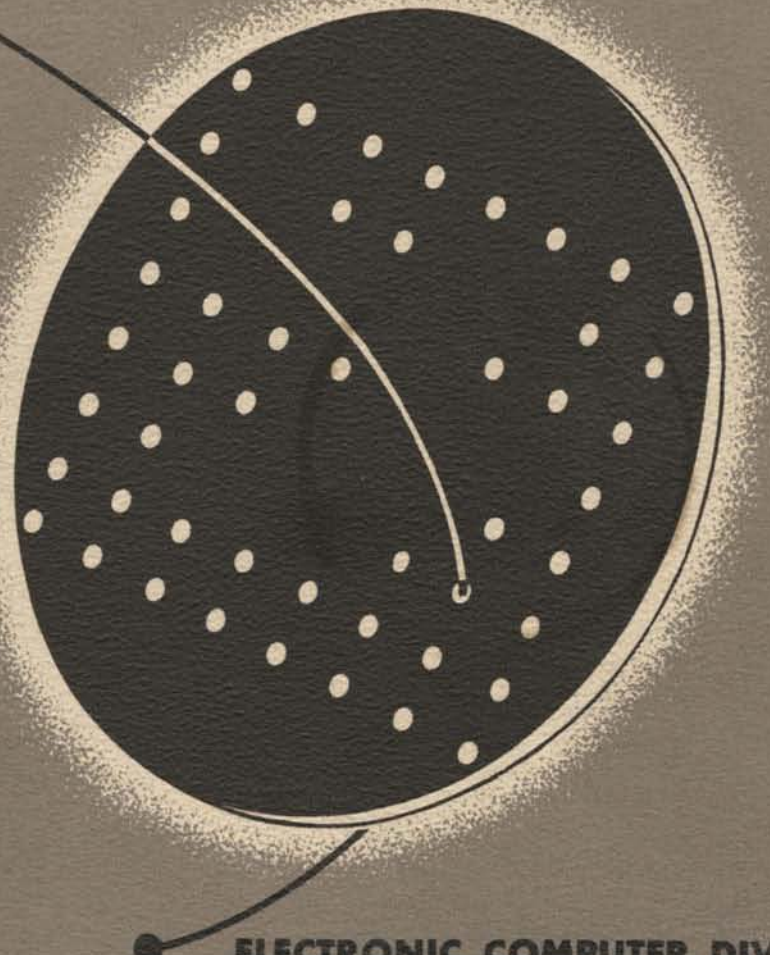
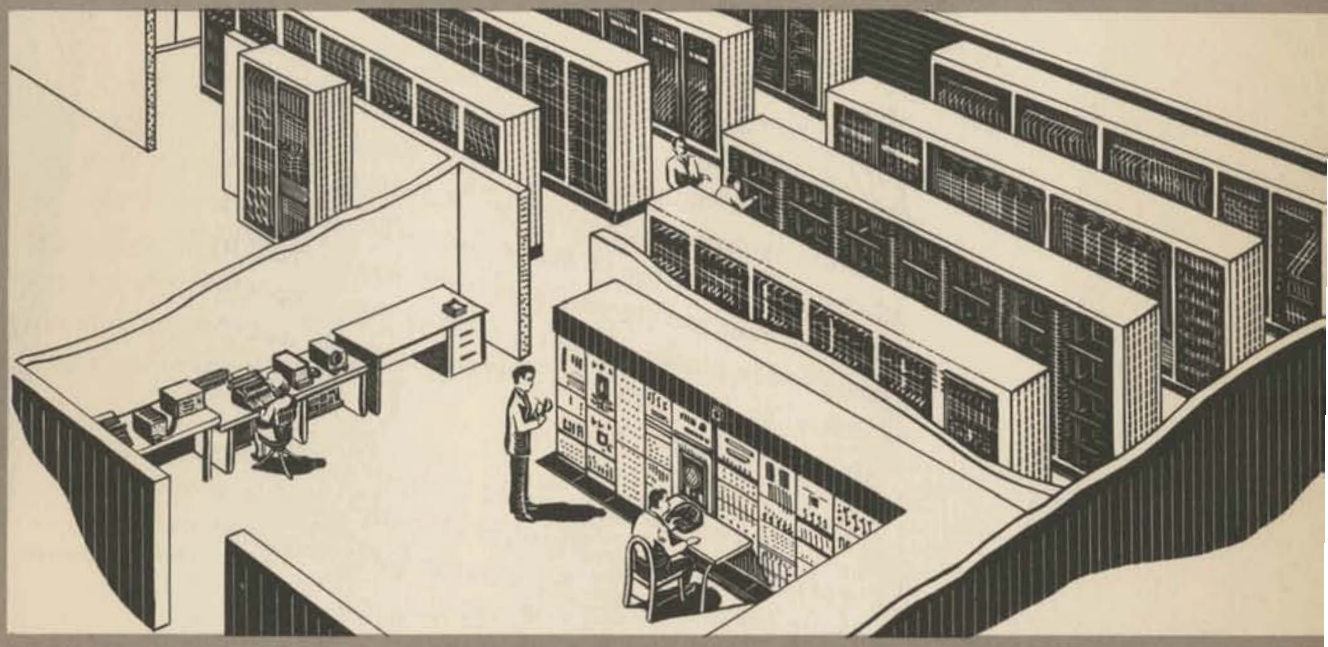
Whirlwind I



ELECTRONIC COMPUTER DIVISION
SERVOMECHANISMS LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Whirlwind 1

A HIGH-SPEED ELECTRONIC DIGITAL COMPUTER



ELECTRONIC COMPUTER DIVISION

SERVOMECHANISMS LABORATORY

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

CAMBRIDGE 39, MASSACHUSETTS

This booklet gives a general description of the Whirlwind I digital computer developed at the Servomechanisms Laboratory, Massachusetts Institute of Technology. Project Whirlwind was initiated by the Office of Naval Research, and for a considerable period was supported exclusively by them under contract N5ori60. It is now supported jointly by the Office of Naval Research and the United States Air Force.

