The Electronic Revolution

An overview of the computers and computing devices that relied solely on electronic means for completing calculations.

James Tam

Computing Technology (Pre WWII - WWII)

- As discussed in previous sections computers prior to this period were entirely mechanical or electromechanical in their design.

Mechanical "computer"

- World War II: the electronics industry (e.g., radio) was given a tremendous boost.

James Tam

Computing Technology (Pre WWII - WWII): 2

- Many people independently thought of using electronics in a calculating machine but the costs were high.
  - First attempt: Schreyer and Zuse
  - First prototype: Atanasoff and Berry
  - First fully working machine: Mauchly and Eckert

- This type of technology would derive its results using electronics (non-mechanical, mechanical parts were incidental rather than a key part of the calculation).

Electronic vacuum tube

Mataresephotos
http://matarese.com/photo/402-mullard-el84-vacuum-tube

James Tam

Categories Of Electronic Computers

- The ABC
- The ENIAC
- The British code breaking machines

James Tam

The People Behind The ABC (Atanasoff-Berry Computer)

- John Atanasoff
  - A professor at Iowa State College (now Iowa State university)

- Clifford Berry
  - A graduate student studying under Atanasoff

James Tam

Images: "A history of computing technology" (Williams)

Motivations For Developing The ABC

- Atanasoff was researching methods of solving complex physics equations.

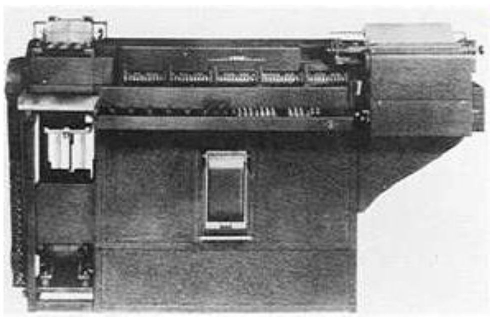
- The drudgery of using the calculators of the day motivated him to find something better.

www.xnumber.com

James Tam

Motivations For Developing The ABC (2)

- He started by modifying the small IBM calculator that was leased to the college to see if it could solve these problems.



www.columbia.edu

James Tam

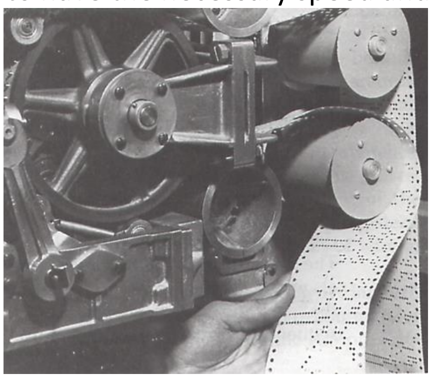
Motivations For Developing The ABC (3)

- His modifications were extensive
- The staff at IBM weren't happy with the modifications

James Tam

Motivations For Developing The ABC (4)

- Atanasoff's experiences with modifying the IBM tabulator convinced him that mechanical-based technology was unlikely to have the necessary speed and durability.



[Link to extra optional video: video of punch cards and punch tape]

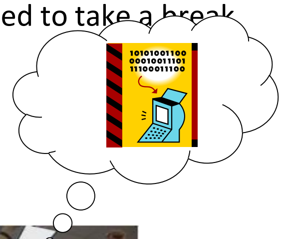
James Tam

Image: "The History of Computing Technology" (Williams)

Motivations For Developing The ABC (3)

- Atanasoff then decided to build his own machine.
- Unfortunately this proved to be more of a daunting task than he first anticipated.

- After a particularly frustrating night he decided to take a break from the lab.



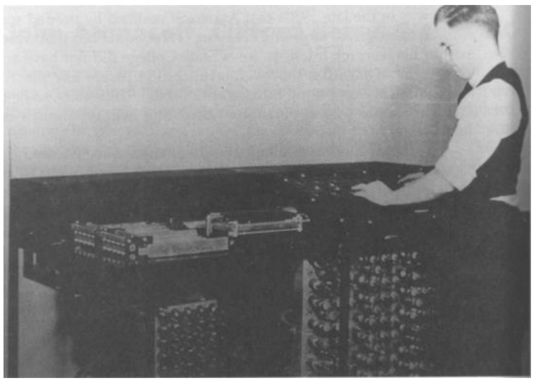
- This lead to an astonishing break through!

James Tam

Wav file from "James Tam"

The First Electronic Computer: The ABC

- After enlisting the aid of Berry and several years of hard work the ABC was *nearl*y completed at a cost of $6000 (including the $450 paid to Berry) in 1942.
- It was the first *prototype* electronic computer!



