Impact du numérique:
L’ordinateur comme outil de recherche

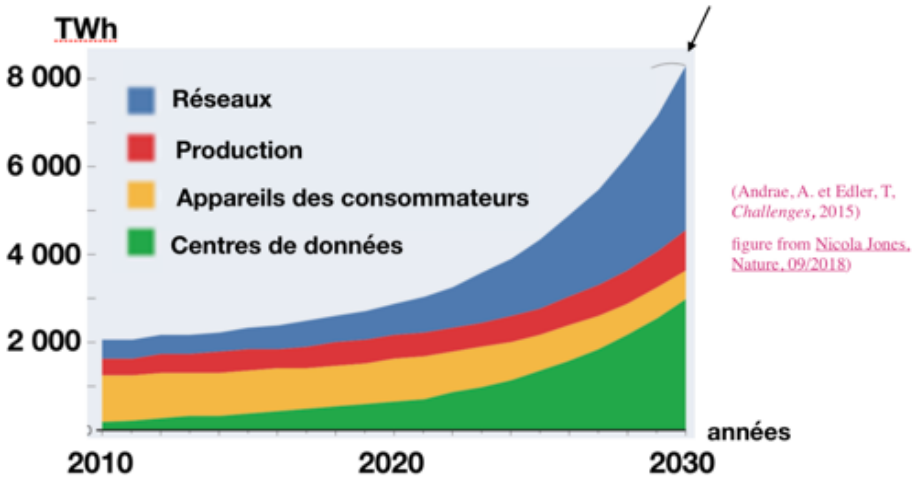
R. Everaers

ENS Lyon

Outline

La transition numérique

- Why do people use computers for calculations?
  - Evolution of Computational power
  - Disruption



(Andrae, A. et Edler, T, *Challenges*, 2015)

figure from Nicola Jones, Nature, 09/2018)

La transition écologique

- More efficient calculations?
  - The power efficiency of computers
  - Cooling and data centers
  - ENS Lyon
  - CPER CINAuRA
- Better calculations?
  - Algorithms
- Less calculations?

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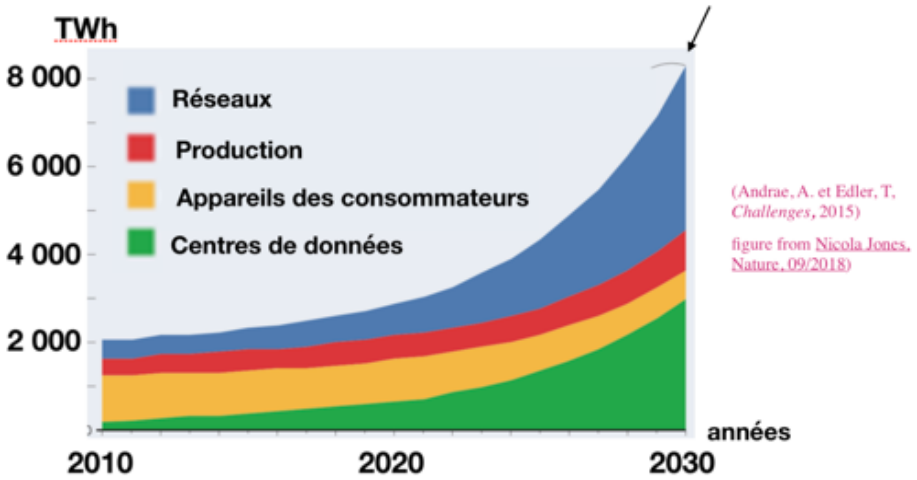

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Floating point operation

- How long does it take you to calculate
  - 1089.435671 x 78.09248173

ENIAC (~1950)

- 17,468 vacuum tubes
- 7200 crystal diodes
- 1500 relays
- 70,000 resistors
- 10,000 capacitors
- ~5,000,000 hand-soldered joints
- Size of 2.4 m × 0.9 m × 30 m
- occupied 167 m^2
- Weight of 27 t
- consumed 150 kW of electricity.

