John von Neumann in Computer Science

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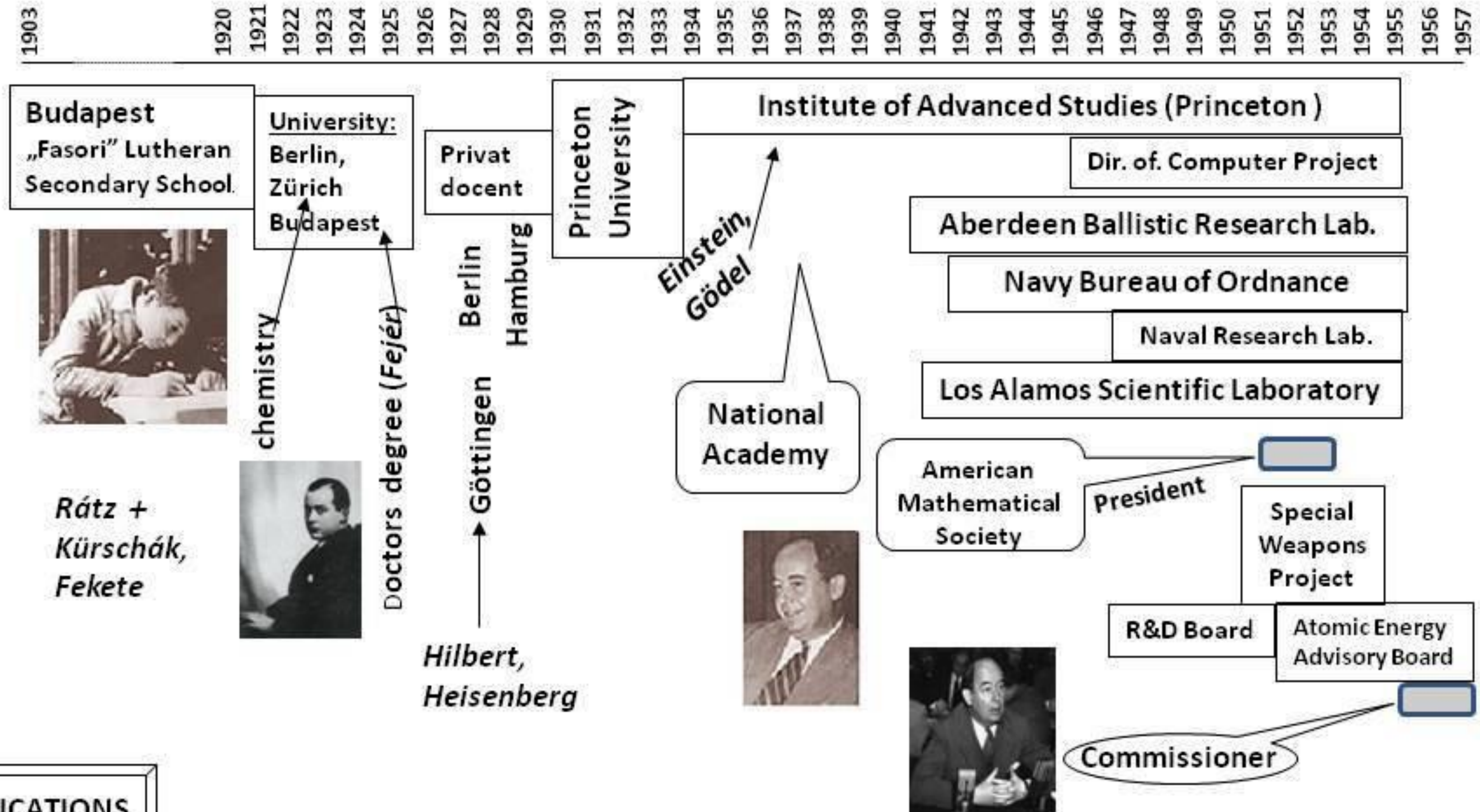
Honorary President of the John von Neumann Computer Society

The 2016 IEEE International Conference on Systems, Man, and Cybernetics
Panel dedicated to John von Neumann “a Pioneer of Modern Computer Science”

John von Neumann (1903-1957)



