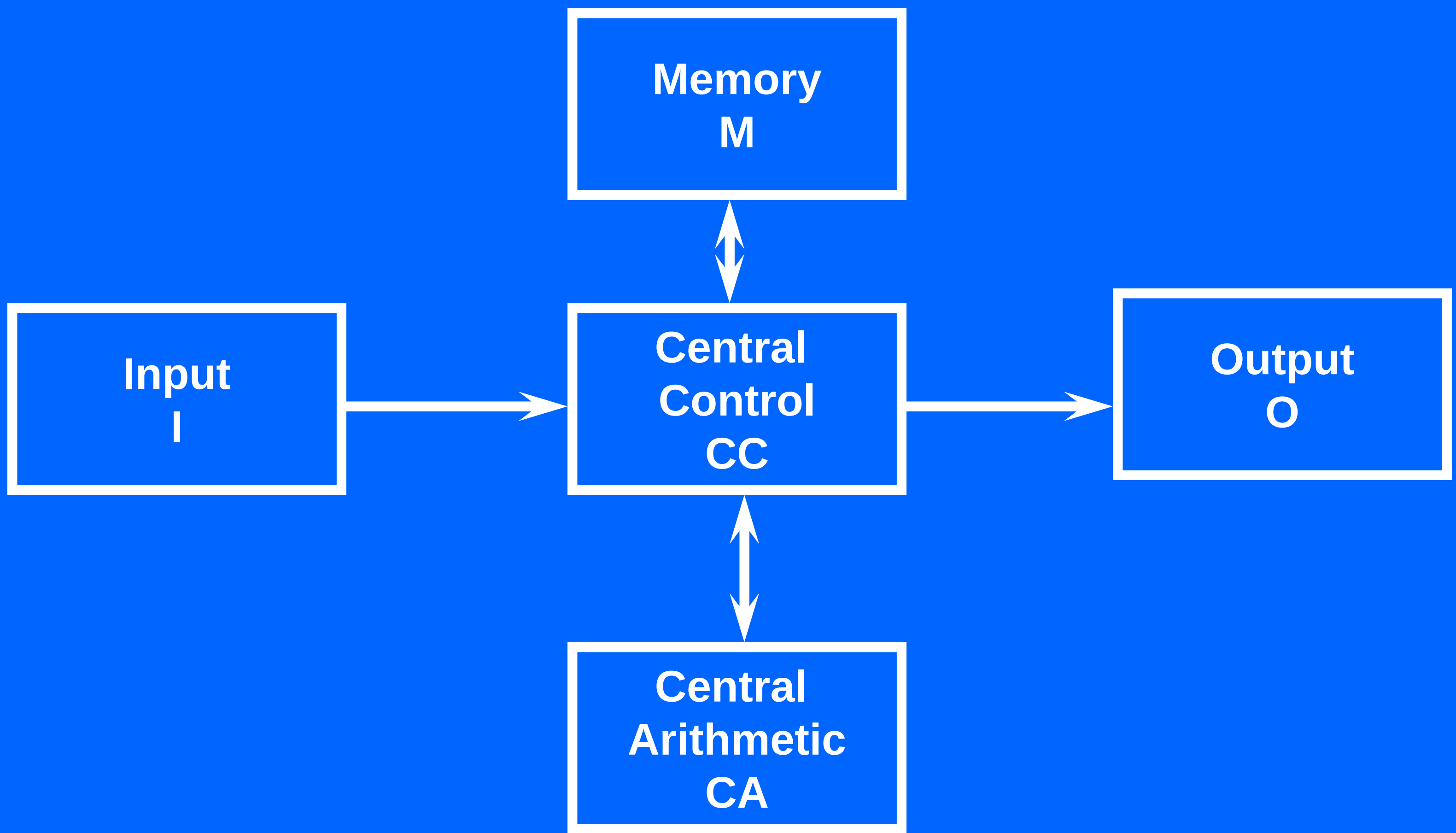
The Videotape Sources: The Pioneers and their Computers

- Lectures at The Computer Museum, Marlboro, MA, September 1979-1983
- Goal: Capture data at the source
- The first 4: Atanasoff (ABC), Zuse, Hopper (IBM/Harvard), Grosch (IBM), Stibitz (BTL)
- Flowers (Colossus)
- ENIAC: <u>Eckert, Mauchley, Burks</u>
- <u>Wilkes (EDSAC … LEO)</u>, Edwards (Manchester), Wilkinson (NPL ACE), Huskey (SWAC), Rajchman (<u>IAS</u>), Forrester (MIT)

What did it *feel* like then?

- What were the computers?
- Why did their inventors build them?
- What materials (technology) did they build from?
- What were their speed and memory size specs?
- How did they work?
- How were they used or programmed?
- What were they used for?
- What did each contribute to future computing?
- What were the by-products? and alumni/ae?

The “classic” five boxes of a stored program digital computer



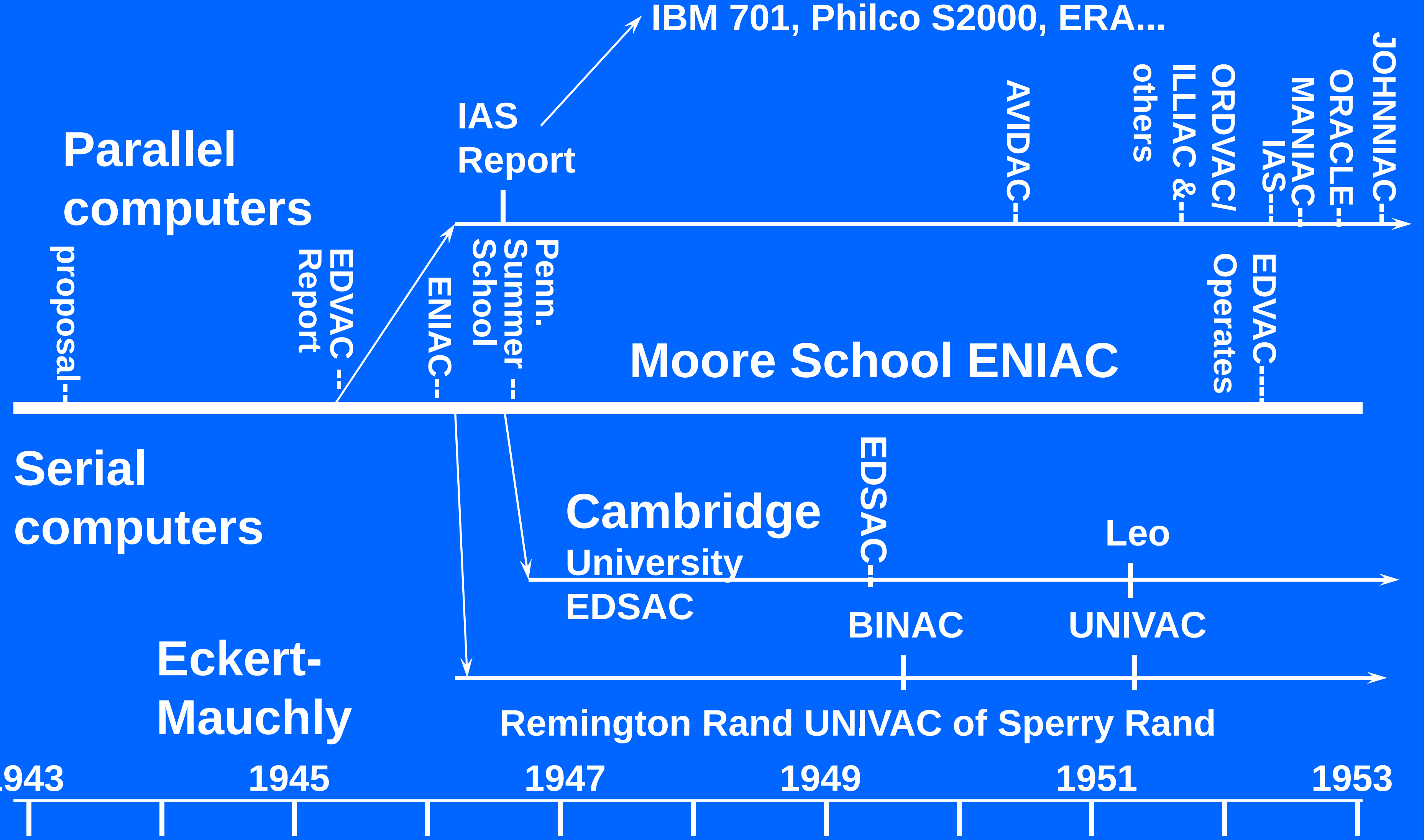
How was programming done before programming languages and O/Ss?

