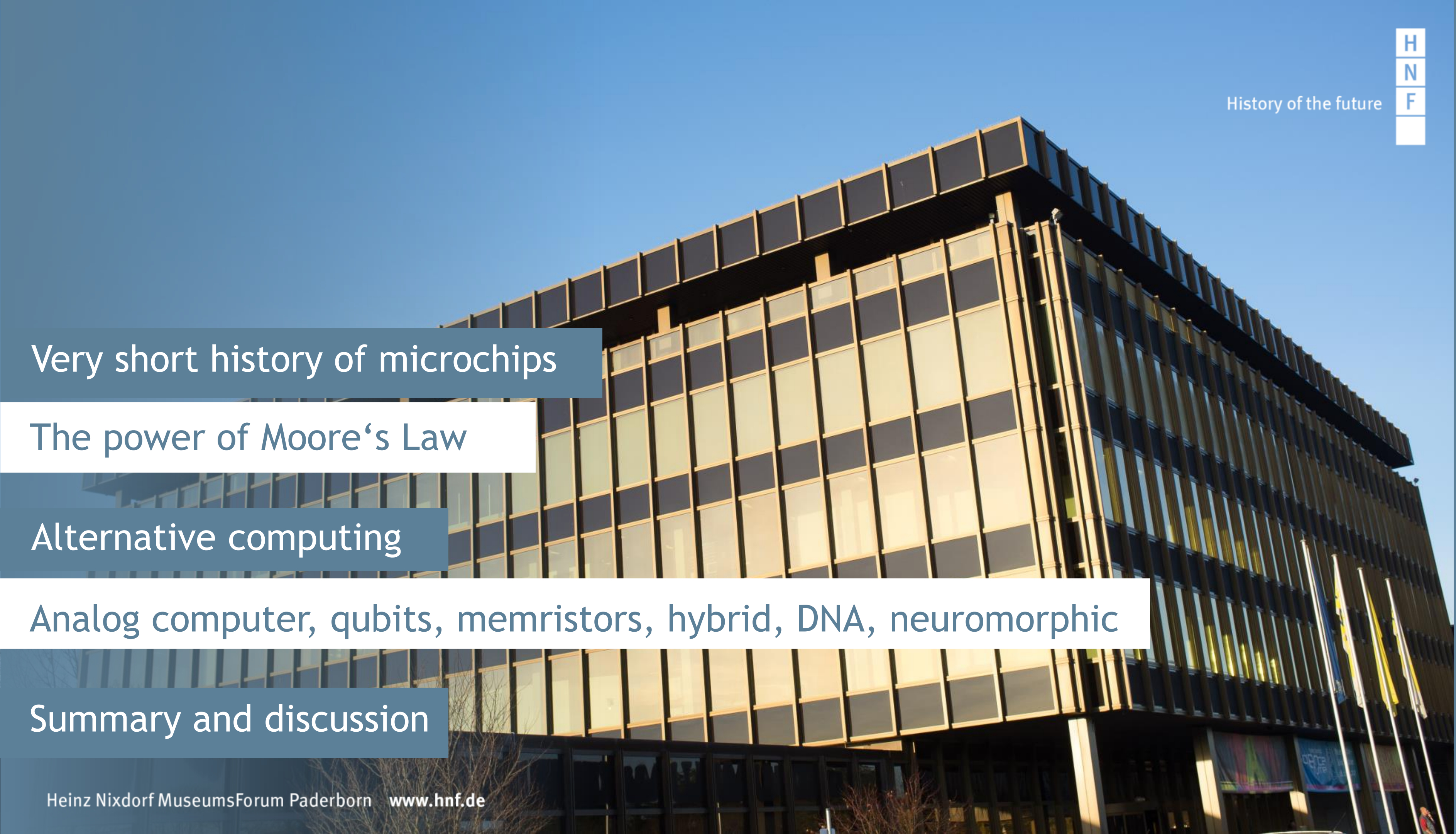
History of the future

HNF

Beyond Common Computing

ICCS2023 Jochen Viehoff



Very short history of microchips

The power of Moore‘s Law

Alternative computing

Analog computer, qubits, memristors, hybrid, DNA, neuromorphic

Summary and discussion

History of the future
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We are not prepared for the end of Moore‘s Law

David Rotman MIT Tech Review February 2023

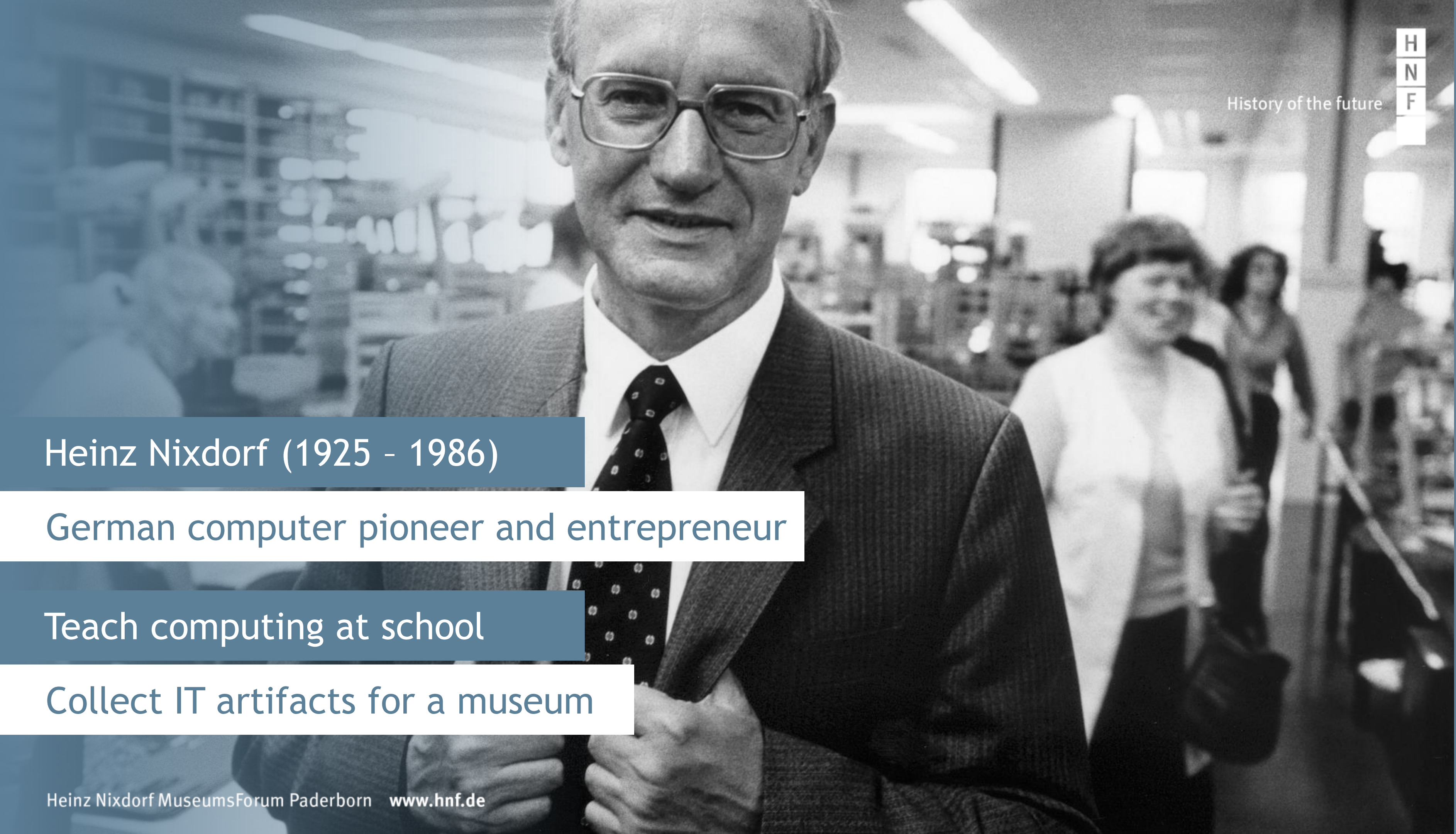
History of the future HNF

Connection Machine 2 / 5

Lattice Gauge Theory / Quantum Field Theory

Lattice size: 16x16x16x32

CM5: fastest computer 1993 1024 cores 131 Gflops peak



HNF History of the future

Heinz Nixdorf (1925 – 1986)