PUBLICATIONS

	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939
„pure" mathematics	1			1	1	1	4	4	1	2	4	1	2	7	8	5	1	
applied mathematics																		
foundation of mathematics		1		1	1	1	2	3		3						1		
physics, quantum mechanics						4	4	3			6	1	2	1	2			
computer science																		
economics, game theory							2									1		

	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956
„pure" mathematics	3	1	2	2		1	1	4	1	1	2	1	1		1	1	
applied mathematics	1	4	3	3	3	2	1	6	1		3	3	1	2	1	4	
foundation of mathematics																	
physics, quantum mechanics		1	1	1													
computer science							1	2	2			2		2	2		1
economics, game theory					1	1					1			1	1		1

Three periods

I. Study (1903-26)

Budapest, Berlin, Zurich

II. „Ivory tower" (1927-38)

Berlin, Hamburg, Gottingen

→ Princeton

III. „Man of action" (1939-57)

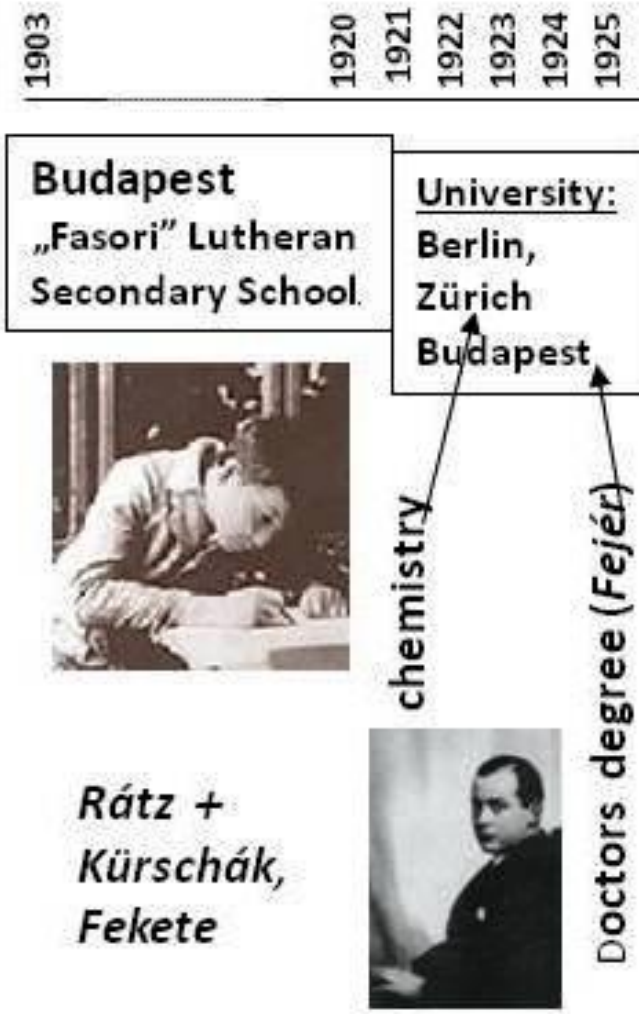
Princeton, Los Alamos, ….

Washington

Marina von Neumann.Whitman:

