II)

ACCUMULATOR
(SHIFT I)

ACCUMULATOR 6
(DENOMINATOR
SQUARE ROOT II)

ACCUMULATOR 10
(MULTIPLIER)

MULTIPLIER 1

MULTIPLIER 2

MULTIPLIER 3

MULTIPLIER 11
(LEFT HAND
MULTI PRODUCTS)

MULTIPLIER 12
(LEFT HAND
MULTI PRODUCTS)

MULTIPLIER 13
(LEFT HAND
MULTI PRODUCTS)

MULTIPLIER 14
(RIGHT HAND
MULTI PRODUCTS)

MULTIPLIER 15
(RIGHT HAND
MULTI PRODUCTS)

ACCUMULATOR 15
(PRINTER 6)

ACCUMULATOR 16
(PRINTER 7&8)

ACCUMULATOR 17
(PRINTER 9&10)

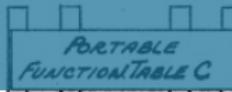
ACCUMULATOR 18
(PRINTER 11&12)

*FUNCTION TABLE 2
PANEL 1

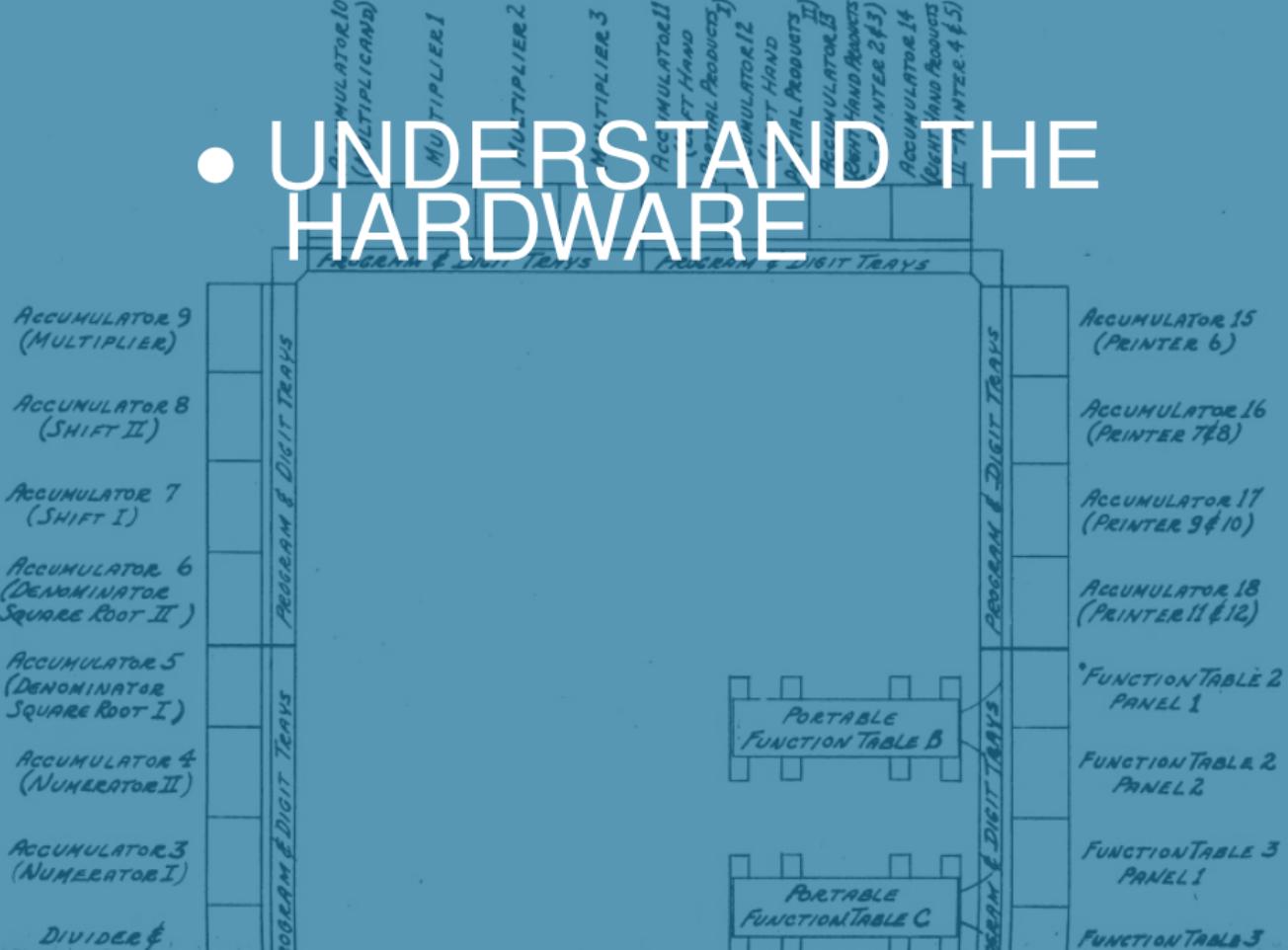
FUNCTION TABLE 2
PANEL 2