- A multiplication of a 10-digit number by a *d*-digit number (for *d* up to 10) took *d*+4 cycles, so a 10- by 10-digit multiplication took 14 cycles, or 2800 microseconds—**a rate of 357 per second**.

Cray Y-MP (~1990)

- gallium arsenide chips that were faster than silicon
- Liquid cooling
- Consumed 250 kW of electricity
- 2-8 vector processors
- Cycle time 8 nsec
- 333 Mflops per processor
- Memory 128-512 MB

Sunway TaihuLight

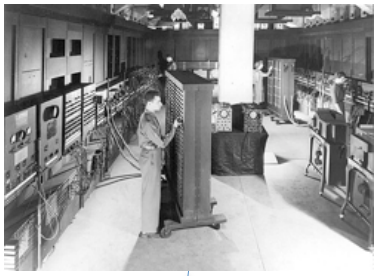
TOP 10 Sites for June 2016

For more information about the sites and systems in the list, click on the links or view the complete list.

Rank	Site	System	Cores	Rmax (TFlop/s)	Rpeak (TFlop/s)	Power (kW)
1	National Supercomputing Center in Wuxi China	Sunway TaihuLight - Sunway MPP, Sunway SW26010 260C 1.45GHz, Sunway NRCPC	10,649,600	93,014.6	125,435.9	15,371

https://www.top500.org

Moore’s “law”

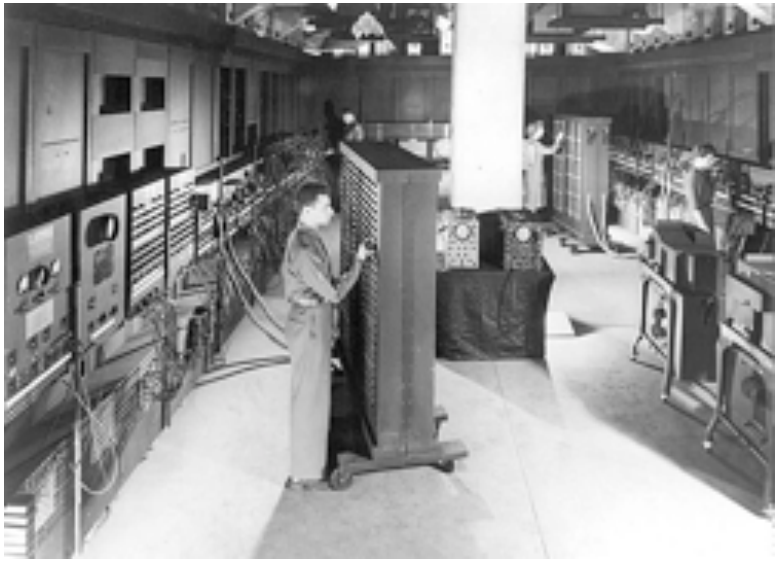


1950

1 Flop/s

Speed up

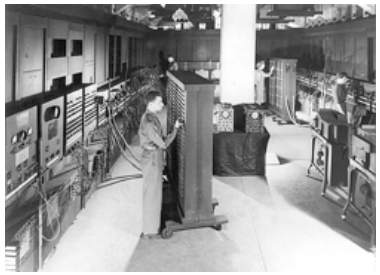
- 3 10^2 Flop/s



- 30000 times faster than human computers

Speed up

- 10^{17} Flop/s



- 10^{15} time faster than ENIAC
  - Needs 15 min to catch up with ENIAC, if ENIAC started the calculation at the Big Bang

