Introduction

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8/25/81

DIGITAL COMPUTER MUSEUM CATALOG

INTRODUCTION

Starting a computer museum today presents analagous problems to those that of the second duchess of Portland. Born in 1714, she was an insatiable shell collector who relied on artistic arrangements until she hired a student of Linnaeus (1707-1778) the father of botanical classification systems. Then the collection was re-arranged according to a taxonomy that would help the viewer understand evolution and relationships. Computing devices -- as beautiful as shells to many people -- need a theory-based classification system.

The purpose of the Digital Computer Museum, to document and preserve the evolution of the computer, from its earliest origin to the latest developments, demands a rigorous, disciplined classification scheme that focusses on the computer itself.

Intuitively, those who have tried to understand computer evolution to consider a tree structure -- the basis of taxonomies -- but none have been fully developed for the purpose. (Bell and Newell, 1971; Bell, McNamara and Mudge, 1978; Rogers, 1980; Science Museum, 1975, Sieworek, Bell and Newell, forthcoming). The National Science Foundation tree (Fig. 1) of early computers shows roots and connections but does not name branches. A number of partial systems and some generally agreed upon terms exist for defining a classification system. The Computing Reviews classification system for contents works very well for the extraordinarily broad range of materials including "mathematics, engineering, the natural and social sciences, the humanities, and other fields with critical information about all current publications in any area of the computing sciences." (Sammet, 1980) The work of the AFIPS Taxonomy Committee, Taxonomy of Computer Science and Engineering, provides a confusing semi-lattice covering all possible issues. (AFIPS Taxonomy Committee 1980) Other trees look at only a part of computing. (Weizer 1981, Sammet 1969) The evolutionary model has also resulted in the identification of generations. (Rosen, 1969)

THE GENERATIONS

Within the broadly accepted idea of technological generations, clear criteria can be identified to mark each one. These are:

- A new base technology

Manual Age

MANUAL AGE

Although the study of mathematics is very ancient, the objects that lead to the birth of the computer are very sparse until the early seventeenth century, when the craft generation starts. Various ways of using coins, beads, stones, and rope evolved. Among these the abacus and its derivatives are probably the most widespread.

DIGITAL CALCULA (or [illegible])

SINGLE REGISTER - BEAD

The abacus is the earliest known computing device and the first hand-held calculator. It postdated the invention of the decimal system by the Egyptians circa 3000 BC. The Greeks and Romans built and used the abacus based on Hindu-Arabic numerals. Unlike earlier notations and devices using stones and marks, the abacus utilizes positional notation, including the representation of zeros, differences, with capabilities for multiplication and division. The Chinese abacus has beads in groups of 5 and 2, representing decimal digits. The Japanese first modified this to 5 and 1 and then 4 and 1, a system known as bi-quinary representation that was also used in early electronic digital computers such as the IBM 650 (ca 1955).

In the operation of the abacus, a single register machine, the moving of the beads also immediately provides the answer.

<u>Abacus</u>, 22x16x3 cm, Wood, 9 Digit, (B93.80).
<u>Abacus</u>, 2x4x6 cm, Green, Marble and Brass, 9 Digit, (B95.80).
<u>Counting Beads</u>, 27x19.5x1 cm, 10 digit, Red, Black, and Green Beads, Wood and Metal, Paint worn off beads, beads missing on top, (B141.80).
<u>Soroban</u>, 4x11x29 cm, (B26.79).
<u>Soroban</u>, 10x2x40 cm, Wood and Bamboo, 21 Digits, (B94.80).

- A new machine structure
- Satisfaction of a need constraint
- Significantly different use.

Generational change is modelled by a series of distinct steps with a new base technology at a significantly different level. The technology base never meets the aspirations and dreams of mankind -- perceived needs are continually rising. A new base technology only creates a higher takeoff plane. (Maslow, 1943) With each new invention, one or two prominent people often note that it will fulfill all the future computational needs; but each time the aspiration for more computational power only grows.

Computers themselves are a technology that may influence a wide spectrum of other phenomena, such as communications and manufacturing. Since the fifties they have become one of the prime movers of technological advance.

A number of ideas and machines are designed and even built out-of-phase with a technology. Ideas that occur before their time often lie dormant in the inventors notebook until the technology evolves to match the idea. Later historians illuminate these early concepts, showing the contemporary entrepreurs that they are not inventors but only implementers of ancient ideas. In the mid-twentieth century, some letters of Wilhelm Schichard dated 1624 were unearthed. These contained the drawings for the first known digital machine to perform calculations. (Cohen 1980) It is very doubtful that these ideas transmitted from Schichard to his friend Kepler influenced any of the mechanical calculators that were subsequently developed. Similarly, Leonardo's notebooks included drawings for many engineering devices including a calculator, but the mechanical technology at the time had simply not progressed to the necessary degree. The actual inventors that develop a baseline machine for a technology are often tinkerers with that technology and not scholars searching the literature for ideas.

When one or more significant ideas are transformed into a project, then its execution includes inventions that become part of the technological base. A new generation is marked after the project has proven itself, shown not to be a fluke, and adds a new layer to the technological base. The Computer Revolution and beginning of the electronic generation added the technological use of vacuum tubes in orders of magnitude never before experienced in the ENIAC project and the use of magnetic core memory from the Whirlwind project. Since a generation is a convergence of technology and inventions, marking its emergence by a single event is inappropriate. A clustering of events, including patents, publications, and start-up dates that converge are used to justify the selection of a particular year, that then has approximately a five percent accuracy.

The Museum collections begin in 1620 with the beginning of the "Craft Generation". Prior to that information processing was carried out manually, much the same for all of history. Using the product of processing rate and memory size to measure computing power, a 20 order of magnitude increase can be counted since people used stone-based, single register for arithmetic. The most significant gap -- a revolutionary change -- occurred with the beginning of the computer era. Before then, memory size was essentially constant at one. Afterwards, computing power began to increase at roughly twice the exponential rate of all past generations.

The name of the generation indicates wide-spread application and use of a predominant technology. The idea that leads to a project triggering a new generation always occurs before the beginning of that generation. The starting date of a generation is marked by the incorporation of a technology into production of a new product, concurrent with significant use. In most cases devices from a previous generation continue to be designed, manufactured and used, often supplying a base on which the new generation is built.

Table 1 lists the need, use and representative inventions for each of the generations. During the pre-computer generations, evolution was exponential -- each period being half as long as the one preceding it. The rapid change is similar to manufacturing learning curves, whereby a particular unit cost declines by 10-20% each time the cumulative number of units of a given type are built. In the Computer Age, the naming conventions given by industry have been used, and they seem to accurately fit the model.

Generations are primary organization element for the collection and its representation in the catalog. The first four sections present the pre-computer generations. Then the fifth section is devoted to the pioneer computers that spanned the revolutionary bridge. And the remainder of the catalog and collection is open ended; inclusive of all historic generations, i.e., at least one generation removed from the present technological generation or fifteen years old.

THE TAXONOMY

Structuring a taxonomy has paralleled the development of the collection and the exhibits at the Digital Computer Museum. The PMS classification describing the structure of computing structures provides the basic framework. (Sieworek, Bell and Newell forthcoming) PMS allows any computing or software structure to be described hierarchically in terms of eight basic information processing primitives; but does not deal with functional behavior, eg., interrupts except those that can be implied by a structure. The PMS system is generally used to provide a structural representation of the components of digital computer systems. In contrast, this taxonomy only encompasses whole computing systems and their antecedents. The following compares the two breakdowns:

MUSEUM TAXONOMY	CODE	CODE	PMS
Memories	M	M	Memories
Controls	K	K	Controls
Transducers	T	T	Transducers
Links & Switches	S	S	Switches
		L	Links
Calcula	D	D	Data Operation
		P	Processor
Digital Computer	C	C	Computer
Automata	A		

The criteria defining the tree is the structure of the computing device, neither the organization that made it nor the purpose that it was meant to fulfill. To make an analogy with the animal kingdom, if the bone structure of a horse is that of a fine race horse then it would be classified as such; it would not matter if it were bred by the government and used to pick up garbage. In computing, the EDSAC, built at Cambridge University, is neither classified as an English or university computer but an EDVAC-related machine in the same family as the Maniac and ILLIAC. Thus, differentiation of manufacturers, countries, or by intended users is not part of the taxonomy.

The classical scientific taxonomy system with its seven levels has been adopted to organize and classify all species of relative inventions. The two top levels, kingdom and phylum, are technology and information, respectively. The Museum collection deals with seven classes within the phylum of "information." (Listed above) Each class, like a specie, has life that starts within a given generation, flowers, and then becomes functionally incorporated within another class. Each started, almost as an independent thread, but are now beginning to merge into two dominant classes: computer and automata.

Memory is probably the oldest class starting with early markings on caves and continuing both as significant parts of computers and automata and also as all kinds of human-readable aids to the brain. See ..... for more complete explanations.

Controls reach back to early analog devices, such as the Greek water clocks, and have been significant in the mechanization process. At the beginning of the 19th century, card controlled looms gave the notion of sophisticated pattern control to industrial processes via the use of a larger scale memory data-set than hitherto used. Card control ended with a great flourish in the early nineteen sixties with the tabulating machines. Again with the computer on the chip, earlier technologies of control devices are rapidly becoming obsolesent to be replaced by the "on-board" micro-processor.

Transducers take information in one form and put it into another. They are often associated with memory systems, allowing their replication, printing use type (an intermediary form) to duplicate the information into books, the books are then "secondary" memory for people. Transducers really began with the Guttenberg's movable type and include teleprinters, tape transports, the telephone, and television sets. These machines are becoming more and more sophisticated and less and less able to be differentiated from computers.

Calculators, other than the manual bead devices, did not develop until the 19th century and have now virtually been displaced by computers. These are the data operators to do the arithmetic in PMS notation. Either calculators are embedded in computers or computers (as they have miniaturized) are embedded in what has traditionally been considered a calculator. The taxonomy of Class Calcula is worked out and explained in the text. (See ....)

Links and switches evolved out of the need for a large number of subsribers all desiring the use of a single system. The first telegraph was a simple device transferring information from a to b. But the growth of the telegraphy and telephony systems in the late nineteenth century created a need to establish elaborate networks linked together with a switching system. The current generation of computers still depend on new methods of linking and switching for cross communication.

Digital Computers emerged in the late forties from a combination of calculator, control, transducer, links and switches, and memory technologies. The section on Pioneer Computers shows the combination of elements that were adopted by the first 16 machines, many of which were patched together with emphases on different Classes. The Class Digital Computer, itself that emerged is certainly more than the sum of these parts, as each has converged and been modified and molded into a new phenomena.

Automata actually started very early with man's desire to replicate himself and their great population explosion took place in the sixteenth century. But only recently, have useful automata been put to work for human purposes and are contemporary to the latest generation of computers. Thus, this class is presently not included per se in the collection; but will be included in the future.

Each of these seven Classes is broken down into Order, Family, Genus, and then identified by Species. Table 2 lists the criteria used for the breakdown of the Classes. Specific descriptions for each of the class are found throughout the catalog.

TABLE 1.

PRE-COMPUTER GENERATIONS

	MANUAL	CRAFT 1620	MECHANICAL 1810	ELECTRO-MECHANICAL 1900
NEED	Taxes	Trade Exploration	Industrial Land Division	Census Business
USE	Counting	Arithmetic Navigation	Surveying Weaving	Sorting Accounting
MACHINE	Abacus	Tables Gunter's Rule	Planimeter Jacquard loom	Hollerith Census Machine Friden calculator

COMPUTER GENERATIONS

	ELECTRONIC 1950	TRANSISTOR 1960
NEED	Defense Weather prediction	Space Science
USE	Firing Tables Weather Forecasting Management	Simulation Training programmers Accounting
MACHINES	Whirlwind UNIVAC 1 ERA 1101	CDC 160, IBM 7090, IBM 1401 PDP-1

TABLE 2.

Criteria used in differentiating orders, families, and genus.

CLASS	ORDER	FAMILY (Technology)	GENUS
Memory	Machine interface	Storage material	Structure of access movement
Controls		Complexity	
Transducers		Phenomena	
Links & Switches		Complexity	
Calcula	Analog or Digital	Complexity	Structure
Digital Computers			
Automata - to be developed			

Fig. 1: The Collections

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          Period that the exhibit covers:
          Craft   Mechanical  Electro-mec   Electronic  Transistor   IC
           1600     1810          1900         1950        1960      1970

MEMORIES  MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM
including books and magnetics

CONTROLS  KKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKK K K
including water clocks, and governors

LINKS & SWITCHES              SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
including telephony and telegraphy

TRANSDUCERS       TTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTT T T T
including typewriters and printers

CALCULA        DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD D D D D
including analog and digital calculators

DIGITAL COMPUTERS                           CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
including processors

AUTOMATA  AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
including robotics
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Craft Generation

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CRAFT GENERATION

By 1620, the beginning of the craft generation, the abacus and counting table devices were in use and mathematical tables were made. In printing, the ability to use movable type was far ahead of paper technology, but a need existed for a convenient calculator or lookup table. John Napier of Merchiston, a mathematically oriented scholar, was bent on making long multiplication "free from slippery errors." His two major inventions -- logarithms(1614) and an inscribed set of rods or bones (1617) with number series that could be carried in the pocket and used as a look up table, immediately became quite popular. The bones were finely crafted sets that were sometimes paired with an abacus or a slate as a storage device. Although they are classified as manipulable tables, it can readily be seen, that their existence might have stimulated ideas for mechanical calculators. The invention of logarithms did, in fact, lead to the rapid development of slide rules, analog calculating devices. In 1620, Gunter placed the logarithmic scale on a rule and then a sector, and these devices rapidly came into widespread use satisfying the growing needs of exploration and trade. The speed of adoption of such devices, carried by navigators, was rapid, with developing trade and exploration and the ease in which they could be copied and crafted. Scientifically the use of logarithms and slide rules were aids to the development of mathematics and use of the mathematical tools in astronomy and for the academicians in the age of enlightenment. Thus, two devices, the bones and the development of rules with logarthmic scales, mark the beginning of the craft generation that was to last about 200 years.