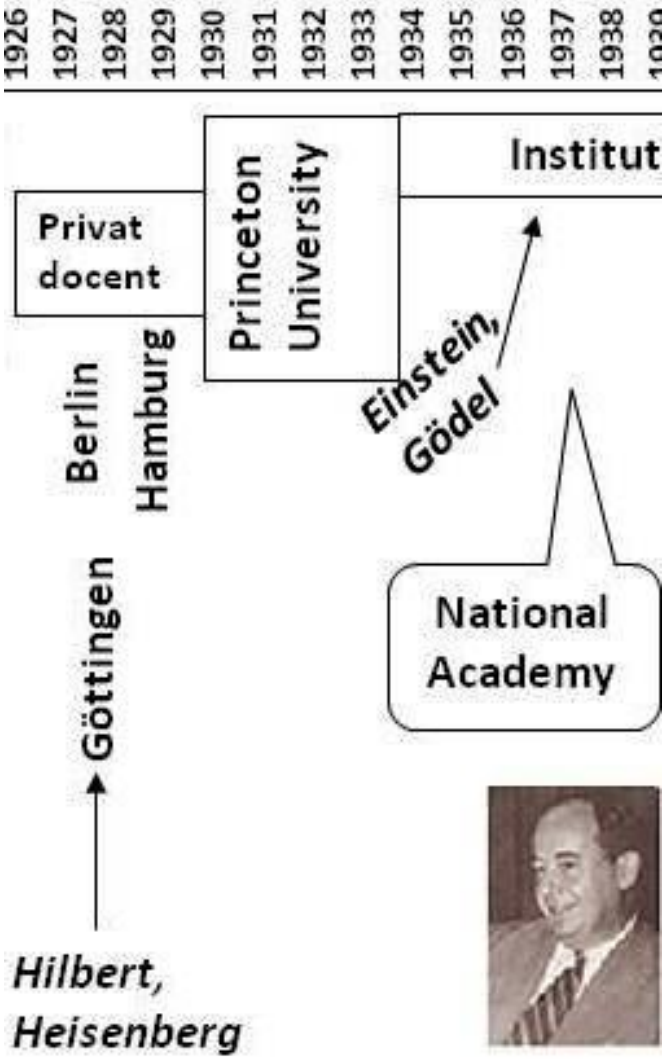
"*...my father led a double life: as a commanding figure in the ivory tower of pure science, and as a man of action, in constant demand as an advisor, consultant and decision-maker in the long struggle to insure that the United States would be triumphant in both the hot and the cold wars that together dominated the half century from 1939 until 1989*."

I. Study



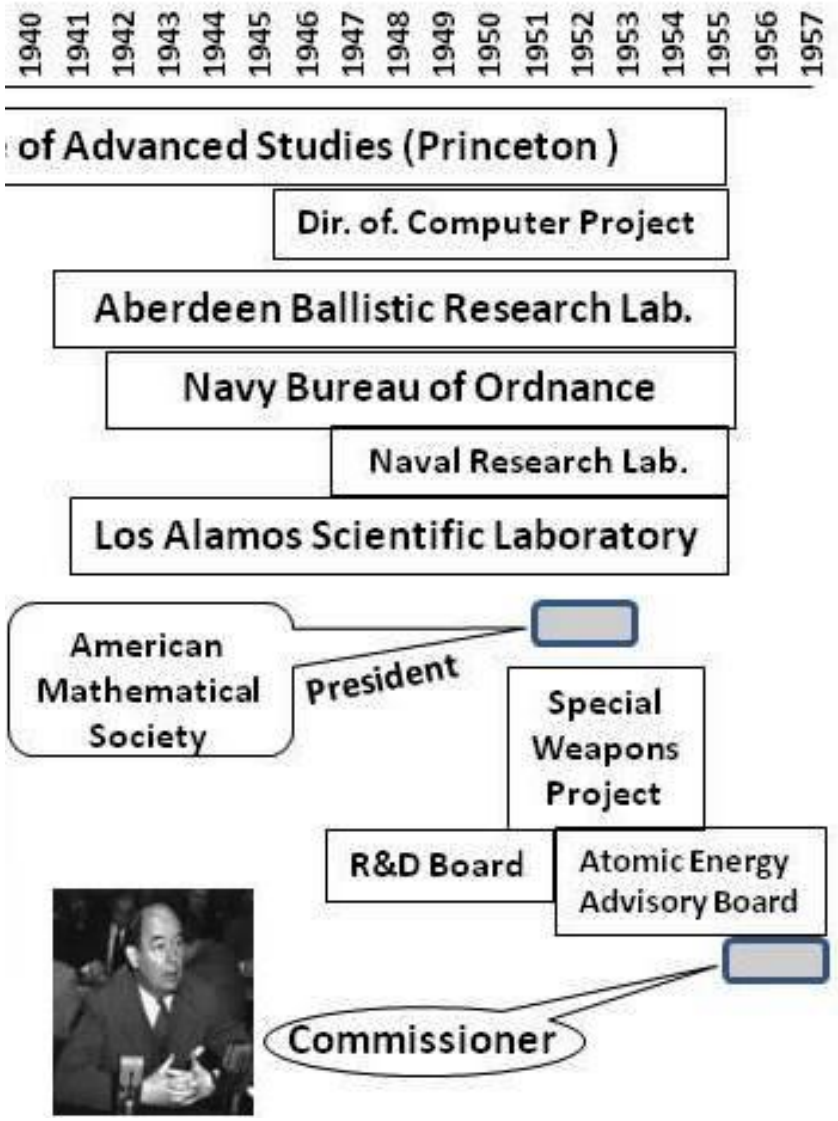
- Rich banker family, received nobility patent in 1913 („von…")
- Early talent (not only in math)
- „Fasor" Lutheran Gymnasium (also: *Wigner*, *Harsanyi*)
- Excellent math. teacher: *Laszlo Ratz* (award for secondary school teachers!)
- Tutoring by TU professors
- Publication at age of 19, together with Prof. Fekete
- Studying chemistry in Berlin, Zurich, plus mathematics in Budapest