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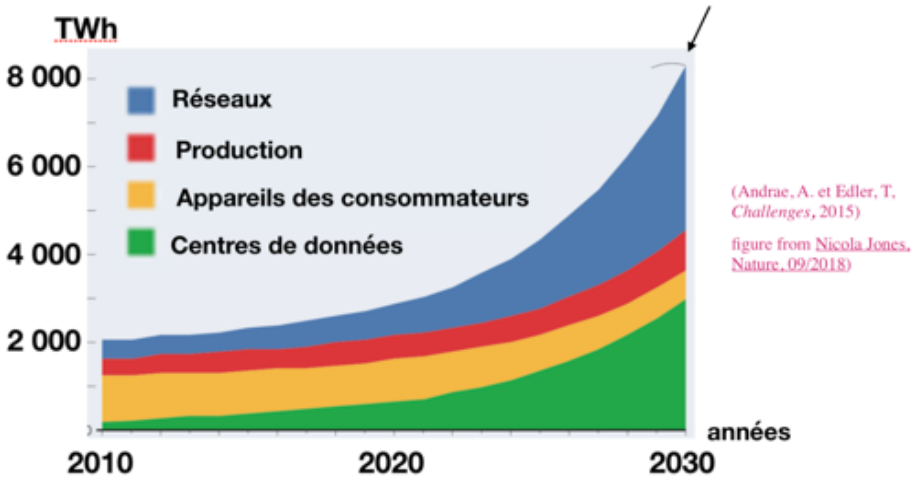

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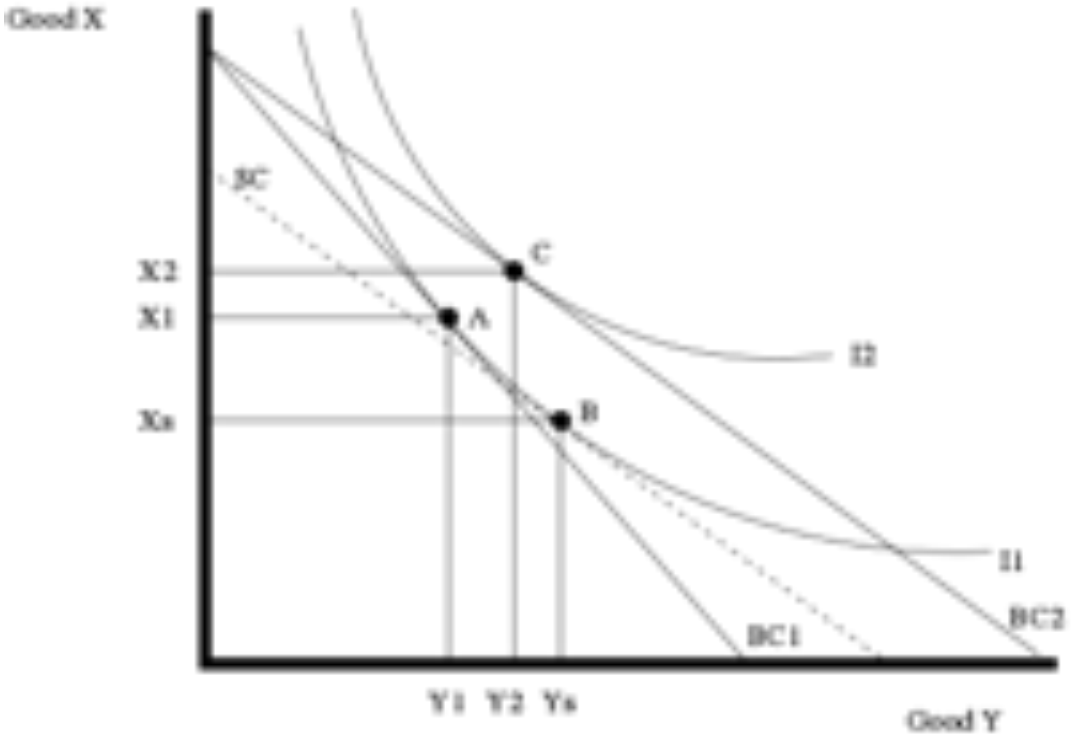
How much IT for Science?