The results that have so far been achieved represent the combined efforts of many; the following have played leading parts in the development of the computer:

H. R. Boyd
S. H. Dodd
R. R. Everett
H. Fahnestock
N. H. Taylor
C. R. Wieser
P. Youtz

This booklet was prepared by R. R. Rathbone

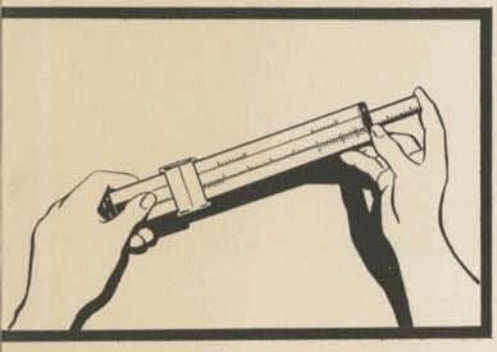
Jay W. Forrester

J. W. Forrester
Project Supervisor

15 August 1951

Computing Devices

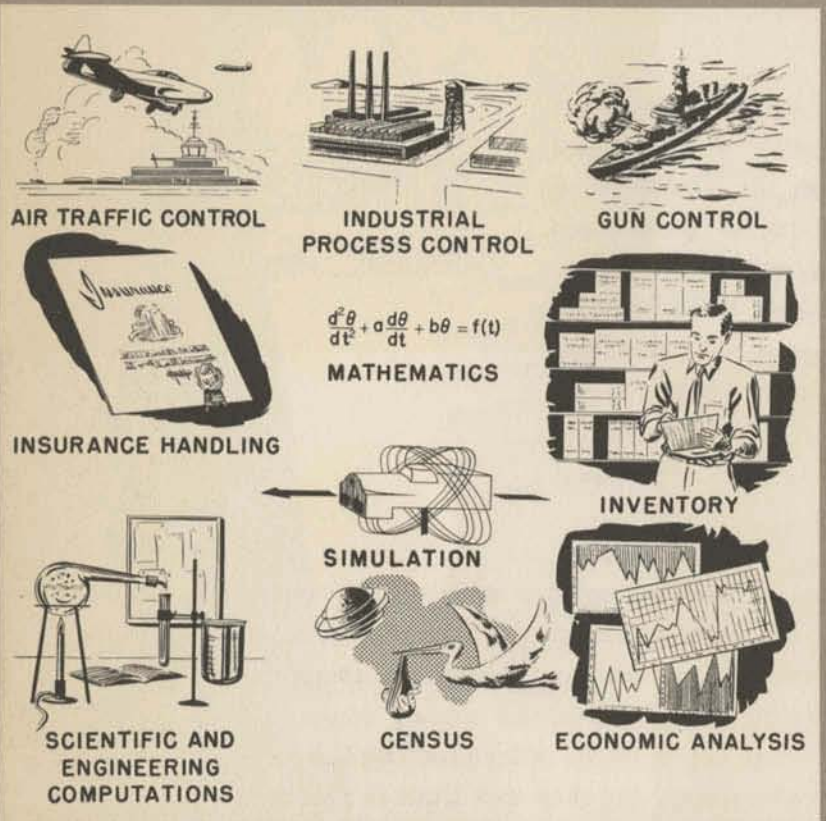
A digital computer counts. Only discrete quantities are used by the machine during a computation, and these are represented numerically. For example, the abacus is a simple digital device on which calculations are performed by sliding counters along digit rods. The precision of a digital computer is determined by the number of digits in the machine (in the case of the abacus, the number of rods and counters), and may be increased by the addition of more digits.



In contrast, an analog computer measures; the quantities it uses are continuous. For example, the slide rule, an analog device, provides continuous mathematical measurements. The precision of any particular analog computer, however, has a definite upper limit, determined by the precision of its fabricated parts, and once this limit is reached, precision cannot be increased without a redesign of the whole machine.

Modern electronic digital computers operate automatically. Usually, high-frequency pulses travel along transmission lines from one element to another and cause electronic circuits to be turned on or off. The resulting electronic states of these circuits represent the numbers in the problem.

Whirlwind 1



Whirlwind 1 is a general-purpose electronic digital computer. Although it will handle only one type of problem at a time, its program can be changed in a few seconds to accommodate the variety of problems involved in the processing of information.

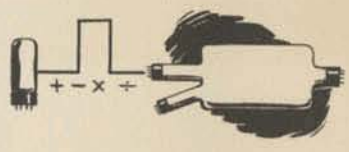
Whirlwind 1 can solve complex mathematical problems by repeated use of the fundamental processes of addition, subtraction, multiplication, and division — at a rate of several thousand times per second.

To solve the same problem by . . .

THE MANUAL METHOD

15 YEARS

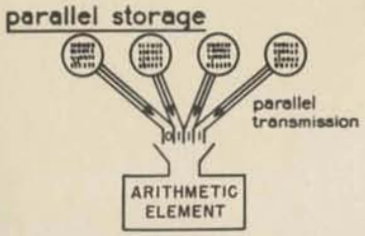
THE WHIRLWIND METHOD



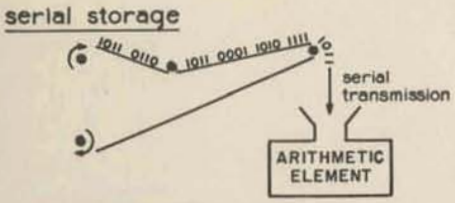
15 MINUTES

Whirlwind 1
is a parallel computer...

