“The Innovators”
The Age of the Digital Revolution

“How a Group of Hackers, Geniuses and Geeks Created the Digital Revolution.”

Session 2

Subjects

Time

- Session 1 Ada, Countess of Lovelace

1840

- Session 2 The Computer, Programming
- Session 3 The Transistor, The Microchip
- Session 4 Video Games, The Internet
- Session 5 The Personal Computer
- Session 6 Software, On-Line
- Session 7 The Web
- Session 8 Ada Forever

1930

Today

Ada

1935 1990 Now

The Computer, Programming

The Transistor, The Microchip

Video Games, The Internet

Software, On-Line

The Personal Computer

The Web

It gets Complex Here.

The course's eight sessions

The book's chapters are silo'ed.
In the narrative of the later sections the systems begin to be integrated to reflect what we have today.

Ada Forever

Session 2

A Leap of 90 Years

- **The Computer**
- **Programming**

A Thought, The Development of the Computer Is Like the Development of the Auto

- Many companies developing in parallel
- Initially a few and expensive
- Once into mass production, a constant spring ahead of new features/options
- Intense Commercial Competition with options
  - Electric starter
  - Automatic transmission
  - Power Steering
  - Power brakes
  - AM radio, FM radio, cassettes, CDs, navigation units
  - Air conditioning
  - Comfort items, bells and whistles
  - Eventually comfort items and options are standard.

Bell Labs and Collaboration

- In the 1920s many of AT&T's patents were expiring and there was the potential of new rivals.
- The telephone systems was very intricate, complex, expensive to operate and call volume was growing.
- AT&T made a major investment in Bell labs to identify better designs and productize them through Western Electric for a more efficient and reliable system to: [1] Be good enough to keep its regulated monopoly [1932 FCC laws] and [2] encourage the flow of investment $$.
- During the 1920s and 1930s it was the place to be. Good salaries and some of the best minds in the world.
- There was collaboration and resources to build and experiment with.

Bell Labs Collaboration and Leap Ahead

- Clarence Hickman in 1934 had a machine in his office connected to his telephone that when he was not there answered and let the caller leave a message — on Magnetic tape. Bell did nothing with it. More on this later.
- Eventually the technology got out to various companies; from Ampex in particular came tape recorder, then wideband tape recorders, then cassettes and VCRs.

- Magnetic medium: first tapes storage for large computers then the hard drive in desktop and portable computers.
- Today - Seagate 1 Terabit hard drive. $56.00

Claude Shannon and Electronic Boolean Logic— the Circuitry of Digital Computers

- Symbiosis
- 1931 Vannevar Bush at MIT builds the first analogue electrical-mechanical computer dubbed the Differential Analyzer.
- Claude Shannon goes to MIT, as a grad student, to work on the Differential Analyzer. He is sent to Bell Labs as a summer job. There he sees work in electronic Boolean logic.
- Back at MIT he writes his master thesis on using electronic circuits to do Boolean functions— the mathematical under-pinning of digital computer operation.

George Boole

- **Boolean algebra was introduced by George Boole in his first book *The Mathematical Analysis of Logic* (1847), and set forth more fully in his *An Investigation of the Laws of Thought* (1854).**
- **The term "Boolean algebra" was first suggested by Henry Sheffer, Harvard Mathematician, in 1913.**
- **Boolean algebra has been fundamental in the development of digital electronics, and is provided for in all modern programming languages.**

Boolean logic: Remember One Thing

Ones [1] and Zeros [0]

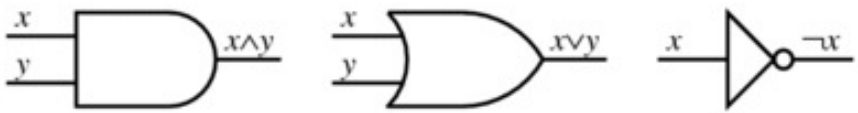


Figure 3. Logic gates

Digital logic gates

- **Digital logic is the application of the Boolean algebra of 0 and 1 to electronic hardware consisting of logic gates connected to form a circuit diagram.**

- **Each gate implements a Boolean operation, and is depicted schematically by a shape indicating the operation.**

- **The shapes associated with the gates for conjunction (AND-gates), disjunction (OR-gates), and complement (inverters).**

Binary numbers, to the base 2

Decimal	Binary
0	00
1	01
2	10
3	11
4	100
5	101

1937 *Annus Mirabilis* of the Computer Age

- **Triumph of four properties, somewhat interrelated, that would define modern computing.**

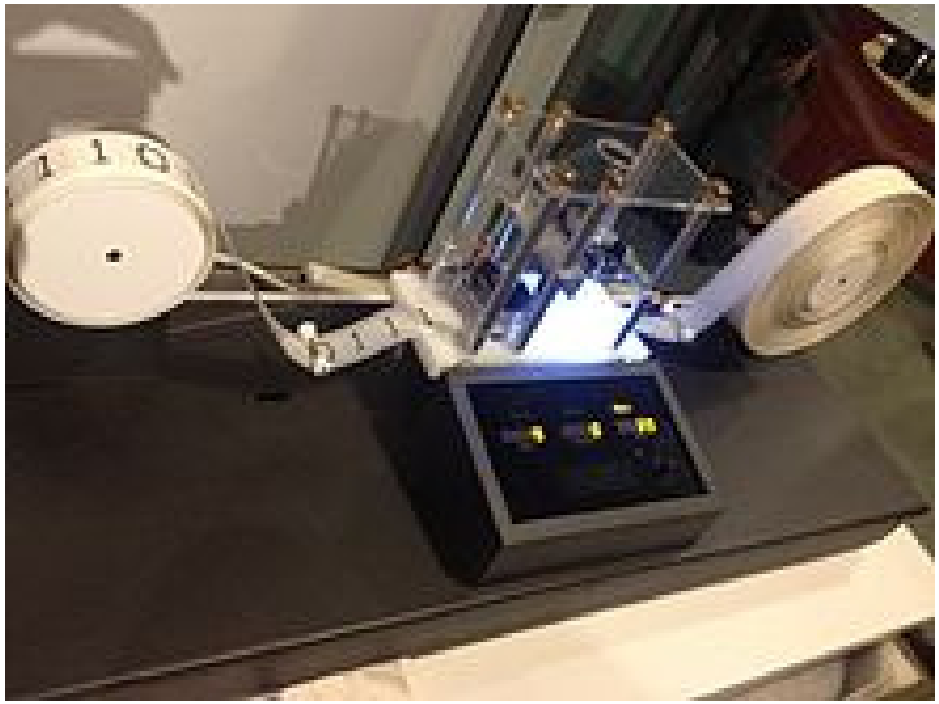
1. **Digital thinking —on/off switches**
2. **Binary data— ones and zeros**
3. **Electronic—vacuum tube and then transistors**
4. **General purpose— have programs and could be <u>easily</u> reprogrammed, in some procedures by themselves, as part of the program.**

Computer Timeline - 3

First concepts of what we consider a modern computer

- **The Turing machine was first proposed by Alan Turing in 1936 and became the foundation for theories about computing and computers.**
- **The machine was a device that printed symbols on paper tape in a manner that emulated a person following a series of logical instructions.**
- **Without these fundamentals, we wouldn't have the computers we use today.**

Turing machine



A Turing machine is a hypothetical device that manipulates symbols on a strip of tape according to a table of rules.