A photo of Clifford Berry and the ABC, courtesy of Dr. Atanasoff

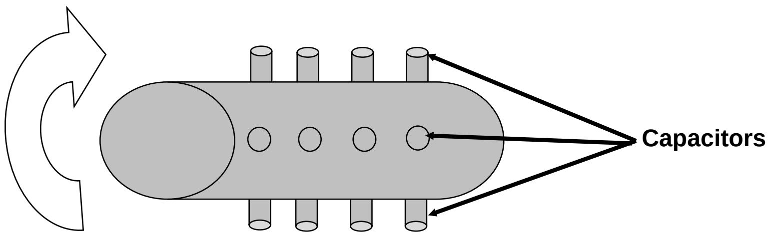
The First Electronic Computer: The ABC

- (At this time the US was involved in the second World War so the government demanded trained technical people to join the war effort).
  - In 1942 Atanasoff left the project (Naval Ordnance Laboratory).
  - The ABC never did become fully operational.

James Tam

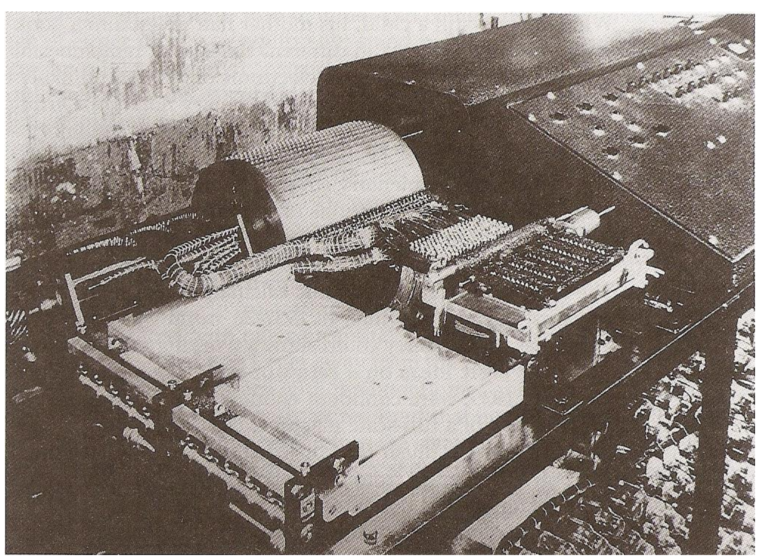
The First Electronic Computer: The ABC (2)

- It was the first machine to incorporate regenerative memory (Williams) that was similar to the kind used in modern D-RAM
- But it was not a stored program computer.



James Tam

ABC: Rotating Drum Memory



James Tam

Image: “A History of Computing Technology” (Williams)

The ABC: Technical Specifications

- Arithmetic unit:
  - 300 vacuum tubes (addition and subtraction)
- Control and memory
  - 300 vacuum tubes

James Tam

The ABC: Controversy

- Who developed the first electronic computer
- The fate of Atanasoff and Berry

James Tam

ABC: Significance

- It included a number of firsts:
  - Demonstrating the use of electronics in a digital calculating machine (excluding Helmut Schreyer and Konrad Zuse).
  - Incorporation of regenerative memory.

External Optional Videos

- Vision Atanasoff and the operation of the ABC along with the card reading input device
  - From the YouTube channel of Iowa state:
    - https://www.youtube.com/watch?v=pFP14xJmOdI
- The ABC in operation
  - From the YouTube channel of the Computer History museum (https://computerhistory.org/):
  - The Atanasoff-Berry Computer In Operation.
    - https://www.youtube.com/watch?v=YyxGIbtMS9E

The ENIAC: Place

http://www.archives.upenn.edu

- 1923: The Moore School of Electrical Engineering was founded.
- Throughout it's history many prominent researchers would visit the school
  - Vannevar Bush
  - John von Neumann
- 1930: The school enters into a relationship with the U.S. Army (Aberdeen Proving Ground: Maryland).
- First project: constructing another Differential Analyzer.
  - Funded by the government (research proving ground)
  - 2 machines (one for Aberdeen and one for Moore)
  - Bush even 'loaned' his chief designer to the project
  - Finished in 1934

James Tam

Calculating Ballistic Trajectories: Details (Williams)

- Given that the following were known and constant.
  - Gun type (guns could be used for different purposes) and size
  - Type of shell being fired
  - Charge of the propellant used
  - Elevation of the gun
- A firing solution could be calculated from a ballistic table.
  - It would contain solutions to 3,000 trajectories
  - (Longer ranged guns would have to consider other factors: air pressure, humidity, wind speed).
- Keep in mind that there is a great deal of variation in real life:
  - Guns ranged from ~5" to 18" (or more in rare cases).
  - Consider the possible elevations where battles have taken place (sea level up to the mountains).
  - Etc.