In a *PARALLEL* computer, all the digits of a number are stored, selected, and operated on *SIMULTANEOUSLY*



In a *SERIAL* computer, the digits of a number are stored, selected, and operated on *SEQUENTIALLY*



A parallel computer requires more arithmetic circuits than a serial type, but its speed and efficiency of using circuits are much higher.

Whirlwind 1 contains 4000 vacuum tubes and some 18 times this number of other components — crystal rectifiers, condensers, and resistors. Components are mounted on open racks arranged in rows according to the physical division of the computer into basic elements. To provide for ease of servicing and testing, the layout of the computer was deliberately made large. The total area occupied is 2,500 sq. ft., but in a redesign of the system, components could be compressed into a much smaller space.

A section of the arithmetic element during installation of power wiring.

Basic Elements of Whirlwind 1

Every computing system has certain basic elements. In the manual system portrayed below, these elements are the messenger who brings in the problem, the operator, the notebook in which he enters incoming data and records answers, the calculating machine, and the messenger who takes the results.

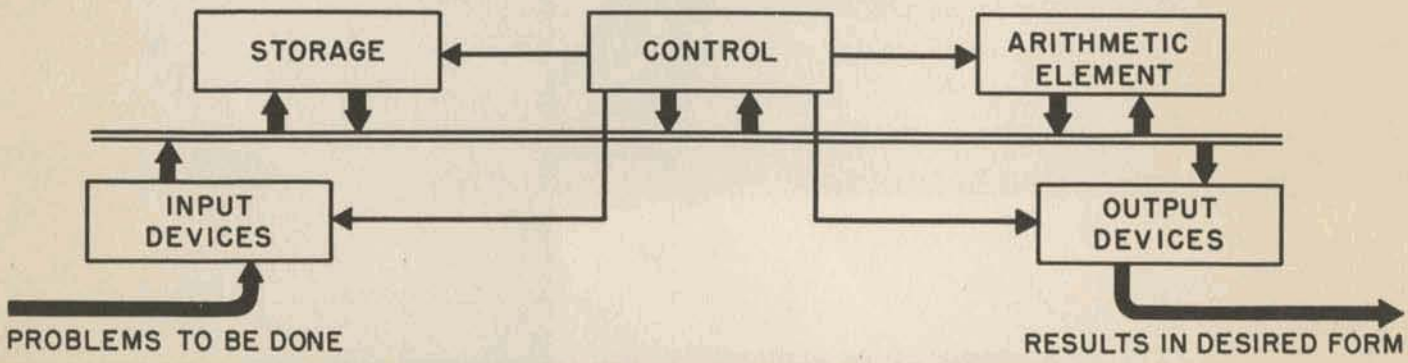
In the WHIRLWIND I system, the operator becomes CONTROL; the desk calculator, the ARITHMETIC ELEMENT; the notebook, STORAGE; and the messengers, the INPUT and OUTPUT devices.

COMPARISON BETWEEN...

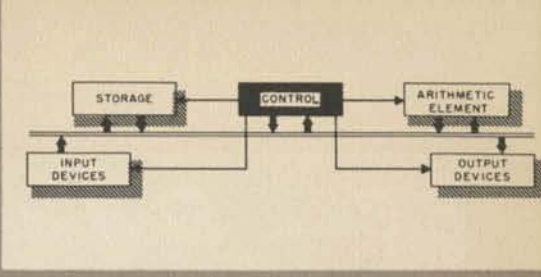
MANUAL COMPUTATION

AND

Whirlwind 1 COMPUTATION



CONTROL



Just as in manual computation the operator controls the steps to be performed, so in WHIRLWIND I computation ...

CONTROL

takes each instruction in sequence from storage, examines it and sends pulses at the proper times to the various parts of the computer to perform the necessary processes

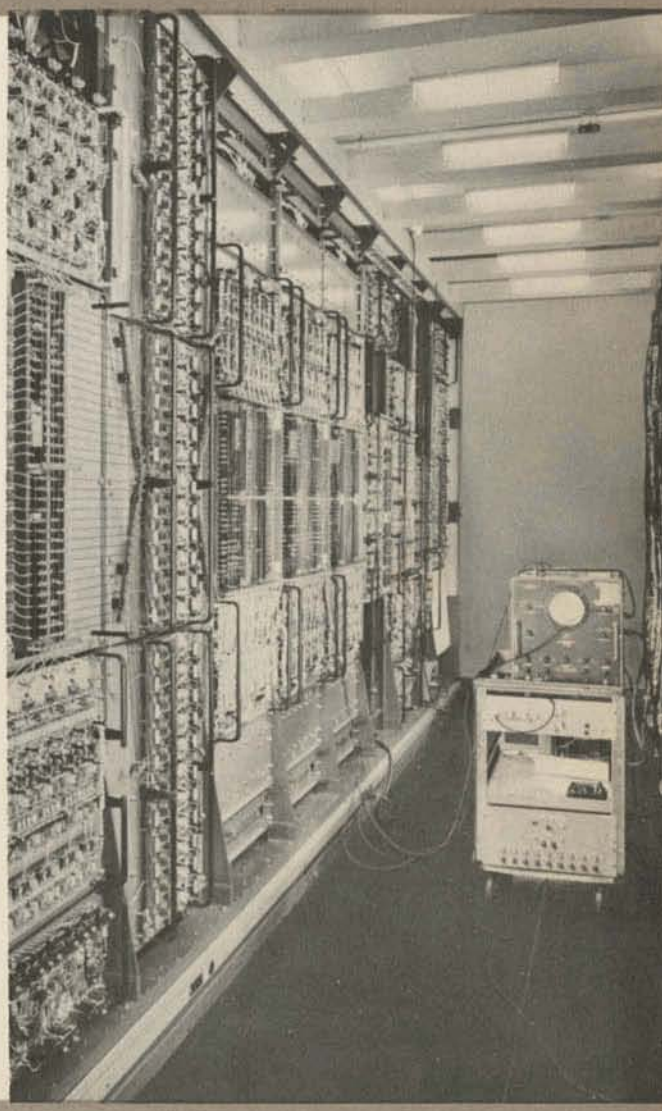
instructs *STORAGE* to select a storage register and read in or read out either numbers or instructions

