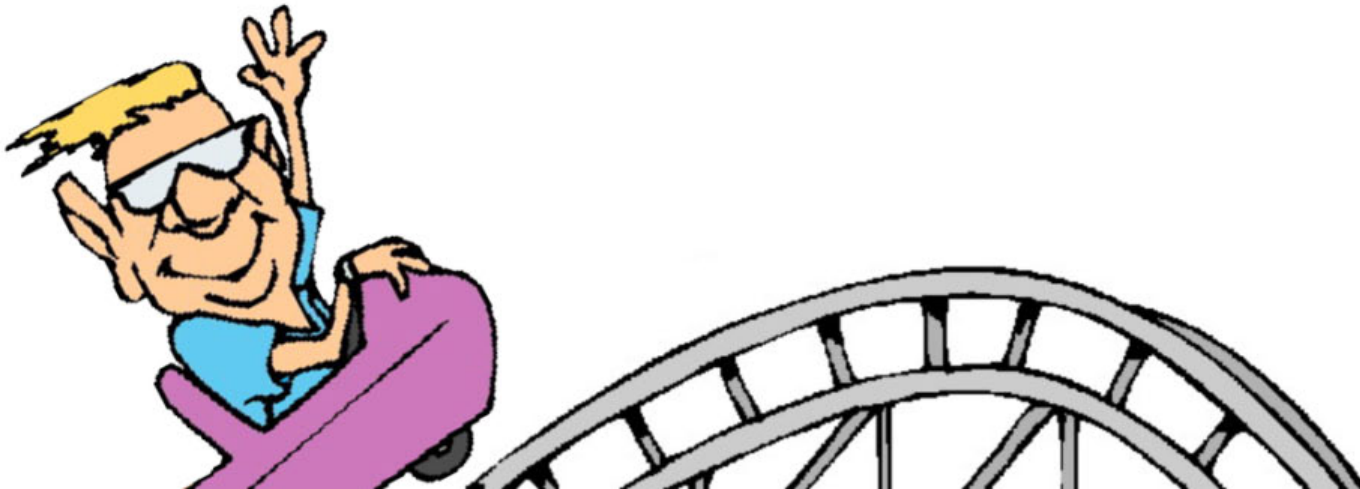


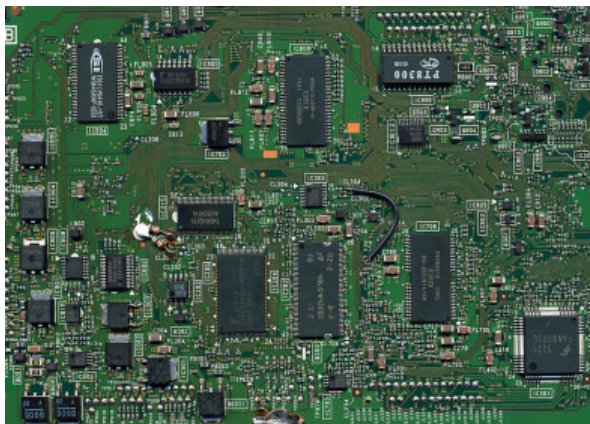
Moore's Law





Gordon Moore on a fishing trip in 2004
Steve Jurvetson. Menlo Park, USA
Wikipedia

In 1965, Gordon Moore,
the co-founder
of Intel and Fairchild Semiconductor,
predicted that
the number of components
on an integrated circuit
would double each year
for at least another decade.