MEMORY

Non-human interface is the first criteria that divides Memory. The earliest aids to human memory were neither machine writable or readable, ranging from stone markings, to beads, and papyrus scrolls. This group also includes the hand-crafted and personally read Napier's bones. The next Order of Memories are those that are either writable or readable by machine, ranging from printed books to semiconductor roms. And finally the third Order, both machine writable and readable did not begin to develop until the Electro-mechanical Generation.

NON-MECHANICAL MEMORY

FIXED PHYSICAL STATE

Napier's bones act as tables that can be rotated. Each rod is inscribed with a set of numbers facilitating the multiplication and division of large numbers. John Napier, Laird of Merchiston in Scotland, invented the rods and described them in his RABDOLOGIAE, (1617). He wrote that the multiplication and division of great numbers is troublesome, involving tedious expenditure of time, and subject to "slippery errors." His tables reduced these difficulties to simple addition and subtraction, and won immediate recognition. A set of Napier's bones is usually made of boxwood or ivory and often contained in a box or case that would fit in a pocket. A set usually contains 10 rods, plus extras representing squares and cubes. Use. Addition is accomplished by reading the appropriate bones along the diagonal. To obtain a product of 224 x 44, the rods 2, 2, and 4 are put alongside each other, and the result is read off by combining the numbers in the fourth row -- 0/8, 0/8, 1/6 -- for the correct answer 896. This is repeated and the two products added together to give 9856. The bones are sometimes paired with an abacus to provide a store.

Napier's Bones, ca 1700, 8x6x2 cm, Wood, (B27.79).

"SUMADOR CHINO", 7.5x20x30 cm, Brown, Green, Paper, Wood, Glass, Loaned by Jim Rodgers (X10.80)
A set of Napierian rods incorporated with a reusable surface.

WRITABLE OR READABLE MEMORIES

PAPER - RANDOM ACCESS

"Table of the Products and Numbers" by Charles Hutton, 1781, 28x42x1 cm, (B2.76).

Compiled in 1781 by Charles Hutton, this early book of mathematical tables contains the products of the numbers 1 through 1000 by the numbers 1 through 100. It also contains squares and cubes of numbers and conversion tables for units of measurement. One of the main problems with handcrafted books is the number of errors. On one page alone, every figure is off by one thousand.

"TRIGONOMETRIA" by William Oughtred, published by R. & L.W. Leybourn, 1657, 14x18x3.5 cm, Original leather binding, (B160.81).

The original set of logarthmic tables and their explanation as made by William Oughtred, who made significant improvements on the slide rule.

ANALOG CALCULA

Analog calculators work by analog, that is, they create a physical model of a mathematical problem. Many physical situations can yield mathematical results, provided they can be interpreted properly. The extent of a lateral or a rotational movement of a mechanism or the voltage level on a wire are examples of quantities which can be used to represent numbers. The most important breakthrough for analog calculators, however, came with the invention of logarithms by John Napier in 1614. This enabled the processes of multiplication and division to be carried out by addition and subtraction through proper positioning of number series along sliding rules. The results are interpolated between the marks on the rule. Other types of analog calculators include devices used in drafting, measuring and integrating, e.g., parallel rules, planimeters, pantographs and harmonic analyzers.

The families in this order are divided according to the complexity of the mechanism itself -- single part, two-three part, multiple part, complex and programmable. This reflects a rough evolutionary development with multiple part devices not developing until mechanical tooling was improved, in the early nineteenth century.

SINGLE PART

DRAWING INSTRUMENTS

Drawing Instruments, ca 18ØØ, 15x17x3Ø cm, Brass, Wood, Marble, Cornelius Conklin (owner), (B92.8Ø).

Drawing Instruments, 2Øx11x4 cm, Steel & Brass, (B19.78).

Cased English drawing instruments made in the second half othe 19th century. Brass and steel instruments, ruling pen with ivory handle; 13 separate items in lift-out tray. Small boxwood rule in space below. Rosewood veneered case and instruments in fine condition except that the large compass is missing its pivot locking nut and the brass has become a bit dull.

Drawing Instruments, ca 185Ø, 16x7x2.5 cm, Green, Shagreen Case, Brass, Steel, Ivory, Silver & Ebony, (B1Ø6.8Ø).

Drawing Instruments, ca 19ØØ, 6x16x2.5 cm, Black Case, Brass, Steel, Wood, Cardboard, (B13Ø.8Ø).

Drawing Instruments, 7x15x2 cm case, Wood, Fabric, Brass, Steel, (132.8Ø).

Drawing Instruments, 1Øx19x4 cm box, Wood, Brass, Velvet, (B133.8Ø).

FIXED RULE

Parallel Rule, ca 187Ø, 45x6x1 cm, Rosewood and Brass, (B24.78).

Parallel Rule, W.H. Harling, ca 1890, 4x33x8 cm, Steel, (B20.78).

Cased presentation of an English rolling parallel rule. Pasted to the inside cover is the presentation certificate, "Bradford Technical College Prize Awarded to Fred Inman at the Annual Examination, 1893, by order of the Lords of the Committee of Her Majesty's most honourable privy council on education."

Parallel Rule, T.S. & J.D. Negus, 8x45 cm, Brass, Inscribed with Degrees (B104.80).

Parallel Rule, ca 1890, 3.5x15x.2 cm, Ebony and Brass, (B122.80).

Proportional Rule and Protractor, C.W. Dizey, New Bond St London, ca 1890, 4.3x15.2x.2 cm, Ivory, (B120.80).

A protractor and architect's proportions are inscribed on one side; engineer's scale and vernier on the other.

Proportional Rule and Protractor, United Chemical Engraving Co. Ltd., 1932, 15x5x.2 cm, Cream, Plastic, Inscribed D.A.E. Carter, (B121.80).

Protractor and table with set scales at 1/20,000, 100,000, and 250,000 inscribed on one side. The other side has scales of one half inch and one inch to the mile, a scale of 1/20,000 in meters and listing of metric equivalents.

Rolling Parallel Rule, 6x46x2.5 cm, Brass, Patent No. 160100, (B105.80).

Rule and Ruled Compass, 3x12 cm, Metal, "W.B.Pierce Co. Civil Engineers", (B138.81).

2-3 PART

"A Treatise on a Box of Instruments and the Slide Rule for the Use of Guagers, Engineers, Seaman, and Students" by Thomas Kentish, Henry Carey Baird, Industrial Publisher, Philadelphia, 1864, 12x18x2 cm, Original cloth cover, 228 pages with a folding plate, (B159.81).

The use of 2-3 part analog calculators for practical geometry, trigonometry, and logarthms are explained. Special sections deal with circles and navigational calculations.

GUNTER RULE

About 1607 Edmund Gunter devised a scale that was to be the predecessor of the modern slide rule. In 1623 he published a description of this scale that is composed of two scales of the logarithms from 1 to 10 placed end to end. Although Napier conceived of the logarithm allowing multiplication or division to be accomplished by addition or subtraction, Napier relied on look up tables.

Use. A pair of dividers is used to measure a distance (the multiplicand and the multiplier) along the rule and add

it to another distance, the multiplicand, forming the combined distance, the product, on the rule. The accuracy of an answer is limited by the length of the rule and the user's ability to resolve a number.

Gunter Rule, ca 1800 5x60x.5 cm, wood, (B4.76).
Gunter Rule, 15x3x.5 cm, Boxwood, (B41.79).
Navigator's Gunter Rule, ca 1800, 5x60x.5 cm, Darkened Boxwood, Minor Warping And Edge Chipping, (B54.80).

SECTOR

The sector is used to solve problems of proportion and works on the principle of similar triangles. Sectors were made with a variety of scales for use in calculation by navigators, surveyors, gunners, and draughtsmen. At first sight they look like a jointed rule usually made of ivory, brass, wood, or sometimes silver. First described by both Galileo in Italy and Thomas Hood in England the sector was in use by 1600.

Use. A pair of dividers is necessary to read the relationships on all sectors. This instrument is marked: "Chords, Sec, Lines, Tangents, tan, Ver Sine, Sines, & Num." The scale layout permits this sector to be used as a Gunter rule as well, although it is not laid out to follow any of the five editions of Gunter.

Navigator's Sector, 33x6x1 cm, Boxwood With Brass Hinge, 21 Scales On both Sides and Outside Edges, (B21.78).
Navigator's Sector, 4x16 cm, Cream, Ivory and Brass, Chipped, (B102.80).
Navigator's Sector, 1800c, 16x3.5x.3 cm, Ivory, Lee & Son, Portsea Engraved, (B119.80).

SLIDE RULE

In 1654, Robert Bissaker made the first real slide rule in which the slide worked between parts of a fixed stock. (Pugh 1975) The term slide rules applies to all instruments designed so as to allow relative motion between the indices and the scales. The classification used here is that established in the Science Museum Catalogue i.e., straight, circular, spiral or cylindrical, and log-log. The collection illustrates the improvements in slide rules. Originally made of boxwood, brass or ivory, in 1886 Dennert and Pape started to use scales on strips of white celluloid to give much greater distinction in reading. The spiral and cylindrical scales allowed an increase of effective length, hence accuracy, without equivalent increase in size. It also shows the diversity and specialization that resulted for peculiar needs at particular times.

STRAIGHT SLIDE RULES

Slide Rule, Dietzgen, 26x3x1 cm, Wood and Paper, (B145.81).
"Slide Rule 689", KEUFFEL & ESSER, ca 1950, 32x6x1 cm,

(B32.52).
Slide Rule, Foto-mem Inc., 2x14x.5 cm, (B37.79).
Slide Rule, Keuffel & Esser Co, Gift of Dick Clayton (D50.76).

Coggeshall Slide Rule, ca 1800, 4x33x.5 cm, Boxwood and Brass, Hinged with Two Slides, (B109.80).

A modified Coggeshal type slide rule with one brass and one wood slide. Navigational scales including meridian, chords, latitudes, and hours are inscribed. Freeth and Co. Brimingham is overstamped.

Coggeshall Rule, Stanley Rule and Level Co., New Britain, Conn, 32x4x.4 cm, Wood and Brass, (B146.81).
"Measuring Made Easy: Or the Description and Use of Coggeshall's Sliding Rule", by J. Good, much Enlarg'd by J. Atkinson, Sen. London.", W. Mount and T. Page, at the Postern on Tower-hill, 1744, 10x16x1 cm, , Paper and Leather, 96 Pages with 2 folding Engraved Plates. Portion of Spine lacking but still tight, without fly leaves., (B139.80).

Taylor (1966) lists John Good (1706-33) as a mathematical teacher and notes a 1751 edition of this work edited by Atkinson, A maker of slide rules. The first plate illustrates Coggeshall's Sliding rule.

Coggeshall Timber Slide Rule, Richardson and Co., Middleton, Co., 4x31.5x.3 cm, Boxwood, Brass, and Steel, (B147.81).

"Hydralculator", Lewis & Tylor, Limited, ca 1940, 7x19x.5 cm, Cream, Cardboard, One Rule on one Side, (B113.80).

"Hydralculator", patent number 396,533, published by Lewis & Tylor Ltd., Gripoly Mills, Cardiff, the manufacturers of "underwriter" super fire fighting hose, for the use of their "Friends in the Fire Service."

Use. To find the quantity of water discharged for any given nozzle and a known pressure, place press on scale "b" opposite nozzle on scale "a', and read discharge through window in slide. To find height of jet for given pressure and nozzle diameter, proceed as above and read opposite arrow in center of slide, the height given on scale "d" for the appropriate nozzle.

Inland Revenue Slide Rule, Dring & Fage, 1825, 60x5x1 cm, Boxwood, One ink Stain, (B55.80).

The rule is specially arranged for the use of excise officers and maltsters in gauging computations. Slide rules for this purpose were first devised by Thomas Everard in 1683, and modified by Vero, Leadbetter and others. In this example, four scales appear on one side and the other side is blank.

"Leadbetter Slide Rule", Dring and Fage, ca 1800, 31x3x2 cm, Brown, Boxwood, Four Sided Slide Rule with Slides on each Side, (B108.80).

"Musketry Rule of 1918", Metallograph Corp., ca 1918, 3x13 cm, Black, Metal, (B83.80).

Teaching Slide Rule, Welch, 2x23x125 cm, Black, Masonite, With Hangers, (B103.80).

"Thomlinson's Equivalent Paper Slide Scale", J Thomlinson Ltd Glasgow, ca 1940, 8x58x1.5 cm, Brown, Wood, One Sided with Two Moving Rules, (B107.80).

This specialized rule was designed for the paper and printing industry. The A scale indicated length, B scale the breadth, and area in square inches was read off the C scale. The D scale was used to read off translations of inches to centimeters, kilos to pounds, 480 and 500 sheet reams, and various weights of different standard paper cuts.

Timber Slide Rule, L.&I.D., ca 1800, 60x5x1 cm, Boxwood, (B30.77).