Despite its simplicity, a Turing machine can be adapted to simulate the logic of any computer algorithm, and is particularly useful in explaining the functions of a CPU inside a computer.

Turing called it an "a-machine" (automatic machine).

The Turing machine is not intended as practical computing technology, but rather as a hypothetical device representing a computing machine.

Turing machines help computer scientists understand the limits of mechanical computation.

Adding machine Age

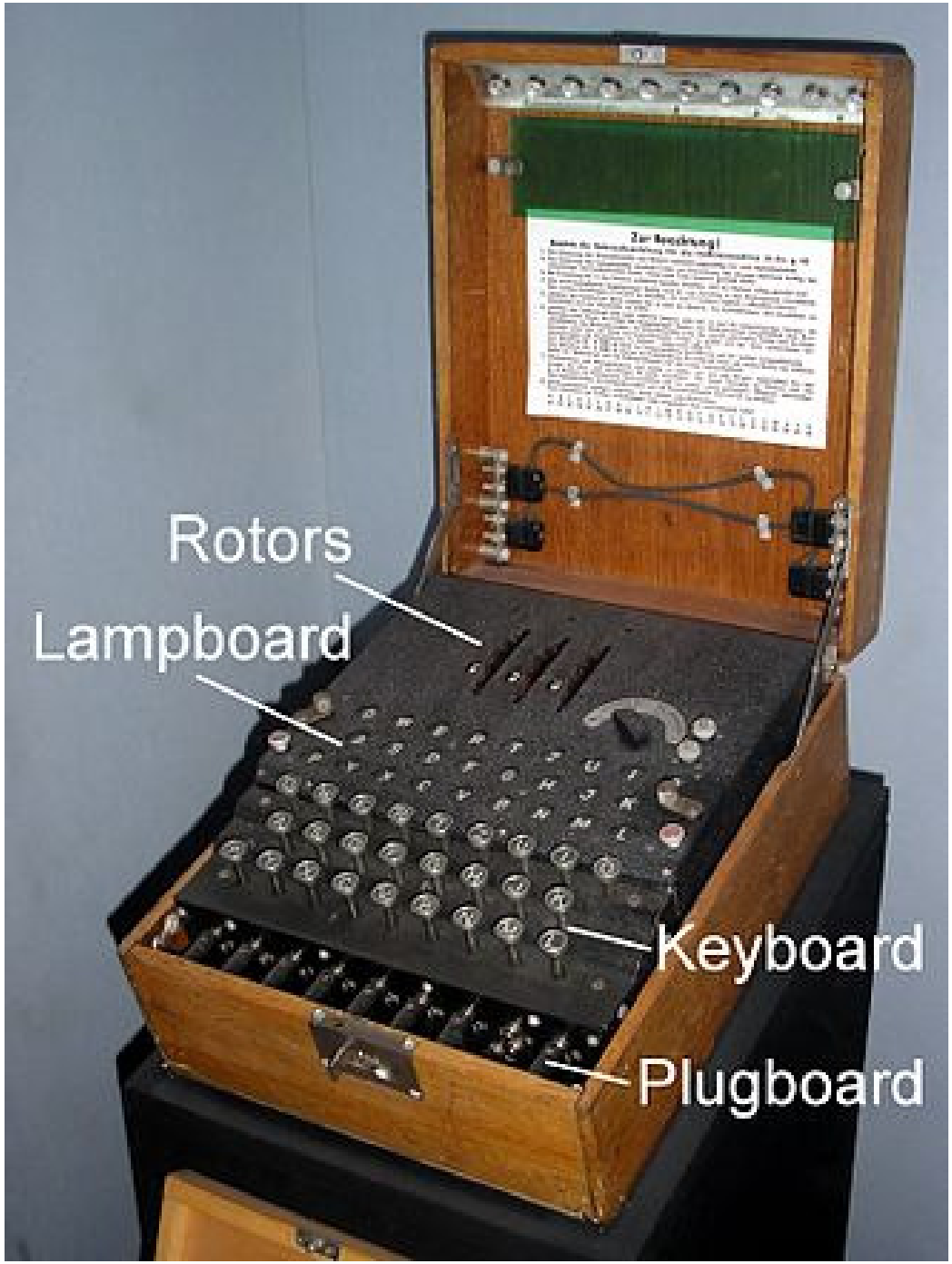
Dr. Turing and Enigma

Currently : The Imitation Game

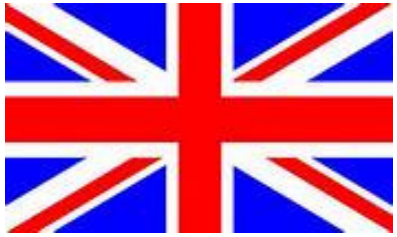
- Turing studied math at Cambridge University. In 1936-1937, he goes to Princeton for his Ph.D.
- He began studying cryptology and tinkered with machines to accomplish it. He is mentored by Dr. John von Neumann who works in statistical probabilities.
- He returns to England and to the British Code and Cypher school.
- When WW II breaks out, the British obtain a Polish deciphering machine and an German Enigma. But, this is not enough to read German traffic!
- Turing and his team [through collaboration] work to break German coded messages. It can't be done by hand! Too many variables. Consequently he designs and oversees the building of his Bombe.

ENIGMA and the B-Dienst (Beobachtungsdienst, Surveillance Service)