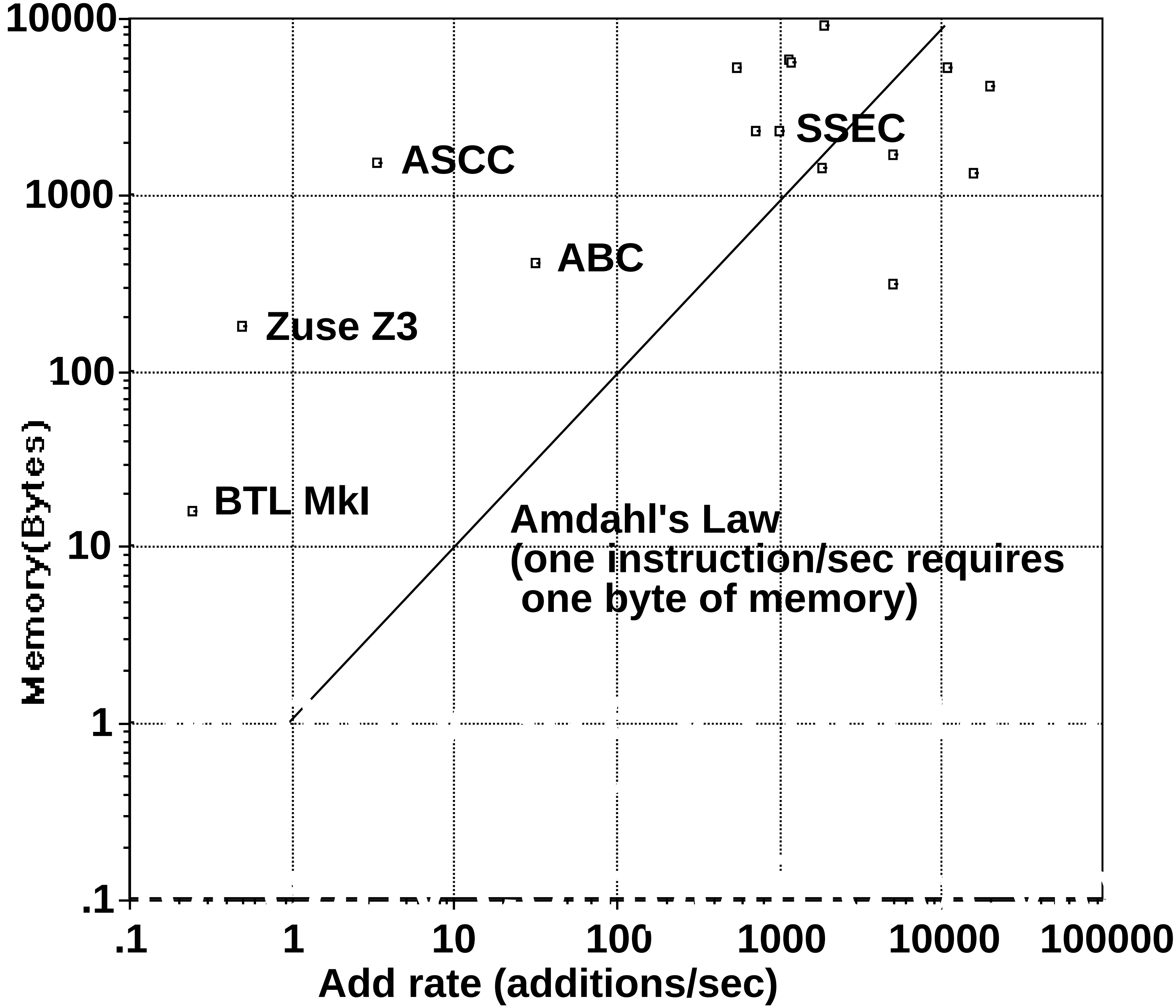
- ENIAC was programmed by routing control pulse cables forming the "program counter"
- Clippinger and von Neumann made "function codes" for the tables of ENIAC
- Kilburn at Manchester ran the first 17 word program
- Wilkes, Wheeler, and Gill wrote the first book on programming, reprinted by Babbage Institute Series
- Parallel versus Serial
- Pre-programming languages and operating systems
- Big idea: compatibility for program investment
  - EDSAC was transferred to Leo
  - The IAS Computers built at Universities

Time Line of First Computers

Year	1935 • 1940 • 1945 • 1950 • 1955 •
BTL	---------o o o o
Zuse	----------------o
Atanasoff	------------------o
IBM ASCC,SSEC	------------o-----------o >CPC
ENIAC	?--------------o
EDVAC	s-----------------o
UNIVAC I	
IAS	--?s-----------o
Colossus	-------?---?----o
Manchester	?--------o ?>Ferranti
EDSAC	?-----------o ?>Leo
ACE	?--------------o ?>DEUCE
Whirlwind	
SEAC & SWAC	

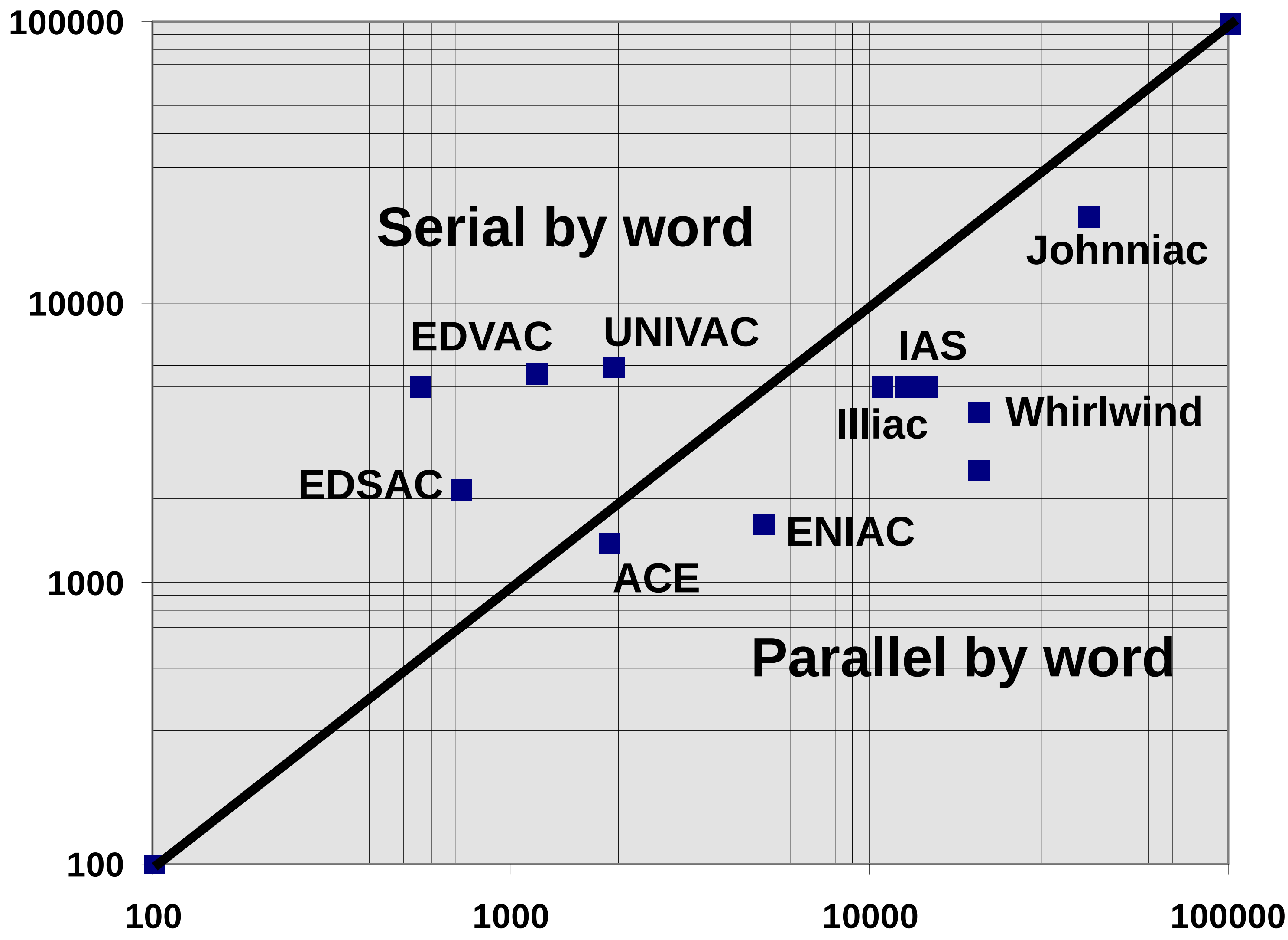
ENIAC Project
Time Line & Descendants



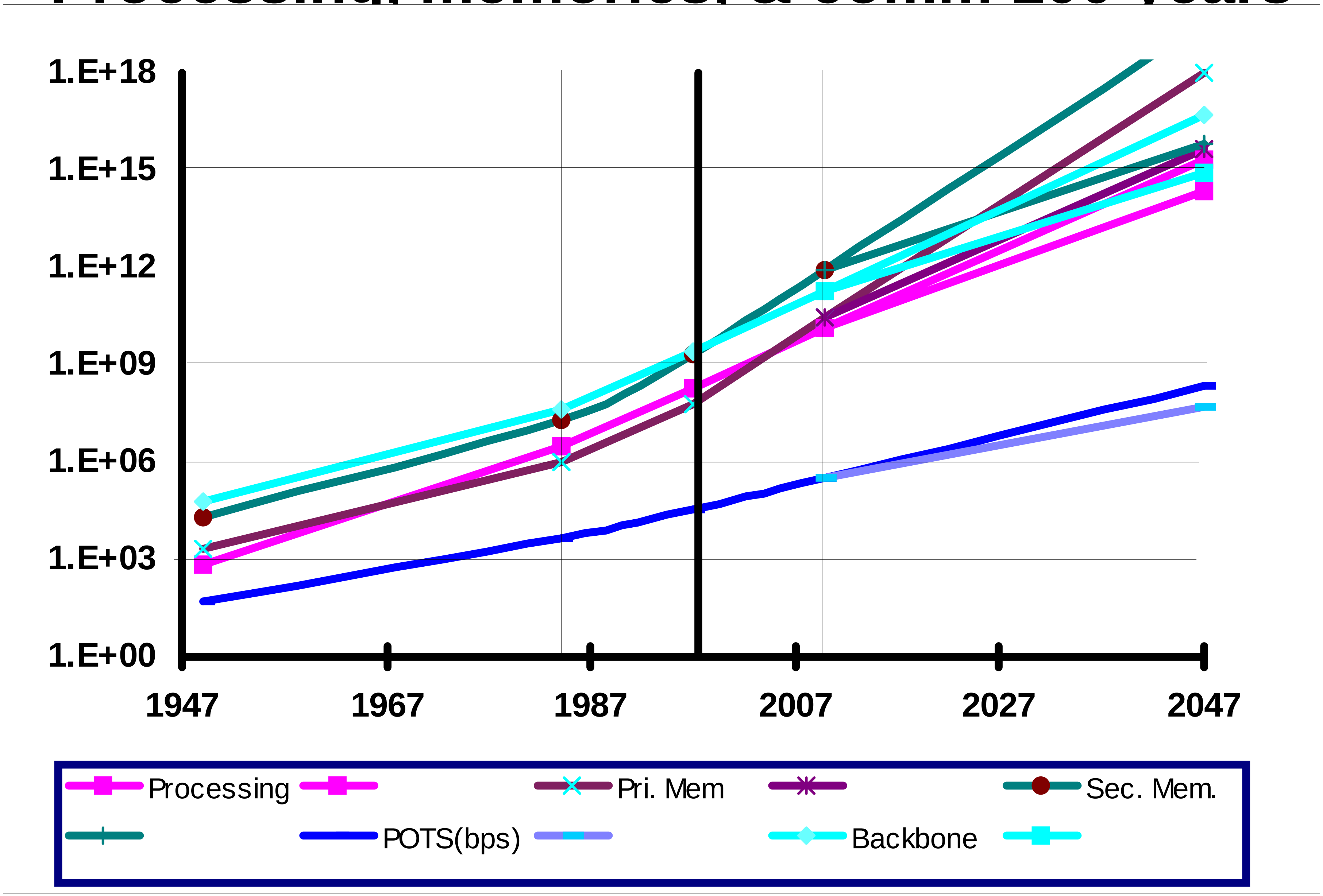


10000
1000
100
10
1
.1
Memory(Bytes)
.1
1
10
100
1000
10000
100000
Add rate (additions/sec)
ASCC
SSEC
ABC
Zuse Z3
BTL MkI
Amdahl's Law
(one instruction/sec requires
one byte of memory)