German computer pioneer and entrepreneur

Teach computing at school

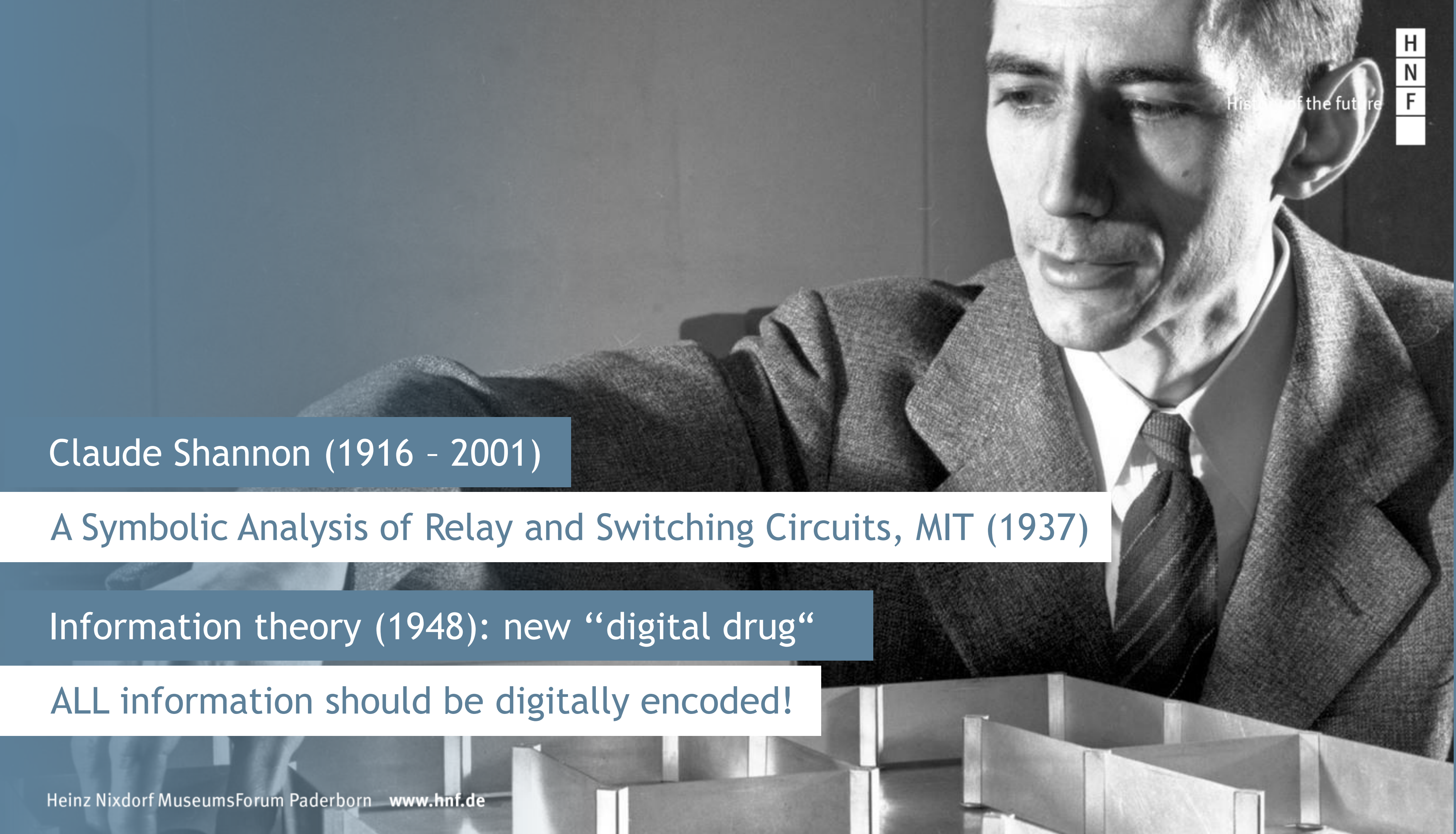
Collect IT artifacts for a museum

Heinz Nixdorf MuseumsForum

Paderborn Germany

Facts & Numbers

- 5,000 years – A “short” history of information technology
- 6,000 m² exhibition space / 2.500 guided tours p.a.
- Student labs / kids‘ lab
- Library and archive
- 7 conference rooms / 700 m² auditorium with 400 seats
- 42 employees
- Educational programs
- Cafeteria and restaurant with 240 seats
- 1000 events p.a.
- 120,000 – 140,000 visitors p.a.



Claude Shannon (1916 – 2001)

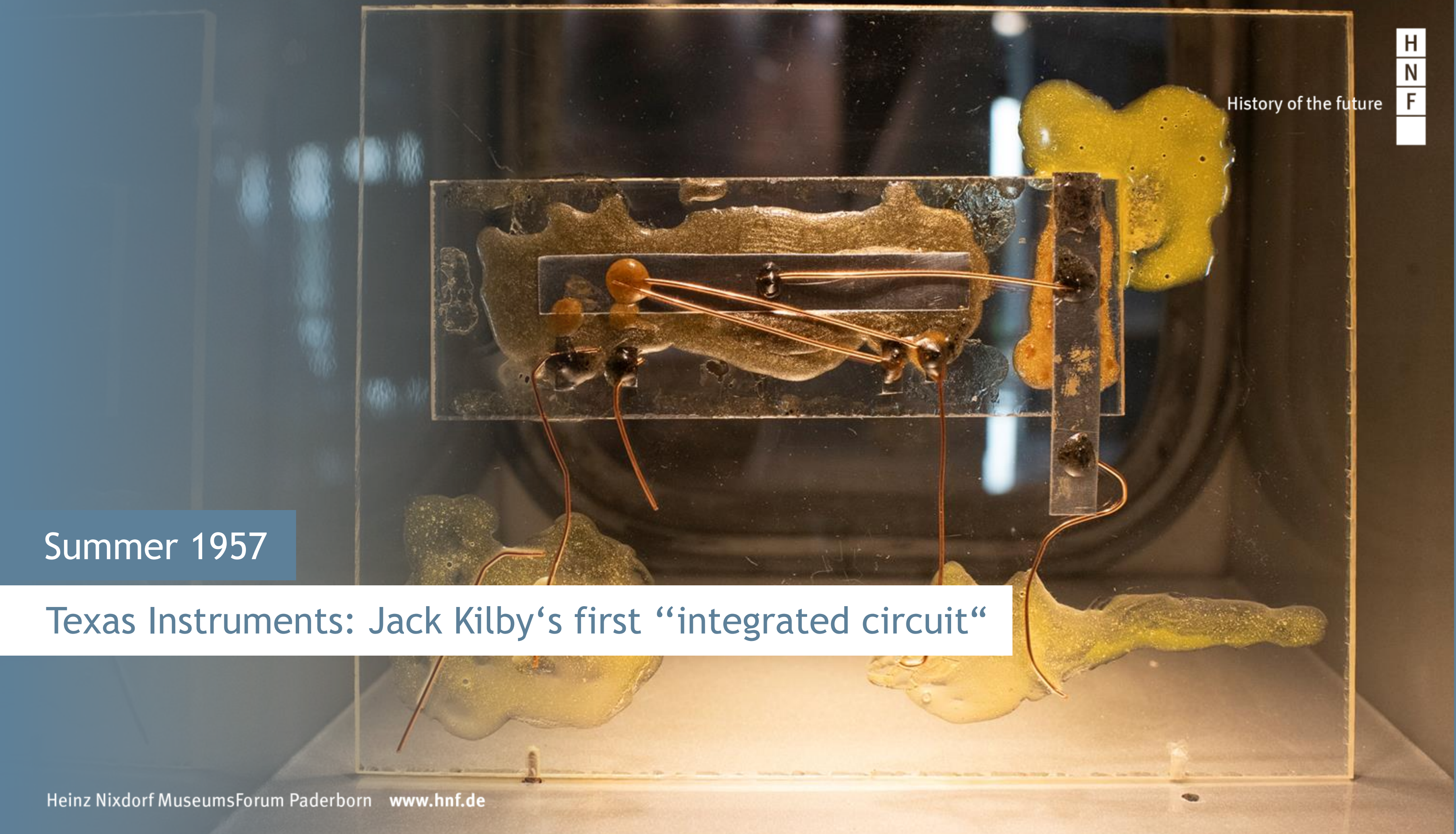
A Symbolic Analysis of Relay and Switching Circuits, MIT (1937)

Information theory (1948): new “digital drug“

ALL information should be digitally encoded!