II: „Ivory tower”



- Teaching at Univ. Berlin (1926-28) and Hamburg (1929-30)
- Fellowship to Gottingen, meeting Hilbert, Heisenberg
- Leaving for US in 1930: Princeton Univ.
- „Founding member” of the Institute for Advanced Studies (IAS), together with Einstein and Gödel
- Leading US mathematician with high international reputation, member of US National Academy.
- US citizenship in 1937 -> start of military oriented activities

III. „Man of action”

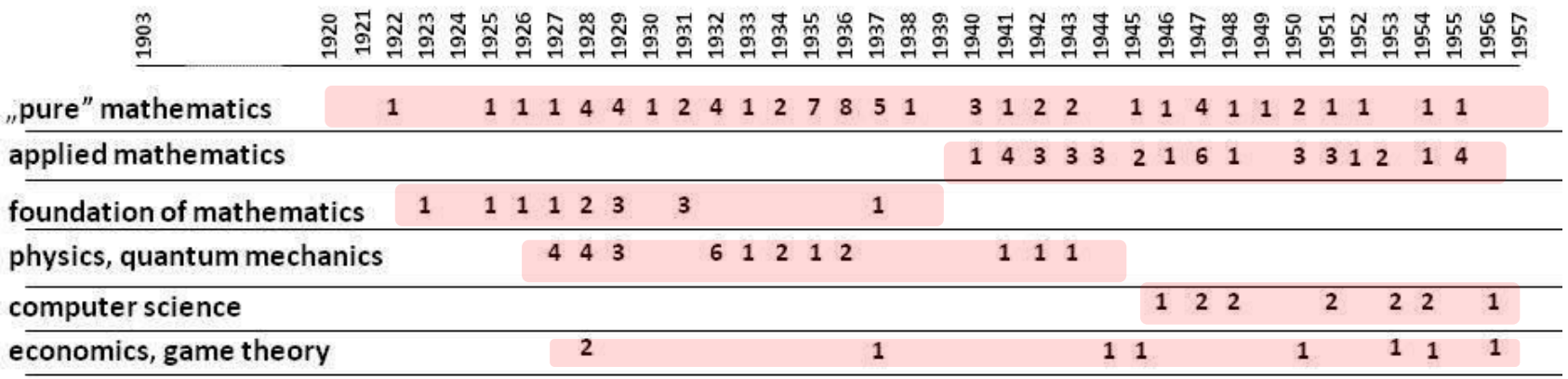


- Advisor to several military institutions
  Manhattan Project –> Atomic Energy Commission
- motivation:
  - to help his new homeland again nacism and communism in WW-II and the Cold War
- scientific interest:
  - theory of explosions, shock waves (-> atomic bomb)
  - game theory (->military strategy)

  plus: „general problem solving wizard”
- loss to pure science

„Although he remained on the faculty of IAS until 1955, the contemplation of pure mathematics… was pushed aside by his involvement in crucial issues relating to the security of the United States to the dismay of his mathematics colleagues”

Publications



- *pure mathematics* was present all over his life
- the 20s-30s dominated by *physics* (mainly quantum mechanics) and the *foundation of mathematics*, while in
- the 40s-50s many publications on *applied mathematics* and *computer science* can be found
- after a few initial publications in the 20s, topics of *ecomomics* (mainly theory of games) flourished in the 40-50s