Use. On one side, the A line on the rule and the B and C lines on the slider are each numbered twice from 1-10, reading from left to right. The fourth line E is inverted, and is so arranged that 144 is opposite 1 and 10 on the A line. So that if length in feet on E be set opposite thickness in inches on C, the volume in cubic feet is read off on B opposite width in inches on A. The B line is subdivided into tenths, while the A, C, and E lines are subdivided into fourths. On the other side of the rule are A, B and C lines with the girt line (marked D) numbered from 4-40 and bearing various gauge points. The A and D lines are subdivided into fourths. The two edges of the rule bear scales of inches divided into quarter-inches.

Timber Slide Rule, Stanley Rule & Level Co., 4x30 cm, Brass and Warranted Box Wood, (B99.80).

Timber Slide Rule, Stanley Rule & Level Co., 4x30 cm, Brass and Warranted Boxwood, Cracked, Warped and Stained, (B100.80).

CIRCULAR SLIDE RULES

"Boucher's Calculating Circle", Manlove, Alliott, Fryer & Co., (B52.79).

"Circular Concise Slide Rule", ca 1960, 8d cm, White, Plastic, No. 28; Reverse has Standard Equivalency Tables, (B114.80).

Circular Slide Rule, The Cleveland Twist Drill Co., ca 1920, 8d x.3 cm, Cream, Plastic, Printing worn off, (B125.80).

This specialized rule is copyright 1911, The Cleveland Twist Drill Company.

Use. The rule indicated drill speeds for wrought iron, machinery steel and soft tool steel. One side shows revolutions per minute for diameters ranging from one-sixteenth to three inches for both high speed and carbon steel drills. The other side shows tap and drill sizes and the decimal equivalent for inch divisions.

"E.A. Sperry's Calculator", KEUFFEL AND ESSER, 6d x2 cm, Pocket Watch Style, (B97.80).

"Fowler's Calculator", Fowler & Co., , 6d x1 cm, (B59.80).

"Fowler's Textile Calculator", Fowler & Co, ca 1900, 6.5d x.7 cm, Chrome, Glass, Paper, Two-sided Circular Rule, (B112.80).

Short scale type of "Fowler's Textile Calculator" with two scales on one side. The other side holds a table equivalency for weft, looms, and reeds.

"Fowler's Calculator", Fowler's (calculators) Ltd Sale, ca 1920, 6d x1 cm, Chrome, Glass and Paper, Long Scale Calculator, (B124.80).

"HALDEN CALCULEX", J. Halden & Co., Ltd., ca 1910, 6 cm diameter, Metal ring with glass discs covering paper scales, (B158.81).

Cajori in his "history of the Logarithmic Slide Rule" (1909) lists this unique instrument as No. 211 and notes the manual.

Lord's Calculator, R. Waddington, Coventry, 7d x1.5 cm, Chrome and Glass, (B123.80).

"Palmer's Improved By Fuller Computing Scale", J.F. Fuller, 1847, 28x28x.5 cm, Cream and Black, Cardboard, "Fuller's Time Telegraph" is on the Reverse, (B110.80).

"Palmer's Computing Scale" patented in 1843 by Aaron Palmer was improved and produced by J.E. Fuller in 1847. This model is printed from the original Palmer plate with Fuller's name and own patent added to the engraving, done by George C. Smith, 186 Washington St., Boston. The reverse side, "Fuller's Time Telegraph" was patented in 1845.

Use. "Palmer's Computing Scale" was used to calculate square measures, cubic measures, timber measures, grain measures, liquid measures and interest rates from 3 percent to 10 percent on a daily and monthly basis. "Fuller's Time Telegraph" (on the reverse) was used to calculate time lapse in days or weeks between any two given dates. In concert these two measures would be useful to dealers in grain, alcohol and other commodity trading.

SPIRAL SLIDE RULES

"Fuller's Spiral Slide Rule", Stanley, 1902, 9x9x33 cm, Cardboard, Mahongany, Brass, (B5.76).

Designed in 1878 by Professor George Fuller, the logarithmic line is arranged spirally on the surface of a cylinder. The logarthmic line is in 50 turns, giving a working length of 41 feet 8 inches. All numbers of four figures either have a mark upon the scale or are midway between two marks, so that results accurate to four figures are easily obtained.

Use. By means of movable cylinders any length of spiral line may be at once transferred to any other part of the scale, and multiplications and divisions containing a series of factors can be worked with facility. Logarithms of numbers are given by means of a scale on the longer index arm together with a circular scale on the first cylinder, so that powers and roots are obtainable. The surface of the middle cylinder bears printed tables of decimal equivalents, natural sines, etc.

"Fuller's Spiral Slide Rule", Stanley, ca 1880, 33x10x10 cm, paper, wood, metal, (B51.79).

"Thacher's Calculating Instrument 4012", KEUFFEL & ESSER ca 1920, 13x13x63 cm, Wood, Varnished Paper, and Brass, (B29.77).

Patented in 1881 by Edwin Thacher, an 1884 instruction book notes, "The originary rule in use is 12 inches long, with radii of 11 and 5 1/2 inches, the divisions of which are cut by hand, copying from a machine divided plate. In the present instrument the radii are 60 and 30 feet, the divisions of which are printed directly from machine divided plates. Those plates contain over 33,000 divisions, calculated to seven places of decimals from Babbage's tables by using a common multiplier, every line being subjected to correction for error of screw and temperature variations, so that possibly every line center is within .0001 inch of its true place."

The instrument consists of a cylindrical slide, which admits of both rotary and longitudinal movement within an open metallic framework of 20 equidistant triangular bars. The bars are connected to rings at their ends which admit rotation within standards attached to the base. Upon the slide are wrapped two complete logarithmic scales, each of which is divided into 40 parts of length equal to half that of the slide. The parts follow each other in regular order around the cylinder, and the figures and divisions which constitute any part of the right are repeated on the left, one line in advance.

Use. By the rotary and longitudinal movement of the slide any of its divisions may be brought opposite to or in contact with any division on the fixed scales. The divisions on the upper lines are transferred to the slide by means of a pointer fitting over the bars, which is also convenient for retaining the position of any division on either line while the slide is being revolved into the required position. Near the commencement of each scale on the slide is a heavy black mark designed to catch the eye.

"Thacher's Calculating Instrument", KEUFFEL & ESSER, 1925, 16d x58 cm, Wood, Brass, And Varnished Cardboard, (B56.80).

LOG-LOG SLIDE RULES

"DIETZGEN MULTIPHASE STYLE-M IMPROVED DECIMAL TRIG TYPE LOG RULE", EUGENE DIETZGEN CO., 1954, 5x32x.4 cm, Aluminum and Plexi, (B144.81).

Mechanical
Generation

MECHANICAL GENERATION

The second pre-computer generation started about 1810 and was brought about by the change from hand craft to mechanical technology. Two machines establish the beginning of the period: the Jacquard loom and the planimeter. In the 1790's Joseph Jacquard integrated a design based on the ideas of Bouchon, deVaucauson, and Falcon, for an automatic harness controlled by punched cards connected to an endless roll that would mechanize fancy weaving. This was shown at an exhibition in Paris in 1801 and by 1812, ten thousand Jacquard looms were in operation in France alone. (Strandh, p. 195). The planimeter, the first instrument for directly measuring an area bounded by an irregular curve, appears to have been invented by the Bavarian engineer, J. M. Hermann in 1814. It was improved by Lamule in 1816, and constructed in 1817. (Pugh, 1975) With the need for surveying and recording land ownership, the planimeter rapidly came into widespread use.

In the mechanical generation, hand-crafted slide rules were spawned for a wide variety of uses; by revenuers to calculate tax on alcoholic beverages, lumbermen for cordage, printers for paper quantity, and traders for interest rates. (Turner, 1980) A company still exists in the North of England that makes specialized slide rules. Although the technology is based on a previous generation and two-three part analog calculators do not need mechanization, they were improved by industrialized forms of production.

The production of mechanical calculators did not start at the beginning of this generation. In 1820, Thomas of Colmar, an insurance agent, experimented with a four-function calculator, but it was not built or distributed until the 1850s. The real flowering of the mechanical calculators began in the last ten years of the century when Baldwin, Burroughs, and Felt were in business in the U.S., and Odhner had started his company in Russia.

ANALOG CALCULA
(described in the Craft generation)

2-3 PART

LEVEL REFERENCE

Gunnery Level, Swift & Anderson Inc., ca 1910, Lead, Brass and Glass, (B66.80).

INTEGRATOR

Integrators are analog calculators that perform the mathematical integration function. The two-three part mileage readers are indeed very primitive forms of this phenomena. In calculus, integration is carried out by continuously summing up rectangles whose height is represented by the value of a function and whose width approaches zero. The infinite sum of all of these results is a value that represents the area under the function. In an integrator this process is duplicated by means of a wheel sliding on a rotating cone or disk. As the function increases, the wheel is slid further out on the disk, making it spin faster to account for the greater area under the function.

"Morris's Measuring Instrument", Morris, 5.5d x1 cm, Metal, Paper, Cloth, Glass, (B128.80).

Map Measure and Compass, Tacro Inc., 7x3.5x.5 cm, Chrome, Paper, Glass, (B129.80).

Map Mileage Reader, Depose H.C., 12x3.5dx.5 cm, Metal, Paper and Glass,, (B140.80).

Map mileage reader and compass, SELSI, ca 1930, 11x3.5x.5 cm, The handle also serves as a pencil, (B152.81).

MULTIPLE PART

LEVEL REFERENCE

Sextant, Heath and Co. Ltd., ca 1920, 35x25x17 cm, Certified at The National Physics Laboratory, (B69.80).

"Platometer", J. Sang, ca 1860, 9x15x37 cm, Brass, (B6.76).

This instrument for directly measuring an area bounded by an irregular curve is based on an idea developed by the Bavarian engineer J M Hermann in 1814. The first commercially successful devices were made by Ernst of Paris. In 1851, John Sang of Kirkcaldy invented and made a "platometer" resembling the planimeter of Ernst.

Use. Operation is based on continuous integration. A curve is traced using the pointer, with the area read off on the dial after the complete perimeter has been traversed. As the pointer is moved the rollers that measure distance on the conical shaft calculate the product of the vertical distance times the horizontal distance. As a curve is traversed in a clockwise direction, the top area is integrated in a positive direction. On the return trip the integration is negative and the net value is provided.

"Directions for Making a Machine to Solve Equations", Rowning, J., 1768, 22x18x2 cm, (B48.79).

This work describes the first analog computer designed to solve algebraic equations of the n'th degree expessed in the form y = a + bx + cx2 + dx3 + . . . + qxn . It was completed in 1768 by Rowning based upon the graphical method invented by A. deSegner in 1751. In 1770 an actual machine mechanized to the second degree was presented to the Royal Society, but apparently no longer exists. Rowning's instrument consists of a number of adjustable straight bars, or "rulers," centred and combined together in such a way as to occupy progressively the various positions in accordance with deSegner's graphical construction. Movement in two directions at right angles to one another is secured by means of two pairs of racks and pinions. The curve is drawn by a pencil on the underside of a piece of pasteboard supported by two adjustable bars.

Use. Segner's method consisted in finding, by graphical construction, the values of y for various assumed values of x, plotting the curve, and reading off the values of x at the points where the curve intersected the axis of x, thus obtaining the real roots of the equation. The impossible or imaginary roots were indicated by the points where the curve approached and reached from the axis of x, without reaching it.

Planimeter, The A. Leitz Co., ca 1900, 2x4x28 cm, German Silver and Steel, (B49.79).

This instrument for measuring the area of any plane figure was invented by Professor Jacob Amsler in 1856. It is a proportional instrument in that the unit can be changed by altering the radius of the tracing arm.

Use. The weighted point is fixed and the tracing pointer guided exactly once round the outline of the figure whose area is to be measured. The difference of the readings on the graduated roller before and after this operation gives the area of the figure in units dependent on the setting of the tracing arm.

"Lowry-bowyer Telemeter", Lowry Mfg. Co., ca 1900, 15x78x7 cm, Aluminum and Wood, (B53.80).

A version of the classical trigonometer signed and dated "THE LOWRY MFG. CO./BOSTON, U.S.A./PAT. 1887, '92, '96". It has two four and a half inch compass bearing dials, one fixed at the end of the twenty-six inch long graduate slotted base plate, the other sliding, and each with graduated pivoted arms of 18 3/8" radius. It was intended for the analog solution of the plane triangle knowing two angles and included side, two sides and the included angle, or three sides. Thus it was useful for problems both of navigation and gunnery.

DRAWING INSTRUMENTS

<u>Pantograph</u>, ca 1850, 85x15x8 cm Case, Brass and Wood, Engraved, J. Davis Cheltenham, (B134.80).

<u>Pantograph</u>, A & W Smith, ca 1820, 59x7x5.5 mahoganny case, Brass, (B153.81).
"A rare type of brass pantograph", P. Delehar.

DIGITAL CALCULA

The Digital Order, Class Calcula has five families: single register, two register, three-four register, complex and programmable. The use of the abacus, a single register, manually built, portable calculator, has not been challenged until the development of equally portable and inexpensive electronic pocket calculators. Abacus-type machines have been unique because with a skilled, accurate operator, they could carry out diverse and complex functions, including long mulitplication and division. They had the characteristic of all single-register machines, i.e., the only record of the operator's input was the current result on the single register. The dual calculator Sharp-Elsi Mate with both a soroban and a four-function electronic calculator was manufactured to preserve a culture, i.e., to teach children to use a soroban and not to use the calculator. If abacus-like machines are so extrordinary, why in fact were mechanical calculators ever invented? Probably, because of the likelihood of human error, and desire for simple aids with some kind of memory to check the human operator.

The Pascaline (1645) is the first of the mechanical, single register calculators. All machines stemming from this, to the Comptometer, utilized one's complement arithmetic for subtracting. Two register calculators, developed in the late nineteenth century, were characterized by using the keyboard as one register and using bi-directional wheels for direct subtraction.