First transistor demo: Bell Labs December 1947

John Bardeen, Walter Brattain, William Shockley

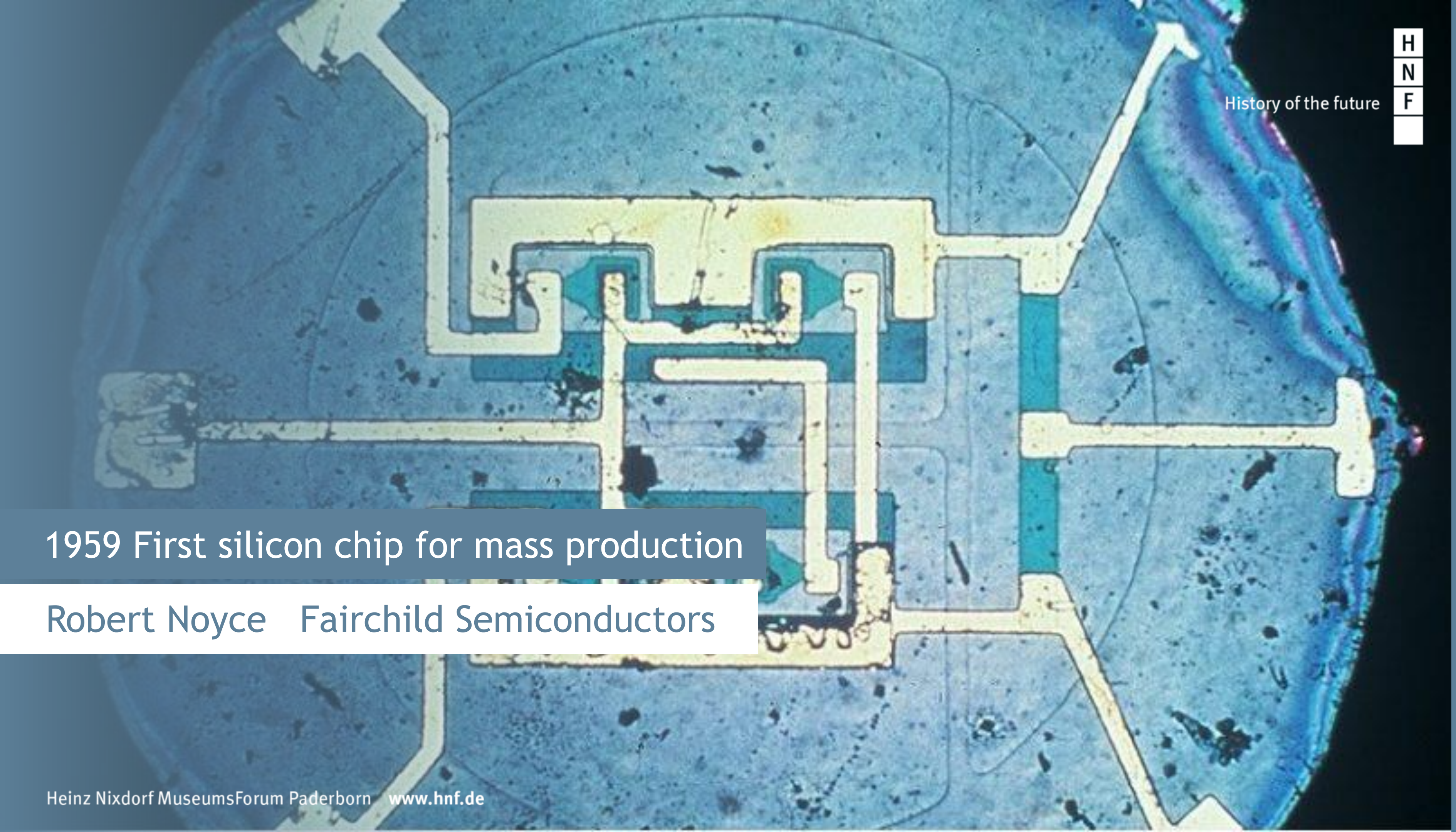


Summer 1957

Texas Instruments: Jack Kilby‘s first “integrated circuit“

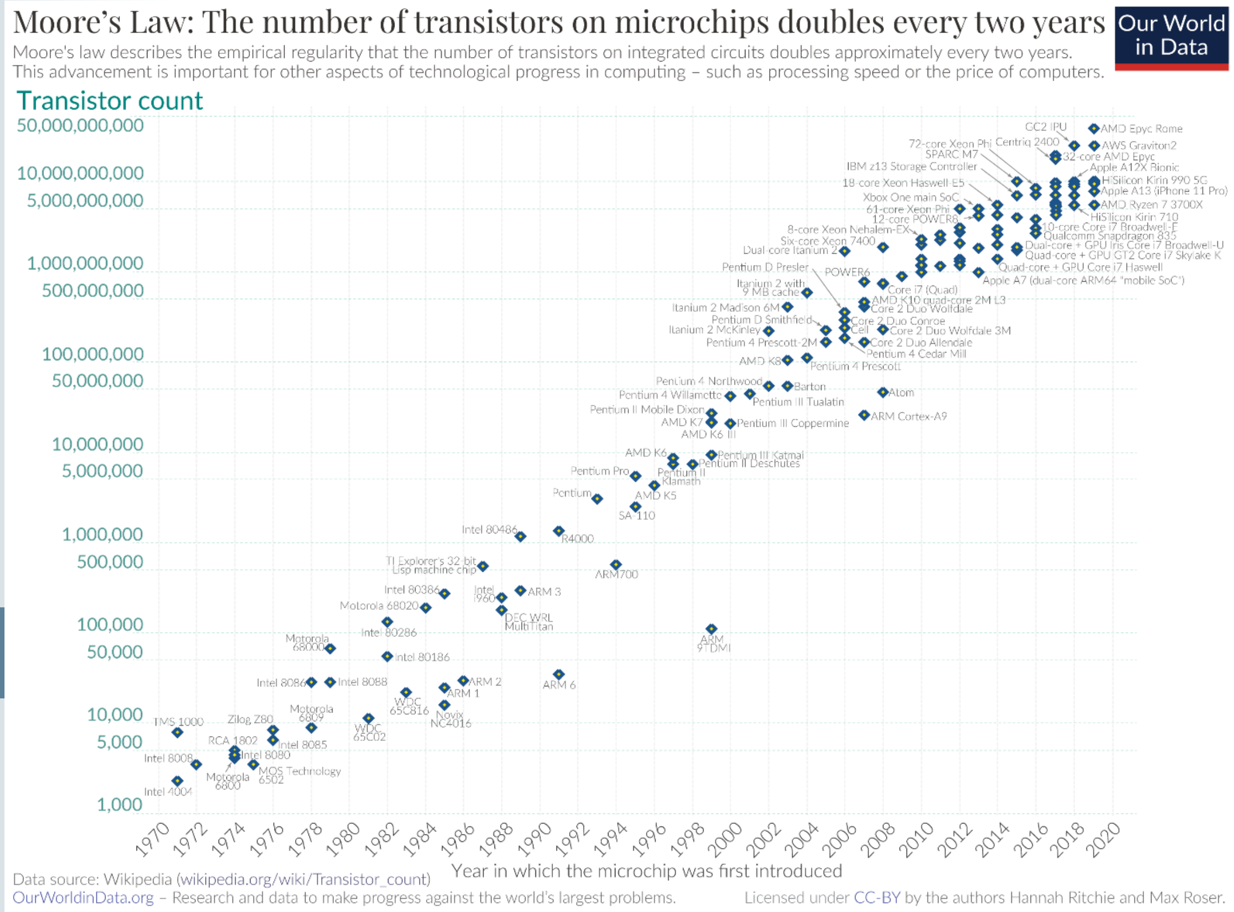
1959 First silicon chip for mass production

Robert Noyce   Fairchild Semiconductors

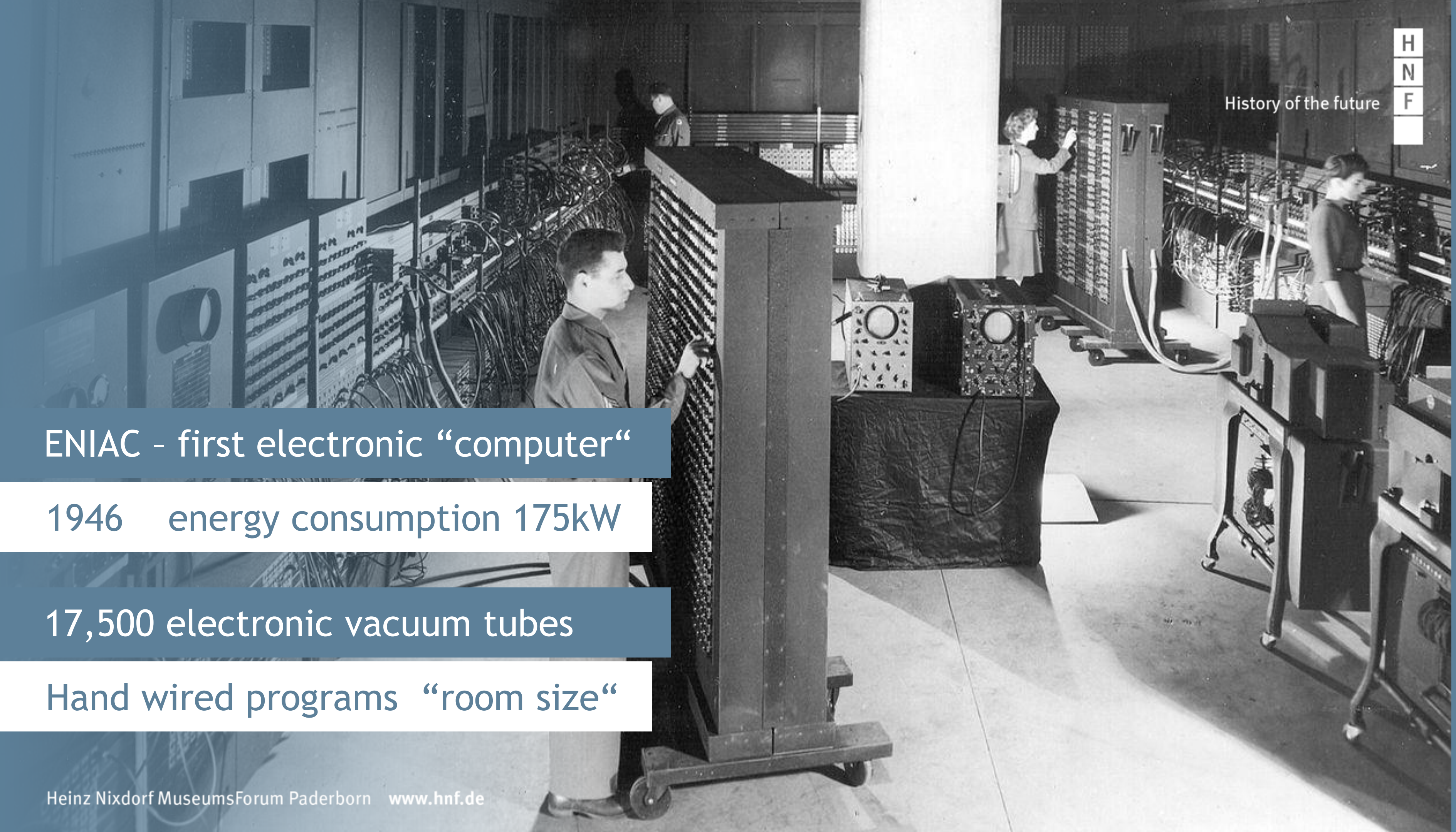


Gordon Moore INTEL

#Transistors double every 12/24 month (1965/1975)