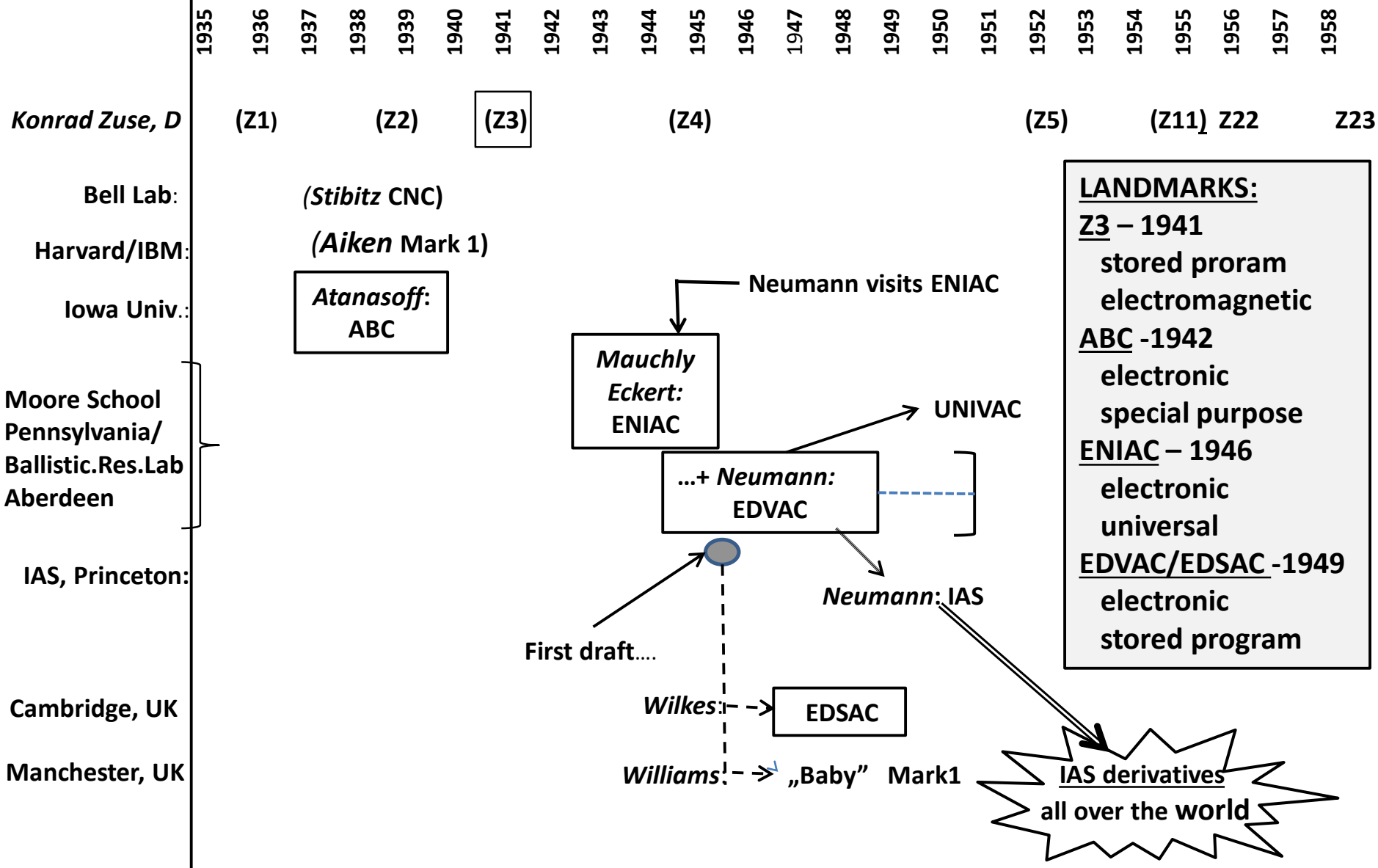
Computing

- Last decade of his life
- „Man of action" period
- Earlier no interest:
  - 1937: letter of recommendation to Alan Turing not mentioning his paper on computing!
- Regarded mainly as tool for scientific research
  - Explosion theory, shock wawes….
    - Los Alamos → Aberdeen