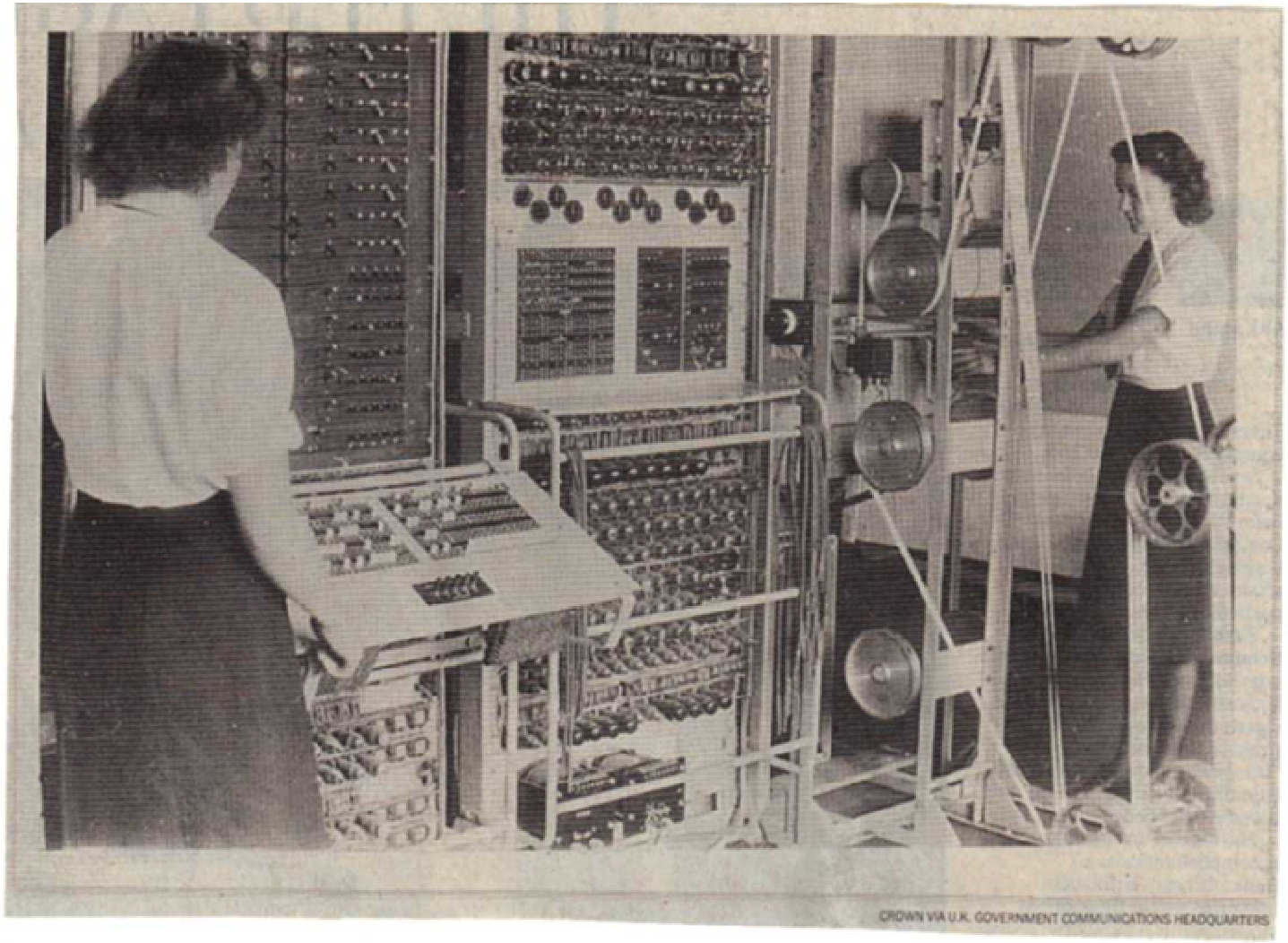
- The early Polish work was an essential part and substantial foundation to further work on decoding ciphers from constantly modernized ENIGMA machines, first in Poland, and after the outbreak of war in France and UK.
- Key Action: Five weeks before the outbreak of World War II, on 25 July 1939, the Poles presented their ENIGMA-decryption techniques and two full sets of decrypting equipment, including special cryptologic Zygalski sheets and cryptologic bomb together with "how to use" lecture by the team, to French and British military intelligence in Warsaw.
- Key Intelligence point: Germans did not know that the British and French had ENIGMA data. Even after the French defeat.
- The B-Dienst was the German naval codebreaking organization; they made extensive use of ENIGMA and had more complex versions than did the German Army and Air Force
- Pre - 7 Dec 1941, The US and UK began detailed collaboration on ENIGMA and the Japanese Purple Code.



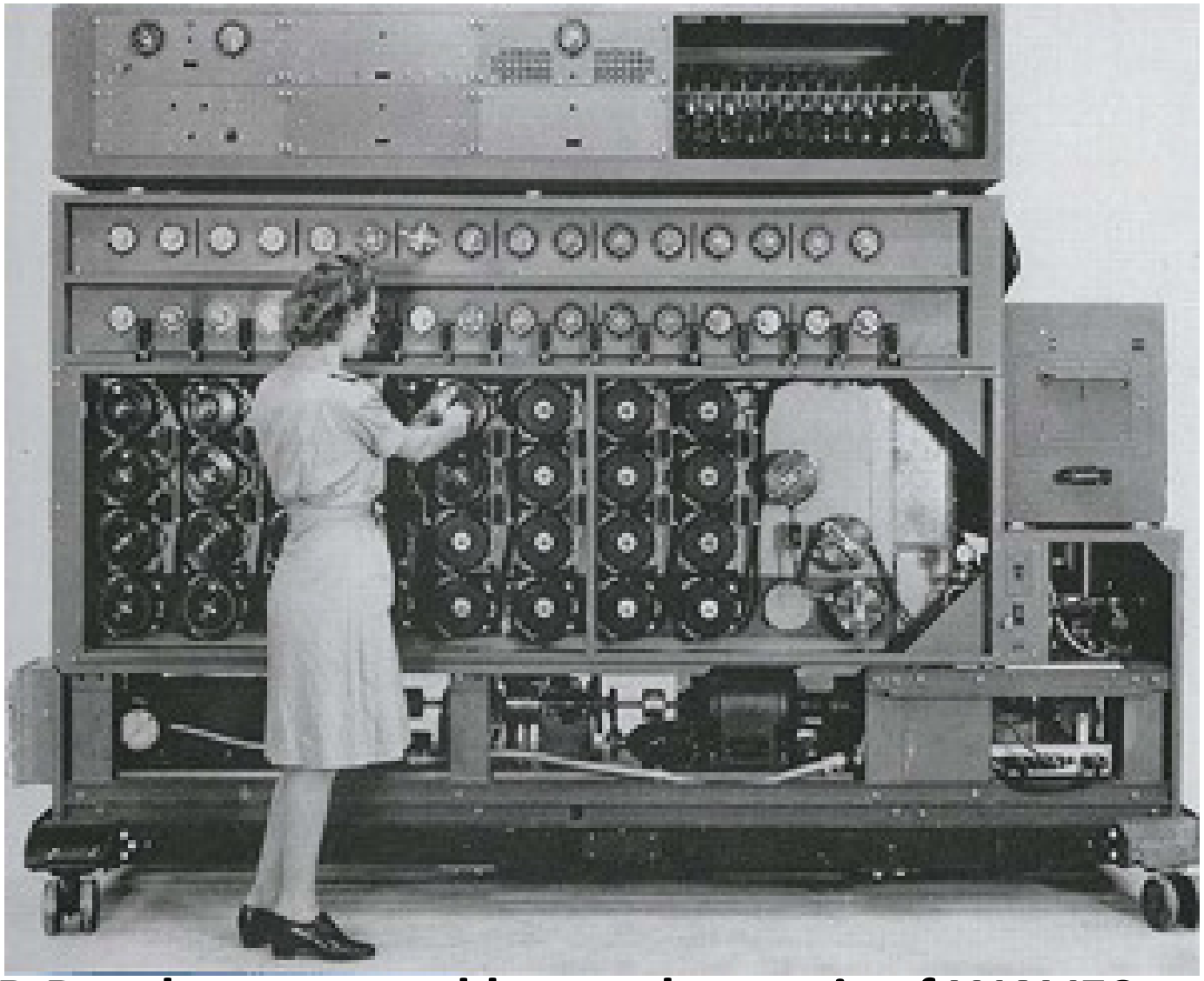
The British had the machine but they did not have the daily code settings



Turing's Bombe worked on replicating the daily code settings



- The Touring Bombe was an absolute kluge and was barely kept operating by the most persistent team of technicians.
- The British were flat out in early 1940s and requested US manufacturing help.
- These most highly classified design were take to NCR in Dayton Ohio and the Bombe was re-engineered to be a reliable and user "friendly" device.
- Over 50 were manufactured and used by both the US and British for the rest of WW II