Moore‘s Law 1965 - … ?



History of the future

ENIAC – first electronic “computer“

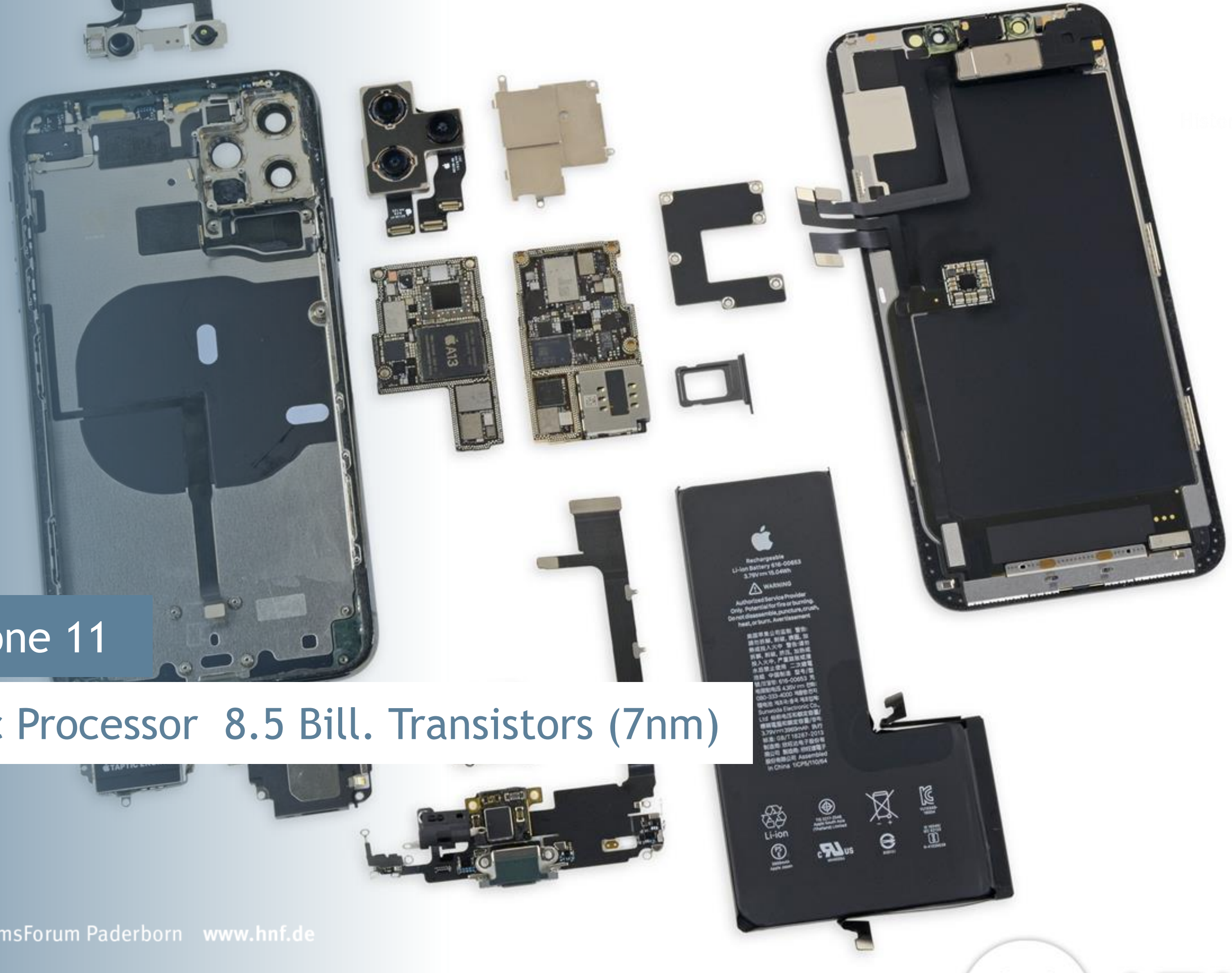
1946 energy consumption 175kW

17,500 electronic vacuum tubes

Hand wired programs “room size“

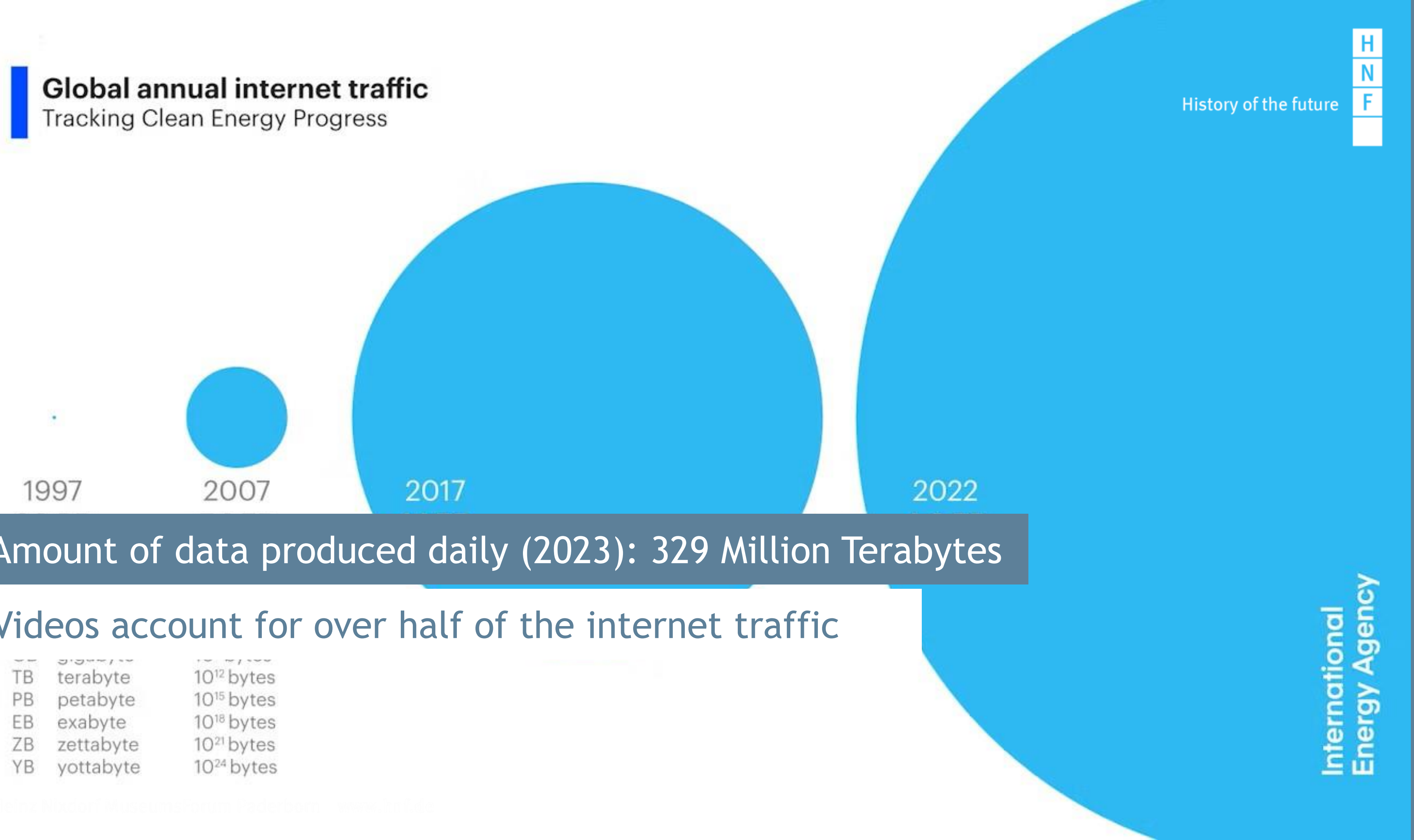
Apple iPhone 11

A13 Bionic Processor 8.5 Bill. Transistors (7nm)