Memory Size vs Add-rate



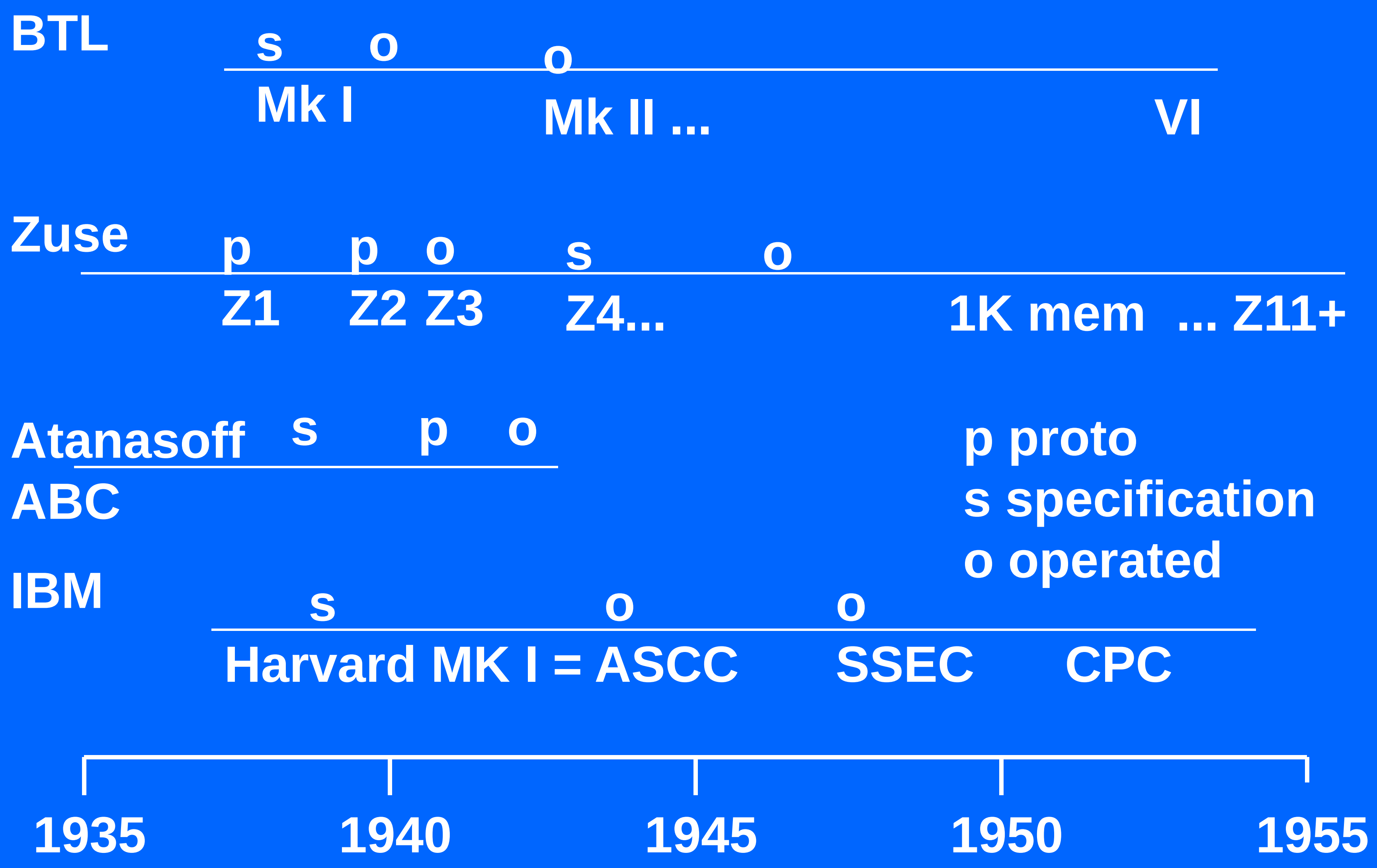
Processing, memories, & comm 100 years



Calculators & Computers

- 1 Pre-WW II, *except* Colossus
  – Stibitz
  – Zuse Z1-Z3
  – Atanasoff
  – Aiken-IBM (Hopper & Grosch) Mark I & SSEC
- 2 ENIAC to the stored progam computer
  – EDVAC to UNIVAC
  – EDSAC to LEO (UK)
  – IAS and it's progeny
- 3 Computers in the UK
  – Colossus
  – Mark I to Ferranti
  – EDSAC to Leo
  – Pilot ACE to Deuce
- 4 MIT & Bureau of Standards
  – Whirlwind to SAGE, TX-O, TX-2, to Digital
  – IBM
  – SEAC & SWAC

Pre-stored program calculators



Organizational Support vs Control

	indiv.	university	industrial	product
Stored program control		EDVAC EDSAC → IAS family ACE → Manchester → Whirlwind, TX →		UNIVAC Leo Deuce Ferranti SAGE
Tape seq. control	Zuse	ASCC	Colossus SSSEC →	CPC
Plugboard control		ENIAC		ibm calcs
Fixed fcn		ABC	BTL MKs	

Inventor-builder versus control

	Inventor & builder	Inventor -- engineering & building
Tape controlled	Zuse (home) Z3	Aiken Harvard IBM ASCC
Calculator (Fixed func)	Atanasoff Iowa State ABC	Stibitz BTL MK I

Organizational support vs type of control for first calculators

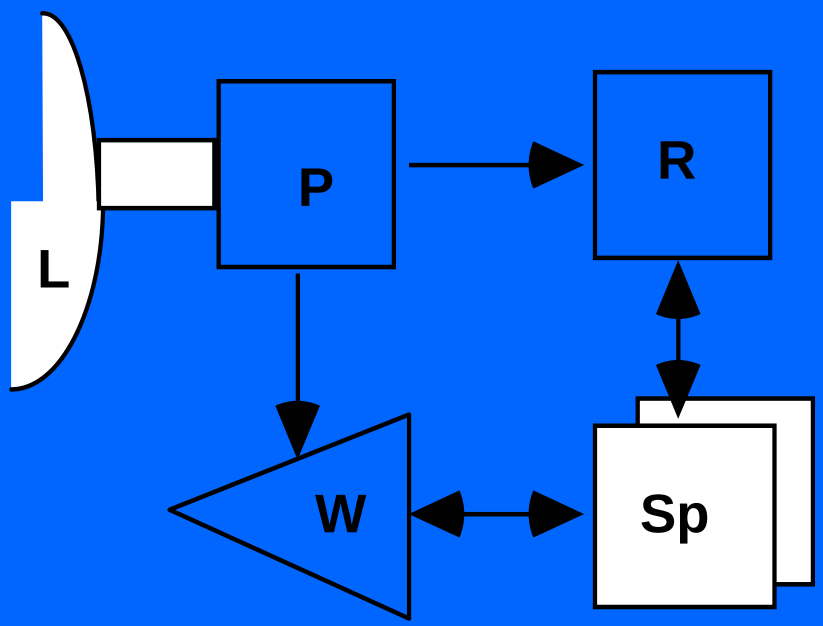
Tape seq. control — Zuse — ASCC — SSEC > CPC

Plugboard control — ENIAC

Fixed fcn — ABC — BTL MKs

indiv. university industrial product

Zuse plan for tape controlled calculator c1935



L punched tape to supply
instructions & data
P sequence control unit
R arithmetic unit
W memory selector
Sp memory unit

Bell Telephone Laboratory Mark I

Inventor	George Stibitz
Builder	Bell Labs
Operational	1939; demo of remote Teletype access
Retired	1949
Cost	-$20,000 ($160,000 in 1993)
Size	8’ x 5’ x 1’
Technology	relays, cross-point switch Teletype
Memory	four 8 digit decimal words (2 complex nos.)
Program	fixed, complex arithmetic calculator
Speed	4 seconds per operation (1/4 ops/sec)
Application	circuit analysis, defense, proto for later calculators

SSEC

User	Wallace Eckert, Columbia University
Builder	IBM; Frank Hamilton, chief engineer
Operational	Jan. 27, 1948 dedication
Retired	??
Cost	??
Size	??
Technology	vacuum tubes, relays, cards, plugboards
Memory	160 digits in vacuum tubes, 300 digits in relays; 400,000 on punched paper tap
Program	IBM punched card stock; stored program
Speed	20 digits, 50 multiplications / sec (14 digits
Applications	astronomy, defense, ??