- **The NCR Bombe operated by a select unit of WAVES resulted in the deciphering of most U-Boat codes by 1943 within 12 hours of transmission.**
- **Operations were largely conducted at the NCR plant in Dayton Ohio and NAVSECSTA, 3801 Nebraska Ave, NW, DC.**

Interesting Thought

- **Turing's Bombe productization was an aspect of collaboration.**
  - **US, British scientists and the US National Cash Register Company**
- **Like a number of "Digital products;" if they can't be produced and maintained, what good are they?**

The first Electric Programmable Computer

- **The Germans developed newer Enigmas that over-powered the Bombe's capabilities!**
- **Response: The Colossus was the first electric programmable computer developed by British engineer Tommy Flowers and first demonstrated in December 1943. The Colossus was created to help the British code breakers read encrypted German messages.**
- **Turing developed the statistical approach implemented in Colossus.**
- **Colossus had some programing capability but it was predominantly a "Decrypter."**

Dr. Alan Turing – Receives Royal Pardon

- (CNN) -- British WW II code-breaker, who was later subjected to chemical castration for homosexual activity, received a royal pardon nearly 60 years after he committed suicide.
- Turing was best known for developing the Bombe, a code-breaking machine that deciphered messages encoded by German machines.
- The German Enigma encrypted messages that Turing cracked at the British government's code-breaking headquarters in Bletchley Park provided the Allies with crucial information. His work is considered by many to have helped change the course of the war and save thousands of lives.
- Turing is considered a mathematical genius and earlier developed the Turing machine, which is considered to have formed the basis of modern computing.
- "Dr. Turing deserves to be remembered and recognized for his fantastic contribution to the war effort and his legacy to science," British Justice Secretary Chris Grayling stated. "A pardon from the Queen is a fitting tribute to an exceptional man." The pardon, under the Royal Prerogative of Mercy, came into effect Dec 24, 2013.

Computer Timeline -5

The first digital computer; a 35 year saga

- **The ABC short for Atanasoff-Berry Computer, started being developed by Professor John Vincent Atanasoff and graduate student Cliff Berry in 1937 and continued to be developed until 1942 at Iowa State University.**
- **The ABC was an electrical computer that used vacuum tubes for digital computation including binary math and Boolean logic but had no central processing unit (CPU).**
- **31 Years**
- **On October 19, 1973, the US Federal Judge Earl R. Larson ruled that the ENIAC patent by J. Presper Eckert and John Mauchly was invalid and named Atanasoff the inventor of the electronic digital computer.**

Computer Timeline-6

Leap 90 years from Ada

First programmable computer

- **The Z1, originally created by Germany's Konrad Zuse in his parents' living room [1936 to 1938] and is considered to be the first electro-mechanical binary programmable (modern) computer and really the first functional computer.**
- **Individual ingenuity**  **no collaboration**
- **A Hacker**
- **He couldn’t interest the German military**

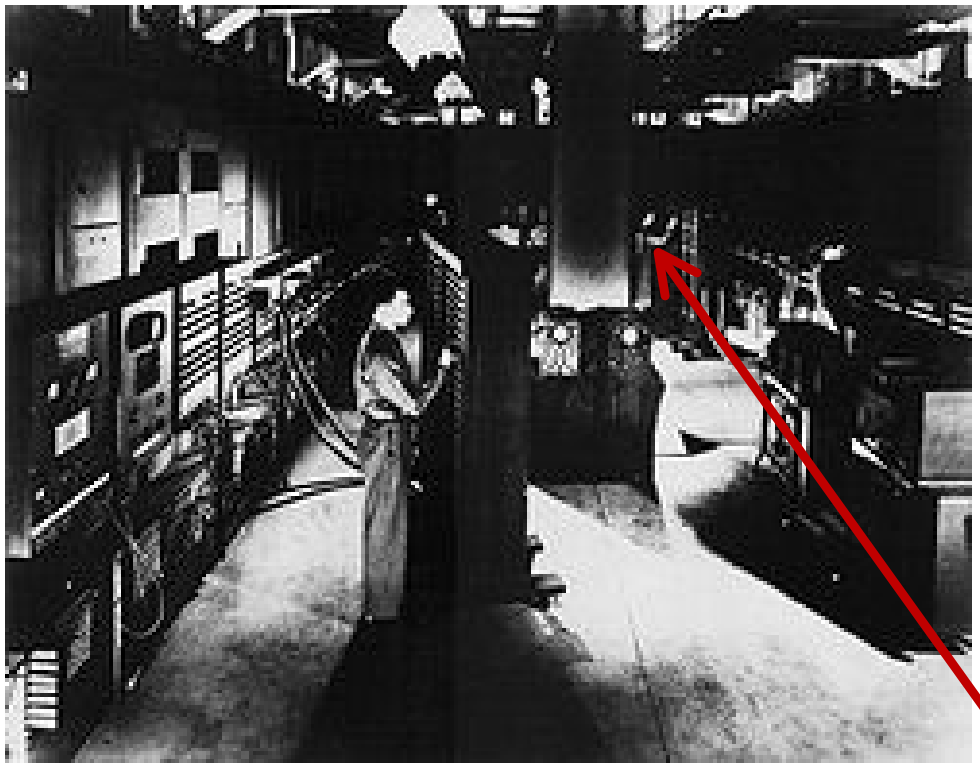
Computer Timeline -7

The first digital computer, con't

- **The ENIAC was invented by J. Presper Eckert and John Mauchly at the University of Pennsylvania and began construction in 1943 under Army funding and was it not completed until 1946. So much for the artillery effort! BUT!!**
- **It resulted from collaboration in both the aggregation of ideas and construction.**
- **It occupied about 1,800 square feet and used about 18,000 vacuum tubes, weighing almost 50 tons.**
- **Although a legal ruling concluded that the ABC computer was the first digital computer, many still consider the ENIAC to be the first digital computer because [1] it was actually built and worked, [2] fully functional and programmable, thus could be used on a myriad of problems.**
- **[3] Most significantly it was in operation for over 10 years.**

ENIAC

First US Device that Could be Called a Computer



(U.S. Army photo)