Apple iPhone 11 with ENIAC tubes

Power consumption 175GW (17 Nuclear Power Plants)



History of the future

Amount of data produced daily (2023): 329 Million Terabytes

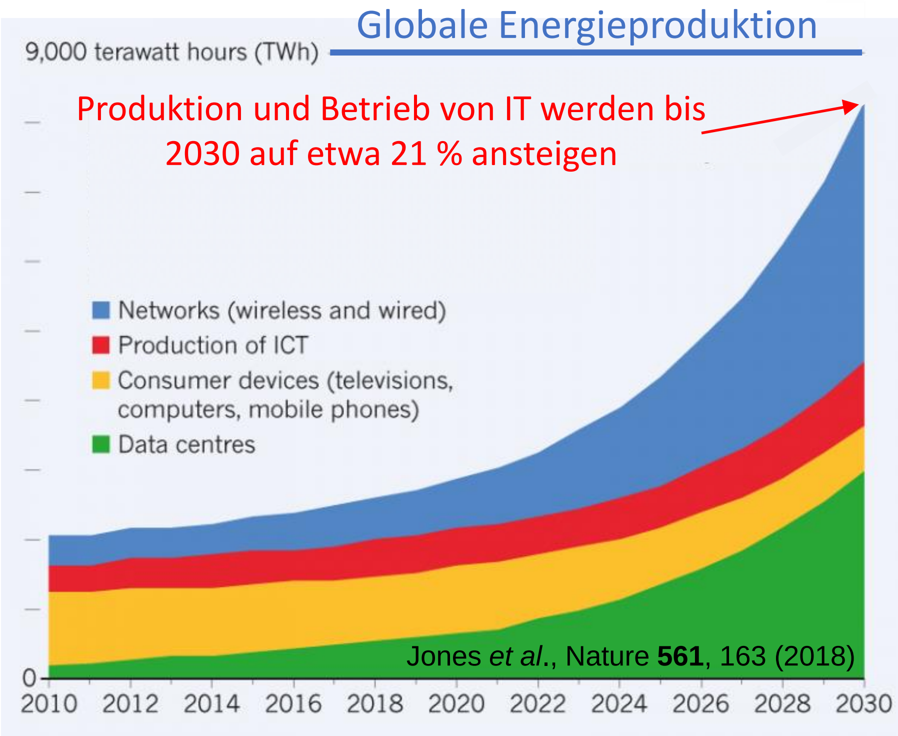
Videos account for over half of the internet traffic

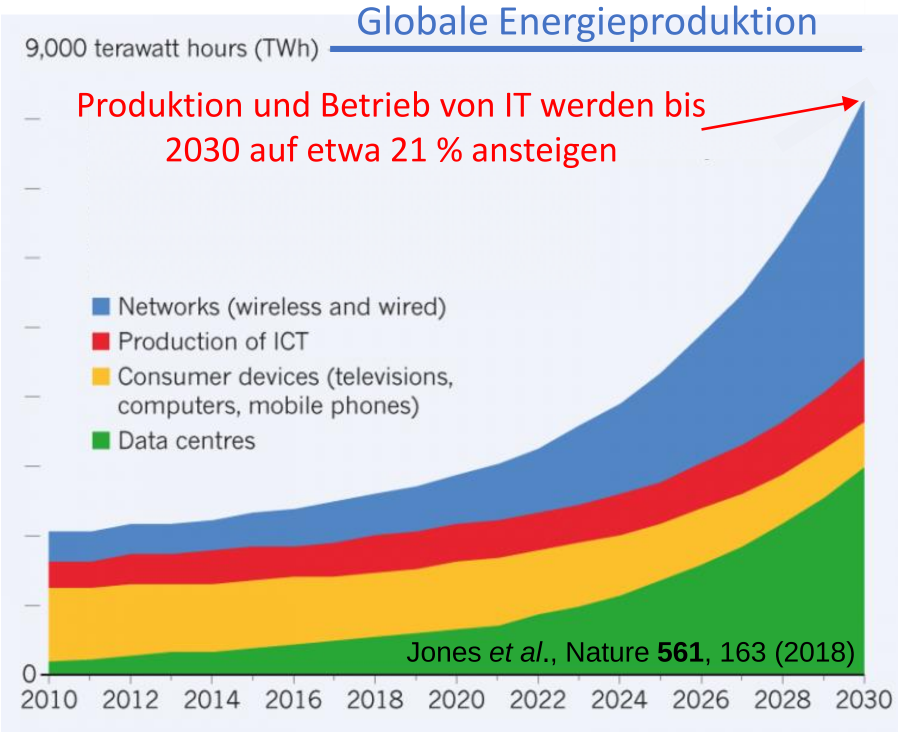
Prof. Martin Ziegler (2021 HNF talk)

70 Bill. kWh per year to run the internet

2022: daily 5 bill. people online

2022: > 7,500 data centers worldwide





Landauer-Limit (1961)