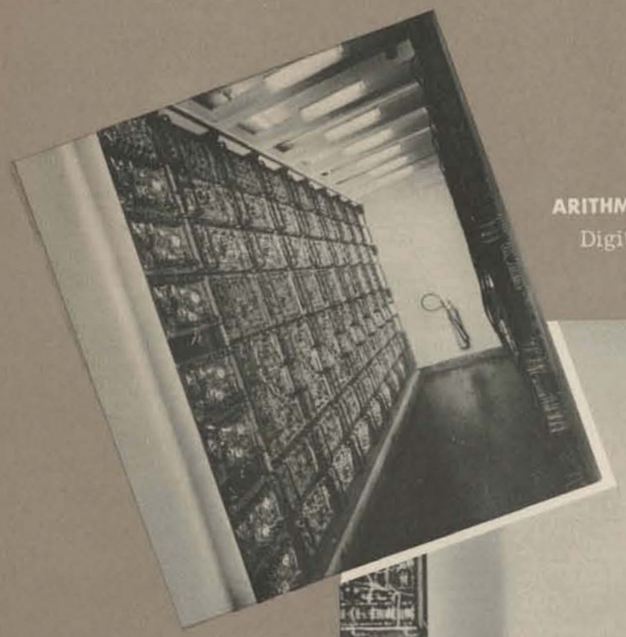
instructs *ARITHMETIC ELEMENT* to clear registers • add • subtract • multiply • divide • compare

instructs *INPUT* to select external device • start • record • stop

instructs *OUTPUT* to select external device • start • read • stop

The control element of WHIRLWIND I selects the operation to be performed by energizing the appropriate one of the 32 horizontal lines shown in the photograph. The selected line then opens the appropriate channels to allow operation pulses to pass to other parts of the computer.



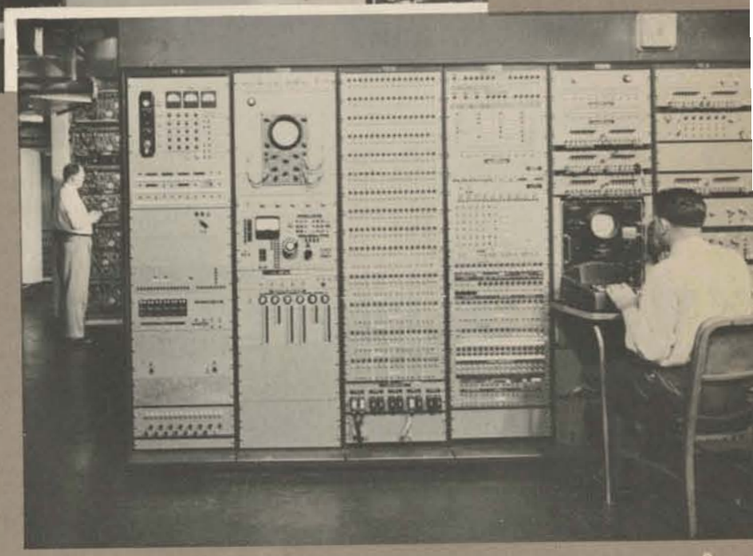


ARITHMETIC ELEMENT

Digits 8 through 15.

THE COMPUTER PROPER

First row, Input-Output; second row, Electrostatic Storage; third row, Arithmetic Element; fourth row, Control.



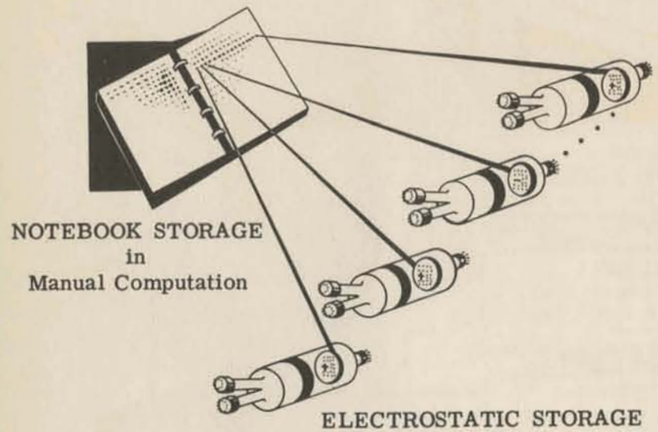
TEST CONTROL

A test center which provides facilities for monitoring computations, determining sources of trouble, and coordinating maintenance procedures.

The computer proper may be seen at the left.

STORAGE

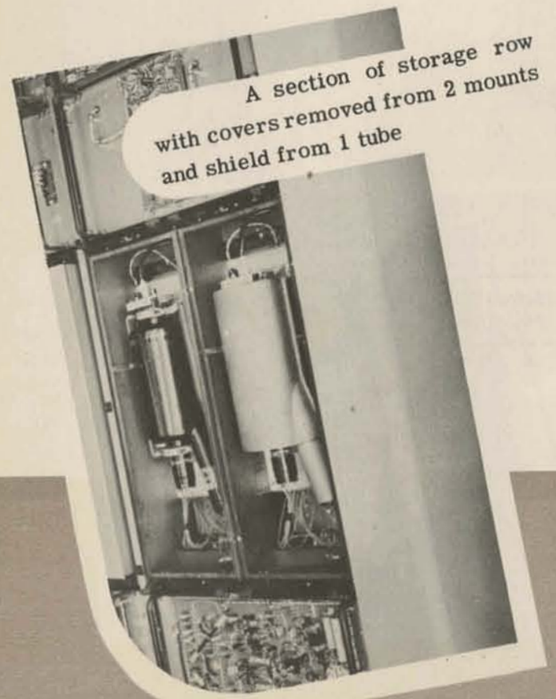
The memory for initial data, instructions, and intermediate results.