FUNCTION TABLE 3
PANEL 1

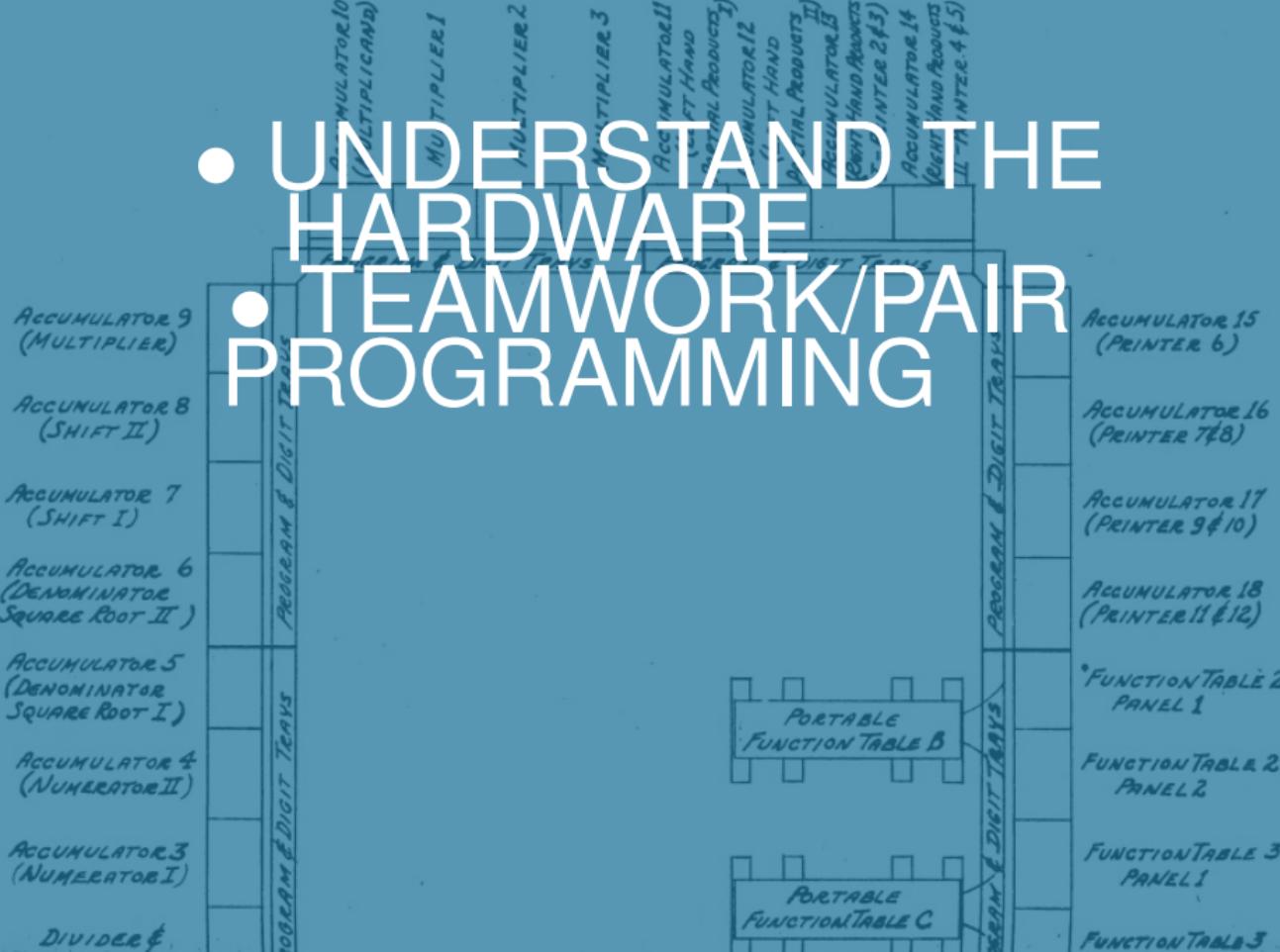
FUNCTION TABLE 3
PANEL 2



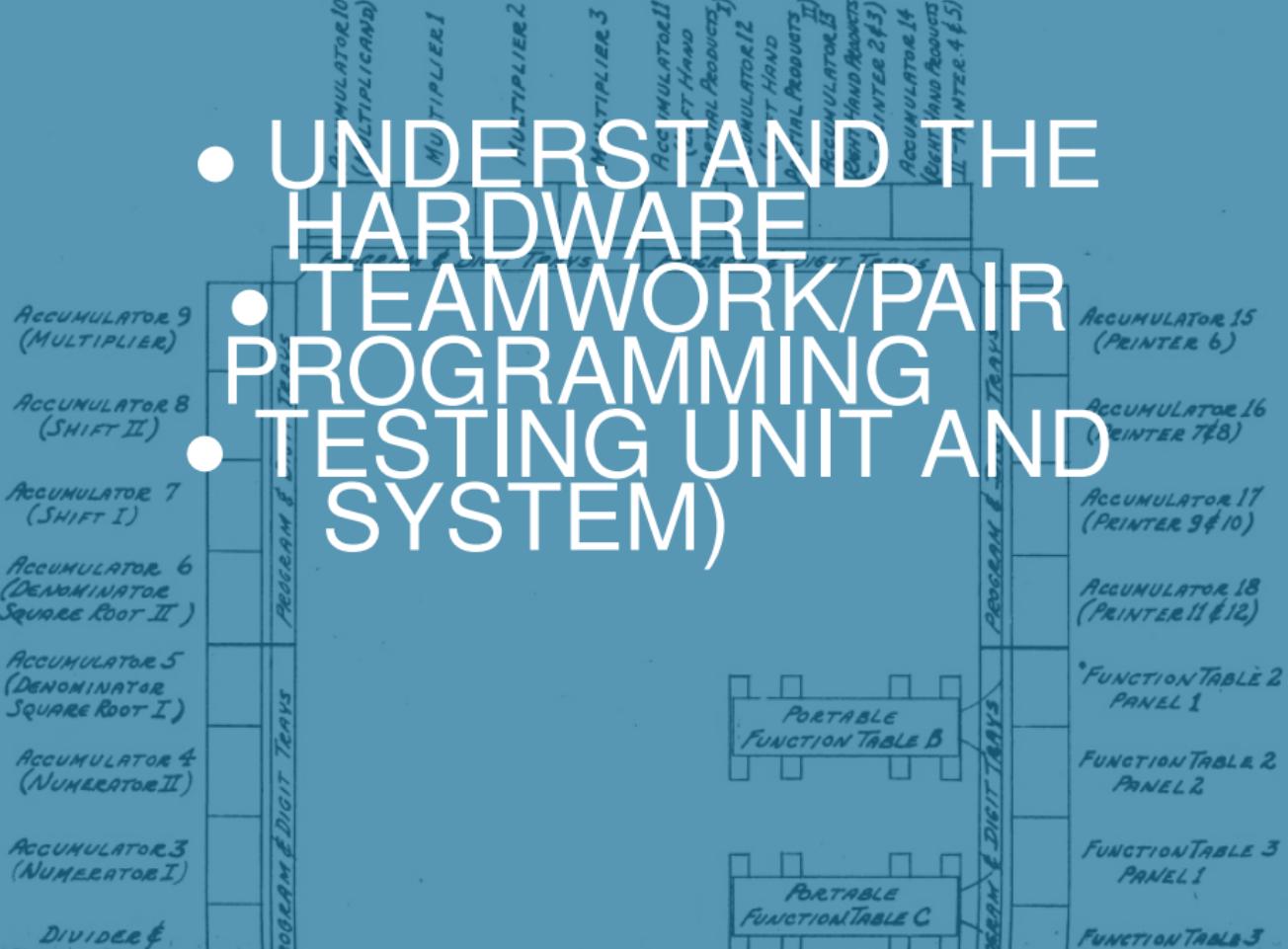
• UNDERSTAND THE HARDWARE



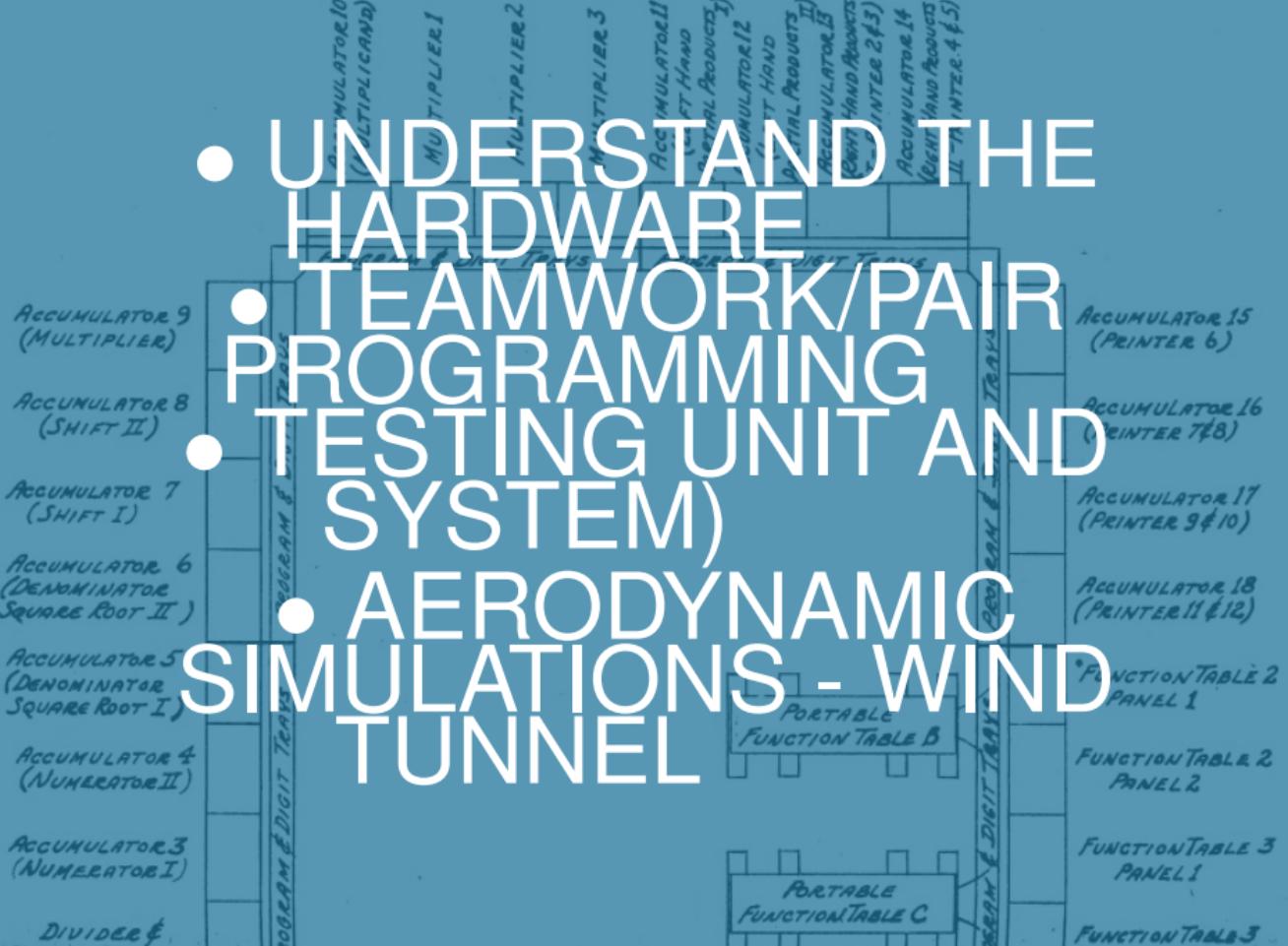
• UNDERSTAND THE HARDWARE • TEAMWORK/PAIR PROGRAMMING



- UNDERSTAND THE HARDWARE TEAMWORK/PAIR PROGRAMMING
 - TESTING UNIT AND SYSTEM)



- UNDERSTAND THE HARDWARE
- TEAMWORK/PAIR PROGRAMMING
- TESTING UNIT AND SYSTEM)
- AERODYNAMIC SIMULATIONS - WIND TUNNEL



- UNDERSTAND THE HARDWARE
- TEAMWORK/PAIR PROGRAMMING
- TESTING UNIT AND SYSTEM)
- AERODYNAMIC SIMULATIONS - WIND TUNNEL
- PEDALING SHEETS