Zuse Z3

Inventor	**Konrad Zuse**
Builder	**Zuse**
Operational	**1941 destroyed in 1944**
Cost	**-$6,500 ($52,000 in 1993)**
Size	**two 3’ x 6’ x 1’racks for memory**
Technology	**relays**
Memory	**64 22-bit floating point words**
Program	**35 mm. (punched) film**
Speed	**2 seconds per operation (0.5 ops/sec)**
Application	**civil engineering stress analysis, proto for aerodynamic calculators**

Harvard Mark I

Inventor	Howard Aiken
Builder	IBM
Operational	Jan. 1943 @ Harvard August 1944
Retired	1959
Cost	$500,000; $4 M 1993 by government
Size	52’ x 8’ x 2’
Technology	relays, punched cards, plugboards
Memory	132 23 digit words plus tape, plugboards
Program	punched card stock tape
Speed	3.3 operations per second
Application	non-linear differential equations defense calculations

Atanasoff-Berry Computer

Inventor	John V. Atanasoff
Builder	Atanasoff & Berry at Iowa State
Operational	1942?
Cost	-$7,000; ($56,000 in 1993) by Iowa State
Size	6’ x 3’ x 3’
Technology	vacuum tubes, capacitor storage, cards
Memory	64 - 50 bit words
Program	fixed, matrix arithmetic calculator
Speed	32 operations per second
Application	matrix solver for partial differential eqns.

ENIAC - Electronic Numerical Integrator and Computer

Inventors	J Prespert Eckert & John Mauchly
Builder	Moore School, University of Pennsylvania
Operational	February 14, 1946
Retired	
Cost	$500,000
Size	40 panels arranged in U-shape
Technology	18,000 vacuum tubes,
Memory	flip flops, function table, plugboard, cards
Program	wires, plugboard, and function table (1948)
Speed	5000 ops/sec,
Application	

Manchester Machines

Inventor Frederick Williams and Tom Kilburn
Builder Manchester University;
Ferranti Mark I, 2/1951
Operational 21 June 1948 (32 words); Mark I April 1949

Retired

Cost

Size
Technology serial

Memory

Program

Speed

Application test electostatic or Williams Tube memory

EDSAC

Inventor	Maurice Wilkes
Builder	Cambridge University
Operational	May-June 1949
Retired	
Cost	
Size	
Technology	vacuum tubes
Memory	1 K words, 17 bits, Mercury delay line
Program	single address
Speed	1400 microseconds, 714 operations/sec
Application	

Institute for Advanced Studies IAS Computer & Architecture

Inventor	John von Neumann with Arthur Burks, Herman Goldstein
Builder	Princeton Insitute for Advanced Studies
Operational	1952
Retired	
Cost	$500,000
Size	22 sq ft, 1K pounds;
Technology	4500 vacuum tubes, Electrostatic tubes
Memory	40 bits x 1024; 16,384 drum
Program	single address
Speed	40 digits,
Application	70 Microseconds; 14,000 ops/sec
Descendants	Avidac, George, Illiac, Johnniac, Maniac, Midac, MSU DC, Oracle, Ordvac, Silliac, Transac 1000-2000, Weizac, IBM 701, ERA 1103

ILLIAC and descendants

Builder	University of Illinois
Operational	9/52
Retired	1962
Cost	$500,000
Size	700 cu ft
Technology	vacuum tubes
Memory	40 x 1024 electrostatic, 12.8 Kw drum
Program	
Speed	93 microseconds; 10700 ops/sec
Application	

EDVAC

Inventors	Prespert Eckert & John Mauchly
Builder	Moore School, University of Pennsylvania
Operational	late 1951
Retired	1962
Cost	$467,000
Size	490 sq ft; 17,000 pounds
Technology	4K tubes, mercury delay lines
Memories	44 bits x 1024; 4608 word drum
Program	4 address
Speed	864 Microseconds +, 1200 ops/sec
Application	ballistic equations, firing tables, data reduction

AVIDAC* & ORACLE

Builder	Argonne National Laboratory, Lamont IL
Operational	AVIDAC (?/1950), Oracle (9/1953)
Retired	
Cost	$700,000
Size	1600 sq ft
Technology	5K tubes
Memory	2048 40-bit words, 4 Mwords of mag tape
Program	
Speed	50 microseconds, 20,000 ops/sec
Application	

*Argonne Version of IAS Digital Automatic Computer;
Oak Ridge Automatic Computer Logical Engine

ORDVAC

Builder	University of Illinois
Operational	3/1952(at BRL)
Retired	
Cost	$500,000
Size	700 cu ft
Technology	vacuum tubes
Memory	1024 x 40 bits electrostatic, 12.8 Kw drum
Program	
Speed	93 microseconds; 10,700 ops/sec
Application	

MANIAC --- Mathematical Analyzer Numerical Integrator and Computer

Builder	Los Alamos
Operational	March 1952
Retired	
Cost	$200,000
Size	128 cu ft
Technology	
Memory	40 x 1024 Electrostatic, 10K word drum
Program	
Speed	80 microseconds; 12,000 ops/sec
Application	
Operation ratio	93%

JOHNNIAC

Builder	RAND Corp
Operational	March 1954
Retired	
Cost	
Size	290 cu ft (12 x 3 x 8)
Technology	selectron tubes > core; 5K tubes, 1400 trans.
Memory	40 x 4096 words, 12K drum
Program	
Speed	25 microseconds; 40,000 ops/sec
Application	

BINAC

Inventor	Eckert and Mauchly
Builder	Eckert-Mauchly Computer Company
Operational	8/1949
Retired	
Cost	
Size	
Technology	s
Memory	
Program	
Speed	
Application	on board missle control for Northrup Aircraft company

Leo

Inventor
Builder
Operational
Retired
Cost
Size
Technology
Memory
Program
Speed
Application

Remington Rand UNIVAC I

Inventor	Eckert & Mauchly
Builder	Remington Rand UNIVAC Div of Sperry-Rand
Operational	?/1951
Retired	
Cost	
Size	
Technology	serial vacuum tubes, delay lines, mag tape
Memory	12 d x 1024 words, mag tape
Program	
Speed	525 microseconds; 1905 ops/sec
Application	commercial
Other	off-line tape to card, paper tape,

template

Inventor
Builder
Operational
Retired
Cost
Size
Technology
Memory
Program
Speed
Application

Gordon	Hello, I'm Gordon Bell. When I got into computing in the late fifties I met many of the pioneers and saw some of the first computers in action. It was inspirational; and I want to help you have a similar experience.
	With this video, I hope you get the feeling of what it was like to invent computing. You'll see and hear the pioneers and their computers in vintage footage and in later day reminesences. I will be your guide in time travel from the dawn of computing in the thirties to its commercialization in the fifties.
Gordon by card sys	In the thirties, card calculating .. while an advance over pencil, paper, and mechanical calculators ...
video of card system	was labor intensive, slow, and unwieldy. Systems like this were used in the war effort, including the design of the A bomb at Los Alamos.
Plugboard	Plugboards were used to instruct the machines. Here I'm specifying an operation by plugging in a wire. These calculators were used for accounting.
Video of desk calc	Scientific problems were laboriously done on desk calculators. Took hours and days to do. And were fraught with the errors of human input. A few scientists and engineers started to dream up machines that could help solve complex problems more directly and simply.
	The first machines were little more than faster and more reliable calculators. But each them made some advances that helped pave the way for the definition of computers. The first tape (talk? episode? lecture? film?) covers these machines.

by UNIVAC	The next three tapes tell parallel stories from pioneer computers through their commercialization. The second traces the ENIAC project to the UNIVAC.
bit of Brit video	The third tells the unique story of computing in the United Kingdom with a variety of early, successful companies.
bit of Whirlwind	The final tape traces project Whirlwind at MIT to the SAGE system built for the Defense Department by IBM, and the first transistorized computer that were the basis of Digital Equipment Corp.
Gordon by card	By 1937, five independent researchers were dreaming about "computing" machines. Four were driven by curiousity and frustration with the error-prone slowness of their own work. They were inner-driven to build a fast, scientific calculating machine.
Zuse	The first was Konrad Zuse in Berlin. While a student of civil engineering, he started to work on the design of mechanical aids to stress calculations. By 1936 Zuse had a basic design for a computer whose operations were specified by a sequence of markings on a tape.
Turing	The same year in England Alan Turing's paper "on computable numbers" was published introducing the concept of a "universal computing machine" to an academic audience. But none of the others were effected by his paper.
Add Atanasoff	At Iowa State University, physicist John Atanasoff was consumed with building a machine to solve simultaneous algebraic equations for the solution partial differential equations.

Add Aiken	And at Harvard physicist Howard Aiken, inspired by the designs of Charles Babbage, was determined to build a machine to solve non-linear differential equations that he was encountering in his disseration.
Add Stibitz to see all 5	And finally at Bell Labs, George Stibitz was experimenting with the use of telephone relays to build a reliable calculator for circuit analysis.

GB & stored timeline	Stibitz was the first to get an operational machine; his story is the BTL Mark 1. He tells the beginning of his story in a 1980 lecture at The Computer Museum:
Stibitz tape	
Memory size vs ops	To give you a road map of each of these machines, this graph shows their memory size versus speed. The BTL Model 1 was the slowest and had the smallest memory size of the first machines. It stored two 8 digit complex numbers. Addition took about 4 seconds, and complex multiply consisting of 4 multiplies and 4 adds took about a minute.
Pictures of Stib mac	Bell Labs built six more relay machines before the end of the war. The largest completed in 1946 had over 9,000 relays in several rooms, consumed 20 kW of power, used floating-point arithmetic, and cost about $500,000. or roughly the equivalent of xx million in 1996. Government paid for them.
	While slow, these machines were very reliable so that, for example in the 1946 while the ENIAC had bursts of speed it seldom ran for more than half an hour. Meanwhile that Bell Labs complex calculators worked 24 hours a day without attendance.