Bit-operation > 3 * 10^{-21} Joule

2037 Total energy production

worldwide needed for ICT sector

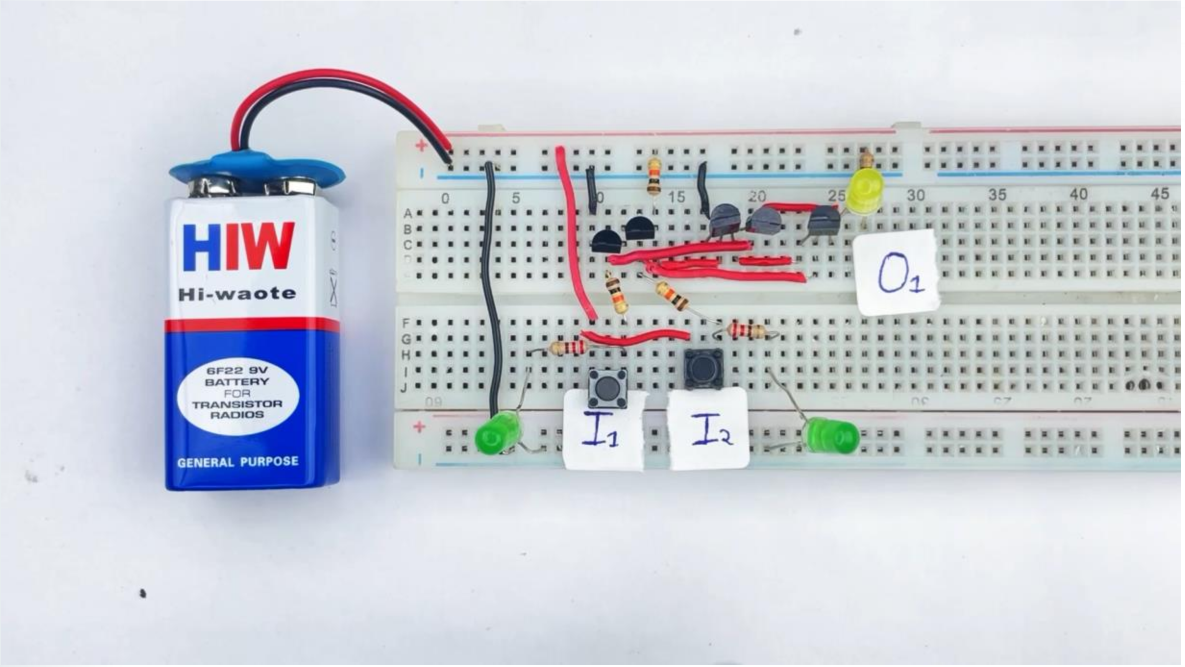
History of the future

We are not prepared for the end of Moore‘s Law

David Rotman MIT Tech Review February 2023

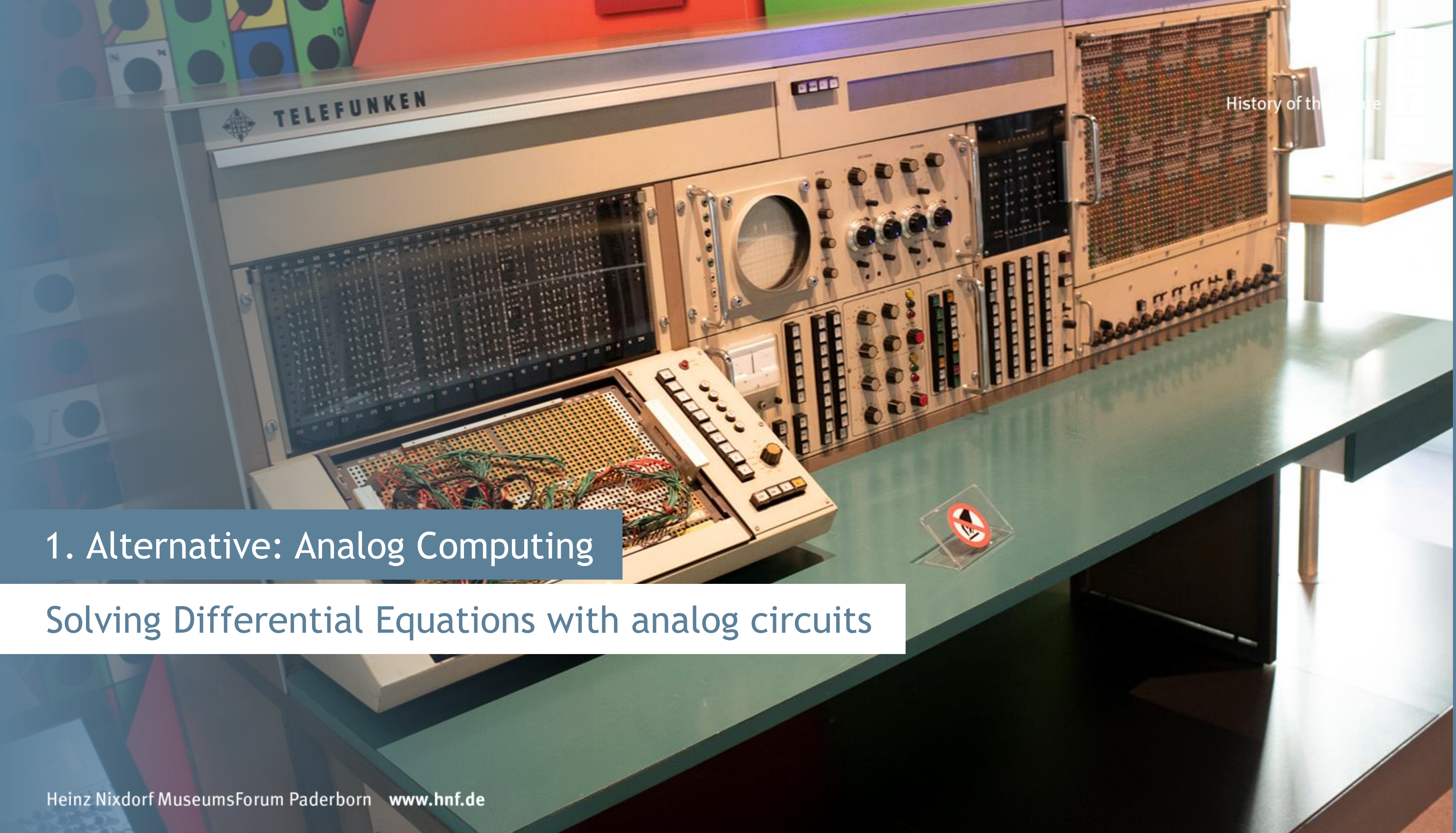
Boolean Math: XOR (⊕)