James Tam

Calculating Ballistic Trajectories: Details (Williams): 2

- A *skilled operator* using a desk calculator could complete the results for a single trajectory in 20 hours.
  - 20 hrs./trajectory x 3,000 trajectories = 60,000 hours for one table
  - (Assuming a 40 hour work week): 1,500 weeks or 28 years (no vacation)
  - (World War I: 1914 – 1918)
  - (World War II: 1939 – 1945)
  - To deal with the "man power" shortages many women were recruited.

http://www.cssu-bg.org

James Tam

Calculating Ballistic Trajectories: Details (Williams): 3

- Computers of the day (e.g., Differential Analyzer) could complete the results in 20 minutes (excluding set up time…remember hammer and wrenches!)
- These calculations excludes the requirements of the U.S. Navy (with their own set of challenges).

www.ciipartbest.com

James Tam

External Optional Videos

- A video showing some of the factors required to calculate a firing solution (A-A anti-aircraft guns):
  - https://www.youtube.com/watch?v=_M10k-t73-s
- A short light hearted video illustrating: the need for faster automatic calculation as well as the transition from mechanical devices to electronic computers.
  - https://www.youtube.com/watch?v=0PYqmm4JGfM

James Tam

The People Behind The ENIAC

- John Mauchly
  - Developed the designs for the ENIAC

From www.computermuseum.li

- J. Presper Eckert
  - Designed the individual circuits of the ENIAC

Image © Michael Denning from www.computerhistory.org

- Joseph Chedaker
  - Supervised the construction team

James Tam

John Mauchly (1907 – 1980)

- He received the Engineering Scholarship of the State of Maryland.
- 1925: He enrolled in Engineering at John Hopkins University.
- 1927: He enrolled for and was directly transferred to the Ph.D. physics program.
- 1933 – 1941: A professor of physics at Ursinus College

James Tam

J. Presper "Pres" Eckert (1919 - 1995)

- He came from a wealthy family

- In school he showed a great aptitude for mathematics.

James Tam

J. Presper Eckert (1919 - 1995): 2

- Enrolled in the Wharton Business school at the University of Pennsylvania.
- Transferred over to the Moore School of Engineering where he worked on:
  - Research on radar technology.
  - Improving the speed and accuracy of the school's Differential Analyzer.
  - 1941 became a laboratory assistant for a defense training summer course in electronics (funded by the United States Department of War)

James Tam

The Meeting Of Mauchly and Eckert

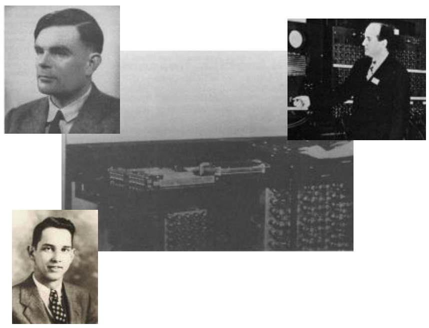
- John Mauchly
  - As mentioned he was a Physics professor at Ursin College.
- J. Presper Eckert
  - A lab instructor at the Moore School (government sponsored electronics course)

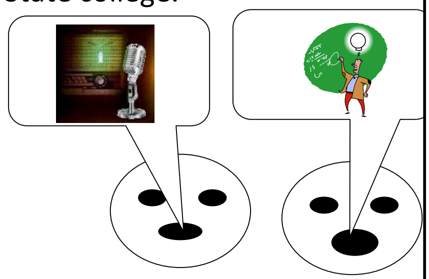
- When some staff positions became vacant at the Moore School (war) Mauchly was recruited into the engineering school.

James Tam

Atanasoff And The Moore School

- December 1940: American Association for the Advancement of Science meeting, Atanasoff and Mauchly first met.
- Summer 1941: Mauchly visits Iowa State college.





James Tam

Image from "History of Computing Technology" (Williams)

Publications

- August 1942: Mauchly wrote his ideas in a paper "The Use of High Speed Vacuum Tube Devices for Calculating".
  - Contrast of electronic vs. mechanical approaches (details from Williams)
    - Differential Analyzer: 15 – 30 minutes
    - Electronic machine: 100 seconds (1.67 minutes)
  - Reaction at the time….ZZZZ
  - One year later….where is it???!!!

James Tam

The War Effort And The Moore School

- The calculation of ballistic tables was falling too far behind!