GB & Zuse'35 Plan	Konrad Zuse had many ideas that would lead to computing rather than just a better calculator. His 1935 diagram of a universal calculating machine used a punched tape to feed information into a control unit that selected a memory cell and specified the arithmetic unit's operation.
GB & Mech. memory	He saw the need for large memories as a critical element of the computer because his interest came from civil engineering and performing stress calculations involving matrix algebra.
	This is one memory bit. A word was selected by a row, and then read or written on a column basis by a series of mechanical levers.
Z1 photo	The Z1, a 1938 prototype, constructed in his Berlin apartment, had a 64 word memory.
	The Z2 prototype used relays for computation and was useful in convincing Germany's Experimental Aircraft Institute to fund the Z3.
Pre-stored timeline	The Z3 was completed in late 1941 and operated till it was destroyed in World War II. A copy was made in 1963 for the Deutsche museum from his 1941 patent application.
Picture of Z3	The Z3 had a 22 bit floating point word with a 7 bit exponent and 14 bit mantissa. It's relay memory of 64 words occupied two 6 x 3 x 1 relay racks. A bit took up about 35 cu inches. Z3 used a total of 2600 relays and 20 stepping switches.
Memory size vs op rate	Arithmetic was done in a Polish post-fix fashion by loading operands into its two registers

and then specifying the operation. Floating point addition took about 2 seconds.

film

Instructions were read from holes punched on used 35 mm film. Other data was read into and written from switches and lights in floating decimal form. Thus the controller for doing the floating point arithmetic was non-trivial. Inventing the notation for designing the relay logic was key to the Z3. Zuse himself was very interested in the programming aspects of computation; this talk is from a 1981 Computer Museum lecture:

Zuse talk

GB & Pre-stored timeline

The Z4 was constructed between 1942 and 45, was rebuilt in 1950. Zuse also had to make a living, and worked for the air ministry. Lesser known are his fixed function calculators used between 1942 and 1944 for aircraft design that replaced 30 calculator operators.

By 1951 it had a 1K mechanical memory with 1/2 second access time. Z4 logic was carried out with relays on its 32 bit floating point numbers. It remained in use till 1959.

British poster

After the war, Zuse started a computer company that built a series of machines before it was that was absorbed by ?? xx Siemens. (may add more text for poster)

GB &stored timeline	John V. Atanasoff was *perhaps* the first to conceive of an electronic calculator using serial, binary arithmetic.
photo Atanasoff	In January 1940 Atanasoff and his research assistant, Clifford Berry, built a prototype to demonstrate serial binary arithmetic and the use of capacitor store. The Atanasoff-Berry Computer or ABC was designed to solve 30 simultaneous linear equations to enable the solution of partial differential equations.
Photo of memory	Capacitors were mounted inside a drum with contacts that were used to read each bit serially as it rotated. Punched cards stored intermediate results.
Memor size vs op rate	The ABC drum memory of 64, 50 bit words rotated once per second. Since the machine had 32 words that were operated on in parallel, the effective add rate was 32/second. Atanasoff also told his story at The Computer Museum in the fall of 1981:
JVA tape	
Gordon	When Atanasoff left Iowa in 1942 to become part of the war effort, the ABC still lacked a reliable card punch. It was not in service; the parts were cannibalized and the only remnant is the drum. Atanasoff's greatest contribution may have been helping break the broad ENIAC patent filed in 1964. He was clearly the first American to use binary arithmetic and vacuum tubes for direct digital computation and to describe and prototype ideas such as non-restoring divide the Eniac patent claimed. In June 1942 prior to the August Eniac proposal, Mauchley visited Atanasoff at Iowa State

	to see the ABC and hear his ideas about electronic computation.
GB & Pre-stored timeline	
	The last story of this era Thomas Watson Sr's funding of the Harvard Mark I; then having received little thanks or publicity, funding the SSEC at Watson Laboratory at Columbia University . However, the inventor was clearly Howar Aiken.
AIKEN	Aiken was motivated to build a scientific calculator to evaluate integrals like those he was encountering as a PhD candidate. He, alone of these pioneers, was inspired by reading the works of Charles Babbage and his plan for an Analytical Engine. By 1937, he had specified the architecture of a machine that he often referred to as a "computing engine."
Photo of GH & HA	It was the imagination and drive of Howard Aiken that created the ASCC for Automatic Sequence Controlled Calculator, or Harvard Mark I, providing the very first experience for IBM into computation that was not controlled by a plug-board.
Picture of IBM eng.	ASCC was engineered, built, and tested by IBM. Operational in January 1943.
Picture of dedication	It was moved to Harvard and dedicated on August 7, 1944.
Grace Hopper	Unfortunately, Howard Aiken died in xx?? and never told his story to the camera. But, Rear Admiral Grace Hopper his co-author of the ASCC manual vividly describes life working on the Harvard

	Mark 1. ...
Grace Hopper talk	
Mem sz vs ops	Both ASCC and Columbia's Electronic much faster SSEC stand out because they have large memories. Like the Z3 they were programmed from a sequence of instructions stored on tape. SSEC was a prototype for IBM's production model CPCs or Card Programmed Calculators. These machines led to important patents for IBM, because they could perform arithmetic on, and then execute, stored instructions.
IBM 650	The IBM engineers working on the SSEC went on to build the highly successful IBM 650.
IBM 701	The SSEC programmers became members of the IBM 701 programming group. But this is the end of the story.
Herb Grosch	The presentation is by Herb Grosch, one of the programmers of the SSEC at the Computer Museum on xx. ...
Org suppor vs control	The inventions were all by one person working alone, at home in Zuse's case, at a university in the case of Atanasoff, Aiken and Eckert, or Stibitz at Bell Labs. All were designed for scientific calculations as distinct from business and commercial record keeping.

The federally funded Bell Labs machines and the IBM ASCC were staffed by America's best engineers, unlike the one person Atanasoff and Zuse efforts.

Zuse's Z3 and Aiken's ASCC were on the mainline to the modern stored program computer because they were program controlled. Computer architects often refer to a design that has a separate store for instructions and data as the Harvard architecture.

Historian Paul Cerruzi has pointed out: "By 1945 there was a common understanding of the nature of the computer, how it should function, and how it should be constructed."

The generation of pioneers who worked in the late forties generally knew about the the Harvard Mark 1 and the Bell Labs machines. But neither the ideas of Atanasoff or Zuse had percolated into the mainstream of developments. Many of the breakthroughs that lead to fast, reliable, programmable machines were yet to come."

This knowledge and birth of the stored program digital computer was marked by John von Neuman's Edvac Draft Report issued on xx, xx, 1945 that was created in conjunction with Eckert and Mauchley. It specified EDVAC, or the Electronic Discrete Variable Automatic Computer. Hence, what we call the von Neuman computer.

115 6
Message 116:
From NASEM001@SIVM.SI.EDU Sun Nov 13 18:34:39 1994
Received: by Forsythe.Stanford.EDU; Sun, 13 Nov 94 18:34:26 PST
Received: from SIVM (NJE origin NASEM001@SIVM) by SIVM.SI.EDU (LMail
 V1.2a/1.8a) with BSMTP id 4798; Sun, 13 Nov 1994 21:33:21 -0500

Comments: Converted from OV/VM to RFC822 format by PUMP V2.2X
Date: Sun, 13 Nov 94 21:33:19 EST
From: paul ceruzzi <NASEM001@sivm.si.edu>
Subject: Can I ask you to review a script?
In-Reply-To: note of 11/11/94 21:32
To: Gordon Bell <gbell@mojave.stanford.edu>
Status: RO

I'd be very happy to look it over. E-mail is best--out fax machine is not too reliable these days. (Regular mail OK too). I'll do what I can.

& 119
Message 119:
From NASEM001@SIVM.SI.EDU Mon Nov 14 11:01:54 1994
Received: by Forsythe.Stanford.EDU; Mon, 14 Nov 94 11:01:15 PST
Received: from SIVM (NJE origin NASEM001@SIVM) by SIVM.SI.EDU (LMail
 V1.2a/1.8a) with BSMTP id 5291; Mon, 14 Nov 1994 13:58:03 -0500
Comments: Converted from OV/VM to RFC822 format by PUMP V2.2X
Date: Mon, 14 Nov 94 13:58:00 EST
From: Paul Ceruzzi <NASEM001@sivm.si.edu>
Subject: Latest text of my overview about 1900 words
In-Reply-To: note of 11/12/94 20:45
To: Gordon Bell <gbell@mojave.stanford.edu>
Status: RO

I'll reply to each of these messages as I read them. Basically I think you are doing fine & are definitely on the right track--I am enjoying reading these a lot.

Zuse--I'd say 1937-38; 1936 is a little to early to say that he had the basic idea of a computer formulated.

His company was absorbed first by Asea Brown Boverei, who kept it long enough to look at the books and then very quickly turned it over to Siemens! So Siemens is correct.

Aiken died in 1973.

At the point where you quote me--I think what I meant to say was that

betwen 1945 and 1950 there was a debate about what a computer was and
what it should look like. By 1950 there was general agreement.

Edvac report was issued June 30, 1945 (there may have been an earlier version on March 31, but I am not certain).

This may not come up but if you do spell out names watch out: Mauchly (not Mauchley), and Ceruzzi (not Cerruzi).

On to the next one.

& 121
Message 121:
From NASEM001@SIVM.SI.EDU Mon Nov 14 12:10:02 1994
Received: by Forsythe.Stanford.EDU; Mon, 14 Nov 94 12:09:53 PST
Received: from SIVM (NJE origin NASEM001@SIVM) by SIVM.SI.EDU (LMail
 V1.2a/1.8a) with BSMTP id 6228; Mon, 14 Nov 1994 14:51:59 -0500
Comments: Converted from OV/VM to RFC822 format by PUMP V2.2X
Date: Mon, 14 Nov 94 14:51:55 EST
From: Paul Ceruzzi <NASEM001@sivm.si.edu>
Subject: Scripts of JVA, Grosch, Hopper
In-Reply-To: note of 11/12/94 20:45
To: Gordon Bell <gbell@mojave.stanford.edu>
Status: RO

This one is fine, too. Mark I was installed in "Cruft" not "Kroft" Lab,
I think.

Note also that despite what Grace said, the Mark I was not a one-address machine. It not only specified two addresses; in the third column you simply punched a code for "go on" 90% of the time. That was because the memory registers were also capable of addition; therefore the simple act of transferring a number from one register to another caused an addition to take place. Ditto for multiplication, since that took place in specially-numbered addresses as well. So the third column was only for an "operation" on rare occasions. (This doesn't have to go in the video tape, but you might want to know)!