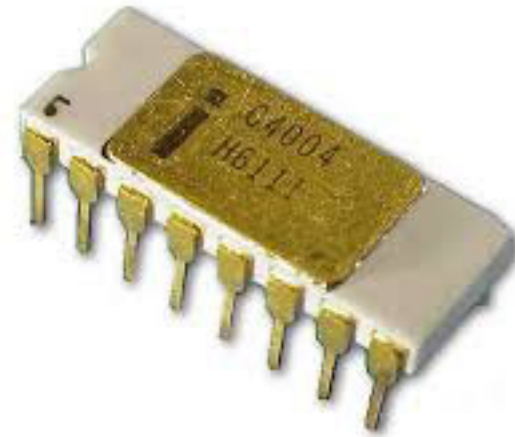
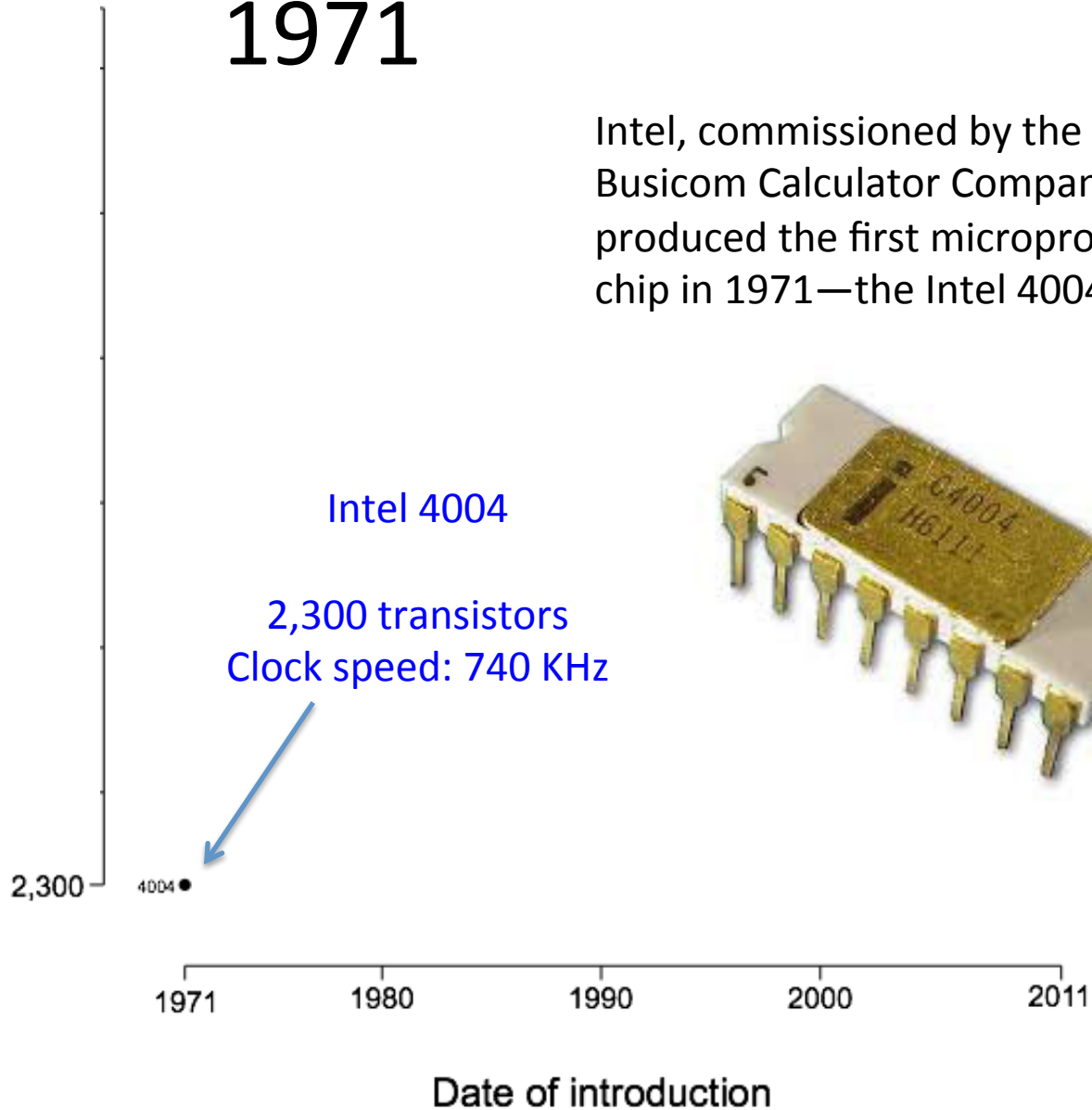


Integrated Circuits on a circuit board
<http://imagegator.net/circuit-board-art-images>

1971

Intel, commissioned by the Busicom Calculator Company, produced the first microprocessor chip in 1971—the Intel 4004

Transistor count



Over the next decade,
microprocessor production ramped up
and a plethora of digital devices,
including, the first personal computers
were brought to market:

- 1971 Busicom Electronic Calculator;
- 1972 Hamilton Pulsar Digital Watch;
- 1975 Atari Home Pong Video Game; Altair 880 PC, (S-100 bus);

In 1975,
Gordon Moore
revised his forecast to
doubling every two years
for the next decade.