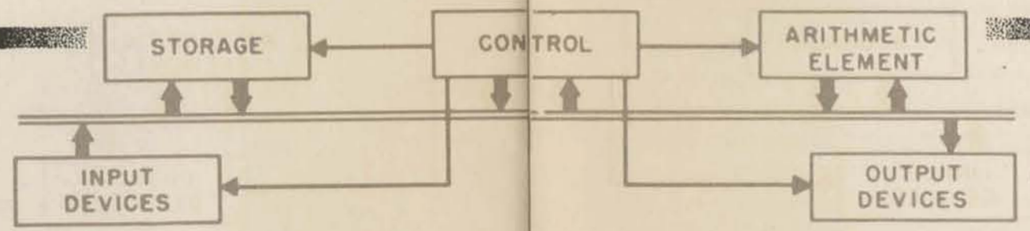
NOTEBOOK STORAGE
in
Manual Computation

ELECTROSTATIC STORAGE
in
WHIRLWIND I Computation

In *Whirlwind I* two separate banks of electrostatic storage tubes are used to provide a total storage capacity of 2048 sixteen-digit binary numbers. Each bank has sixteen tubes. The first digit of a number is stored in the first tube of a bank; the second digit, in the second tube; etc. The computer handles all sixteen digits of the number simultaneously.



A section of storage row with covers removed from 2 mounts and shield from 1 tube

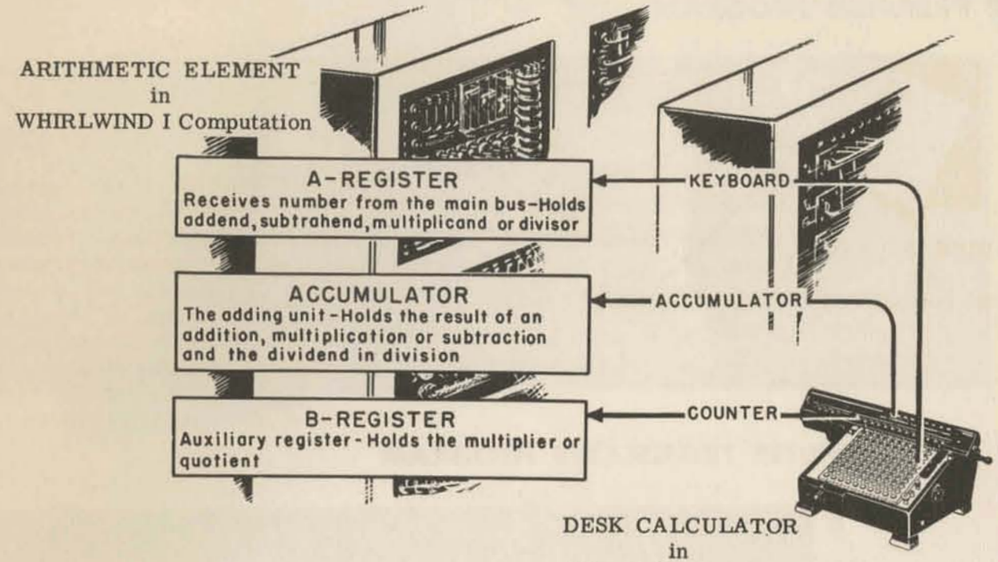


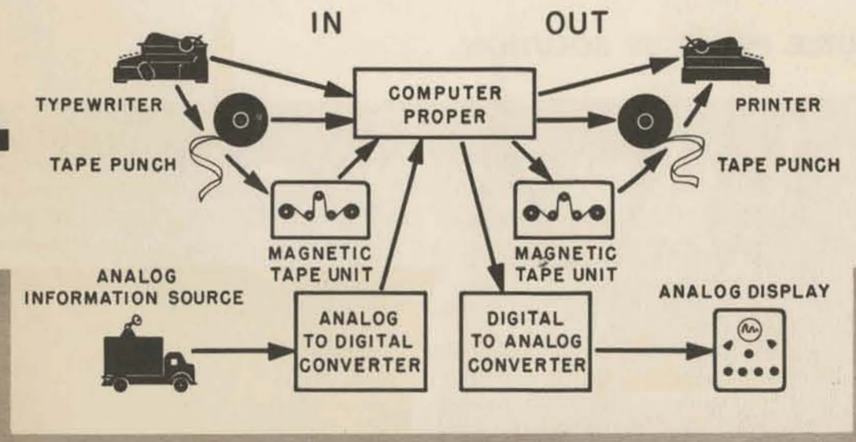
INPUT AND OUTPUT

The alternative ways of getting information into and out of WHIRLWIND I. Selection of the device is done by Control.

ARITHMETIC ELEMENT

The section which performs arithmetic operations
add • subtract • multiply • divide





How The Whirlwind System Operates

USER PREPARES PROGRAM

Before Whirlwind I can solve a problem, the user must break down the general processes for its solution into steps which the machine can handle. These steps must then be coded into a program as instructions and numbers.

Instructions, written in a special code of letters and decimal figures, tell the computer what to do; numbers are simply the decimal equivalents of the quantities involved in the problem. Each instruction and number is assigned to a specific storage register in the computer: instructions to consecutive registers, in the order of their execution; numbers to any remaining registers.