www.clipartbest.com

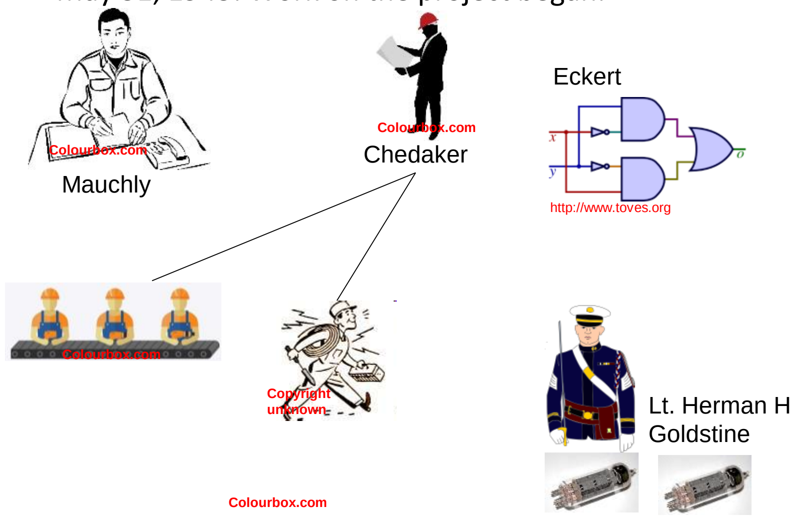
- April 9, 1943: Meeting between the Moore School and the Ballistic Research Laboratory people.
  - Mauchly and Eckert attempted to reconstruct the paper of notes made by Mauchly's secretary.
  - Moore School: proposed the name "<u>*E*</u>lectronic <u>*N*</u>umerical <u>*I*</u>ntegrator" (Integrator: remember the Differential Analyzer).

The War Effort And The Moore School (2)

  - Mauchly: focused on the 'general' use of the machine (more than just Integrals).
  - Army: add the phrase "<u>*a*</u>nd <u>*C*</u>omputer".
  - Thus the name: "<u>*E*</u>lectronic <u>*N*</u>umerical <u>*I*</u>ntegrator" + "<u>*a*</u>nd <u>*C*</u>omputer" was used. (ENIAC)
- January 1944: the design of the machine was complete enough so actual progress could be made on the machine itself (rather than on 'test circuits').
- July 1944: two accumulators, a power supply and signal generator could perform simple calculations.
- ???: complete and fully working (many later modifications were often just improvements).

The ENIAC

- May 31, 1943: Work on the project began.



Presper Eckert: Contributions

- A younger member of the team (remember he was a 'TA')
- Considerable hands on experience (radar research)

Elegant and new solution?

Brute force but proven to work?

- Little work time was wasted.

The ENIAC: Results

- It was big!
  - Real big!!!!
  - x100 times bigger than other machines of the time
- "…the most complex bit of electronic ever put together" (Williams).
  - ~US telephone network

James Tam

Image: "A History of Computing Technology" (Williams)

The ENIAC: Results

- Dimensions:
  - 8' high x 3' wide x 100 long
- Weight:
  - 100 tons
- Energy consumption:
  - 140,000 watts (140 kilowatts)
- Vacuum tubes:
  - Original design: 5,000 needed
  - Completed design 18,000 used
    - Along with 1,500 relays and 10,000 capacitors
- Costs
  - Original budgeted cost: $150,000
  - Actual cost: Over $486,000

James Tam

The ENIAC: The Component 'Units'

- The ENIAC was divided up into component 'units'
- Each unit would be contained behind panels
- Behind the panels:
  – A unit would contain its own memory and control (vacuum tubes and relays).
  – There was also a complex array of switches, indicator lights and connector sockets.

James Tam

The ENIAC: Component Units, Williams

- Type 1: Memory: 20 accumulators
  – Each accumulator could store a 10 digit signed number
  – Accumulators could be combined to increase the number of digits.
- Type 2: Multiplication unit:
  – A hard wired single digit multiplication table
  – Similar to Napier's bones and paper: a complex multiplication would be determined by computing the partial products and then summing the products.
    - Partial products: 4 – 5 faster than technology that employs repeated additions.
    - Two ten digit numbers could be multiplied in under 3 milliseconds.
    - The ENIAC was an electronic implementation of the Harvard Mark I (electro-mechanical): Multiplication: ~6 seconds.

James Tam

The ENIAC: Component Units, Williams (2)

- Type 3: A combined division and square root unit
- Type 4: Three function tables: could store tables of function values
- Type 5: Input unit (120 punch cards/minute)
  - A memory buffer was constructed out of 8 relays
- Type 6: Output unit (100 punch cards/minute)
- Type 7: Master programmer (repeating instructions ‘loops’)

- The punch card machines were the greatest source of breakdowns in the ENIAC.
  - Normally it’s a very reliable technology.

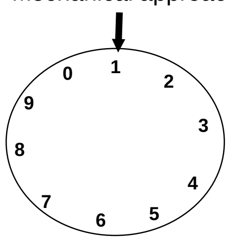
The ENIAC: Bottleneck, Williams

- The accumulators were frequently the limiting speed factor of the machine.
- Sometimes the 20 accumulators could not store all the partial results.
  - The results would then have to be printed and fed back into the machine as a new calculation.
- Multiplication and division would so resource intensive (partial values) that although the machine could perform them quickly if all the results could be stored they were usually avoided whenever possible:
  - Multiple adds/subtractions
  - Bit shifting
  - Using the principle of constant differences between functions (Babbage)

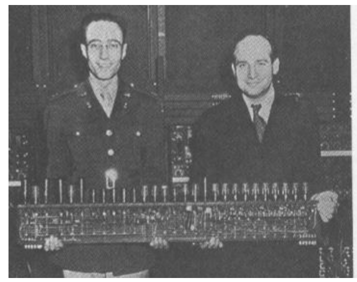
Memory Of The ENIAC

- Many of the components were just electronic equivalents of the mechanical version.
- E.g., to store a single digit:

Mechanical approach



The approach used in the ENIAC



"A History of Computing Technology" (Williams)

James Tam

The ENIAC: Cooling, Williams

- Vacuum tubes technology produces a great deal of heat.
- The computer was air cooled
  - Two 12 horse power motors pumped 600 cubic feet of air per minute through each panel
  - Contrast: home ceiling fans max ranges ~400 – several thousand cubic feet of air (source unknown)
- Each panel had it's own thermometer
  - The temperature for each panel could be individually regulated
  - There was fail safe that would shut down the entire machine if any panel exceeded 120 F/49C.

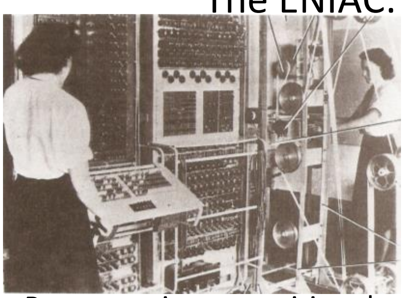
James Tam

The ENIAC: Cooling (2)

- Normal failure rate
  - Failure rate: 18,000 vacuum tubes, one would fail every 2 – 3 days.
  - A floor fan could be used to cool a panel during this time.
- During servicing the panels had to be opened (air leak) and the fail safe disabled.
  - Due to an unfortunate oversight a fire occurred that destroyed 2 units

James Tam

The ENIAC: Programming



- Programming = re-wiring the cables going to/from sockets.
- Bus wires determines:
  - Which units are activated
  - Which units to send data
  - Whether instructions should be repeated
  - If a memory accumulator should be reset to zero
  - Etc.

James Tam

Image: “A History of Computing Technology” (Williams)

The ENIAC: Programming (2)

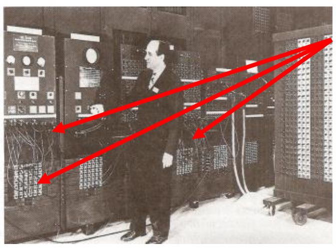
- Numerical buses
  - Transmit the number and the complement of the number (subtraction via negate and add)
  - 12 wires:
    - 10 wires for up to 10 digit numbers
    - 1 wire for the sign
    - 1 wire for grounding the connection.

The ENIAC: After Completion

- Spring 1945: the ENIAC was functioning well although it was still considered in test mode (beta).
  - It had run actual ballistic programs as well as calculations for the Los Alamos atomic energy group.
- Later in 1945: dismantled and shipped to the Ballistics Laboratory (Aberdeen, Maryland).
  - The war was over so the machine was put to work on a wide variety of problems. (For several years the ENIAC was the only large scale, electronic computer used daily).
- Vacuum tube technology: very reliable when 'always on'
- It continued to provide good, reliable service for another ten years.

The ENIAC: Later Enhancements

- A magnetic drum to store intermediate results.
- More (core) memory added:
  - Store intermediate results
  - Act as an input/output buffer
  - 100 words (digits) in a cabinet (7’ high x 2’ wide x 2.5’deep)!
- However: the ENIAC was not originally conceived as a stored program computer.



‘Hard wired’ computer program instructions

“A History of Computing Technology” (Williams)

James Tam

The ENIAC: Programming (3)

- Later the ENIAC became programmable (modern sense):
  - The machine’s operating speed as now slower but this was more than offset by the decreased time needed to setup the machine (Williams)

James Tam

The ENIAC: The End, Williams

- It was shut off for the final time on October 2, 1955.
- 10 years at Aberdeen Proving Grounds (Maryland) the ENIAC was conjectured to have completed more calculations than the whole of the human race prior to 1945!
- Parts of the machines are on display at the National Museum of American History (Smithsonian) and other locations (e.g., School of Engineering and Applied Science at the University of Pennsylvania).

Optional External Videos

- Information about the ENIAC project (original video not available, here's an alternative from the Computer History Archives project):
  - https://www.youtube.com/watch?v=bGk9W65vXNA
- Mauchly, the person behind the technology:
  - Original video not available.
  - Alternative video interview:
    - https://www.youtube.com/watch?v=M9jUMUbDWNc
- J. Presper Eckert interview:
  - https://www.youtube.com/watch?v=G8R6li54R20

The ABC And The ENIAC (Williams)

- The ABC was the first *prototype* (partially working) electronic computer (not quite completed).
- The ENIAC was the first *fully operational* electronic computer.

World War II: Code Breaking And Computing

The Allies

•British code breaking machines/projects

- The machines of Bletchley Park ('bombs')
- The Robinsons
- The Colossus (and the Colossi!)