X	Y	X ⊕ Y
0	0	0
0	1	1
1	0	1
1	1	0



Logic gates: core elements for digital computers

XOR gate with 5 transistors



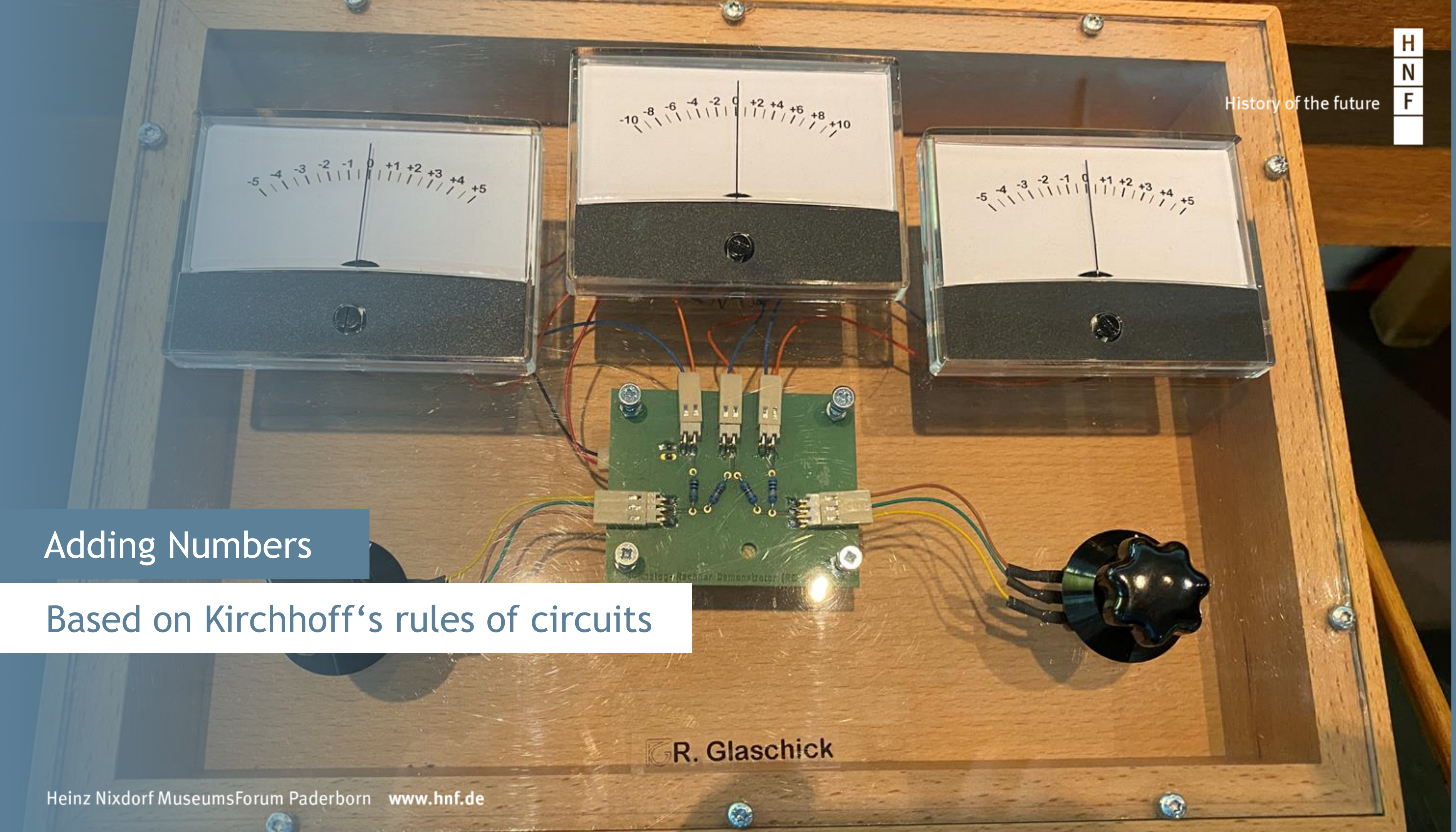
1. Alternative: Analog Computing

Solving Differential Equations with analog circuits

History of the future

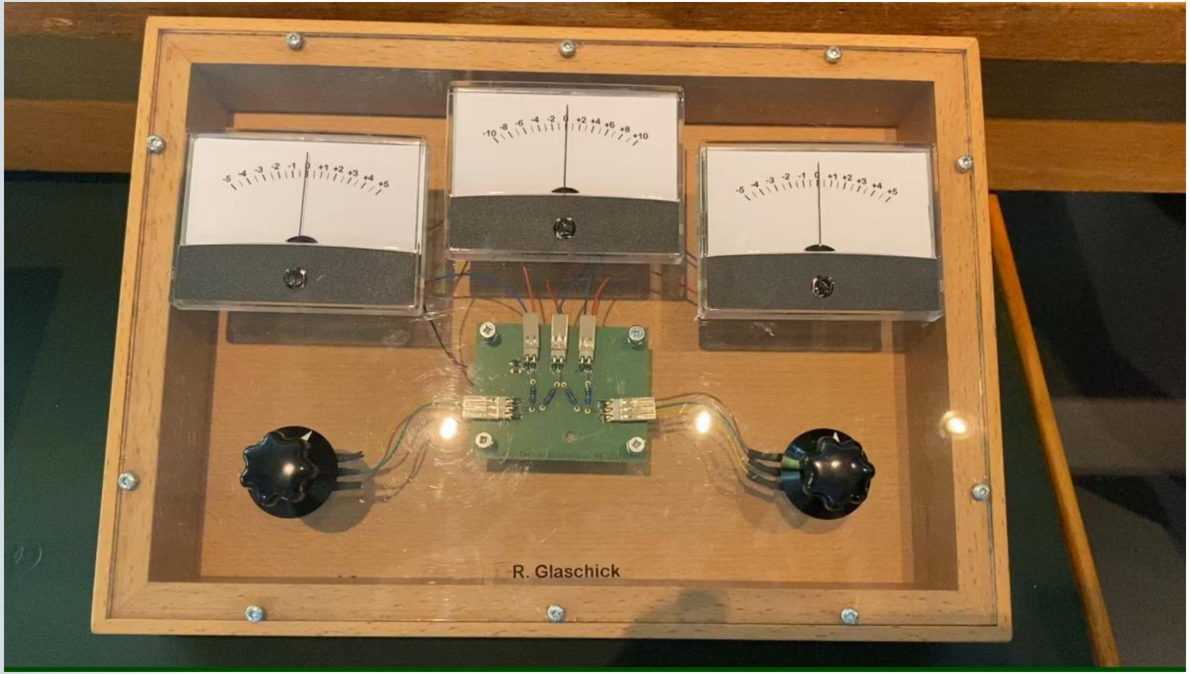
Analog Computing

Solving Differential Equations in Simulations



Adding Numbers

Based on Kirchhoff‘s rules of circuits

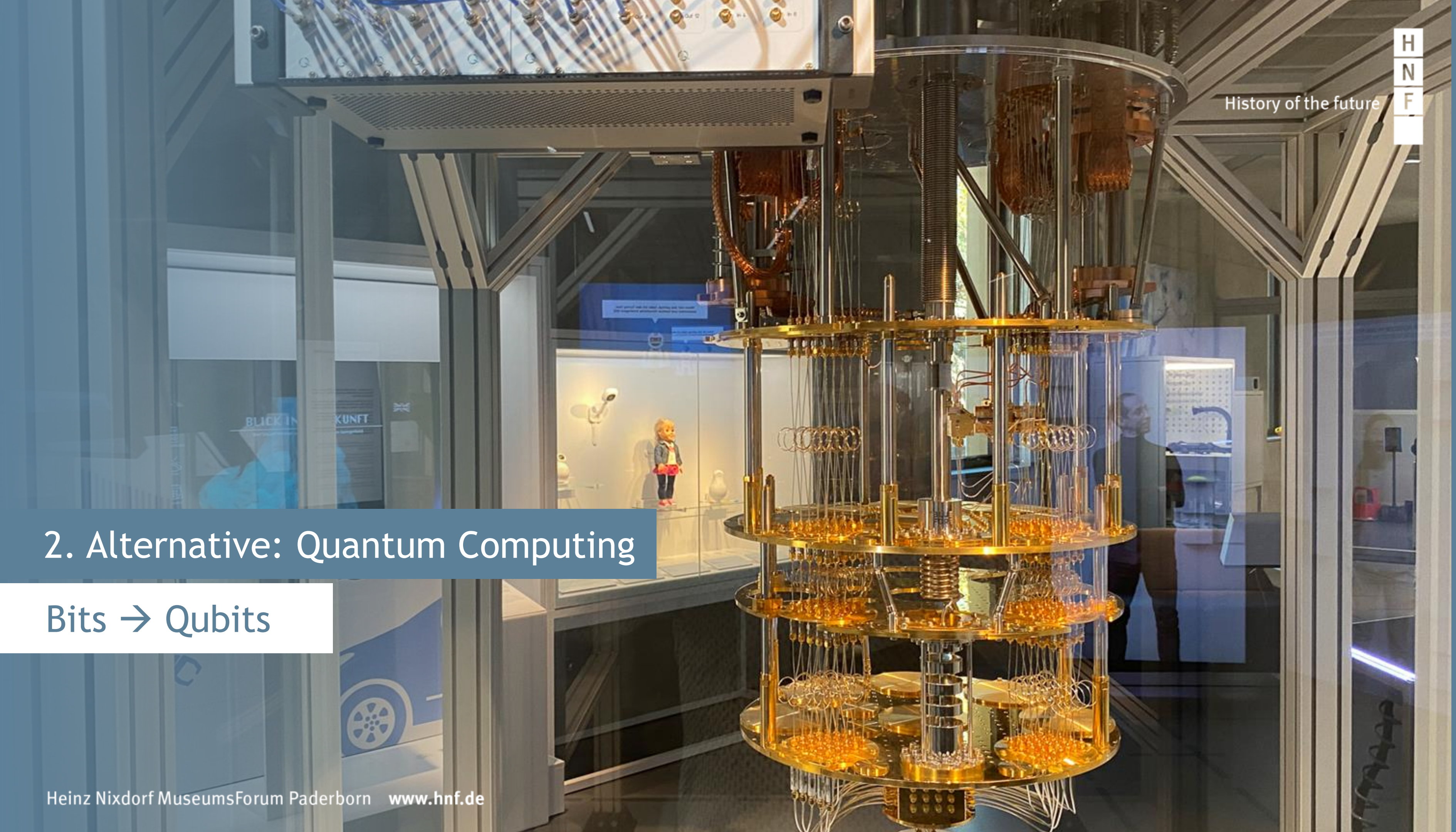


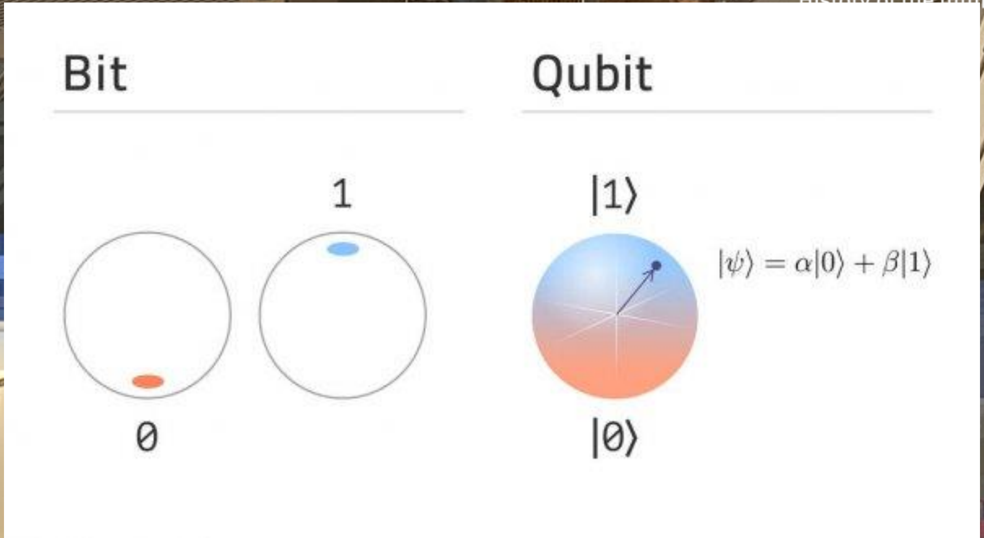
Adding Numbers

Based on Kirchhoff‘s rules of circuits

2. Alternative: Quantum Computing

Bits → Qubits



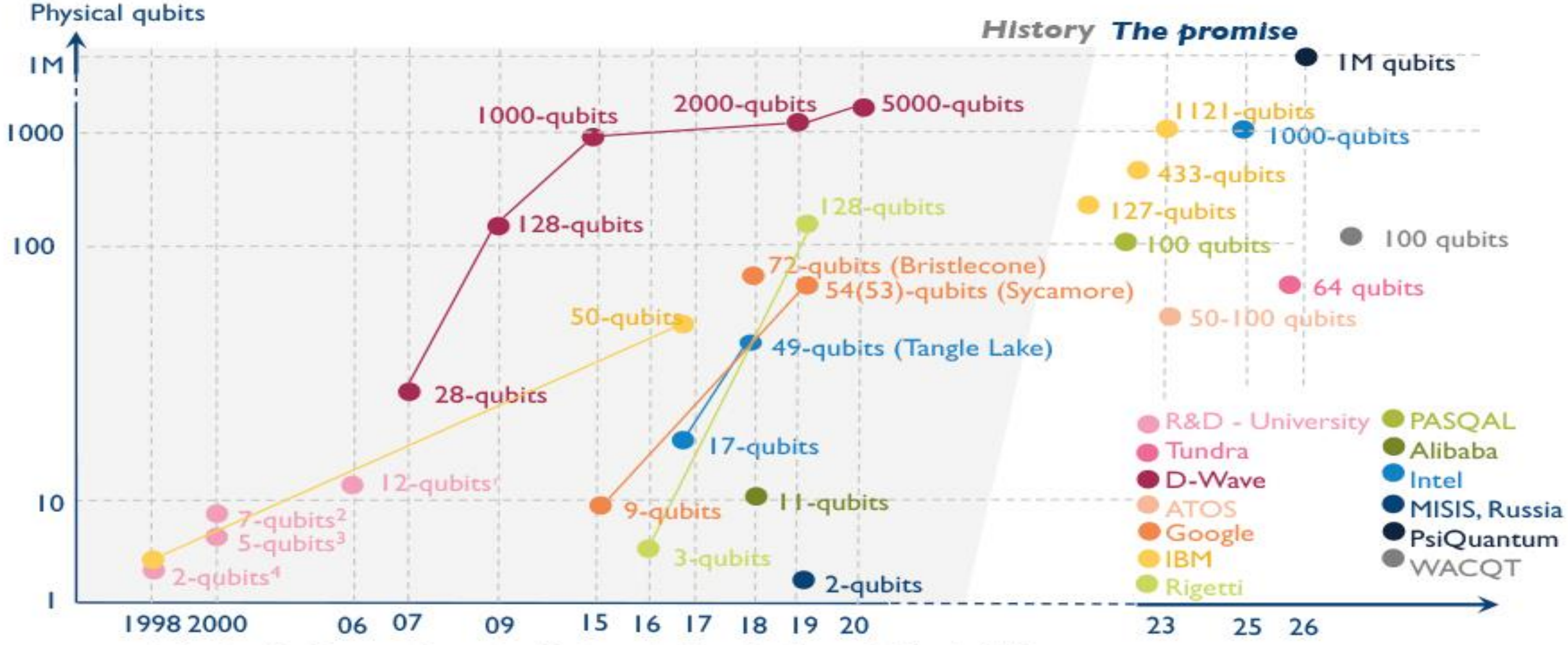


Complex problem solver

Cryptography, drug research, material sciences, machine learning

1998-2026 Physical qubit roadmap for quantum computer

(Source: Quantum Technologies 2021, Yole Développement, June 2021)