Three and four register calculators were derived from

Leibniz's concept of a stepped-wheel mechanism allowing an automatic carry, thus multiplication and division. Otto Steiger's Millionaire, a heavy brass machine, based on purely mechanical principles, also had the first fully automatic multiply. Millionaire production came to a halt in the thirties, these machines were kludged with key punches and motors to meet the growing competition of electric motor-driven machines.

In the 187Øs, both Frank Baldwin and Wilhelm Odhner developed a compressed version of the stepped wheel device with one large wheel and all operations based on its rotation. This type machine was widely distributed in Europe under the names Odhner and Brunsviga. Its concept was most refined as the Curta, produced through the sixties.

In 1911 when Baldwin was old enough to retire he met Frank Monroe and they started the Monroe Calculator Company (Chase, 198Ø). The Monroematics, electric calculators, were among the first electrified automatic machines.

Four-function electronic calculators are with us, and school children and everyone needing to balance a check book have become about attached to them as they are to their watches. The inexpensive, the four-function electronic pocket calculator has replaced almost all other forms of analog and digital calculators.

Complex digital calculators stem from Babbage's difference engine, built by Scheutz as a project.

<u>SINGLE REGISTER</u>

Three kinds of mechanisms divide this family into three genuses: Pascal wheel; Pascal strip; and Keyed wheel. The original machine was based on a toothed wheel driven by a stylus. Pascal's bulky machine with its long teeth was replaced by many streamlined variants. As teeth on the wheels became more compressed the volume of the machine was taken up by the diameter of the circles themselves, giving rise to the Pascal strip -- simply an elongated circle. Thus, the Pascal strip family provided a portable, cheap and, from 193Øs-195Øs, a relatively widespread use alternative. However, from the human factors standpoint working at a office desk, key punch equipment is faster and more accurate. Dorr E. Felt was the first person to patent and manufacture a key-punch variant of the wheel, the Comptometer, marketed mainly for the growing bureaucracy of the turn-of-the-century industrialization.

PASCAL WHEEL

<u>Pascal Adder</u>, Roberto Guatelli, 1645, Bronze, (B15Ø.81).

A replica of the first mechanical adding machine. <u>Use</u>. The dials show the French monetary unit, the <u>livre</u>, which was divided into 12 deniers, each subdivided into 2Ø sols. The essential part of the machine was its decimal carry; each toothed wheel moved forward one unit (one-tenth of a revolution on each wheel except those of deniers and sols) when the previous wheel had completed one revolution. Subtraction is based on complementary numbers revealed by moving the strip at the top of the calculator.

"SEE CALCULATOR", Selective Educational Equipment Corp., 1968, 18x4x1 cm, (B31.79).

A small replica of the Pascal-type adder made to illustrate the mechanism.

"Quixsum Adding Machine Model C", Precision Adding Machine Co. Inc., ca 1930, 7x18x48 cm, (B38.79).

The Quixsum is a good example of how the stepped wheel principle of Pascal can be used to operate any special measures, not necessarily base ten. In this case it adds English units of feet and inches.

Use. To add a number to the register, the appropriate digit is dialed. The result is displayed in a notch at the top of each wheel.

"Addometer" Reliable Typewriter & Adding Machine Corp., 1x5x30 cm, Black, Metal, (B85.78).

"Addometer" Reliable Typewriter and Adding Machine Corp., 1x5x30 cm, Dark Gray, Metal and Fiber, (B96.80).

"BRI-CAL POCKET ADDING MACHINE", BRI-CAL, 1900, 12.5 cm diameter, Black, Metal, Loaned by Dick Rubinstein (X13.80).

PASCAL STRIP

"BABY CALCULATOR", ca 1950, 1x8x6 cm, Tin, (B76.80).

"BABY CALCULATOR", 14.5x7.5x7 cm, Black, Gold and Red, Metal, (B149.81).

"B.U.G. Calculator", ADDI-COSMOS, 4.5x20.5x4 cm, Brass, Steel, Wood, fabric, (B131.80).

"EXACTUS", ca 1950, 7x11x.5 cm, (B36.79).

A linear form of the simple Pascal two function calculating device that uses complement arithmetic.

Use. Addition or subtraction is carried out by dialing the numbers starting with the least significant. A carry is performed by moving the final digit around the corner to the next linear register.

KEYED WHEEL

All machines in this category are derived from the invention of Dorr E. Felt who holds an 1887 patent (#371,496) for the machine. In 1884, at age 22, Felt, a machinist, conceived his idea while watching the ratchet feed motion of the planer that he ran. He says: "Watching the planer-feed set me to scheming on ideas for a machine to simplify the hard grind of the bookkeeper in his day's calculation of accounts. I realized that for a machine to hold any value to an accountant, it must have greater capacity than the average expert accountant. Now I know that many accountants could mentally add four columns of figures at a time, so I decided that I must beat that in designing my machine. Therefore, I worked on the principle of duplicate demonominational orders that could be stretched to any capacity within reason. The plan I finally settled on is displayed in what is generally know as the "Macaroni Box" model. This crude model was made under rather adverse circumstances. The construction of such a complicated macine from metal, as I schemed up was not within my reach from a monetary standpoint, so I decided to put my ideas into wood. It was near Thanksgiving Day of 1884, and I decided to use the holiday in the construction of the wooden model. I went to the grocer's and selected a box which seemed to me to be about the right size for the casing. It was a macaroni box, so I have always called it the macaroni box model. For keys I procured some meat skewers from the butcher around the corner and some staples from a hardware store for the key guides and an assortment of elastic bands to be used for springs. When Thanksgiving day came I got up early and went to work with a few tools, principally a jack knife. I soon discovered that there were some parts which would soon require better tools than I had at hand for the purpose, and when night came I found that the model I had expected to construct in a day was a long way from being complete or in working order. I finally had some of the parts made out of metal, and finished the model soon after New Year's day, 1885." (Felt in Turck, 1921) He produced eight finished machines before September, 1887, and two were immediately put into service for training operators.

One of the first trained operators, George W. Martin wrote Felt on November 6, 1887, "...in accordance with your request I have called on as many businessmen as I will have time to call on owing to the fact that the Gas Co. has written for me to come to work next Monday morning. The names and addresses are as follows: Sprague Warner and Co., Michigan Avenue and Randolph Pelkin and Brooks, Lake and State Streets, Melville E. Stone, Editor, of the Daily News, and the Freight Auditor of the C.B.&Q RR. These Gentlemen are very much please with the machine and say they will give it a trial as soon as you put it on the market." (Turck, 1921, p. 71)

According to Turck, "significant proof of Felt's claim as the first inventor of the modern calculating machine is justified by the fact that no other multiple-order key-driven calculating machine was placed on the market prior to 1902." (Turck, 1921, p.75)

Use. For each digit a push button from 1 to 9 is selected which rotates a Pascal-type wheel with the corresponding number of increments. Numbers are subtracted by adding the complement (shown in smaller numbers). The carrying of tens is accomplished by power generated by the action of the keys and stored in a helical spring, which is automatically released at the proper instant to perform the carry. Through effective marketing and training of skilled operators versed in complement arithmetic at Comptometer Schools, these machines became the workhorse of the accounting profession in the first part of the century. They never successfully advanced into the electro-mechanical era, but remained purely mechanical, two-function adding and subtracting machines.

"Burroughs Model 5", Burroughs, 28x25x12 cm, Black, Metal, (B7.76).

"Burroughs" Burroughs, 18x25x27 cm, (B8.76).

"Burroughs Adding Machine Model A", Burroughs, 22x15x12 cm, Black, Metal, 5 Digit, (B14.76).

"Burroughs" Burroughs Adding Machine Company, ca 1920, 15x30x25 cm, Black, Metal, Complement Arithmetic Nine Digits, (B22.78).

"Burroughs Calculator", Burroughs, ca 1910, 18x23x30 cm, Black and green, Metal, 11 Digit, Stands on legs at a tilt for ease of operation, (B155.81).

"Comptometer", Felt & Tarrant Manufacturing Co., 1914, 37x28x15 cm, Green, Metal, (B9.76).

"Comptometer", Felt & Tarrant Mfg Co., ca 1920, 36x22x15 cm, Bronze, Metal, (B57.80).

"Plus" Bell Punch Co. Ltd., 15x30x40 cm, Green, Metal, Model #909/C/V/504.929/A, (B81.80).

An electrified modification of the Comptometer.

TWO REGISTER

TAB INDICATOR

"American Adding Machine", American Can Company, ca 1920, Black, Metal, Digits worn, (B137.81).

Essentially a Pascal-like single register machine, only the digits are grooved and stay in place showing the entry (a second register) until they are cleared.

KEYED WHEEL

One register is formed by the depressed keys in contrasts to the single register comptometer type where the keys are on springs. The other register is the accumulator. In many cases, these also started as printing and adding machines. The first practical machine resulted from William S. Burrough's patent of 1892. Prior to this a number of machines were patented and experimented with, particularly the patents of Henry Pottin (No. 312,014, 1885) and William S. Burroughs (Nos. 388,116 and 388,118, 1888). Like the comptometer type, until the adaptation of Wm. E. Swalm's patent of 1910 (No. 1,028149), complement arithmetic was used for subtraction. In 1907, Burroughs sold 13,314 adding and listing machines, and with 58 different styles of Burroughs (including comptometer copies) claimed to be the leading producer in an ad in the February 1908 issue of Office Appliances Magazine.

"Allen-Wales Printing Adding Machine", Allen-Wales Adding Machine Corp., 20x20x40 cm, Black, Metal, (B89.80).

"Burroughs", Burroughs, 28x38x40 cm, (B42.80).

"The Burroughs Adding and Listing Machine", Burroughs, ca 1900, Black, Metal with beveled glass sides, (B156.80).

"The Burroughs Adding and Listing Machine", Burroughs, ca 1910, Black, Metal with beveled glass, Adapted for motorized operation, (B157.81).

"Wales Visible Adding Machine", Wales the Adder Machine Co., 20x24x38 cm, Metal and Plexi Replacements for Glass, (B88.80).

3-4 REGISTER

STEPPED WHEEL

In 1820, Chevalier Charles X Thomas of Colmar designed and introduced the first multiplication machine made commercially available for general sale. Although it was not patented until 1851, the main features of the 1820 design remained unaltered. The mechanism has three parts, concerned with setting, counting, and recording respectively. Any number up to 999,999 may be set by moving the pointers to the numbers 0 to 9 engraved next to the six slots on the fixed cover plate. The movement of any of these pointers slides a small pinion with ten teeth along a square axle, underneath and to the left of which is a Leibniz stepped wheel. The Leibnix wheel, a cylinder having nine teeth of increasing length, is driven from the main shaft by means of a bevel wheel, and the small pinion is thus rotated by as many teeth as the cylinder bears in the plane corresponding to the digit set. This amount of rotation is transferred through one of a pair of bevel wheels, carried on a sleeve on the same axis, to the 'results' figure wheel on the back row on the hinged plate. This plate also carried the figure wheel recording the number of turns of the driving crank for each position of the hinged plate. The pair of bevel wheels is placed in proper gear by setting a lever at the top left-hand cover to either "Addition and Multiplication" or "Subtraction and Division". The "results" figure wheel is thereby rotated anti-clockwise or clockwise respectively.

Use. Multiplying 2432 by 598 may be performed as follows: Lift the hinged plate, turn and release the two milled knobs to bring all the figure wheels to show zero; lower the hinged plate in its position to the extreme left; set the number 2432 on the four slots on the fixed plate; set the lever on the left to "multiplication" and turn the handle eight times; lift the hinged plate, slide it one step to the right, and lower it into positon; turn the handle nine times; step the plate one point to the right again and turn the handle five times. The product 1,454,336 will then appear on the top row, and the multiplier 598 on the next row of figures.

"Arithmometer", Chevalier Charles Savier Thomas, ca 1850, 10x18x58 cm, Brass, (B3.76).

"Tates Arithmometer", C & E Layton, 10x17x58 cm, Brass and Wood, (B82.80).

This machine, which is of the Thomas type, embodies the modifications patented in 1884 and 1903 by S. Tate, who in 1883 was the first in England to manufacture this type of calculating machine. His patents were later taken over by C. and E. Layton.

"BUNZEL", Thomas-type arithmometer, Bunzel Mfg, Vienna, ca 1910, Wood, Metal, (B143.81).

AUTOMATIC STEPPED WHEEL

The Millionaire was invented in 1893 by Otto Steiger and was the first direct multiplying calculator to be commercially successful. Between 1894 and 1935, 4,655 millionaires were sold.

Use. One turn of the crank automatically multiplies the accumulator by a single digit specified by a pointer in the upper left hand corner of the machine. The pointer is reset for each digit in the multiplier until the computation is complete.

"Millionaire", EGLI & CO., 1903, 17x52x28 cm, Brass, 6 Digit, (B1.75).

"Millionaire", EGLI & CO., ca 1910, 18x29x76 cm, Brass 10 Digit, (B17.78).

"Millionaire", Hans W. Egli, 18x29x76 cm, Brass, 8 Digit, (B91.76).

"Millionaire", Hans W. Egli, ca 1920, Brass, Electrified 8 Digit Model, (B136.81).

ROTARY

The German patent of W. T. Odhner, 1891, was acquired by Messrs. Grimme, Natalis & Co., and was embodied in a machine known as the "Brunsviga".