- Better algorithms and faster computers
  - Bigger systems, longer runs, more data, more complexity…
- But is this necessary?
  - Or is computing just lazy thinking?
- How good is good enough?
  - State of the art
- Technological change is a driver of science
- Progress/improvements create demand

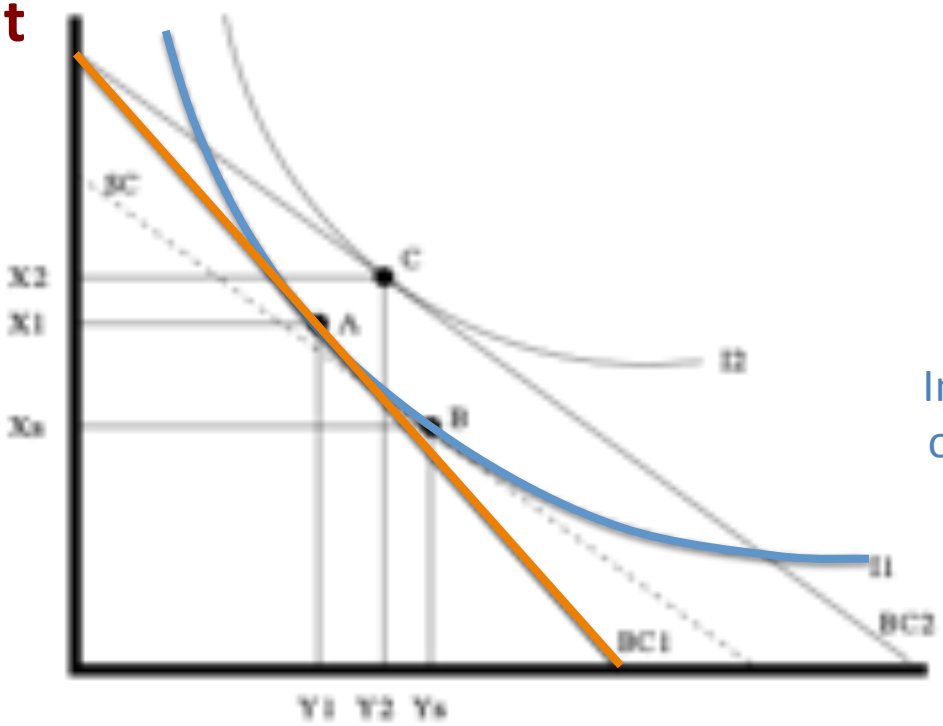
Substitution effects: Maximizing “utility” …



https://en.wikipedia.org/wiki/Substitution_effect

Substitution effects: Maximizing “utility” …

Experiment



Indifference curve of constant utility

Budget constraint

IT for Simulation and Data Analysis

https://en.wikipedia.org/wiki/Substitution_effect

Substitution effects

- Suppose
  - the lab/ENS/Ucible/CNRS spends 80% of its budget on experiments and 20% on calculations/data analysis/IT
  - the price of the IT drops by 50% at constant total budget
- Will we
  - Calculate as much as before and hence spend 90% on experiments and 10% on IT?
  - Double the amount of computation at constant budget?
  - Calculate even *more*, because the numerical tool has become relatively more powerful?

Substitution effects

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  - the lab/ENS/Ucible/CNRS spends 8[illegible]ts budget on experiments and 20% on calcul[illegible]ata analysis/IT
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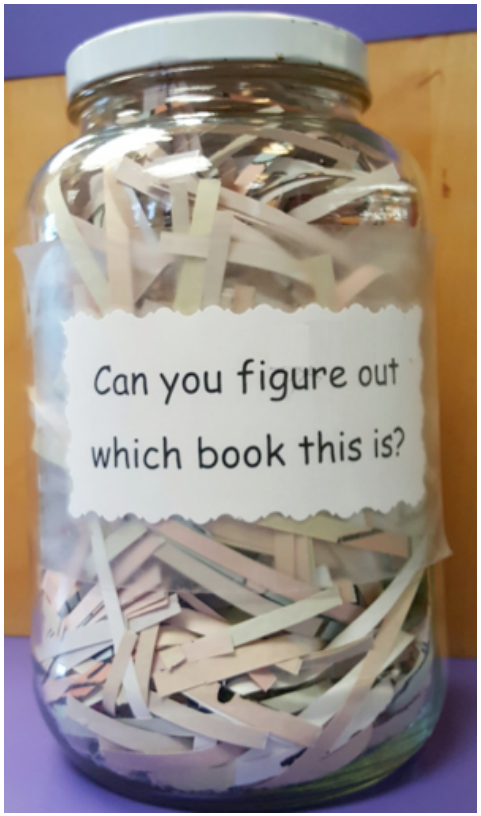
a factor of 10^{12}