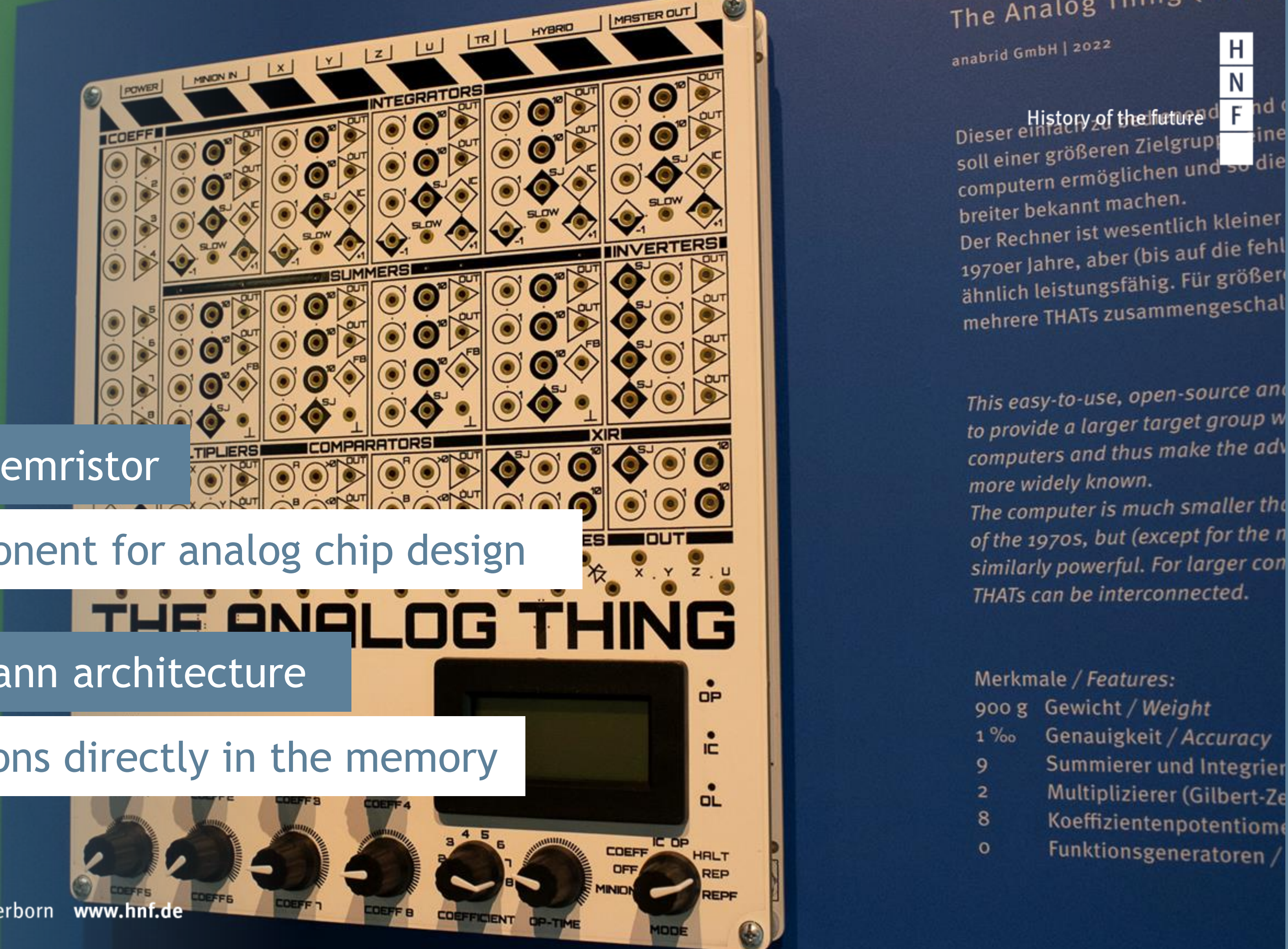
[1] (Institute for Quantum Computing, Perimeter Institute for Theoretical Physics, MIT)
[2] (Los Alamos National lab)
[3] (TU Munich)
[4] (Oxford University, IBM, UC Berkeley, Stanford, MIT)

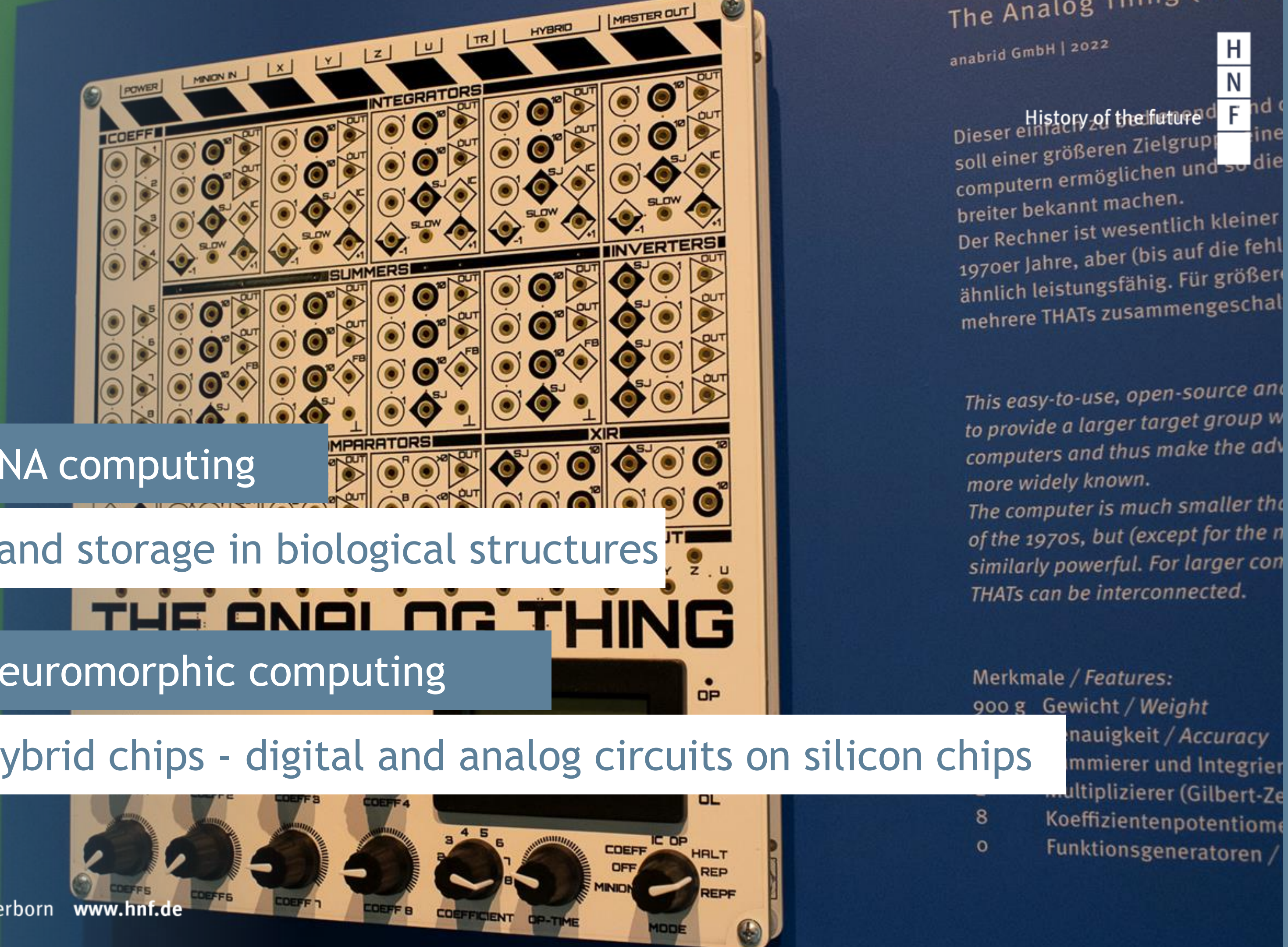
3. Alternative: Memristor

Electronic component for analog chip design

Avoid von-Neumann architecture

Do the calculations directly in the memory





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4. Alternative: DNA computing

Data processing and storage in biological structures

5. Alternative: neuromorphic computing

6. Alternative: hybrid chips - digital and analog circuits on silicon chips

Are we prepared for a digital world without Moore's law?

Can we learn from nature how to build more energy efficient computers?

Is transistor-based binary information processing holistic enough?

R. Feynman: The quantum world can only be simulated with quantum computers

Research on alternative computing is making rapid progress


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