Use. Although the machine performs multiplication by repeated addition as in the Thomas type, the use of the Odhner wheel instead of the Leibniz toothed wheel led to a more compact design. The Odhner wheels fit very close together on the axle on the back. A setting lever, the end of which projects through a slot in the cylindrical portion of the cover plate, forms part of each wheel. If a lever is set against any figure (1 to 9) of its slot, a corresponding number of pins are made to project from its wheel. When the operating handle is turned, these pins gear with small toothed wheels of the product register, which in turn gear with the number wheels in front. The product register is mounted on a longitudinally movable carriage arranged in front of the machine, which carries a second counter for registering the multiplier or the quotient. The handle is turned in a clockwise direction for addition and multiplication, and counter-clockwise for subtraction and division.

"Trinks-brunsviga" Trinks-brunsviga, ca 1940, 15x12x36 cm, (B80.80).

This example is a further adaptation of the Brunsviga and sits on a wood board that was part of a disappearing desk top.

"DE TE WE" Harmann Manus, Gift of Declan and Margrit Kennedy (D190.80).

"Original Odhner", Odhner, ca 1920, Grey, Metal, (B135.80).

"Curta" Contina Ag Mauren, 10d x 12 cm, Black, Metal, (B87.79).

The Curta is the ultimate example of the rotary mechanical calculator. Its small size requires better manufacturing technology than any other mechanical calculator. Model I had an 8 digit input setting, 6 digit counter, and 11 digit accumulator. Model II had an 11 digit setting, 8 digit counter, and 15 digit accumulator. Prior to the electronic calculator, the Curta was the only four-function portable calculator and as such was especially popular for use at car rallies.

CONTROL

CARD-CONTROLLED - LOOM

The Origin of Punched card program control can be traced to 18th century developments in the French silk weaving industry.

In 1725 Basile Bouchon, the son of an organ manufacturer, devised a perforated tape control for weaving ornamental patterns. Before then, draw looms were operated by two people, one to control the shuttle, and the other to control warp threads by means of cords. A row of perforations across a tape automatically selected the warp threads in Bouchon's loom, reducing the assistant's task to that of pressing the mechanism against a set of needles that sensed which holes had been punched.

In 1728 Falcon, a master silk weaver in Lyons, constructed a loom replacing the perforated tape with a row of connected punched cards. His loom used several rows of needles so that four hundred or more cords could be controlled. At Falcon's death in 1765, about forty of his looms were in operation.

In 1746, Jacques de Vaucanson, the celebrated inventor of automata, designed the first draw loom to function completely automatically. While this innovation was significant, the use of a perforated cylinder rather than a row of cards was retrogressive.

In 1804 Jacquard commercialized and improved de Vaucanson's fully automatic loom utilizing the punched cards of Falcon. Each card carried an individual pattern line. Mounted on a belt, the cards wound over a prism shaped like squared cylinder which revolved with a ratchet system. To extend a pattern, more cards were added, so that complex non-repetitive patterns could be created on the loom.

By the 1830s, thousands of examples of Jacquard looms were operating in France. It is then understandable that Charles Babbage in 1836 chose to use Jacquard mechanisms as program-control devices to direct the wheels and gears in his Analytical Engine.

"Jacquard Loom Mechanism", ca 1805, 16x36x40 cm, Wood, Brass, and Steel, Paper Cards Added by Peter Delehar, (B117.8Ø).

A rare and important contemporary model of the first true device invented by J. M. Jacquard (1752-1834) for use in the French silk weaving industry. The loom was automatic. Patterns in fabric were generated by programmed punched cards.

TRANSDUCTION

COPIER

"The Edison Mimeograph No. 1", A.B. Dick, ca 19ØØ, 13x33x43 cm, Wood Case and Frames, (B78.8Ø).

TYPEWRITER

"Bennett", 27x12x4 cm, Black with Yellow Letters, Metal, (B142.81).

Very compact with three positions for the keys and a wheel device. Small sized ribbon and removable carriage.

"Bing No. 2" Bing, ca 193Ø, 15x28x38 cm, 1926 patent pending, (B43.8Ø).

"Corona No. 3", Corona, ca 192Ø, 23x25x12 cm, Black, Metal, Carriage folds up over Keyboard, (B63.8Ø).

"CORONA FOUR", Corona Typewriter Co., Inc. Groton, NY, ca 192Ø, 26x31x11 cm, Black, (B154.81).

"Dial Typewriter", MARX, ca 195Ø, 15x15x3Ø cm, (B75.8Ø).

"Favorit 2" Adler, ca 194Ø, 36x28x11 cm, Black, German Keyboard, (B67.8Ø).

"Featherweight Blickensderfer", Blickensderfer, ca 19ØØ, 25x3Øx13 cm, Aluminum, 5Ø1 Special Stamped on Base, (B116.8Ø).

The "Blick" was the first typewriter intented to be readily portable. It was designed by Georges Blickensderfer and patented in 189Ø and first sold in 1893.

Use. Each key had three positions, upper and lower case and a figure that positioned three levels of the printing wheel.

"Junior Typewriter", MARX 28x13x18 cm, Gray and Blue, Tin, Bent & Rusty, (B1Ø1.8Ø).

"Molle No. 3", Molle Typewriter Co., 25x28x33 cm, Black, Metal, (B65.8Ø).

"NOISELESS TYPEWRITER", The Noiseless Typewriter Co., 1915?, 3Øx3Øx3Ø cm, Black, Metal, Text typed on the machine. Loaned by Ed Luwish (X5.8Ø).

"Underwood Typewriter No. 5", Underwood, 22x3Øx3Ø cm, (B15.76).

Electro-Mechanical Generation

ELECTRO-MECHANICAL GENERATION

The inventions that were critical for the electro-mechanical generation were fundamentally in place by 1900. These include the use of electro-magetics, electric-driven motors, battery-driven circuitry, and relays. Links and switches with telegraphy and telephony were developed throughout the mid-nineteenth century. Power for the early telegraphs was generated in conjunction with the railway system. Most early systems were point to point, along lines minus the technology for development as a network. The Hollerith tabulator and sorter developed for the 1890 census provides a truly significant project leading to a new generation. Its first commercial application was not until 1895, when a version was installed for accounting at the offices of the New York Central Railroad. (Randall 1973, p. 126) The 1900 census saw improvements in the system with the addition of automatic card handling mechanisms. In 1901 the first patent application for a motor-driven calculator was made. (No. 726,803 "The Universal Accountant" issued to Frank C. Rinche, April 28, 1903) The electric motor driven calculator was not produced in quantity until the 1920s. (Chase 1980)

Although the pieces of the technology were known prior to 1900, the infrastructure of the electricity grid had not been installed. This was essential to transform the to useful tools. On September 4, 1882, the first American power compnay, the New York Edison Illuminating Company, started generating electricity at the Pearl Street Station. (Stein, 1976, p. 244) Edison and others had difficulty raising money for these capital intensive projects and electrification had to be established as the infrastructure to support the use of electric-mechanical devices.

DIGITAL CALCULA

TWO REGISTER

KEYED WHEEL

"Olivetti" Olivetti, 15x15x30 cm, Plexi-glass, Metal, Paper Tape, (B86.79).

3-4 REGISTER

MOTOR-DRIVEN WHEEL

"Friden Calculator Model D-8", Friden, 38x26x20 cm, (B12.76).
Marchant Electric Calculator, Marchant, Gift of Professor

Robert Floyd (D235.81).

"Marchant", Marchant, 1950 c, 40x25x31 cm, Metal, (B62.80).

"Monroe Electric Calculator No. 1", Monroe Calculating Machine Co., 38x31x24 cm, (B10.76).

"Monroe" Calculator, Monroe Calculating Machine Co., 15x30x26 cm, Gray, 8 Digit, (B40.79).

"Monroe No. 1", Monroe Calculating Machine Co., 20x25x30 cm, Metal, (B90.79).

COMPLEX

ACCOUNTING TABULATOR

Working as a statistician at the United States Census Bureau, German-American Hermann Hollerith first conceived of using punched cards as data carriers for the 1890 census. The 1880 census had taken over seven years to complete, the population then numbering over 50 million and increasing rapidly.

Hollerith's solution was to introduce a rectangular card divided into 240 squares, in each of which a hole could be punched according to a code. Each square corresponded to a question; a punched square represented the answer "yes", an unpunched square a "no". In that way one card could contain information about a person's age, sex, ethnic background and so on.

Hollerith developed his methods further and started a company which, in the following decades, was to provide the business world with a whole family of punched card machines for bookkeeping and statistics. Hollerith's company flourished and became one of the cornerstones of IBM, founded in 1912.

The Hollerith Electric Tabulating System, Reproduction by Roberti Guatelli, 1890 (1981), tabulator 75x120x90 and sorter 90x35x75 cm, Brass, Oak, Glass, (D231.81).

Cards were read by the machine. The card was placed on small containers holding mercury, one container for each row of holes, and then the die with electrically conducting pins was brought down upon the card. The holes permitted contact between the pins and the mercury containers, and the coded information was registered by the comptometer - the dials on the front of the machine. The upper left dial counted the U.S. total, and the others corresponded to the state total in which the particular "card" lived. The corresponding slot in the sorter would then open, and the operator would drop the card in.

Keyboard Punch (Hollerith), Reproduction by Roberto Guatelli, 1890, 10x40x50 cm, (D242.81).

Blank cards were punched by using a enlarged pantograph of the layout that could be easily read. Locating the correct whole on the template and punching it then transferred a punch onto the card.

MEMORY

WRITABLE OR READABLE

MECHANICALLY STABLE

RANDOM

Paper Tape for Facom, Fujitsu, 72 hole unit paper tape, Gift of F. Kurosaki (D76.79).

TRANSDUCTION

Ediphone, Utility Shaver, Voice Recorder, Edison, 1900, 30x30x90 cm, Black, Metal, Gift of Dan Leblanc (D121.80).

Dictaphone, Shaver, Transcriber, Columbia Graphophone Co, 1910, Black, Metal, (D123.79).

"IBM" IBM, 26x44x40 cm, Gray, Justowriter Corp On Motor Housing, (D16.76).

Clary Printer, (adding machine adapted for computer output), Martin Marietta Corp, 1960, 45x35x45 cm, Gray, Metal, Keyboard covered, Gift of Clyde Still (D208.80).

LINKS AND SWITCHES

TELEGRAPHY

NEEDLE TELEGRAPH

In October of 1847, a week after Werner Siemens founded what was to become Siemens Company, he received a patent for the needle telegraph. He wrote his brother on 11 October 1847, "I have already spend 8 days in the new building. Above me there is already a lot of filing and raspoing going on. Halske lives two floors up. We still badly need machine tools." A year later the company received an order to set up with minimum delay a communications link between Berlin and Frankfort so the the high level political decisions of the First German National Assembly in Frankfort could be discussed as soon as possible in Berlin. On 28 March 1849, the election of King Frederick William IV of Prussia was transmitted electrically over 500 km in the same hour as its announcement. (Weiher and Goetzeler 1977)

Telegraphen-Bau-Anstalt von Siemens & Halske, Needle Telegraph, 1847

Use. The piano key-type letters activate the impulse with the aid of a Wagner-Neef hammer to automatically maintain an electrically controlled synchronism between transmitter and receiver. Loaned by the Siemens Company. (X19.81)

Telegraph Sender & Receiver, Bunnell?, 1870'S, 45x30 cm, Brown, Rodney Banford (D229.8Ø).

Telegraph Key, Electric Specialty Mfg Co., Cedar Rapids, Ia., ca 19ØØ, 7x8x18.5 cm, black, metal, (B151.81).

Western Union Teleprinter, Teletype Corp, ca 193Ø, 35x3Øx3Ø cm, Green, Metal, Model 2-B, Loaned by Ed Luwish (X8.8Ø).

DMCAT1.5

Pioneer Computers

SUBJECT INDEX

CLASS SCHEDULE

TIME									
MON.									
TUE.									
WED.									
THU.									
FRI.									
SAT.									

FINAL EXAMINATIONS

DAY	DATE	TIME	PLACE	COURSE

NAME ______________________ TELEPHONE ______________

ADDRESS ____

SCHOOL ______________________ CLASS ________________

CEL - U - DEX CORP.
NEW WINDSOR, N. Y. 12550

PIONEER COMPUTERS

The mid-thirties brought needs for increasingly complex engineering calculations. George Stibitz recalled:

> In 1937, Bell Labs began to need greater calculating power for development in mathematical form as a theory of communications engineering. The basic principles were expressed in terms of complex numbers because they nicely represent the characteristics of alternating currents used by the power and communications industries. Twelve girls (if you don't mind the expression) did nothing but calculate complex numbers with 8 place precision using desk calculators. The arithmetic of complex numbers when it has been converted to multiple operations with real numbers and carried out on desk calculators is even more tedious and subject to errors than bookkeeping. Furthermore, the computing load was increasing rapidly. (Stibitz, 1980)

By the forties, the concern was defense, and the first true working computers were funded by various parts of the national war efforts on cryptology in Great Britain (Randell, 1980) and to compute firing tables in the U.S. To give an idea of the order of magnitude of the need, Goldstine estimated,

> The human cum desk calculator (10 seconds per multiplication) would then spend about 2 hours on the multiplying; and with our estimate of a factor 6, about 11 hours doing an individual trajectory. This was a little right, perhaps a little low. The Harvard-IBM machine (3 seconds) required about 2 hours; the Bell machine (1 second, about 2/3 hour; and the Mark II (0.4 seconds) about 1/4 hour. The differential analyzer took, as we have said, about 10-20 minutes. ... None of these was sufficient for Aberdeen's needs since a typical firing table require perhaps 2,000-4,000 trajectories--assume 3,000. Thus, for example, the differential analyzer required perhaps 750 hours --30 days-- to do the trajectory calculations for a table. (Goldstine, 1972, p.138)

Thus, the war effort clearly provided a significant need for computing on a power never clearly articulated before and with new electronic technologies that appeared to be suitable for use. Goldstine funded Presper Eckert and John Mauchly to put together a team and build a computing machine to fulfill this need, but the academic, engineering, and scientific communities were skeptical that an order magnitude change was possible. (Stern forthcoming)

The EDVAC report, written by Von Neumann, and based on the work of Eckert, Mauchly, Burks, and others involved with the ENIAC project, puts down the realistic specifications for the general purpose, stored program computer. (Von Neumann, 1945) It excited the academic community, and led to the origin of a number of computer projects. (Bigelow 1980) Similarly, a report by Alan Turing in England spawned interest there. A number of projects in laboratories and universities that developed between 1945 and 1950 then convinced the scientific, government and business communities of the reality of potential of the stored program, general purpose digital computer.