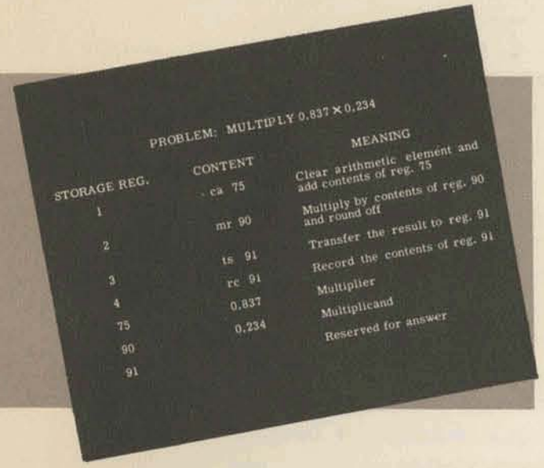
COMPUTER TRANSLATES PROGRAM

When the program is ready, an operator types it into special input equipment which converts the letters and decimal numbers into an intermediate code which the computer then translates into its own language — binary notation. The translated version is stored on perforated paper tape or magnetic tape, as the case demands, and may be fed to the computer at a later time and at a faster-than-typewriter rate. All Whirlwind I computations are performed in binary arithmetic which uses only the digits zero and one.

COMPUTER PROVIDES SOLUTION

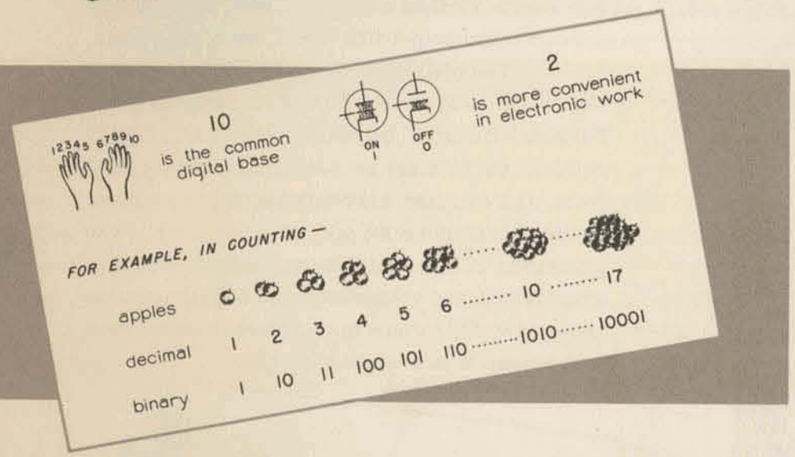
As soon as the program is in computer storage, Whirlwind I is ready to begin the solution of the problem. Control takes the first instruction from Storage, examines it, and sends the appropriate command pulses to carry it out. Control then goes on to each instruction sequentially, and causes it to be performed.

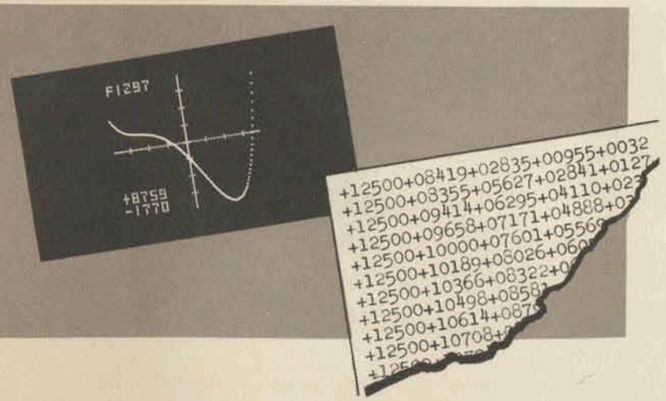
The last instruction tells the computer how to deliver its results. These may be in the form of a table, an oscilloscope display, or a stream of impulses that will control a machine or any other device.



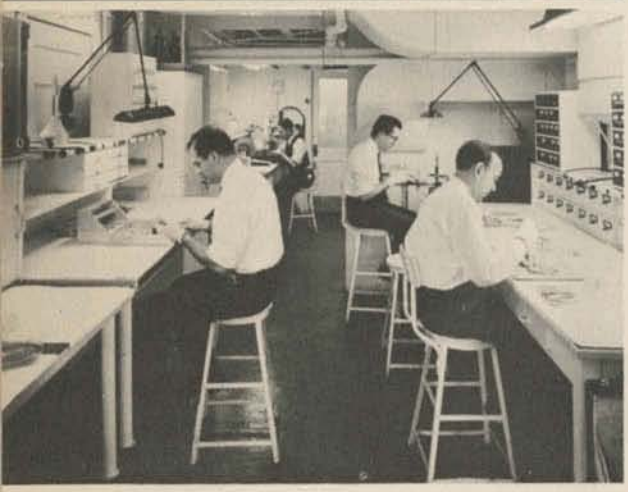
PROBLEM: MULTIPLY 0.837 × 0.234

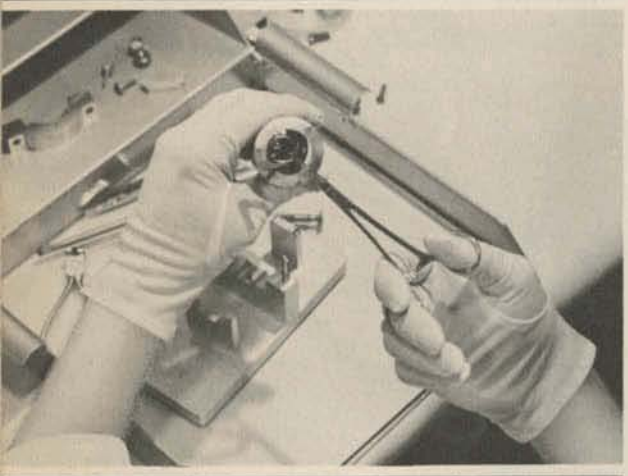
STORAGE REG.	CONTENT	MEANING
1	ca 75	Clear arithmetic element and add contents of reg. 75
2	mr 90	Multiply by contents of reg. 90 and round off
3	ts 91	Transfer the result to reg. 91
4	rc 91	Record the contents of reg. 91
75	0.837	Multiplier
90	0.234	Multiplicand
91		Reserved for answer