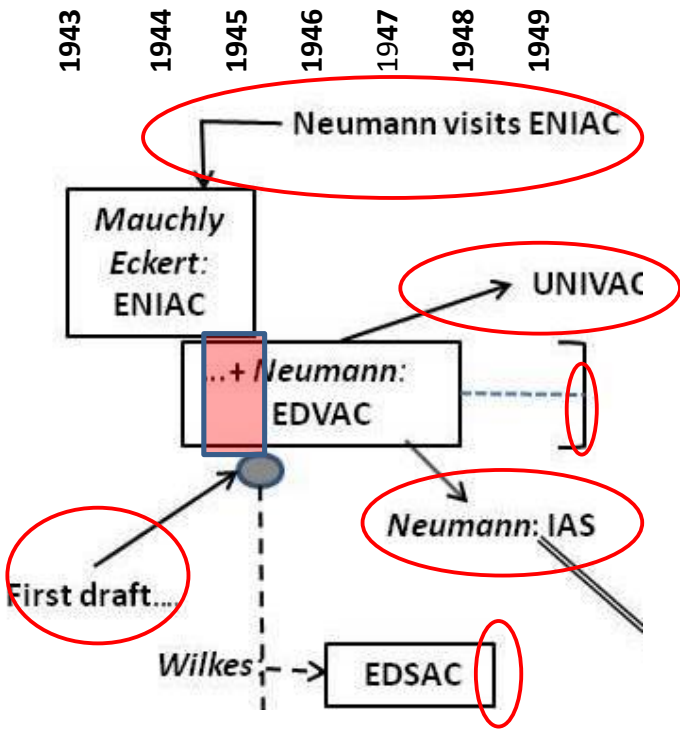
Stanislav Ulam:
„ His work, from the beginnings of the Second World War, concerns a study of the equations of hydrodynamics and the theory of shocks. The phenomena described by these non-linear equations are baffling analytically and defy even qualitative insight by present methods. Numerical work seemed to him the most promising way to obtain a feeling for the behaviour of such systems. This impelled him to study new possibilities of computation on electronic machines .."

ENIAC: electronic computer being built for artillery table calculations

Genesis of the digital computer



The birth of a design



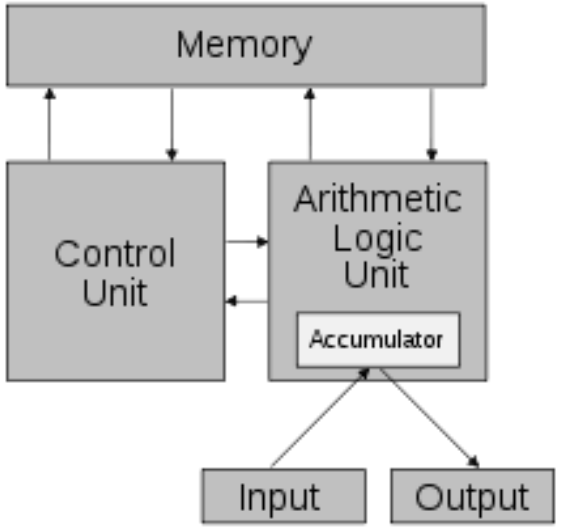
- ENIAC, the first programmable electronic computer was launched in Feb 1946
- Developers (Mauchly and Eckert) started design of an improved computer (EDVAC) in 1944
- *Neumann* joined in Fall 1944, „commuting" from Los Alamos (~2000 miles)
- Basic ideas (including stored program) worked out at regular (weekly) meetings of
  Mauchly, Eckert, Neumann, Goldstine, Burks…
- Results summarized by *Neumann* (in letters from Los Alamos)
- Split in the EDVAC team:
  - *Mauchly* and *Eckert* leaves Moore School in March 1946
  - *Neumann* continues with EDVAC and starts to build the IAS computer
- Although EDVAC was completed and delivered to Aberdeen in 1948, official launch was delayed until 1951, so EDSAC became the first stored program electronic computer in the world

Significance of the „First Draft”

- **Swift from**
  - **„technology driven” design to**
  - **„logic driven” design**
- Definition and detailed description of the main units of the computer (= „*Neumann architecture*”)
- Definition of an instruction set and detailed logical description of the execution of the instructions
- Originally intended to inside use, but later became widely distributed *(prevents patenting -> controversy)*
- Together with the plans of the IAS machine was used for designing many computers in the US and all over the world

  = „IAS derivatives”

(Eckert-Mauchly: Progress Report on EDVAC, September 1945):
„He substituted physical structures and devices with idealized elements in order to avoid dealing with technical problems, which could distract our attention from the logical considerations.”