Although a driving meta-need was the war effort, World War II was over by the time Von Neumann was specifying the IAS project at Princeton. He identified a second meta-need, that of good weather prediction. The equaions for greater accuracy in prediction were known in 1911-12 but time consuming to compute. Von Neumann's first experiments were so successful that as a result the U.S. set up a statistical weather prediction service. No conceptual breakthroughs had been made: it was only a case of carrying out the computations more carefully and with greater speed. With the advanced fourth generation computers, the one week theoretical limit of weather prediction as understood as a subset of celestial mechanics has not been reached. (Leith 1981)

DIGITAL CALCULA

COMPLEX

RELAY CALCULATOR

BELL TELEPHONE LABORATORIES CALCULATOR I

- Relay Breadboard of Bell Telephone Laboratories Calculator, 1939, Reproduction and gift of George Stibitz, (D127.80).

"Communications Milestone: Invention of the Electrical Digital Computer", Bell Laboratories, ca 1980, Color, 3/4" videotape, 8 min. running time (V4.81).
George Stibitz recalls early computer development in this Bell Labs publicity piece. Stibitz, whose electromechanical calculator was a forerunner of the modern computer, demonstrates his first binary adder and documents the first long-distance data link.

George Stibitz Lecture, Digital Computer Museum, 1980, b&w, 3/4" videotape, 58 min. running time (V12.81).
George Stibitz's Pioneer Computer Lecture, May 8, 1980

EQUATION-SOLVER

ATANASOFF-BERRY COMPUTER

- ABC Memory Drum, Atanasoff, 1935-1940, Loaned by Dr. Clair Maple, Iowa State University (X11.80).
- ABC Breadboard, Atanasoff, 1935-1940, Loaned by Dr. John Vincent Atanasoff (X12.80).

J. V. Atanasoff lecture, Digital Computer Museum, 1980, b&w, 3/4" videotape, (v10.81).

J. V. Atanasoff's Pioneer Computer Lecture, November 11, 1980.

PROGRAMMABLE

RELAY CALCULATOR

Z 3, Z 4

Konrad Zuse Lecture, Digital Computer Museum, 1981, B&W, 3/4" videotape, (V15.81)

Konrad Zuse's Pioneer Computer lecture, March 4, 1981

COMPUTER

The EDSAC

"The EDSAC Film", Cambridge University Mathematics Laboratory, 1951; narration added 1976, Colour, 3/4" videotape, 10 min. running time (V3.81).

The EDSAC, the first full-scale stored-program computer, is the subject of this 1951 documentary. Cambridge University Mathematics Laboratory staff act out the story of a computer program from problem formulation through run, with memory contents displayed on EDSAC's CRT, to final results. Maurice Wilkes added an introduction in 1976.

"The EDSAC", Maurice Wilkes Lecture, Digital Computer Museum, 1979, Color, 3/4" videotape , 2 tapes, 82 min running time (V13.81).

The ENIAC

"The ENIAC", John Brainerd lecture, Digital Computer Museum, 1981, B&W, 3/4" videotape, (18.81).

John Brainerd's Pioneer Computer Lecture, June 25, 1981.

The Pilot Ace

"The Pilot Ace," J. H. Wilkinson Lecture, Digital Computer Museum, 1981, B&W, 3/4" videotape, 2 tapes (V14.81).

J. H. Wilkinson's Pioneer Computer Lecture, on the Pilot Ace, April 14, 1981.

Whirlwind

Word length: 16 bits;
Memory size: 2048 words;
Speed: Approximately 42,000 single address instructions per second;
Clock rate: 1 Mhz; 2 Mhz (for arithmetic element);
Arithmetic element: Accumulator, A and B registers.
Instruction format: Single address 5 bit op code and 11 bit address;

Power consumption: Approximately 150,000 kw;
Size: Occupied Barta Building, Cambridge.
Component count: 5000 vacuum tubes and 11,000 crystal diodes;
Availability: >95%;
Maintainability: Used marginal checking of grid and screen bias voltage;
Project leaders: Jay W. Forrester and Robert Everett.
Project start: 1945;
Operated: November, 1950 with 256 words; and August 1953 with core memory.
Decommissioned: at MIT in May 1959; operated at Wolf R&D from 1963-1973; Moved to Digital, 1974.
Use: Prototype for Air Defense Computer, precursor to IBM built AN/FSQ7 computer. Used to develop Linvill's sampled-data system theory.
Achievements: First core memory. First high speed, parallel computer for real time. Control organized in an array permitting diodes to be used for specifying register transfer operations needed for degining each instruction in what Maurice Wilkes later described to be microprogrammed. First use of marginal checking to detect weak components. Self checking procedure for faulty components. First use of cathode ray tubes for light pen input. Data-transmission via phone lines; vacuum tube process improvements.

Whirlwind Register/Logic Module MIT 1950,(D104.76); Whirlwind Core Plane MIT 1953 (D29.73); Whirlwind Core Memory Stack, MIT, 1953,(D30.73).

Jay Forrester Lecture, Digital Computer Museum, B&W, 3/4" videotape, 2 tapes, 84 min. total running time (V11.31).

Jay Forrester's lecture on the design and engineering of the Whirlwind; Third Pioneer Computer Lecture, June 2, 1980.

"See It Now" (excerpt on Whirlwind), CBS, 1952, B&W, 3/4" videotape, 6 min. running time (V1.81).

Edward R. Murrow features the Whirlwind computer, the new "electronic marvel," in this 1952 excerpt from the CBS "See It Now" news program. Jay Forrester, Whirlwind project leader and director of the MIT Digital Computer Laboratory, demonstrates the capabilities of the computer using paper-tape input, display scope, and teletypewriter output.

"The Whirlwind Film", ca 1953, Color, 3/4" videotape, Running time: 13 min. (V8.81).

The Whirlwind's structure is shown in detail as a scientific application program is written, debugged at 3 a.m., and run. This film on computer operations and applications was made after Jay Forrester invented core memory for the Whirlwind.

Electronic
Generation

ELECTRONIC GENERATION

In 1950, the computer era had been established: at least seven corporations had announced their intent to build computers -- Zuse AG, Ferranti, Elliott Brothers, Ltd., J. Lyons and Co Ltd., UNIVAC, and IBM -- and the ERA 1101 was on the marketplace. (Science Museum, 1975)

Industry itself and its leaders had been changed by the technological advances of the war period. Goldstine states:

> In my opinion, it was Thomas Watson, Jr. who played the key role in moving IBM into the electronic computer field. When he came out of the Air Force in 1945 his experience as a pilot had apparently convinced him of the fundamental importance of electronics as a new and prime technology for our society. He therefore exerted considerable pressure on IBM..." (Goldstine, 1972, p. 329)

COMPUTER

LGP-30 - Librascope General Precison Computer (X14.81)

Word Length: 31 bits, including a sign bit, but excluding a blank spacer bit
Memory Size: 4096 words
Speed: .260 milliseconds access time between two adjacent physical words; access times between two adjacent addresses 2.340 milliseconds.
Clock Rate: 120 Khz
Power: 1500 Watts
Arithmetic element: Three working registers: C the counter register, R the instruction register and A the accumulator register.
Instruction format: Sixteen instructions using half-word format.
Technology: 113 vacuum tubes and 1350 diodes.
Number Produced: 320-490
First Delivery: September, 1956
Price: $47,000
Software: ACT I (Fortran type compiler)
Successor: LGP-21
Achievements: With the Bendix G-15 the first of the desk-sized computers offering small scale scientific computing. Revolutionizing the computer industry with the potential for low-cost distributed processing.

The Maniac

"The Maniac", Los Alamos Scientific Laboratory, 1957, Color, 3/4" videotape, 29 min. running time (V5.81).

This 1957 production describes the MANIAC computer's architecture and operating principles for a general audience. The Los Alamos-designed machine features cathode ray tube memory and binary-coded-decimal input by punched paper tape.

COMPONENTS

LOGIC MODULE

Deuce Arithmetic Logic Element, English Electric Co, 1955, Gift of Professor Murray Allen, University of New South Wales (D4.75).

IBM 650 Logic Module, IBM, 1955, Gift of Professor Murray Allen, University of New south Wales (D12.75).

G15 Logic Module, Bendix Computer Corp, 1955, (D109.80).

READABLE & WRITABLE MEMORY

WAVE STORAGE

CYCLIC

Mercury delay line.

Mercury was used to propagate an acoustic wave and hold information. A two meter tube held about 1000 bits, with a delay time of approximately one millisecond with a bit separation of about one microsecond or two millimeters. Early computers such as the Pilot ACE, EDSAC, and Bureau of Standards computers used both long and short delay lines.

Deuce Mercury Delay-line, English Electric Co, 1955, Short register, 64 bit, 64 microsecond delay line. Gift of Murray Allen, University of New South Wales (D3.75).

ELECTRIC CHARGE

RANDOM

Maniac Electrostatic Memory & Williams Tube, Atomic Energy Commisssion, 1949, Gift of Dale Sparks, Los Alamos Laboratory (D214.80).

MAGNETIC FLUX

RANDOM

Illiac 54x128 bit Core Memory, Gift of Clifford Carter, University of Illinois (D19.75).

? RCA Selectron Tube-from JOHNNIAC, RCA, 1950, Gift of John Postley (D215.80).

One of forty RCA Selectron tubes installed on the Rand Corp JOHNNIAC Computer in 1950. The tubes constituted the 256 word 40-bit memory that operated the machine. In 1954 a 4000 word magnetic core memory replaced the tubes.

? cyclic Mark IV 64 bit Magnetic Shift Register, Aiken-Harvard, 1944, Gift of Bob Trocchi (D6.75).

Transistor Generation

TRANSISTOR GENERATION

"What is a Transistor?

Transistors are made from silicon by the introduction of minute quantities of impurities that determine the electrical properties of the host material. By precisely controlling both the location and the concentration of impurities (called dopants), engineers can build up the transistor structure.

Doping impurities come in two types. The first adds free electrons to the silicon, coverting it from a near insulator to a conductor of electricity (although the conductivity is much less than that of a metal). The second type removes electrons from the bonds keeping the silicon atoms in the solid, leaving behind electron vacancies or 'holes'. The holes behave like positively charged carriers of electricity and thus the second type of dopant also raises silicon's electrical conductivity. Silicon that conducts electricity by way of free electrons is called n-type, whereas material that conducts by the way of holes is called p-type.

Transistors consist of three segments of doped silicon back to back, as it were. The sequence of segments is important; the allowed orders are n-type-p-type-n-type and p-type-n-type-p-type. There are two general classes of transistors, but both can have either the n-p-n or p-n-p sequence of doped silicon segments. The historic first transistor built at Bell Laboratories in 1948 is called a bipolar transistor because electrical current flowing through the device from one end to the other passes through both n- and p-type silicon and both electrons and holes contribute to the current. Bipolar transistors are also called current controlled because a small electrical current entering the device through the center segment controls whether the device as a whole conducts electricity. A voltage applied only to the two end segments will not cause the transistor to conduct electricity. Viewing the transistor as a switch, one says that the current into the center segment turns the switch on or off.

The second class of transistor is the insulated gate field effect transistor. In this type of device, a thin insulating layer (usually silicon dioxide) is placed between the central segment and its electrode. A voltage applied to the electrode creates an electric field which converts the region of the central segment just under the electrode from one conductivity type to the other (n- to p-type of vice versa). Thus, field effect transistors differ from bipolar devices in two ways: they are actuated by a voltage applied to the central segment rather than by a current, and all the current is carried by one type of carrier in three segments of the same conductivity type.

With the invention of the integrated circuit in the late 1950s, it became clear that the field effect transistor offered distinct advantages because fewer processing steps were needed to make this type of device and because it took up less space in the silicon. The type of field effect transistor called metal-oxide-semiconductor (MOS) has become the dominant form of commercial integrated circuit. The biggest advantage of the bipolar device is switching speed. Thus, for those applications requiring this capability, such as high-speed logic circuits in computers, bipolar is widely used. Moreover, new forms of bipolar circuits that are more amenable to miniaturization than the older types are being investigated and may well turn out to be important as MOS microcircuits in the next generation of microelectronics, the VLSI era." (Robinson, 1980)

By 1960 transistors had replaced tubes as the technological base for computers. Their properties, lending themselves to automated design and manufacture no longer meant that the innovative machines would come from handcrafted projects in laboratories and universities, but from industrial research and development. The end of the fifties saw the last spurt of laboratory built machines: Lincoln Lab's TX-0 (Transistor Experimental project), MANIAC 2, Bell Labs Leprachaun and ILLIAC II. In 1959, a Siemens 2002 was delivered to the Technical University of Aachen. The same year IBM introduced their fully-transistorized 7030, the 7090, and the 1401. In 1960,the CDC 1604 and 160, and Digital Equipment Corporation's PDP-1, the IBM 1620, and the UNIVAC 1105 were announced. The full range of computers were then available for purchase: ranging from business to scientific, and from small to super, i.e., from $100,000 to $10,000,000.