& 122

Message 122:
From NASEM001@SIVM.SI.EDU Mon Nov 14 13:11:49 1994
Received: by Forsythe.Stanford.EDU; Mon, 14 Nov 94 13:11:38 PST
Received: from SIVM (NJE origin NASEM001@SIVM) by SIVM.SI.EDU (LMail
 V1.2a/1.8a) with BSMTP id 6471; Mon, 14 Nov 1994 15:04:49 -0500
Comments: Converted from OV/VM to RFC822 format by PUMP V2.2X
Date: Mon, 14 Nov 94 15:04:46 EST
From: Paul Ceruzzi <NASEM001@sivm.si.edu>
Subject: Zuse and Stibitz scripts
In-Reply-To: note of 11/13/94 13:57
To: Gordon Bell <gbell@mojave.stanford.edu>
Status: RO

This is fine, too. The point that Zuse was trying to make but did not articulate very well was that he feels that he could have implemented conditional branching with "a single wire." But he did not because of various reasons, which he now says are trivial. But he is anxious that history record that his machines could have been truly general purpose and flexible, even though as first built they could only execute a single, linear stream of instructions. (like the Harvard Mark I) The z4 was modified after 1950 to do conditional branches. I think you'll agree with me that it probably would have taken more than "a single wire," but that is what he claims and he is the designer.

One final note, about the reconstructed Z3. The original was destroyed, but Zuse had his company build a reconstruction, based on some original drawings that survived, in 1963. (The only major change was the use of newer type relays for the memory unit, which was not fully rebuilt). I saw this reconstruction operate in 1990. That is enough to convince me that Zuse really did invent a computer in 1941--he would not have had ulterior motives to "cheat" in 1963, as he might have in later years. And this reconstruction is now one of the oldest operating computers in the world in its own right!

Hope these comments help. Looking forward to the finished product. At some point I hope to talk to you about my writing project for which we did the interview a few summers ago. It is almost done, and I have high hopes for it filling a big gap in the market for a single-volume history of computing.

xx length of Eniac and its space.

Intro paragraph, part 1, part 2

xx Hi, I'm Gordon here at the Computer Museum, Boston. In part 1 we talked about pre- world war II machines that led to the modern, stored program computer. In this part, I'm going to describe the transition from one-of-a-kind laboratory built tools to the formation of a computer industry.

The story begins with Prespert Eckert and John Mauchly. Here's Eckert talking about his role in this industry formation.

Here's Eckert talking about the formation of computing.

Assume a tape.

Maurice Wilkes 1995 Tribute to Presper Eckert, stated "Presper Eckert and John Mauchly, met at the Moore School of Electrical Engineering in Philadelphia and there collaborated on the design and construction of a large scale digital computing machine. That machine was the Electronic Numerical Integrator and Computer—ENIAC – and it changed the history of the world as far as computing is concerned. The Moore School (part of the University of Pennsylvania) was uniquely fitted to be the birthplace of the modern digital computer. It was a place where digital computing was actually happening."

The ENIAC project concluded with the design and eventual construction of EDVAC. The Draft EDVAC Report by John von Neumann is the seminal description of the first stored program computer. In 1946 Penn held a summer school

about EDVAC. It was attended by many who would build computers, including Wilkes.

This story is about three of the branches forming the stored program computer that came from the ENIAC project.

<u>TIME LINE TREE FIGURE</u>

The first outgrowth is Cambridge University's EDSAC led by Wilkes. He created the world's first, useful operational computer. It helped stimulate the formation of a British computing industry.

The second branch is the Institute for Advanced Studies architecture computers. A dozen or so machines were made at various laboratories using their basic design. Others, including IBM, built variants.

The final branch is the Eckert Mauchly Computer Corporation that ended up as <u>the Remington Rand UNIVAC division of Sperry-Rand.</u> It produced, UNIVAC I, the first successful U. S. commercial computer.

To be sure ENIAC influenced other efforts, but this is about the direct descendants.

Arthur Burks, who worked on ENIAC narrates a film compiled from clippings left over from a newscast.

Burks and ENIAC (Dedicated 2/15/46) film … "E wasn't a stored prog C, but it led to it"

ENIAC Specs

ENIAC was moved from Penn to Aberdeen's Ballistic Research Laboratory and operated until 1955. Clearly, ENIAC was an amazing engineering accomplishment.

This rack in one of 40 panels in a xx by xx space. Eniac was dramatically larger than any other system and used 18,000 vacuum tubes. ENIAC was designed and built by a dozen engineers working two years. Eckert commented that the user requirements caused the size to more than triple from the initial design.

Wilkes stated "When the design work of ENIAC was finished and the construction was in progress, Eckert and Mauchly had time to think about future developments. It did not take them long to realize that the potential existed for building much more powerful electronic computers that would also be much smaller in scale. Their thinking was advanced when John von Neumann, acting as a consultant to the Ballistic Research Laboratory began to pay visits to the group."

So now we begin the story of where the stored program computer we know and love gets invented.

The ENIAC team, as well as other machine builders, recognized that the time-consuming process of setting up

problems to "control" computation we now call programming had to be solved.

<u>ENIAC was more general than a numerical integrator. it's function tables could store instructions and emit control pulses to the function units.</u> It had conditional branching. Eventually, a special function table memory was built that could also take in instructions from punched cards.

In September 1944, John von Neumann of Princeton's Institute for Advanced Studies was appointed a consultant to the ENIAC project. He had learned about the "control" or "programming" problem a year early in England. One task he took on was to select a permanent code for the function tables. These became known as the von Neumann code for the ENIAC. However, Eckert made it very clear that the name was not because von Neumann discovered the stored program computer concept – only that he had selected the instructions.

A second, but related problem with the early calculators were that paper tape, punched cards, and plugboards held the instructions. Recall both Aiken and Zuse controlled their calculators with tapes. These slow devices were a poor match for electronic speeds. At a 1948 conference, Mauchly commented that "Calculations can be performed at high speed <u>only</u> if instructions are supplied at high speed."

<u>EDVAC SPECS</u>

Eckert and Mauchly's new machine was called EDVAC standing for Electronic Discrete Variable Automatic Computer. It was to have an electronic memory that could keep up with the arithmetic circuits and solve the "control" problem. It had only four thousand tubes and a 44 bit word length. EDVAC was built at Penn and moved to Abardeen's Ballistic Research Laboratory in 1950 … but the physical machine is incidental to computing.

John von Neumann, published the "First Draft of a Report on the EDVAC" on June 30, 1945. This report outlined the computer architecture that remained pretty constant for the next fifty years. Von Neumann's EDVAC Report describes five elements of a stored program computer. Central Arithmetic -- CA; Central Control – CC; Memory, M; Input, I; and Output, O. xx <u>Interestingly, the report used human analogies to describe the parts, including memory and neurons</u>. He discusses the advantages of synchronous clocking and binary. No specific operation code is given in the report. He suggested that the word length should be at least 27 bits or 8 digits.

Wilkes stated: "The central idea of the report was to use a single high speed memory to hold both numbers and instructions. My reading of the evidence is that Eckert had arrived at this idea before von Neumann visited the group."

Von Neumann's name gave the clear credibility to crystallize, carry and <u>perhaps</u> implicitly claim the concept.

Wilkes further states that Eckert begins his conviction that the ENIAC was more complicated than it need have been and that it could be simplified by more rationalization of function. In particular he identifies three quite different kinds of memory: 1. Flop-flops in accumulators 2. Function tables (read-only memory) 3. Interconnecting cables with their associated switches used for setting up the program."

Thus, the stored program concept was most likely invented by early 1944, prior to von Neumann's arrival at Penn. The invention provided for programming flexibility and feeding the electronic computer's voracious instruction appetite.

In September 1945, Eckert and Mauchly proposed EDVAC based on the "the stored program concept". Their report stated that "an important feature of this device was that operating instructions and function tables would be stored exactly in the same sort of memory device as that used for numbers."

Later attempts by Eckert, Mauchly, and others to clarify roles in the invention failed. At the 1976 International Research Conference on the History of Computing, held in Los Alamos, Mauchly wrote "Eckert and I were planning on stored programs long before von Neumann had heard of the EDVAC project."

Here's Mauchly, at Los Alamos, describing their effort.

Mauchly Tape Insert

xx Much attention could be paid to Penn's efforts because the project became de-classified. Researchers came from around the world to visit. In the summer of 1946, the Moore School offered a series of summer lectures to bring everyone interested in computing. Wilkes and Williams came from England; Aiken came from Harvard to speak, but the focus was plans for the EDVAC.

xx Sir Frederick Williams and Tom Kilburn had the first operational stored program computer at the University of Manchester. With only a 32 words of 31-bits, it was only built to test the Electrostatic Williams Tube Memory for their Mark I. However, it ran a 17 word program for 52 minutes on 21 June 1948. In February 1951, their Mark I designed along the lines of the IAS parallel architecture was introduced as a product by Ferranti Corporation. But that's another story.

after the summer school, Maurice Wilkes returned to Cambridge with the burning desire to build an EDVAC-like machine. The project got started in October 1946. EDSAC became the first full-scale stored program computer to operate. It first ran on 6 May 1949. EDVAC instructions had 4 addresses stored in a 44 bit word. Thus an instruction could point to the optimum memory locations. EDSAC instructions had one address and were stored in a 17 bit word. So EDSAC traded-off potential performance for a memory efficiency. <u>Both used serial mercury filled, acoustic delay lines.</u>

Wilkes' EDSAC movie shown at the 1951 Joint Computer Conference in Philadelphia provides us with a great view of what the computing was like then.

Wilkes' EDSAC film

xx Edsac's notoriety attracted attention for commercialization. The president of the Lyons Company realized that a computer could be a valuable tool for his business. Lyons owned tea shops in England. Lyons formed a company to commercialize EDSAC. Here's the film about their computer, Leo.

Leo film

GB The von Neumann Story IAS and -iacs intro

xx Let's now go to Princeton's Institute for Advanced Studies and the IAS parallel machines. The design was described in a series of papers by Arthur Burks, Lt Herman Goldstein and von Neumann. A paper entitled, The Preliminary Discussion of the Logical Design of An Electronic Computing Instrument was published 28 June 1946. <u>exactly one year after the Draft Edvac Report.</u>

Brian Randell points out that "although the IAS computer was not finished until 1952, the series of reports that were issued by the project were widely circulated and served many people as textbooks on logical design and programming. The plan was to use an electrostatic storage

tube … as an alternative to mercury delay lines. This provided random access rather than cyclic access with each word being read in parallel, rather than serially."