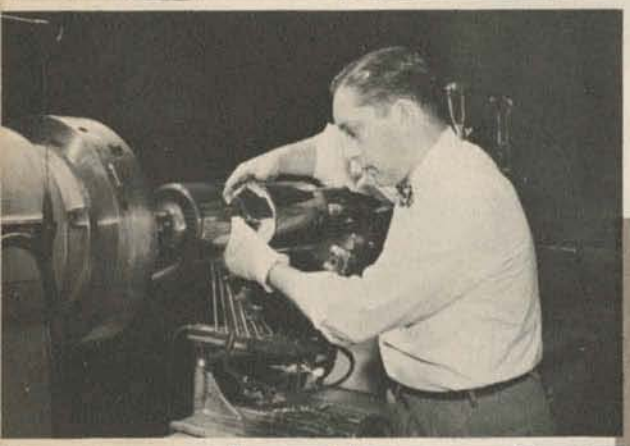


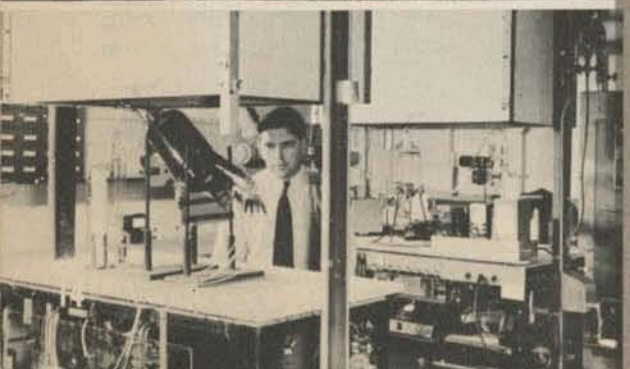


Often the program contains an instruction which directs the computer to examine the results it has already calculated and to determine from these results which of two alternative paths it will follow. Such decisions might be whether to repeat a certain series of steps or to continue with a new series. Thus the computer is able to modify and generate parts of its own program.









Electrostatic Storage Tubes

The electrostatic storage tube, like the television picture tube, uses a movable electron beam to distribute information over a surface. The diagram below illustrates the operation of the storage tube. A high-velocity electron gun "writes" a binary digit as a charged spot on a dielectric storage surface. Whether the spot is charged positively (for digit 1) or negatively (for digit 0) depends on the voltage level of the surface at the time of writing. A holding gun, producing an electron flood, keeps digits "in storage" for as long a period as desired. The high-velocity gun is also used to "read." When the read beam strikes a charged spot, a signal appears on the output line from the signal plate.

The electrostatic storage tubes used in Whirlwind I were designed and constructed in the Servomechanisms Laboratory at M.I.T. Many delicate parts must be assembled with special tools, and extreme care must be taken to guard against hand moisture and dust particles. The processes of component mounting, tube sealing, evaporation, and activation require patience plus know-how, and extensive tests are made on each tube before it is accepted for use.