The Axis

Geheimschreiber (secret writer)

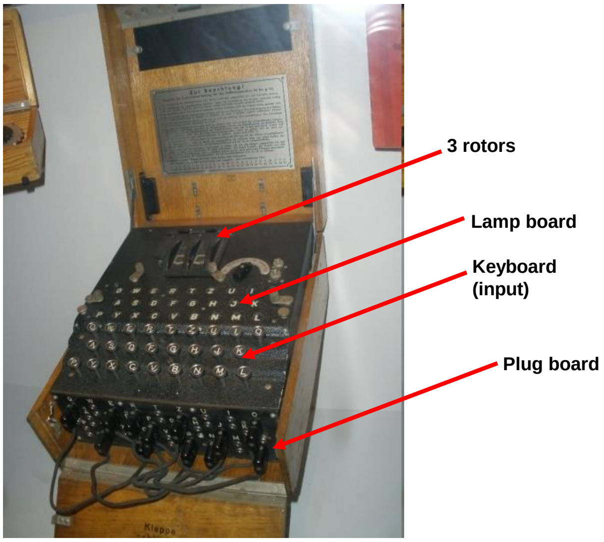
The enigma machines (but commercial versions were purchased by other nations e.g. Poland->England)

The Enigma

- Developed by Germany between the two world wars (WWI: 1914 – 1918, WWII: 1939 – 1945).
- It was designed to convert ordinary language ("plain text") into an encoded ("encrypted form") to be sent via radio or telephone lines.
- There were two version: one for the military and one for business.
  - The commercial machines were made publically available in 1927.
  - The German military began to use the Enigma code on one of their radio stations in 1928.

James Tam

The Enigma: Basic Encryption

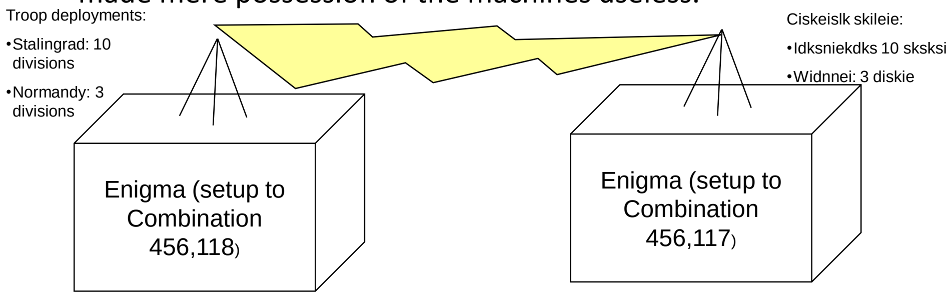


An enigma machine (Imperial War Museum: England) courtesy of James Tam

James Tam

The Enigma: Combinations

- The sheer number of possible combinations (100 billion!) made mere possession of the machines useless.



The Allies (British): Decrypting The Enigma Encryption

- Simply possessing one of the Enigma machines wasn't sufficient.
- Nor was it sufficient to know the code settings used for a particular time.
- Poland:
  - When the German military began to broadcast radio transmission (1928) using the Enigma encoded messages. The Polish radio operators alerted the Cipher Bureau.
  - Polish Cipher Bureau: purchased and modified a commercial copy of the Enigma.
  - 1928 – 1931: little headway was made and the project was abandoned in 1931.

The Allies (British): Decrypting The Enigma Encryption: 2

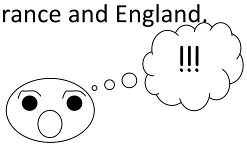
- 1932: Martin Rejewski: a mathematician was assigned to study the encryption problem again.

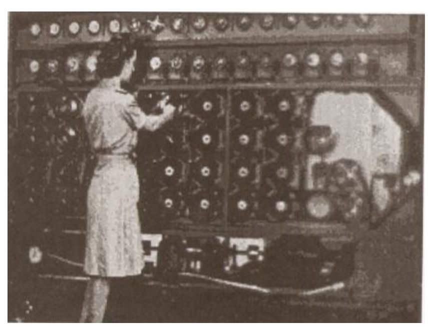
http://ulm.ccc.de

- His initial efforts resulted in some success and additional people were added to the project.
  - ~75% of the German messages were deciphered.
  - ‘Encryption: technology race’ between the Polish and German technological developments.

The Allies (British): Decrypting The Enigma Encryption: 3

- 1939: it was evident that war was imminent: the policy of ‘appeasement’ was not working.
  - The Poles called a meeting of the intelligence agencies of: Poland, France and England.