Disruption

Svante Pääbo, MPI Leipzig

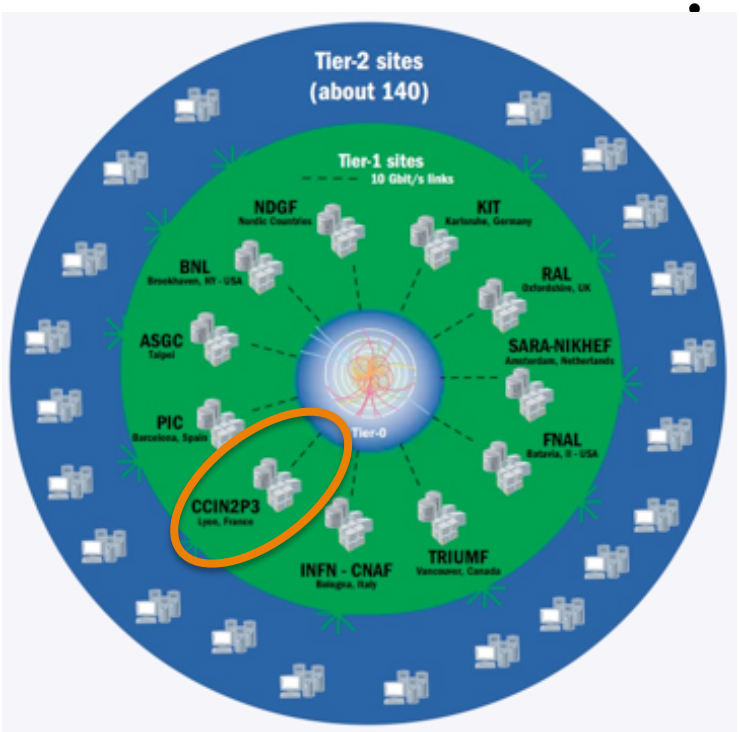
- High energy physics

- DNA sequencing



Worldwide LHC Computing Grid

https://en.wikipedia.org/wiki/Worldwide_LHC_Computing_Grid



- The data stream from the detectors provides approximately 300 GByte/s of data, which after filtering for "interesting events", results in a data stream of about 300 MByte/s. The CERN computer center, considered "Tier 0" of the LHC Computing Grid, has a dedicated 10 Gbit/s connection to the counting room.

  The project was expected to generate 27 TB of raw data per day, plus 10 TB of "event summary data", which represents the output of calculations done by the CPU farm at the CERN data center.

  This data is sent out from CERN to thirteen Tier 1 academic institutions in Europe, Asia, and North America[12], via dedicated links with 10 Gbit/s or higher of bandwidth.
- More than 150 Tier 2 institutions are connected to the Tier 1 institutions.
- The data produced by the LHC on all of its distributed computing grid is expected to add up to 10–15 PB of data each year.[15]

AI / machine learning

- The next big thing …

PSMN

PÔLE SCIENTIFIQUE DE MODÉLISATION NUMÉRIQUE

Mésocentre de Calcul

- Lyon
  - **PSMN 12000 cœurs**
  - FLMSN +7000 cœurs
- Toulouse
  - Calmip 15 000 cœurs
- Normandie
  - CRIANN 10 000 cœurs
- Grenoble
  - CIMENT 7000 cœurs
- Strasbourg
  - 5400 cœurs
- Bordeaux
  - 4000 cœurs
- Reims
  - Romeo 3000 cœurs
- Aix-Marseille
  - 3000 cœurs