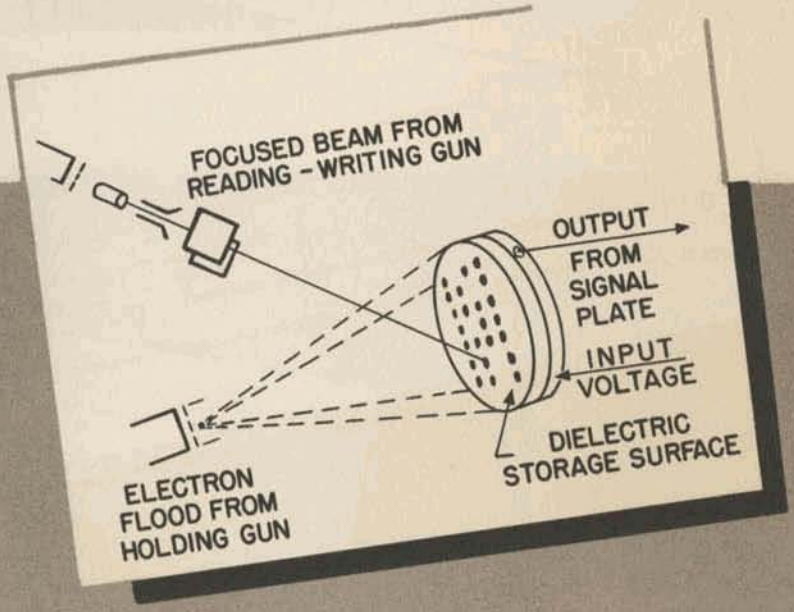


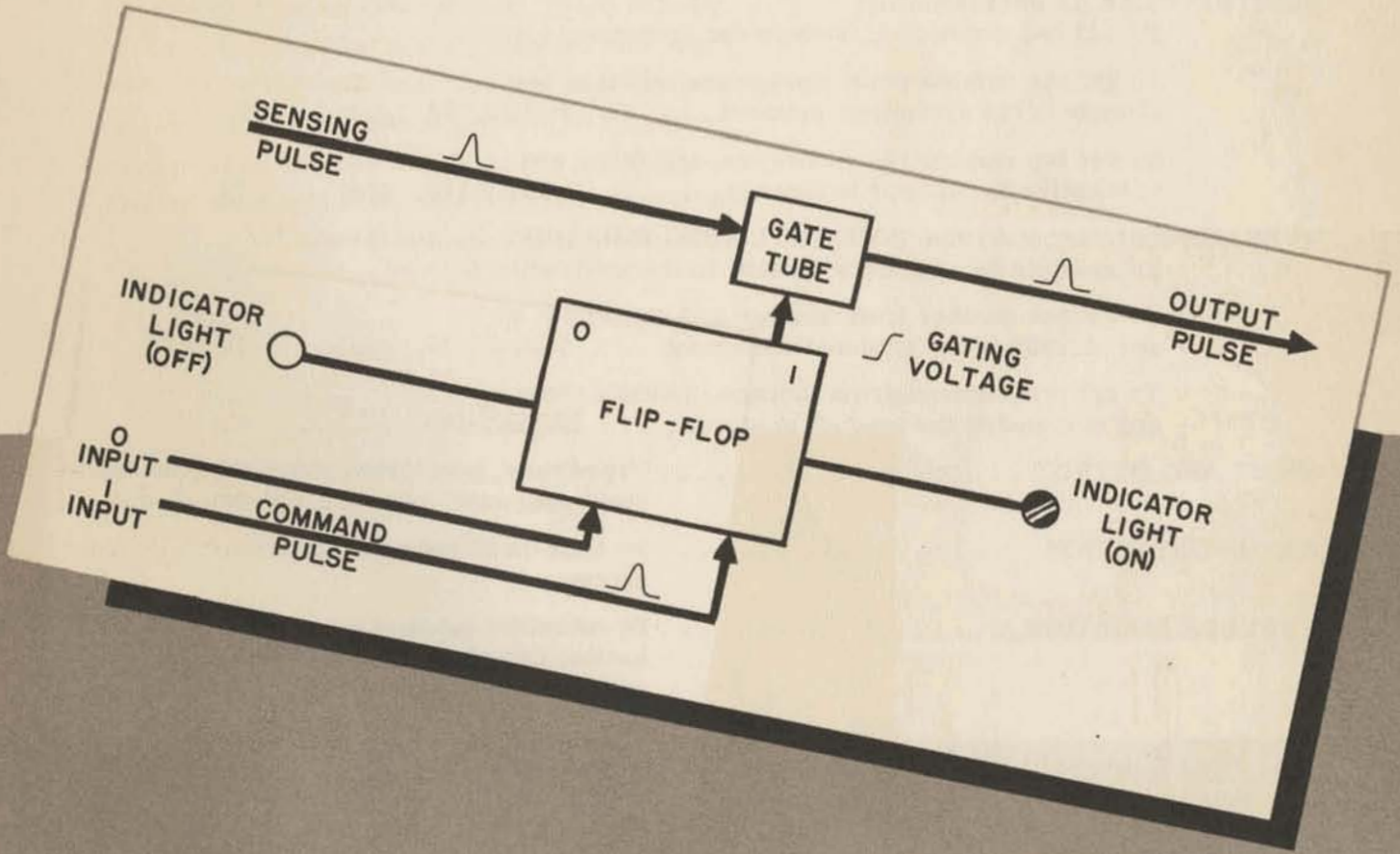
DIAGRAM OF ELECTROSTATIC STORAGE TUBE

Principal Electronic Circuits

The computations of Whirlwind I are executed by high-frequency pulses in electronic circuits. The principal circuits are the FLIP-FLOP and the GATE TUBE. The FLIP-FLOP is a two-position electronic switch. Two vacuum tubes are so connected that one tube or the other is conducting — but not both. The FLIP-FLOP is capable of maintaining either position indefinitely until it is switched by a command pulse. Thus, if we interpret one position as a 1 and the other as a 0, we may store intelligence in the FLIP-FLOP by sending a command pulse to establish the desired position.

The GATE TUBE is used to control pulse travel. A sensing pulse arriving at one grid of the GATE TUBE will appear at the output only when a gating voltage is applied simultaneously to the second grid. By connecting the output of one tube of the FLIP-FLOP to the second grid of the GATE TUBE, we can control the opening and closing of the "gate."

Whirlwind I uses about 275 FLIP-FLOPS and 1500 GATE TUBES in its Control and Arithmetic Element.



A TYPICAL COMPUTER CIRCUIT

Summary of Whirlwind 1 Specifications

TYPE OF COMPUTER	General purpose, high-speed
DESIGN	Electronic, digital
NUMBER SYSTEM USED	Binary
REGISTER LENGTH (basic)	16 Binary digits
METHOD of HANDLING NUMBERS	Parallel digit transmission, addition, and storage
TYPE of INTERNAL STORAGE	Electrostatic storage tubes
CAPACITY of INTERNAL STORAGE	Initially 256 registers; when complete, 2048 registers
ACCESS TIME to INTERNAL STORAGE	Initially 25 microseconds; when complete, 6 microseconds
BASIC FUNCTIONAL DESIGN	0.1-microsecond pulses, representing instructions or numbers, are distributed via gate tubes, which pass pulses only when a coincidence signal from a memory device, such as a flip-flop, is present
PULSE REPETITION FREQUENCY	2 megacycles in arithmetic element, 1 megacycle elsewhere

ADDITION TIME (in microseconds)

To add two numbers already in the arithmetic element	2
To get one number from storage and add it to one already in the arithmetic element — Initially 60, goal	24
To get two numbers from storage, add them, and to transfer the answer to storage — Initially 180, goal	72

AVERAGE MULTIPLICATION TIME, INCLUDING ROUNDOFF (in microseconds)

To multiply two numbers already in the arithmetic element	20
To get one number from storage and multiply it by one already in the arithmetic element — Initially 75, goal	39
To get two numbers from storage, multiply them, and to transfer the product to storage — Initially 195, goal	87

INPUT AND OUTPUT	Typewriter, perforated paper tape, magnetic tape, magnetic drum, oscilloscope display
ERROR DETECTION	By built-in identity checks and miscellaneous alarms
TROUBLE LOCATION	By automatic marginal-checking system which locates deteriorating components during test periods