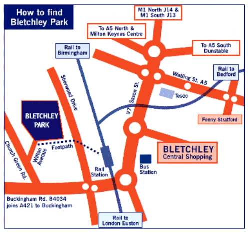


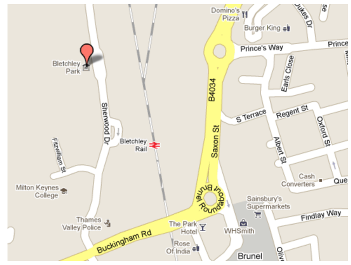


Polish built bomba(“bomb”) from “A History of Computing Technology” (Williams)

The British Code And Cipher School

- Worked on deciphering the German codes at Bletchley Park outside of London:





- Intelligence work involved a great deal of secrecy:
  - Information was strictly on a "need to know basis" for the people working there.
  - Even now much of the information is still classified "Official Secrets Act": http://www.legislation.gov.uk/ukpga/1989/6/contents

James Tam

The British Code And Cipher School (2)

- The combination of secrecy surrounding the work at Bletchley Park and the code names used, 'work on bombs' resulted in a great deal of confusion.
  - "…but the only thing these bombs destroyed was the German Air Force message security" (Williams).
- What is known:
  - The British constructed several new versions of their own 'bombs' which were based on the Polish original.

James Tam

Alan Turing (1912 – 1954)

- A distinguished British Mathematician from Cambridge
  - He produced distinguished first-rate work (Williams)
- After graduation he remained to work at the college and produced a famous paper:
  - “On Computable Numbers with an Application to the Entscheidungs-problem”
  - His work was known to scholars throughout the world.
  - 1936 he spent the year at Princeton: (Einstein, von Neumann).
- During the war he worked at Bletchley Park as a code-breaker (contributed to the design of the machinery as well as applying his Mathematical knowledge)
  - An eccentric person
  - A ‘pure’ scholar

Image from “History of Computing Technology” (Williams)

Alan Turing (1912 – 1954): 2

- He was a scholar and only ran in his “spare time”
  - Alan Turing achieved world-class Marathon standards. His best time of 2 hours, 46 minutes, 3 seconds, was only 11 minutes slower than the winner in the 1948 Olympic Games. In a 1948 cross-country race he finished ahead of Tom Richards who was to win the silver medal in the Olympics.
  - https://www.turing.org.uk/book/update/part6.html (last visited October 2020)
- For more information: “Allan Turing: The Enigma” by Hodges A. (Simon and Schuster)
- Optional external movies you can watch for more information about Alan Turing and his work (caution: mature themes).
  - Breaking the Code, a regular (theater) movie that (according to Michael R. Williams) a mostly accurate picture of the person and his life.
  - The Imitation Game. (JT: quite entertaining)

The Robinsons

- 1942 (mid year): staffing levels at Bletchley Park were such that different sections (groups) were formed.
  - Each section was housed in a 'hut'.

www.bbc.co.uk

James Tam

The Robinsons (2)

- Division of work into huts:
  - Top Secret: information was on a need to know basis (no joke or exaggeration).
- By this time the bombs were too slow to be used in the decryption process and new techniques needed to be developed.
- General Post Office (Telephone Division)
  - Dollis Hill: West London
  - What the Dollis Hill people thought they were working on was significantly differently from what they were actually working on.

James Tam

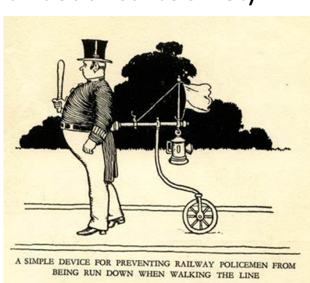
The Robinsons (3)

- M.H.A. Newman:
  - Envisioned a new machine that could automate a part of the decryption process.
  - Dr. C.E. Wynn-Williams: known for his previous work designed the machine envisioned by Newman

James Tam

The Robinsons (3)

- Machine name: Heath Robinson (unusual device named for an unusual cartoonist).



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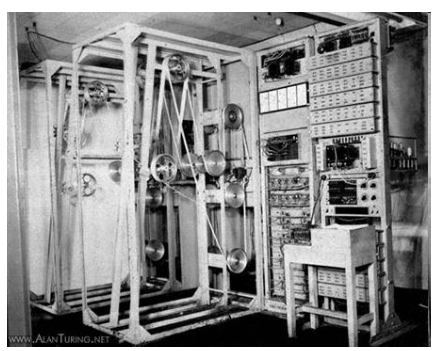


Heath Robinson computer: http://www.rutherfordjournal.org

James Tam

The Robinsons (4)

- Known specifications:
  – Much of the information is still 'classified' but some details have been released.
  – Partly implemented using vacuum tubes and telephone relays.
  – Not a general purpose computer.
  – Evaluate some type of Boolean operations on information read from two endless loops (punched paper).

James Tam

The Robinsons (5)

- Quickly constructed
  – Unreliable
  – 'Proof of concept': high speed electronic devices could still aid in the decoding process.
  – At least three machines constructed: Heath Robinson, Peter Robinson, Robinson and Cleaver.