Randall also states "that as a result of the papers, many parallel binary machines, or von Neumann machines as they came to be known, were started up. One such project … resulted in the IBM 701, forerunner of a whole series of machines which within a few years became the dominant large-scale scientific computers."

IAS SPECS FIGURE

The IAS design specified a 40 bit word that held two instructions. The memory was held in a bank of 40 cathode ray tubes. 12 bits were used to address memory and six bits specified the operation code. Their design uses a function table register, FR, to address instructions, retaining the ENIAC heritage and nomenclature.

Thus, the parallel IAS machine, the EDVAC Report describing the stored program concept, and "the von Neumann" computer all became synonymous. Parallelism gave the IAS more than a factor of 40 in perfomance over the EDVAC.

All together the IAS had about a dozen direct descendants.

AVIDAC/ORACLE SPECS

The first to operate was Argonne's AVIDAC in 1951. Their colleagues at Oak Ridge had them built a copy called Oracle.

ORDVAC/Illiac/Illiac descendants SPECS

The University of Illinois built ORDVAC for BRL and a modified version, ILLIAC, for themselves. SILLIAC, CSIRAC, Weizac, Cyclone, Mistic, and computers at Iowa State and Michigan State were created in Illiac's image.

RAND JOHNNIAC SPECS

Johniac, here, was build by The Rand Corporation that served to test transistor logic. xx It eventually acquired a core memory that was placed here at the top of the machine.

Xx Los Alamos had a unique need for computation during the war. Nicholas Metropolis, the father of Monte Carlo simulation describes that environment and the development Maniac. The tape was made at the June 1976 Los Alamos conference.

Metropolis film inserts

MANIAC SPECS

MANIAC, Los Alamos's version of the IAS became operational in early 1952. This film is an excellent description of the IAS computers. Even 50 years later, it is a

<u>wonderful introduction to the "five classical boxes" often used to define a computer</u>.

<u>Maniac film</u>

In March of 1946Prespert Eckert left <u>the Moore School</u>. They formed Eckert-Mauchly Computer and John Mauchly Company in December 1948. Their first product, BINAC was shipped to Northrup for on board missile control in August 1949.

BINAC was really a circuit prototype for the ambitious UNIVAC I that was accepted by the US Census Bureau in March 1951.

UNIVAC SPECs

The UNIVAC I used a delay line memory to store 1,000 12 digit words. Each word held two 6 digit, single address instructions. Decimal, like ENIAC, it was designed for data-processing. UNIVAC had extensive checking circuitry and a complete I/O system including tape, printers, off-line data conversion.

In order to deliver their million dollar machines, Eckert and Mauchly had to get funding to survive.   Remington Rand purchased them. With capitalization, about 20 UNIVACs were delivered by 1954. In 1952, Remington Rand also purchased the Engineering Research Associates making scientific drum computers. These evolved to the 1103 that

competed with IBM's 701. Both used a 36-bit word and parallel architecture, like the IAS design.

Memory size vs operation rate figure

This figure gives the memory size plotted against operation rate for the various computers I've described. In the beginning, the notion of Amdahl's Law wasn't so clear because memory size was determined by what could be built. Operation rates fell into either the serial or parallel group. Notice that memory size was quite small and limited to about 1 K words, evolving to 4K words in the mid 50s.

This November 1952 newscast shows the UNIVAC in action predicting the election. UNIVAC called the landslide after looking at just a few returns, but it's keepers wouldn't let it speak out.

Univac Election film

This story covers about a decade from 1943 to 1953. At the beginning, no computers existed. By the end, many laboratory-built computers were in operation. Several computer companies, including IBM and UNIVAC, were designing and shipping scientific and business computers.

Figs:
4 time lines

- **Eniac, edvac report, summer school, edvac**
- **Edsac … Leo**

- **IAS and its machines**
- **Binac... Univac**

speed vs memory size

Specs for all the computers

approx 2000 words or say 16 minutes

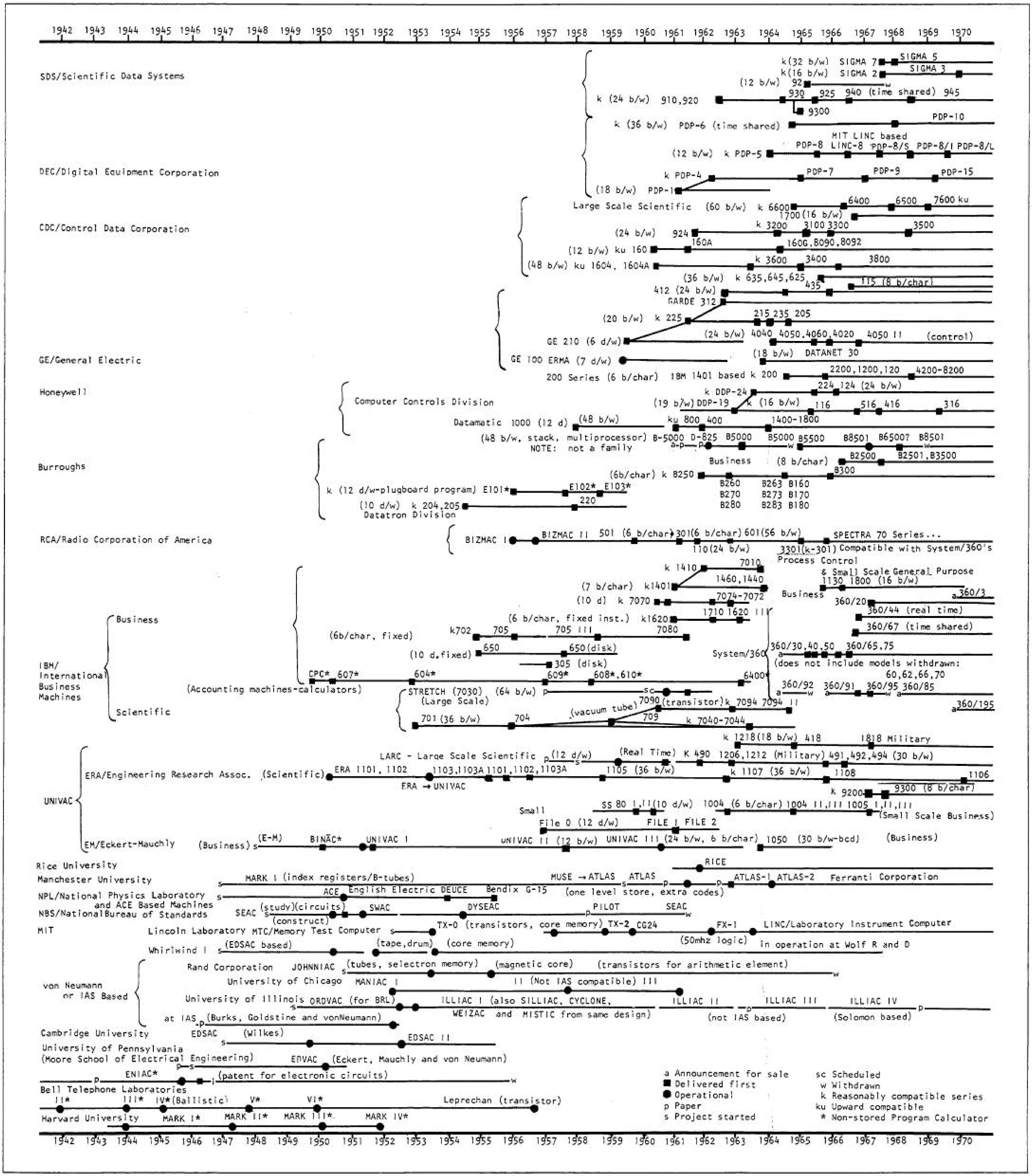
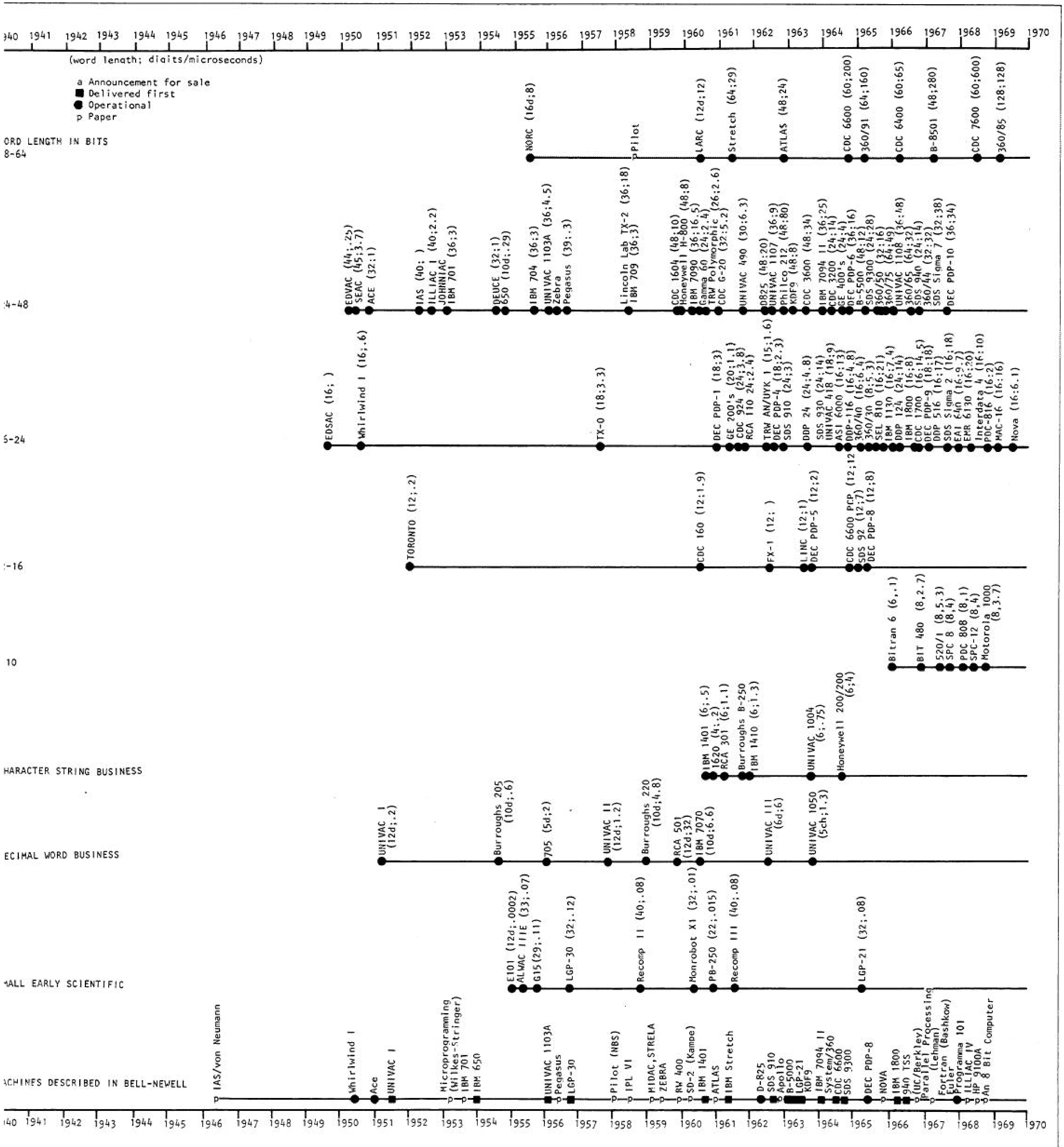