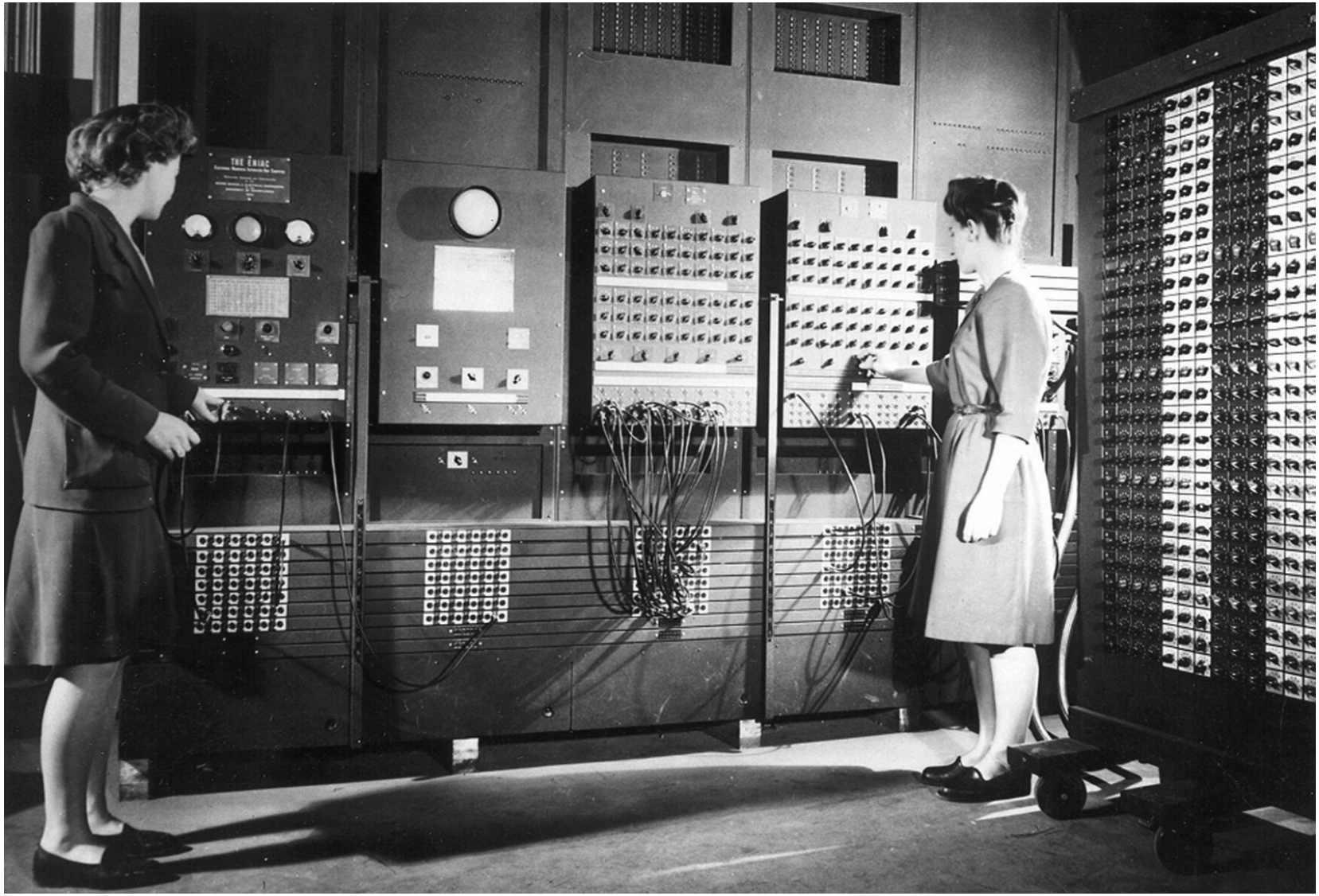
1944 -US Army Captain Irwin Goldstein (foreground), U of Mich, Math Ph.D. sets the switches on one of ENIAC's function tables at the University of Pennsylvania Moore School of Electrical Engineering.

Massive machine built on simple tubes requiring an entire building.

One of the first uses of a computer to assemble ordnance trajectory tables from very complex equations requiring thousands of approximations.

This photo has been artificially darkened, obscuring details such as the women who were present and the IBM equipment in use.

Virtually the entire programming staff were unsung and under-recognized women



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

Courtesy of University of Pennsylvania

Military Necessity

- Dr. John von Neumann from Princeton's Institute for Advanced Studies is enlisted into the Manhattan project in 1943.
- Problem: Not enough natural Uranium.
  Solution: Manufacture the more complex Plutonium.
- Von Neumann proposes an explosive lens to form the Plutonium bomb's critical mass and thus its explosion. There are a vast number of complex simultaneous equations that need to be solved for the design to work.
- He jumps from the few computers available till he comes upon the ENIAC.
- There, by comingling both the data and programming instructions in the same memory, the programming could change itself on the fly based on intermediate results.
- With this, he optimized the lens design in early 1945. This is the explosive heart of the Trinity NM and Nagasaki Plutonium bombs.
- Not quite a stored program computer, but getting there.

Post WW II Electronic Computing Development Begins on a Vast Scale and Is Confronted By:

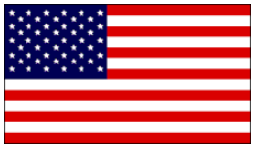
- Multiple technologies
- Programmability
- Available memory often limited operations, both in capabilities and cost
- Data inputs limitations: punched cards, tape, direct entry [type]
- Slow and complex responses back to the operators
- Costly materials
- Weight, power consumption, size

Computer Timeline -8

The first stored program computer

- **The early British computer known as the EDSAC is considered to be the first stored program electronic computer.**
- **The computer performed its first calculation on May 6, 1949 and was the computer that ran the first graphical computer game, nicknamed "Baby".**
- **In parallel, the Manchester Mark 1 was another computer that could run stored programs. Built at the Victoria University of Manchester, the first version of the Mark 1 computer became operational in April 1949 and was used to run a program to search for Mersenne primes [numbers 2^n-1]; it ran for nine hours without error on June 16 and 17 that same year.**

Computer Timeline -9



The first computer company

•The first specific computer company was the Electronic Controls Company and was founded in 1949 by Eckert and Mauchly, the same individuals who helped create the ENIAC computer. The company was later renamed to EMCC or Eckert-Mauchly Computer Corporation and released a series of mainframe computers under the UNIVAC name [now Unisys].

Patent issue

First US stored program computer

•First delivered to the US Government in 1950, the UNIVAC 1101 or ERA 1101 is considered to be the first computer that was capable of storing and running a program from memory.

First commercial computer

•In 1942, Konrad Zuse begin working on the Z4, which later became the first commercial computer after it was sold to Eduard Stiefel, a mathematician of the Swiss Federal Institute of Technology in Zurich on July 12, 1950.

Computer Timeline -10

IBM's first mass produced computer

- On April 7, 1953 IBM publicly introduced the 701, its first electric computer and first mass produced computer.

The first PC (IBM compatible) computer

- Later IBM introduced its first personal computer called the IBM PC in 1981. The computer was code named and still sometimes referred to as the Acorn and had an Intel 8088 processor, 16 KB of memory, which was expandable to 256 and utilized PC-DOS [Microsoft]

The first computer with Random Access Memory [RAM]

- MIT introduces the Whirlwind machine on March 8, 1955, a revolutionary computer that was the first digital computer with magnetic core RAM and real-time graphics.