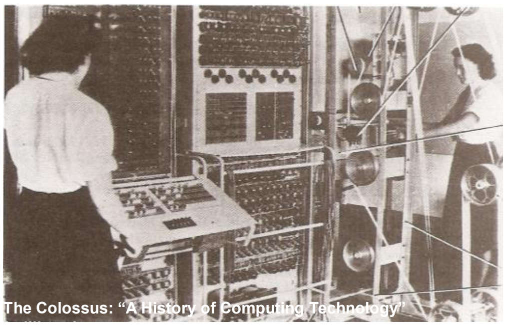
Peter Robinson
http://www.english-heritage.org.uk

Robinson and Cleaver
www.skyscrapercity.com

James Tam

The Colossus, Williams

- Mr. T.H. Flowers (London Post Office: tape reader project)
  - Brought directly into the project as an electronics expert to help redesign the Robinson machinery to make it more reliable (vacuum tubes over relays).
  - A completely new all electronic design (1,500 vacuum tubes) was used.



The Colossus: "A History of Computing Technology"

  - First used in operation December 1943.

The Colossus (2)

- The first job given to the machine was completed in 10 minutes ("the savior machine" hailed as "The Colossus").
- Some of the known specifications (many still 'classified'):
  - Bi-quinary storage of information in the registers.
  - An internal clock was used to synchronize operations.
  - Controlled by a plug board and wires.
  - Card readers (Robinsons) were used as input.
- Due to foresight and very good planning the second Colossus machine was built in less than a year!
  - First Colossus completed Dec 1943
  - When March 1944 came around: Many more! < June 1944

The Colossus (3)

- It's believed that up to ten were fully functional at the end of the Second World War.
- The eventual fate of most the machines is still unknown.
  - One machine was moved to Iran (Russia: Cold War)
- Similar to the Robinsons: the Colossi were required to complete high speed Boolean operations on data read from tape.
- In some ways the forerunner of the modern computer:
  - Because the basic mathematical operations can implemented using Boolean logic, in theory the machines could be general purpose (proof: base 10 multiplication performed),
  - Conditional branching possible: different plug board instructions could be executed depending upon a value stored in one of the registers (still 'classified' so details are sketchy).

James Tam

Video: British Code Breaking Machine

- Colossus operating at Bletchley:
  - Up to 7 minutes it talks about the technology behind the machine as well providing a bit of background information about the work at Bletchley, after that the narrator talks about later computers.
  - https://www.youtube.com/watch?v=KkSxC9pFGZs

James Tam

American 'Bombs'

- Few details are available.
- One of the last remaining American 'bomb' code breakers resides at the National Museum of American History (Smithsonian Institution).
  - Copy (identical?) of British machines.
- Other hints at American code-breaking efforts
  - Alan Turing visiting the U.S. during the war (Bell Labs)
  - "…the people who should be knowledgeable in such matters [code breaking efforts] (even if they won't admit it) acknowledge that the Colossi were far in advance of anything available in the States at the time." (Williams)

After This Section You Should Now Know

- What is the difference between electronic and mechanical/electro mechanical computing devices
- What were the three main categories of electronic computers
- What was the first electronic computer (partially and fully completed)
- The technical specifications of the first electronic computers
- The general appearance and cost/resources used in the building of the first electronic computers
- The history behind the names of the first electronic computers
- Who were the people behind these computers and what were some of the major events in their lives
- What were the approximate dates/time frames of significant developments in the mechanical monsters

After This Section You Should Now Know (2)

- The ABC
  - What was the motivation behind its development
  - What were the circumstances behind its conception
  - How did the regenerative memory work
- The ENIAC
  - The major events in the history of the Moore school
  - The type of research work was done at the Moore school
  - What were the events that lead up to the development of the ENIAC
  - What were the different parts of the ENIAC, what they consisted of and how they worked
  - What was the major computational bottleneck
  - Why multiplication and division operations were theoretically fast but in practice slow and what alternatives were employed

James Tam

After This Section You Should Now Know (3)

- (The ENIAC continued)
  - What was a 'unit' in the ENIAC and what did it consist of
  - How was numerical information stored in memory
  - How the cooling system worked
  - The method of programming the ENIAC
  - What were some of the later enhancements
  - The eventual fate of the ENIAC
- The Enigma: who developed it, what was it used for, how did it work
- The British code breaking machines
  - What were the 3 categories or families of code breakers
  - The events leading up to the development of the machines at Bletchley Park

James Tam

After This Section You Should Now Know (4)

- (The British code breaking machines continued)
  - The events leading up to the development of the Robinson machines and the technical specifications of these machines
  - The events leading up to the development of the Colossus and the second Colossi
  - The technical specification of the Colossi
  - What were the American code breaking efforts during the second world war

References

- "A history of computing technology", Michael R. Williams 2nd Ed (IEEE 1997)
- "Allan Turing: The Enigma" by Hodges A. (Simon and Schuster)
- https://www.nsa.gov/Portals/70/documents/news-features/declassified-documents/crypto-almanac-50th/The_Breaking_of_Geheimschreiber.pdf

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