IAS derivatives

Plans for the IAS machine were widely distributed to any schools, businesses, or companies interested in computing machines, resulting in the construction of several derivative computers referred to as "IAS machines," although they were not software compatible in the modern sense. Some of these were:

AVIDAC (Argonne National Lab.)
BESK (Stockholm)
BESM (Moscow)
CYCLONE (Iowa State Univ.)
DASK (Copenhagen)
GEORGE (Argonne National Lab.)
IBM 701 (19 installations)
ILLIAC I (University of Illinois)
MUSASINO-1 (Tokyo, Japan)
JOHNNIAC (RAND)
MANIAC I (Los Alamos)
MISTIC (Michigan State Univ.)
ORACLE (Oak Ridge)
ORDVAC (Aberdeen)
PERM (Munich)
SARA (SAAB)
SEAC (Washington, DC)
SILLIAC (Univ. of Sydney)
SMIL (Lund Univ.)
WEIZAC (Israel)

View on the future of computers

- Computer is for performing **complicated scientific and technical calculations**
- Using computers for simpler („clerical”) tasks is a waste of computing power. (even the use of programming tools, like assembler, programming languages was opposed as „useless”)
- At that time:
  - no data processing by computers (electromechanical punched card machines)
  - no connectivity between computers

"My father … expected that the whole world wouldn't need more than a few, perhaps a dozen, computers, since their purpose was cutting-edge research with huge computational requirements.”

⇒**Neumann did not (could not) foresee the modern use of computers**.

Nevertheless, consequences of some of his achievements (apart from the logical structure of computers), still have considerable effect in modern computer science.

Some results with present day impact

- Neumann's (postumus) paper on **self-reproducing automata** is referred to in many areas, including *genetics* (DNS structure), *synthetic biology*, *artificial chemistry, spacecraft building* etc.
  3D printing opened the possibility to build a printer, being able to reproduce itself.

"We are trying to prove the hypothesis: rapid prototyping and direct writing technologies are sufficiently versatile to allow them to be used to make a von Neumann Universal Constructor."

RepRap project, Univ. Bath, UK 2005

- The theoretical foundation of **building reliable systems from unreliable elements** is equally important now, when our IT world is based on the organized cooperation of different **interconnected services**

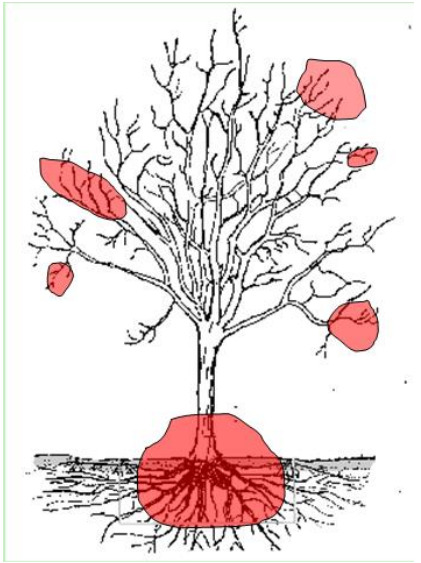
"*The trick is to make highly reliable systems out of unreliable components. John von Neumann... was the first to study this problem in the 1940s; in his time, computer parts were notoriously flaky*.„

Jini, - system for distributed computing based on Java, 2001

- Brain research is now in the center of interest of IT research, trying to simulate the operation of the brain and/or building computers with ideas borrowed from its structure. Neumann"s last (unfinished) work „**The computer and the Brain**" may serve as basis of both kind of considerations, outlining the similarities and differences between the operation of a computer and the (human) brain.

Conclusion

- „Invention” of the electronic digital computer:
  - complex process with many players,
  - Neumann: logical design of the architecture (including stored program)
- Still can be considered as basis of the modern world of computing, although with completely changed technologies, circumstances and applications
- In his theoretical works - inspired by problems of computing – many significant ideas can be found, influencing present day research as well



Not only the root, but some leaves too

- Last works of Neumann might be seen as building blocks of a **general, mathematical theory** of automata (and computing), which really can pretend to the title of

“A theory that transformed the world to a Cyberspace”

Thank you for your attention !

http://itf2.njszt.hu/objectum/Neumann_SMC2016

https://www.academia.edu/35388326/John_von_Neumann_in_Computer_Science