The early sixties brought the space race creating new computing needs in science and education. This generated new demands for computing power that, once available, led the first generation of "hackers" to enhance the machines into super toys. The Gemini flight inspired a group in Cambridge to use the computer scope to simulate space flight and space wars. Active communication between users from coast to coast rapidly developed into a computer game culture. The children of the first hackers started to college in the eighties and are as distinctive as the so-called tv generation since they grew up with computers as playmates.

Simultaneously, business was beginning to define a need based on computing versus tabulating and sorting. Champine (80) has listed the phases that characterize the development of commercial applications. As early as 1955, the full range of business uses were envisioned that are continuing to create a need for larger and faster business computers. But he notes that only the leading edge users were implementing the intermediate level functions in the late fifties. Thus, business data processing only began to drive the development of computers with second generation machines.

ANALOG CALCULA

COMPLEX
LEVEL REFERENCE
Auto-pilot
Hawk Missile-auto-pilot, Raytheon, 1960, Gift of Joe Kuprevich (D144.80).

DIGITAL CALCULA

3-4 REGISTER
Anita Electronic Calculator, ANITA, Gift of Leonard Woodall (D209.80).

COMPUTER

Atlas Computer
- Atlas 1 PCB, Ferranti Corp., 1959-63, Gift of Professor Sumner (D1.75).
- Atlas Digits, Ferranti Corp., 1959-1963, Gift of Professor Sumner (D2.74).
- Atlas I Computer PCB, Ferranti, 1962, Gift of Robert Hopgood, Rutherford Laboratories (D128.80).
- Atlas I Fixed Memory, Ferranti, 1962, Gift of Robert Hopgood, Rutherford Laboratories (D129.80).
- Atlas I Memory "THE SUPERVISOR", Ferranti, 1962, Gift of Robert Hopgood, Rutherford Laboratories (D130.80).
- Atlas I Computer Form Flash Plates, General Dynamics 1972, Gift of Robert Hopgood, Rutherford Laboratories (D131.80).

IBM 7030 "THE STRETCH" IBM, 1961, Gift of Computer Service, Brigham Young University (D250.81).
Word Length: 64 bits plus 8 bits for parity and error checking
Memory Size: 1 to 8 16k core memory stacks, self-contained each with its own clock, addressing circuits, data registers and checking circuits, addressing of up to 256k word locations.
Data Transfer Rate: Addressing of memories and transfer of information from and to memories by a memory bus permits new addresses, information, or both to pass through the bus every 220 musec.
Central Processor: The processor consists of the instruction unit, the look-ahead unit, a parallel arithmetic unit and a serial arithmetic unit. Multi-programming through program interruption and address monitoring, and overlapped or parallel execution of instructions is possible.
Instruction Format: Halfword formats accommodate indexing and floating-point instructions. Fullword formats are used by variable-field-length instructions. Five instruction sets and 765 different types of instructions are used.

Technology: Standard Modular System Transistor Cards. Used 150,000 high speed drift transistors, and provided interleaved magnetic core memory with 2.18 usec access cycle.
Number Produced: 9
Price: $6-8 Million
Project Start: 1954
Project Leaders: S.W. Dunwell; Gene Amdahl, John Backus, Werner Buchholz, B. O. Evans, Jerrier Haddad, Lloyd Hunter, Ralph Palmer, and John Sheldon
First Delivery: April 1961 to the Los Alamos Scientific Laboratory
Software: Algebraic and Fortran compiler
Use: Large scale scientific research, for example: nuclear reactor design, hydrodynamic problems, problems in nuclear physics.
Achievements: Techniques for parallel processing amd multi-programming were interleaved memories, instruction look-up units, overlapping fetch and execute instructions, interrupt handling and address monitoring. The 7030 also introduced an 8-bit byte for character representation, up to 256 characters could be represented. The magnetic core memory developed for the STRETCH was also used on the IBM 7090.
Innovations (adapted by Hurd, 1981)

1. A fast, diffused-base, alloyed-emitter transistor, known as the drift transistor, offering improvements in quality, consistency, and speed.

2. A logic circuit design called transistor current switching or emitter-coupled logic that permitted faster operation than prior logic circuit design.

3. A memory having an access time of about 2 microseconds (compared to the fastest memories available in 1960 -- about 6 microseconds).

4. A method of memory interleaving of up to four 2-microsecond memories, which permitted an average memory access time of about one-half microsecond.

5. A "lookahead" feature that increased the speed at which an application could be performed by the system. The lookahead feature read instructions that were three levels ahead of the one being performed and determined the appropriate memory references and memory allocations for these instructions.

6. The most sophisticated interrupt system to that date.

7. The incorporation of multiprogramming with a system of memory protection.

8. A disk drive which had a set of parallel read/write arms contained in a single mechanism for high-speed operations. With capabilities of attaching to the Stretch more than one two million word disks with a data rate of several million bits per second per channel, this exceeded the performance specifical of competitive storage products.

9. A mass storage device, called TRACTOR, used large

tape cartridges and a mechanical means for storing and retrieving. The use of proportional sensing within a vacuum-tube tape drive enabled the tapes to accelerate, reach high speeds, decelerate quickly, and stop without breaking the tape.

10. Error-correcting codes were used involving memory.
11. Computer-aided design was developed for the Stretch.
12. Methods were developed for automated assembly and testing of printed circuit boards.
13. The distinction between character and decimal and binary machines, fixed-word-length and variable-word-length machines, and fixed-record and variable-record machines was eliminated. Werner Bucholz coined the word "byte" to deal with the issues of variable-sized parts of words.

"Stretch: The Technological Link Between Yesterday And Tomorrow", Brigham Young University, 1981, Color, 3/4" videotape, 15 min. running time (V16.81).

The "Stretch", IBM's 7030, was the supercomputer of 1961. The system's innovations, including lookahead, array processing, and error correction codes, are highlighted in interviews with former users and footage of the machine in operation.

<u>LINC Computer</u>, Lincoln Lab, 1961, (D118.79)

Word Length: 12 bits
Memory Size: 2048 words
Speed: Approximately 125,000 single address instructions per second
Clock Rate: 500 khz using dec 4000 series modules
Arithmetic Element: Six 12-bit registers
Instruction Format: single and double operand, multi-mode
Technology: Discrete transistor using dec 4000 series modules
Power Consumption: 1000 watts
Size: 69"x32"x32", plus separate tape, keyboard, console, and interconnection boxes.
Price: $43,600
Project Leaders: Wesley Clark and Charles Molnar
Project Start: 1961
First Shipment: March, 1962
Withdrawn: December, 1969
Number Built: 50 total, 21 by DEC
Successors: DEC LINC, LINC-8, PDP-12
Achievements: Laboratory system to accept analog and digital inputs directly from experiments and to provide signals for control. First truly personal computer with automatic file system via two LINC tapes, interactive program editing, development and control via crt.

<u>LINC-8</u>, Digital Equipment Corp, 1965, (D119.80).

Word Length: 12 bits

Speed: Approximatley 667,000 memory accesses per second
Clock Rate: 1 Mhz (same as PDP-8)
Instruction Set Processor: Both LINC and PDP-8
Arithmetic Element: Four PDP-8, six LINC 12-bit registers
Instruction Format: Single and double operand, multi-mode, 12 bit instructions
Technology: DEC "Flip Chip" R-series general purpose modules. (Discrete components)
Power consumption: 2,000 watts
Size: 69"x32"x33"
Price: $38,500
Project start: 1965
First shipment: August, 1966
Withdrawn: December, 1969
Predecessor: LINC
Successor: PDP-12
Achievements: System where both processors could operate in parallel. Utilized either LINC or PDP-8 software.

PDP-1, Digital Equipment Corp, 1960, Gift of Inforonics Corp (D116.79).
Word length: 18 bits
Speed: 100,000 single address instructions per second
Clock rate: 5 Mhz and 500 Khz for input-output
Arithmetic element: Accummulator and input-output
Instruction format: Single address 5 bit op code, 1 indirect bit, 12 address bits. Extended field with 15 address bits.
Technology: Early second generation Digital 1000 series 5 Mhz and 4000 series 500 Khz systems modules
Power consumption: 2160 watts
Size: 69"x88"x28"
Price: $120,000
Project leader: Benjamin Gurley
Project Start: Summer 1959
First Shipment: Bolt, Beranek and Newman, November 1960
Number built: 50
Achievements: First commercial computer with graphics display. Operation as time shared computer, BBN, September 1962. Original space war program by Steve Russell at MIT.

PDP-7, Digital Equipment Corp, 1964, Gift of Computer Science Department, Worcester Polytechnic (D143.80).

PDP-8, Digital Equipment Corp,
Word lenght: 12 bits;
Memory Size: 4096 words (expandable to 32,768 words);
Speed: 333,333 signle address instructions/second; 1.5 microsecond memory cycle time;
Clock rate: 1 Mhz;
Arithmetic element: accomulator and 8 auto-index registers in memory;
Instruction format: Sincle address 3 bit op code, indirect bit, 1 page bit and 7 page address; 32,768 word addressable memory;

Technology: Digital R-series logic;
Power consumption: 780 watts;
Size: 8 cubic feet;
Number poduced: approximately 5,000;
Price: $18,000 with 4096 word memory and teletype type 33ASR;
Project start: 1964;
First delivery: April 1965;
Predecessor: PDP-5;
Successors: PDP-8S, LINC-8, 8-I, 8-L, 8-F, 8/M, 8/A, VT78;
Software: PAL-8 assembler, Macro 8 assembler, Fortran II, DDT (Symbolic debugger), Editor, RT-8 and OS-8 operating stand-alone operation systems using Dectape and diskpaks;
Use: Real time control and data collection. First "OEM" computer. Data commmunication. Small business data processing. Timeshared computation for very low cost/terminal;
Achievements: Originated concept of minicomputer; Provided the lowest cost computation and performance/cost at the time; Producible in high volume manufactured using wire-wrap technology; Improved ease of interfacint (first DEC computer to use I/O bus structure); By packaging, price and supply established the two tier supplier/OEM structure; Lowest cost per terminal with TSS/8 (smallest scale timesharing system).

<u>PDP-12</u>, Digital Equipment Corp, 1967, (D156.80).
Word length: 12 bits
Speed: Approximately 667,000 memory-processor accesses per second
Clock rate: 1 Mhz (same as PDP-8)
Instruction Set Processor: Both LINC and PDP-8
Arithmetic element: Four PDP-8, six LINC 12-bit registers
Instruction Format: Single and double operand, multi-mode 12-bit instructions
Technology: DEC "Flip-Chip" general purpose modules. Discrete components.
Power Consumption: Less than 2000 watts
Size: 76"x35"x33"
Price: $28,000
Project Start: June, 1967
First Shipment: June, 1969
Withdrawn: June, 1975
Number built: 1,000
Predecessors: LINC, LINC-8
Achievements: Improved price, price per performance and larger display. Lowered LINC-8 cost by building a single physical processor to execute either LINC or PDP-8 instruction set.

<u>TX-0 Computer</u>, Lincoln Lab, 1956, (D154.75).
Word Length: 18 bits
Memory Size: 8192 words
Speed: 80,000 single address instructions per second

Clock Rate: Variable, controlled by delay-line (max rate = 5 Mhz)
Arithmetic Element: Accumulator; In-Out Register for program-controlled Input-Output; Index Register
Instruction Format: Five bit op code, (2 bits initially used) + 13 bit address (16 bits for initial 65,536 word memory)
Technology: Discrete transistor circuits and core memory
Power consumption: Approximately 5,400 watts
Air Conditioning: 15 tons
Size: Built into 9000 square foot room at MIT
Component Count: 3,600 surface-barrier transistors (SBT) of Philco type 2N240
Total Hours: Approximately 50,000 hours with 12 transistor failures
Project Staffing: Lincoln Laboratory Division 6, Group 63; William Papian, head; Wesley Clark, logical design; Kenneth Olsen, circuit design and construction (followed by Benjamin Gurley) Richard Best and Jack Mitchell, memory design. John Clarke supervised construction.
Project start: Late 1955
Use: Research on electro-physiological signal processing; speech analysis and synthesis; picture processing; simulation of sensory aids for the blind; bubble chamber photograph analysis; handwriting analysis; interactive programming; symbolic program tracing and debugging.
Achievements: Tested transistorized circuitry for use in computers. Tested a large, 65,536 word (18 bit+ parity bit per word) vacuum tube driven core memory. Improved real-time interfacing.

"Tomorrow: The Thinking Machine", CBS, 1961, B&W, 3/4" videotape, Running time: 1 hr. (V6.81)

Artificial intelligence is the topic of "The Thinking Machine," a 1961 episode of the CBS News Tomorrow show, narrated by Jerome Weisner and David Wayne. Machine "learning" is compared with human and animal behavior. Highlights include an interview with Claude Shannon, a robot-sequence clip from the silent film classic "Metropolis", and three versions of a TV western written on MIT's TX-0 computer.

WRITABLE OR READABLE MEMORY

MAGNETIC

RANDOM

Rope

Apollo Guidance Computer, Read Only Rope Memory, Burroughs, 1963,Gift of Dr. Albert Hopkins, Draper Laboratories (D115.76).

? Non-destructive Read-out, RCA, 1965, Gift of Cliff Granger (D162.80).