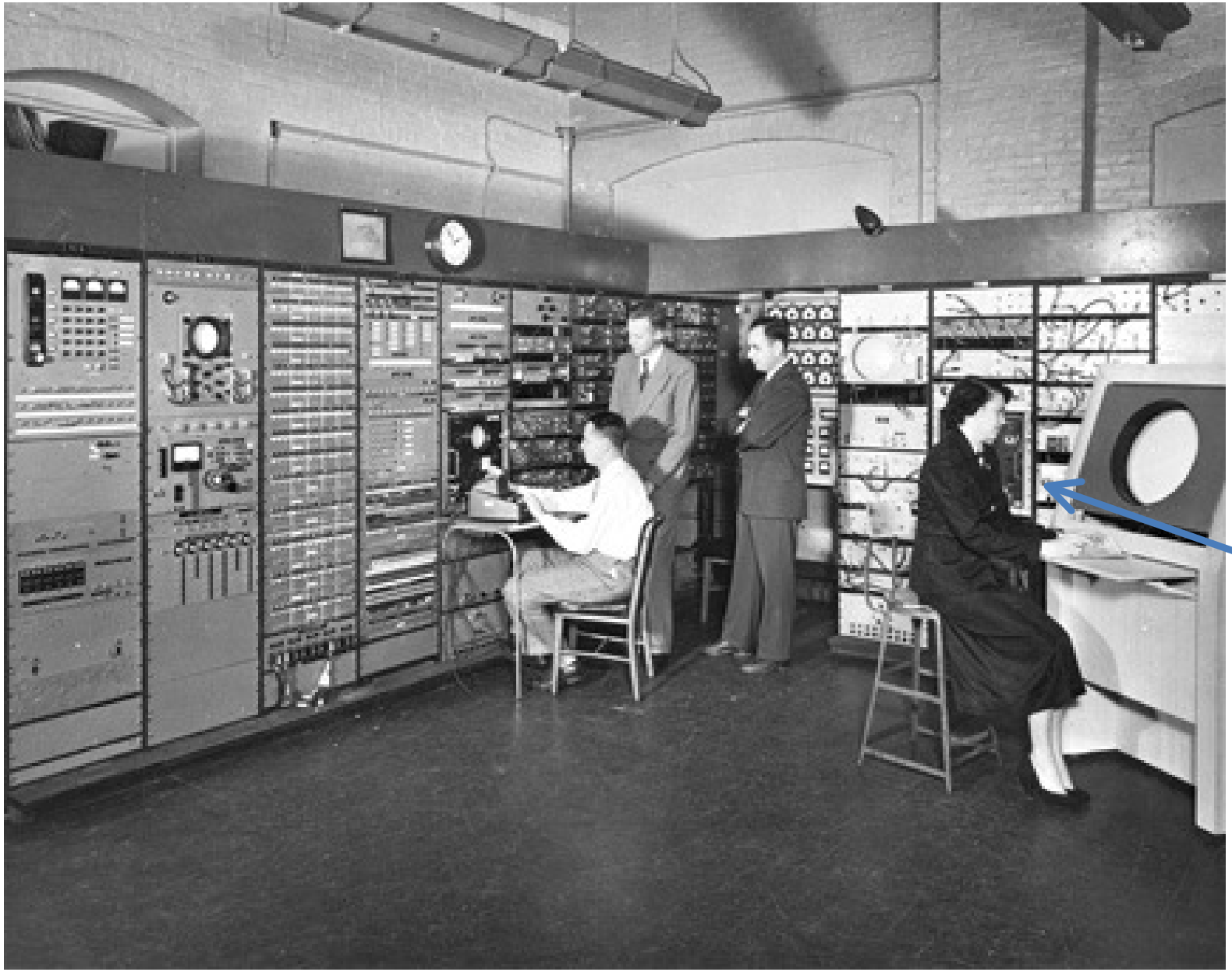
What is Random Access Memory?

- **RAM (*random access memory*) is the place in a computer where the operating system, application programs, and data in current use are kept so that they can be quickly reached by the computer's processor.**
- **RAM allows data items to be read and written in roughly the same amount of time regardless of the order in which data items are accessed.**

Memory Advances Enable the Computer

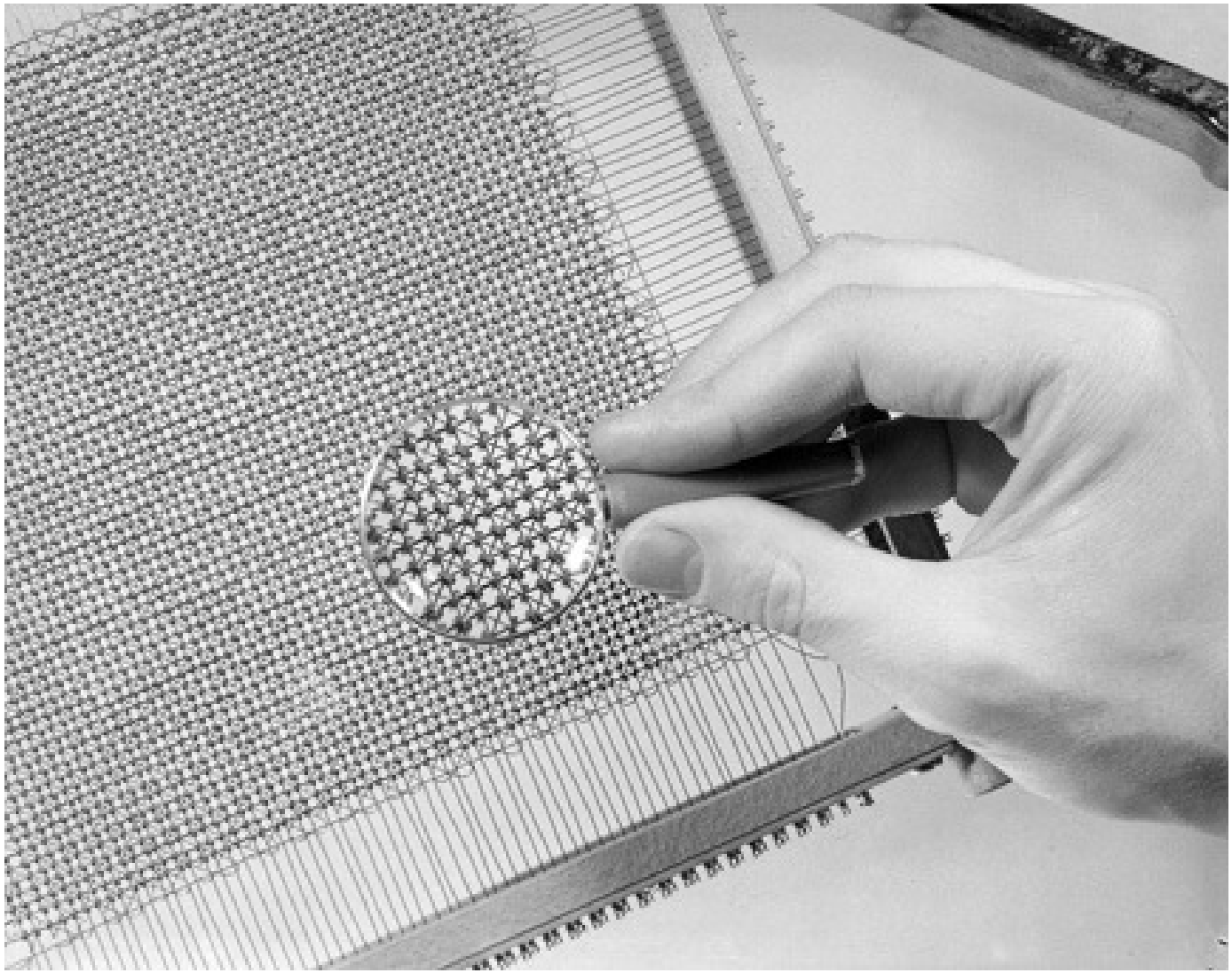
- **Memory transitions from electrical [tape, drums, cores, etc.] to electronic.**
- **Price plummets, capacity expands exponentially, faster in/out operations.**
- **Physical size drops, power requirements drop, reliability increases.**

- **With other advances, the 1969 Astronauts could fly to the Moon using 1/1000th of the capacity of an 2015 iphone6.**



One of the aforementioned early female contributors to computer development

Stephen Dodd, Jay Forrester, Robert Everett, and Ramona Ferenz at early Whirlwind I test control in the MIT Barta Building. [1950]



Close-up of magnetic core memory showing 64x64 arrangement of magnetic elements on surface plane. Circa 1954

30 Second In-Place Stretch

Computer Timeline 11

First Transistorized Computer

The TX-O (Transistorized Experimental computer) is the first transistorized computer to be demonstrated at MIT in 1956.