Fig. 2a. Time chart: computers by originator.



2b. Time chart: computers by word size.

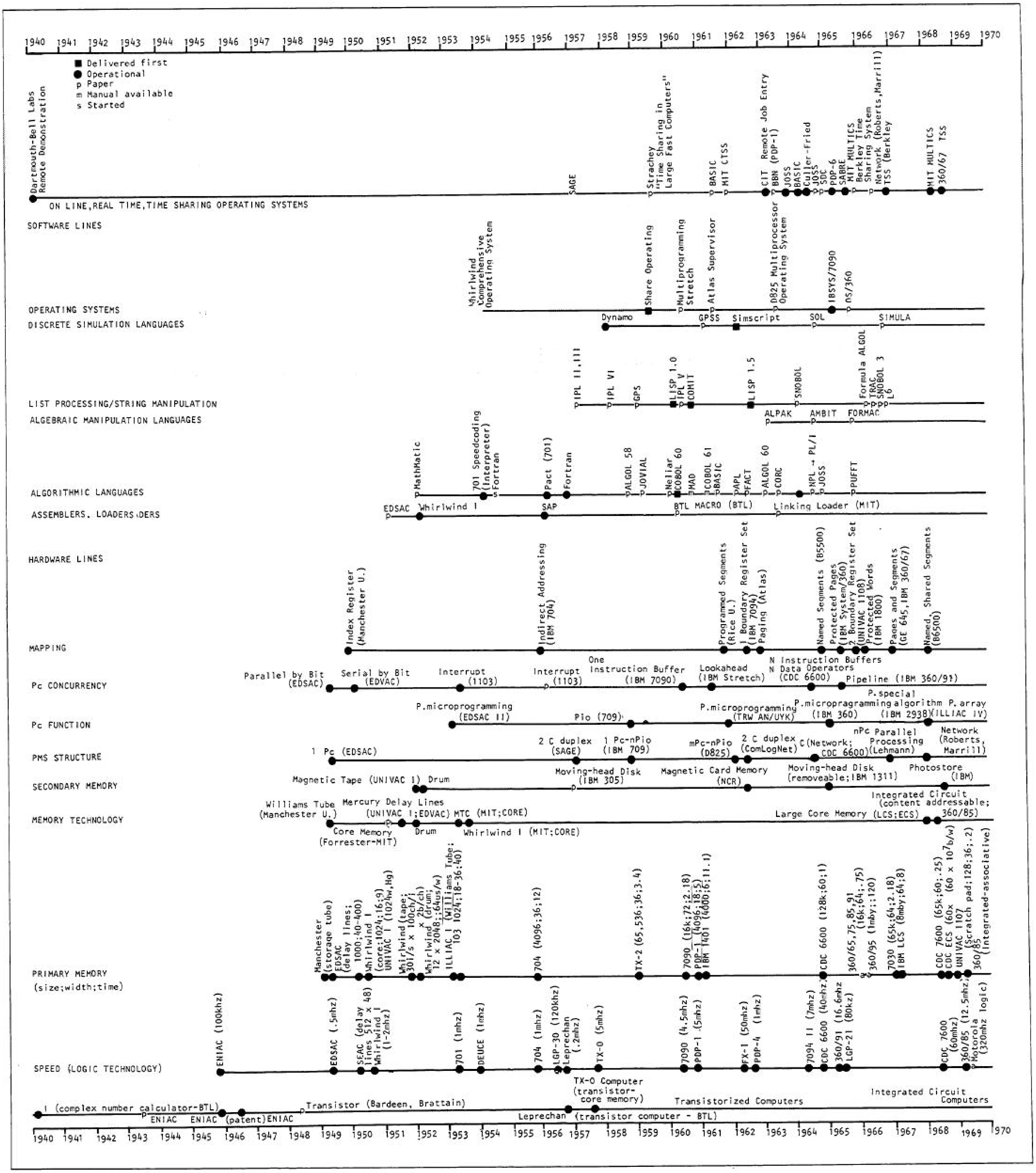
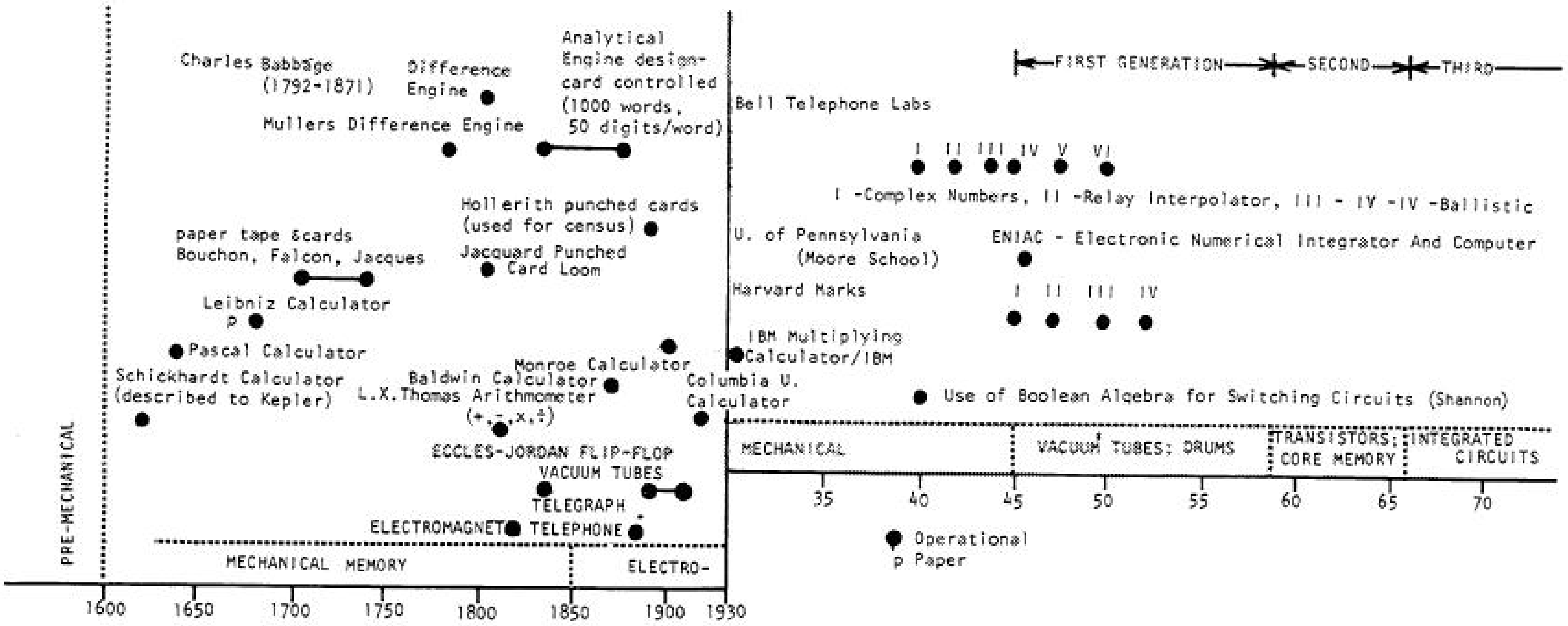


Fig. 2c. Time chart: technology.



Charles Babbage
(1792-1871)
Difference
Engine
Analytical
Engine design-
card controlled
(1000 words,
50 digits/word)
Mullers Difference Engine
Hollerith punched cards
(used for census)
paper tape &cards
Bouchon, Falcon, Jacques
Jacquard Punched
Card Loom
Leibniz Calculator
p
Pascal Calculator
Schickhardt Calculator
(described to Kepler)
Monroe Calculator
Baldwin Calculator
L.X.Thomas Arithmometer
(+,-,x,÷)
Columbia U.
Calculator
ECCLES-JORDAN FLIP-FLOP
VACUUM TUBES
TELEGRAPH
ELECTROMAGNET
TELEPHONE
PRE-MECHANICAL
MECHANICAL MEMORY
ELECTRO-
1600
1650
1700
1750
1800
1850
1900
1930
FIRST GENERATION
SECOND
THIRD
Bell Telephone Labs
I
II
III
IV
V
VI
I -Complex Numbers, II -Relay Interpolator, III - IV -IV -Ballistic
U. of Pennsylvania
(Moore School)
ENIAC - Electronic Numerical Integrator And Computer
Harvard Marks
I
II
III
IV
IBM Multiplying
Calculator/IBM
Use of Boolean Algebra for Switching Circuits (Shannon)
MECHANICAL
VACUUM TUBES; DRUMS
TRANSISTORS;
CORE MEMORY
INTEGRATED
CIRCUITS
35
40
45
50
55
60
65
70
Operational
p Paper