WRITABLE AND READABLE MEMORY

WAVE STORAGE

CYCLIC

Magneto-strictive

Delay-line stores hold information as a series of impulses circulating continuously along a closed path. In a magnetostrictive delay-line electrical impulses signifying data are converted into stress waves which travel the length of the nickel wire. The application of a magnetic field to the wire causes it to change dimension thus converting electrical impulses to stress waves, or vice versa. Coils similar to those found in an electro-magnet are used for inserting and recovering digital information from the delay-line. The Elliott Brothers' Computers in England were the first to use the magnetostrictive principle for storage of data. (Lavington, 1980)

Magneto-strictive Delay-line, Ferranti, 1958, Gift of Oliver Strimple (D230.80).

ICT Sirius Computer had 10 decimal digits per word, with 1000-10,000 words stored on delay-lines. Compile-add time cycle of 250 usec, and storage cycle time of 4000 usec.

MAGNETIC FLUX

RANDOM

CORE

Cores are made of ferromagnetic material that is able to become strongly magnetic when subjected to relatively weak magnetic forces. A magnetic field is generated in the vicinity of any conductor that is carrying a current. The direction of the magnetic field is related to the direction of the current flow in such a way that reversing the direction of the current results in a reversal of the direction of the induced magnetic forces. Each core has four wires: two which write selecting the proper one in a co-incident (x-y) axis. A third wire reads and a fourth wire inhibits a build up of energy. A number of core planes are then piled into a core stack or cube and in the transistor and integrated circuit computer generations were the most prevalent type of primary memory.

Ferrite Memory Stack-experimental, Digital Equipment Corp, 1975, Gift of Cliff Granger (D160.80).

Experimental Ferrite Core Memory, RCA, 1964, Gift of Cliff Granger (D161.80).

Ferrite Core Memory Cube, RCA, 1960, Gift of Cliff

Granger (D169.80).

Ferroxcube Core Memory, Ferroxcube Corp of America, 1968, (D195.80).

Ferrite Core Memory, Ferroxcube Corp of America, (D196.80).

Core Memory Board, RCA, (D197.80).

Core Memory, Digital Equipment Corp, (D200.80).

18 Mil Planar Memory (8k), Digital Equipment Corp, (D198.80).

DISK

Minuteman Missile Fixed Disk Memory, Autonetics, 1962, (D107.80).

Telex Disk, 3M CORP, 1962, 75 cm diameter, Copper, Metal, Gift of Don Sordillo (D80.80).

PLATED WIRE

Plated Wire Memory, Honeywell, (D114.80).

? MOBIDIC Memory Board, Sylvania, 1956-57, Gift of Frank Feigin (D192.80).

? Flip-chip Power Supply, Digital Equipment Corp, (D193.80).

? ILLIAC II Block Multiplexor Switch, University of Illinois, 1962, Chassis-interplay, Gift of Clifford Carter (D216.75).

? Illiac II 48bit Register, Mesa Transistor, University of Illinois, 1963, Gift of Dale Sparks, Los Alamos Scientific Laboratory (D120.80).

LINKS AND SWITCHES

Teletype Receiver and Transmitter Module, Digital Equipment Corp, 1963, System Building Block 4707, (D217.80). First functional unit package for controlling telegraph line. Identifical forerunner of one-chip circuits known as UARTs, Universal Asynchronous Receiver and Transmitter.

TRANSDUCTION

Friden Paper Tape Reader, Friden, 1964, Model SP-2, Loaned by Ed Luwish (X9.80).

??COMPONENTS

LOGIC MODULES

Analex Logic Module, Analex, 1962, (D21.79).
System Logic Module, Digital Equipment Corp, 1958, Gift of Dick Best (D22.79).
Adder Module-NORC, IBM, Gift of Herbert Lechner, Stanford Research Institute (D27.80).
Delay Line Memory/Logic Module, Computer Controls Corp, 1958, (D108.80).
SMS Logic Module, IBM, 1960, (D113.80).
PDP-6 System Logic Module, Digital Equipment Corp, 1964, Gift of Don Vanada (D212.80).
PDP-6 Signed Photo, Digital Equipment Corp., 1967, (B70.67).
PDP-8 Flip-flop R201, Digital Equipment Corp., 1966, 1x15x7 cm, (B71.74).
Dec Flip-chip Modules, Digital Equipment Corp, 1965, (D213.80).
22XX Printer Buffer Array, IBM, 1971, (D132.80).
Bit Slice (Triple Flip-flop), Digital Equipment Corp, (D201.80).
Bendix Bit Slice, Bendix Computer, 1968, (D202.80).
System Building Block, Digital Equipment Corp, (D203.80).
Ferroxcube FF1, Phillips Mfg, (D204.80).
Decimal Counting Unit, Berkley Scientific Corp, (D205.80).
Bendix Bit Slice, Bendix, (D207.80).

IC Generation

IC GENERATION

DIGITAL CALCULA

FIVE OR MORE REGISTER

Slide Rule Calculator, Texas Instruments, 1973, Gift of Mike Riggle (D237.81).

DIGITAL COMPUTER

Advanced Scientific Computer Exhibit, Gift of Texas Instruments;

- ASC Emitter Coupled Logic Board, Texas Instruments, 1971, (D238.80).
- ASC ECL Mother Board, Texas Instruments, 1971, (D239.80).
- ASC ECL Mother Board, Texas Instruments, 1971, (D240.80).
- ASC Logic & Harness Connector Bulkhead Cabinets, Texas Instruments, 1974, (D224.80).
- ASC Disk, Texas Instruments, 1974, (D225.80).

Word length: 32 bits
Memory size: Memory Control Unit (MCU) provides facilities for controlling access from eight processor ports to a central memory having a 24-bit address space (16 million words).
Data transfer rate: 50 million words per second per port; total transfer capacity of 400M words per second.
Clock rate: 12 MHz
Central Processor: Provides both scalar (single operand) and vector (array) instructions at the machine level. 48 programmable registers consisting of 16 base address registers, 16 arithmetic registers, 8 index registers, 8 vector parameter registers.
Instruction format: Multiple pipelined instruction processing units. Instruction size, 32 bits with 16-, 32-, or 64-bit operands.
Technology: Pipeline architecture.
Power consumption: 500 KW
Size: 4000 square foot floor area (includes main frame, disks, operating system, etc).
Number produced: Seven.
Price: $8M-15M
Project start: March 1966
Project leader: Harvey Cragon
First delivery: 1971
Software: Fortran Compiler (NX and FX)
Use: Large scale scientific and technical problems.
Achievements: Pipeline processing capabilities as architectural attribute. Super computer capabilities along lines of CRAY-1, Star-100. Modular, high speed general purpose data processing system used for large scale scientific and technical problems.

PDP-11/20, Digital Equipment Corp, (D140.80).
- PDP-11/20 Logic Modules, Digital Equipment Corp, 1970, (D141.80).
- PDP-11/20 Module Artwork, Digital Equipment Corp., 1969, 100x94 cm, Mylar in Plexi, (B77.72).

COMPONENTS

Integrated Circuit Manufacturing Steps Card, Digital Equipment Corp, (D37.80).

CONSOLE

PDP11/45 Console Panel & BOARD, Digital Equipment Corp, 1973, Plastic, (D199.80).

LOGIC MODULES

PDP-8/I Logic Module 220, Digital Equipment Corp, 1970, Gift of Harry Moyer (D102.80).
CCC Logic Module, Computer Controls Corp, 1965, Gift of Gordon Bell (D111.80).
CCC Logic Module, Computer Controls Corp, 1965, (D194.80).
STAR Logic Module, Control Data Corp, Gift of Lawrence Livermore Laboratories (D218.80).
CDC 6600 Transfer Board, Control Data Corp, Gift of Lawrence Livermore Laboratories (D223.80).
Cray I Interface Module, Cray Research, Inc, 1976, Gift of G. Michaels and W. Becker, Lawrence Livermore Laboratories (D226.80).

PRIMARY MEMORY

Thin Film Memory, RCA, 1966-1970, Gift of Gordon Bell (D112.80).
Memory Driver, (D210.80).
PDP-11 Planar-structured Core Memory, Digital Equipment Corp, 1975, (D241.80).

SECONDARY MEMORY

Prototype RL01 Disk Drive, Digital Equipment Corp, 1975, Gift of Hertrich Development, Inc. (D163.80).
IBM Data Cell Cartridge, IBM, 1969, Gift of Lawrence Livermore Laboratories (D220.80).
A direct access storage device which stores data on individual magnetic strips. These strips are contained in removable, interchangeable data cells. The IBM 2321 Data Cell Drive has 10 data cells with 20 subcells per cell, each subcell has 10 magnetic strips. Each data cell can contain 39.2 million bytes or 78.5 packed decimal digits. A single 2321 data cell drive can have on-line access to a maximum of 392 million bytes or 784 million packed decimal digits and signs. (See IBM Manual GA26-3574-2 and GA26-5988-7.)
IBM 2321 Data Strips, IBM, 1969, Gift of Lawrence Livermore

Laboratories (D219.80).

IBM 1360 Photo-digital Storage System Module, IBM, 1967-1969, 2.5x2x5 cm, Gray, Plastic, Gift of Lawrence Livermore Laboratories (D221.80).
A storage module has 32 chips of film, each chip contains 32 fields and each field has 128k bits(?). The Storage System is equivalent to magnetic tape 800 bpi. There are 10k cartridges in photostore on line. There is random access to any bit. The reading rate is 2x10**6 bps.

CDC 38500 Cartridge, Control Data Corp, Gift of Lawrence Livermore Laboratories (D222.80).
The original CDC 6600 was built under contract to Lawrence Livermore. Multiple arithmetic and logical units and ten peripheral processors, which were small computers themselves, made the 6600 a very powerful and fast computer. Peripheral processors direct, monitor and time-share the central processor.

DMCAT2.4

1ST Generation

LSI GENERATION

DIGITAL COMPUTER

VAX Computer Exhibit

- VAX SBI Memory Board, Digital Equipment Corp, 1976, (D164.80).
- VAX Star 64K MOS Memory Array, Digital Equipment Corp, 1976, (D165.80).
- VAX Proto-type UBA, Digital Equipment Corp, 1976, (D166.80).
- VAX Test Tapes, Digital Equipment Corp, 1976, (D167.80).
- VAX Logic Module, Digital Equipment Corp, 1976, (D170.80).

  This board was an experiment in fine line routing (8 mil conductors and spacing). The logic is the 11780 UMD Module. It is significant in that it was the best routing solution that the top automated p/c vendors in the country (Algorex Data Corp) could achieve. (The production version of the module was done in-house, using 15 mil conductors and spaces.) It contributed toward influencing DEC to adopt fine line as a standard and was used extensively in developing the process which eventually came to be used for the 11750.
- VAX poster signed, Digital Equipment Corp, 1976, (D171.80).

MINC, (Modular Instrument Computer) Digital Equipment Corp, 1975, (D155.80).

Word length: 16 bits
Memory size: 32,768 words
Speed: Approximately 200,000 single instructions per second
Clock rate: 3 Mhz
Instruction set Processor: PDP-11(LSI-11)
Arithmetic element: Data path on an LSI chip, 8 general purpose registers
Instruction format: Double operand, multi- mode, 16 bit instructions
Power consumption: Approximately 500 watts
Size: Roll around cart (24"x30"x40")
Component Count: 4 LSI chips forming the LSI-11 processor, 300 MSI and LSI chips for memory and peripherals
Project start: August, 1975
Packaging model demonstrated: August, 1976
Running system demonstrated: August, 1977
Product announcement: October, 1978
First shipment: December, 1978
Number produced: 1500 annually
Input-Output: Real-time plug-in modules for analog, digital event processing and signal conditions.

Graphics CRT. IEEE 488 and serial communications lines.
Software: Real-time and graphics BASIC. Optional languages and facilities available on PDP-11.
Use: Science-based discipline computation, including general purpose programming, mathematical modeling, graph plotting, laboratory management. Real-time use including data acquisition, signal processing or experiment control.
Achievements: Improved human interface as scientific and laboratory computer through software, modular hardware and documentation. Improved cost and performance per cost of ownership by portability, higher mean time between failures (MTBF), customer installation, built-in service and diagnostics, and direct phone link to factory for information.

- MINC Grip Strength Tester, Digital Equipment Corp, 1979, Gift of Laboratory Data Products Group, Digital Equipment Corp (D188.80).

MPS 8008 Micro-processor Computer Module, Intel, 1972, (D101.79).

PDP-11/23 Micro-computer Processor Module, Digital Equipment Corp, 1979, (D33.80).

COMPONENTS

LOGIC MODULES

Altair 8800 CPU Board, MITS, 1975, Loaned by Ed Luwish (X6.80).
LSI-11 Computer Module, Digital Equipment Corp, 1975, Gift of Steve Teicher (D35.80).
Four Channel Asynchronous Serial Interface, Digital Equipment Corp, (D36.80).
Wafer of UART Die & Chip, General Instrument, 1972, Gift of Vince Bastiani (D103.80).
6120 IC CPU Diagram and Micro-photo, Harris Corp, 1980, Gift of Don White (D105.80).
S-100 CPU Board, SDS-SD Sales, 1976, Gift of David Ramsberger (D236.81).

PRIMARY MEMORY

64k Byte Memory Module, Digital Equipment Corp, (D34.80).
Altaire 4k Dynamic Ram Board, MITS, 1975, 10 x 30 cm, Loaned by Ed Luwish (X7.80).

TERMINAL

VT105, Digital Equipment Corp, 1976, Gift of Laboratory Data Products Group, Digital Equipment Corp, (D157.80).
VT50-AA, Digital Equipment Corp, Gift of Dana May (D227.80).