Computer Timeline - 12

The first minicomputer

- In 1960, Digital Equipment Corporation released its first of many PDP computers, the PDP-1.

The computer — workstation —desktop —laptop — tablet

The first mass-market and desktop computer

- In 1968, Hewlett Packard began marketing the first mass-marketed PC and the first desktop computer, the HP 9100A.

The first workstation

Definition: A workstation is a special computer designed for technical or scientific applications.

- Although it was never sold, the first workstation is considered to be the Xerox Alto, introduced in 1974. The computer was revolutionary for its time and included a fully functional computer, display, and mouse. The computer operated like many computers today utilizing windows, pull down menus and icons as an interface to its operating system.
- We will pick up on this later.

Chipping Around the Edges - Computer Like Functions are buried

- In 1972, IBM engineer George M. Laurer developed the Universal Product Code, the Barcode.

- On October 11, 1973, IBM introduced the IBM 3660, a laser-scanning point-of-sale barcode reader which would become the workhorse of retail checkouts.
  - On June 26, 1974, at Marsh's Supermarket in Troy, Ohio, a pack of Wrigley's Juicy Fruit chewing gum was the first-ever retail product scanned.

Other Early US Computer companies

- National Cash Register>Western Electric>Lucent
- Burroughs>Unisys
- Wang
- General Electric
- Digital Equipment Corporation>Compaq>Intel/HP
- Data General>EMC
- Tandem>Hewlett Packard
- Control Data Corporation> Ceridian Corp
- Prime>HP
- Apollo>HP
- Gateway>Acer
- Micron
- Cray
- Sierra
- Silicon Graphics> Rackable Systems
- Remington Rand/Sperry/Unisys
- Honeywell>GE>BULL>NEC
- Scientific Data Systems> Xerox
- Tandy/Radio Shack> Difficulty
- Sun Mircosystems>Oracle
- In house in small batches: RCA, Raytheon, TRW, Westinghouse, others

Black – In business
> Acquired by
Red- Out of Business
Blue - Drop/changed product line

Two Paths: Big Super Computing and Personal Computer (Desktops, Laptops and Handheld)

- Twice a year, the high-performance computing (HPC) market gets a list of the 500 fastest supercomputers in the world, and there usually is a good amount of anticipation in the run up to the release of the Top500 roster.
- However, at the SC14 supercomputing show this week, the 10 fastest systems looked eerily like those on the list released in June. In fact, only a supercomputer—a Cray CS-Storm system for an unidentified U.S. agency at No. 10—was new.
- And still at the top of the list was China's massive Tianhe-2 supercomputer.
- The organizers of the Top 500 list also noted the continuation of a slowing growth rate of performance in the supercomputing space over the past two years. That trend can be seen not only at the top of the list, but also in those systems at the bottom.
- However, that should change over the next couple of years. The U.S. Department of Energy on Nov. 14, 2014 awarded $325 million to IBM, Nvidia and Mellanox Technologies to build two new systems that agency officials said will be five to seven times more powerful than current systems they will replace—which currently sit at No. 2 and 3 on the Top 500 list.

IBM, Cray Dominate List of Top 10 Fastest Supercomputers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eWEEK

Evolving Toward Personal Computing Later in Session 5

- **The desk top**
- **The ubiquitous laptop**
- **The Tablet**
- **The big cell phone**

Worldwide Standardized Time From the Railroads to the present

- **Standardized Time starts in 1885 with time zones instituted by the railroads in the US and Canada and British maritime, hence worldwide, time keyed against the meridian at Greenwich.**
- **Now US standard time is ubiquitous**
  - **US Naval Observatory's Atomic Clock [Earth Time]**
  - **Internet/global communication**
  - **Global transportation**
  - **Global finance**
  - **GPS**
  - **TV**

Which way is counter-clockwise?
What is a quarter to 3?

Want to set your watch , go to: tycho.usno.navy.mil

Programming

Programming Evolved as an Art

- **From 1943 through 1950 there just were not many computers. Most developments were under-written by the Government for WW II needs.**
  - **U of Penn**
  - **Harvard**
  - **MIT**
  - **Bell Labs**
  - **British Bletchley Hall**
  - **Cambridge University**
  - **University of Manchester**
  - **Each was different and had different and difficult programming regimens. All had memory capacity issues.**
  - **Often the programming was left to women mathematicians. The men played with the hardware, the toys. The small cadre of women fortuitously were more methodical and thorough in a systems and process approach and eventually got the computers to operate efficiently.**

Computers, Programming and Software

- **Computer hardware,** the device's physical components.

- **Programming,** a library of standard instructions [add, divide, move, compare, if/then, etc.] that the software assembles to solve a problem or to control something.

- **Software** is any set of machine-readable instructions that directs a computer's processor to perform specific operations. It directs data to be inputted and results to be displayed or do some thing.
  - Computer hardware, programs and software require each other and neither can be used without the other.

- **Musical analogy:** Hardware is the instruments, programming is the sheet music and software are the notes played on the instrument. Conductor is the operating system.

The Process of Standardizing Programming

- **In 1957, IBM developed the FORTRAN (FORmula TRANslation) scientific programming language**.

Ada, A Single High level Reusable Programming Language—Appropriate Honor

- The Ada language resulted from the most extensive and most expensive language design effort ever undertaken.
- Up until 1974 half of the DoD applications were embedded systems. An embedded system is where the computer HW and SW are integral in the device they control.
- More than 450 programming languages had been used to implement different DoD projects, and none of them were standardized.
- Consequently, the 3 services developed a single high-level reusable language for embedded systems: Ada.
- By 1977, a complete language design specification for Ada was created. A series of competitions down selected from 4 contractors to 1. In May 1979, Cii Honeywell/Bull's (the only foreign contractor) design was chosen. After some testing and revisions in 1981, the Ada language was then frozen for five years.

Is Ada Still Around?

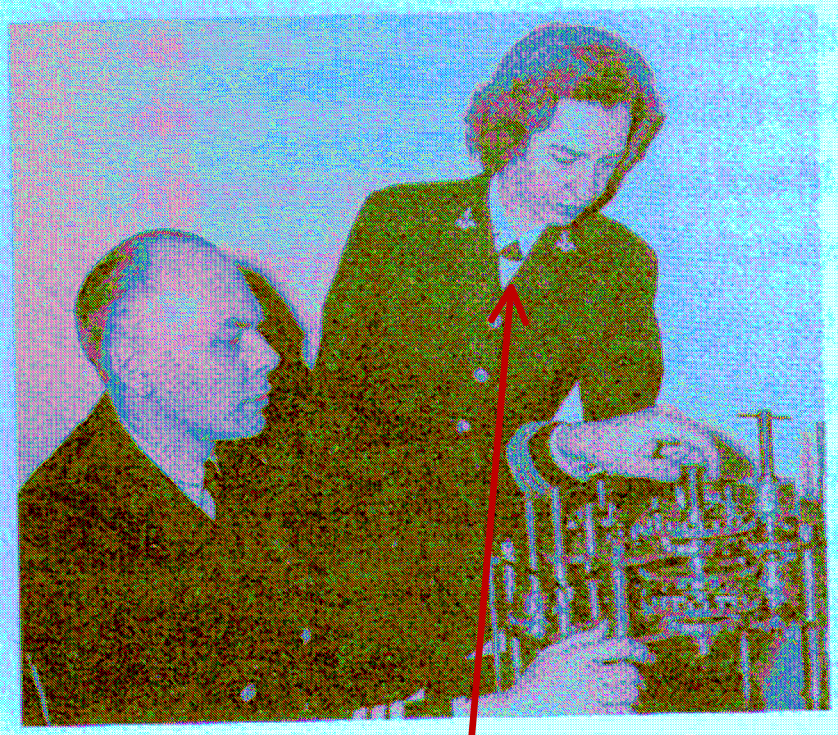
- Did some research:
- High reliability mission critical systems
  - Boeing 777 uses Ada
- Was not liked by many, ponderous
- Desire to use C
- My experience: 1998-2005 moved to non embedded system with windows and Sun computers with UNIX

Amazing Grace — Grace Hopper

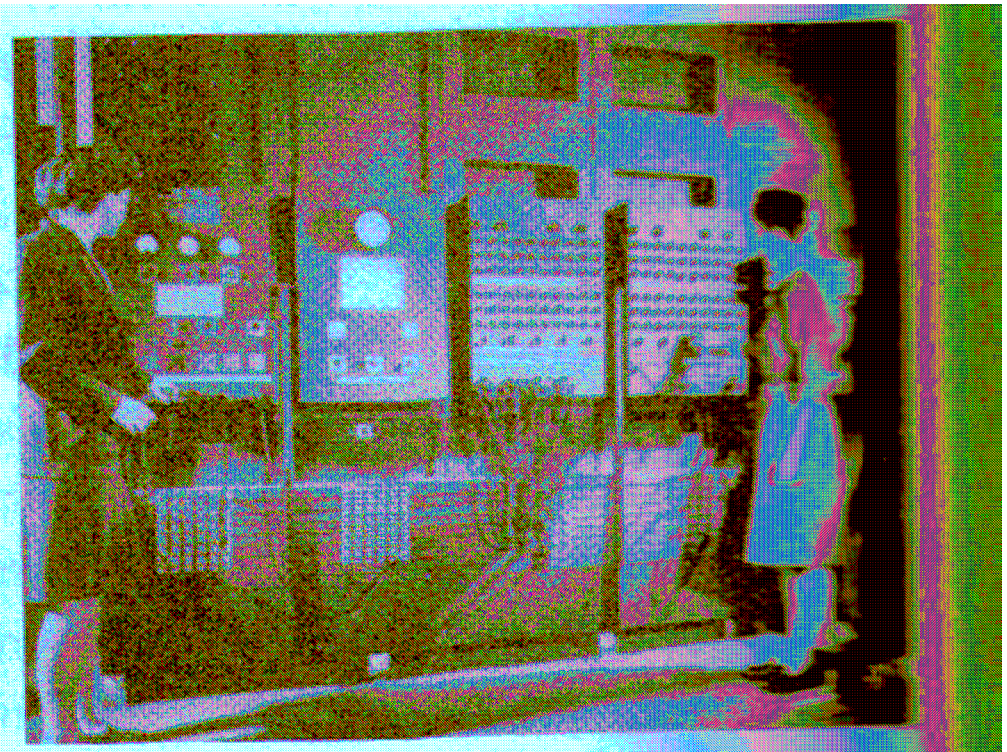
- Navy Rear Admiral Grace Murray Hopper, Ph.D. Math, Yale 1934
- A pioneer in the field, she was one of the first programmers of the Harvard Mark I computer [1944], and invented the first compiler for a computer programming language.
- She popularized the idea of machine-independent programming languages, which led to the development of COBOL, one of the first high-level programming languages.
- She is credited with popularizing the term "debugging" for fixing computer glitches (inspired by an actual moth removed from a computer).
- Owing to the breadth of her accomplishments and her naval rank, she is sometimes referred to as "Amazing Grace".
- The U.S. Navy destroyer USS *Hopper* (DDG-70) is named for her, as was the Cray XE6 "Hopper" supercomputer.

Compiler?

- **A compiler is a special program that processes statements written in a particular programming language and turns them into machine language or "code" that a computer's processor uses.**
- **Typically, a programmer writes language statements in a language such as Pascal or C one line at a time using an editor.**
- ***whatis.techtarget.com/definition/compiler***



Howard Aiken and Grace Hopper (1906–92) with a part of Babbage's Difference Engine at Harvard in 1946.



Jean Jennings and Frances Bilas with ENIAC

Grace Hooper


If it's a good idea… go ahead and do it. It is much easier to apologize than it is to get permission.
Adopting

Jean Jennings (1924–2011) in 1945.

Betty Snyder (1917–2001) in 1944.

ENIAC Programmers

Memory

- **In the beginning… memory was electrically complex, clunky, expensive, slow, physically large and difficult to interface with…thus it limited the software and the data that computers could processes.**
- **One of my first civilian projects in 1970 was on a double drawer [28in high] rotating NiCo mass memory drum, with flying heads, in a nitrogen environment with 75 kilobits of data storage.**
- **Once memory became electronic, first through hard drive discs and now solid state, the size dropped microscopically and the price plummeted along with vast improvement in read and write capacity and speed.**
- **Key: Memory is no longer a computer limitation.**

Demise of the University Setting of Computer Innovation: Early 1950s

- **The computer moved from an academic research tool of limited utility to the needs of the vast commercial world.**
  - **The key University leaders followed new interests**
  - **Universities had an internal tension of academic pursuits vs enterprises, except as we shall see later, Stanford.**

Open Source vs. Proprietary

- The Web and the internet profited and expanded by being open sourced.
- Not so computer hardware manufacturers who needed industrial based facilities and supply chains.
- Some hardware companies became so involved in protecting their patents that they overlooked the fast evolving desk top and laptop revolution — and withered.
- DEC is a good [bad] example: from a company [spanning 1957 to 1992] with 140,000 employees (1987) building nearly all of the computer's components and software; it shrank till it was absorbed by Compaq and Compaq was in turn absorbed by HP.
- DEC overlooked the development of the “microcomputer” and then the PC.

Computerization

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