1977 Apple II; Commodore PET; Tandy TRS-80;

1978 Atari 400/800, Texas Instruments Speak and Spell.

1979

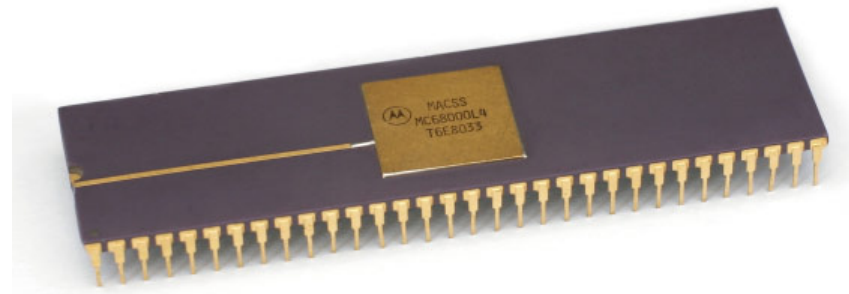
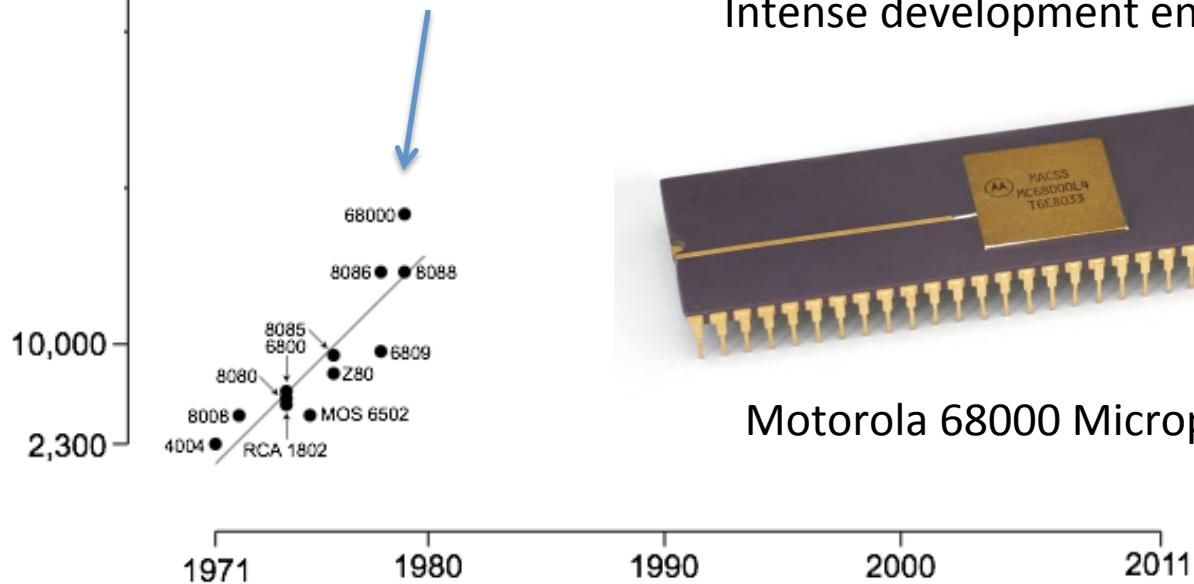
Motorola 68000
40,000 transistors.
20 MHz max clock speed.
Introduced 1979,
still in production.

US Microprocessor Production Companies burst into existence:

- Intel
- Motorola
- Texas Instruments
- Fairchild
- Zilog
- National Semiconductor

Intense development ensued.

Transistor count



Motorola 68000 Microprocessor

Date of introduction

Digital device developers lapped up the new chips:

- 1980 Sinclair ZX80;
Nintendo Handheld Video Games;
Commodore VIC-20;
the first folding laptop PCs;
- 1981 IBM-PC; Texas Instruments TI-99;
- 1982 Osborne Executive Portable PC,
Commodore 64;
- 1984 Apple Macintosh;
- 1985 Commodore Amiga.



By today's standards, the early PCs were primitive.



An Osborne Executive portable computer (1982) with a Zilog Z80 4 MHz CPU

an Apple iPhone (2007) with an ARM11 412 MHz CPU

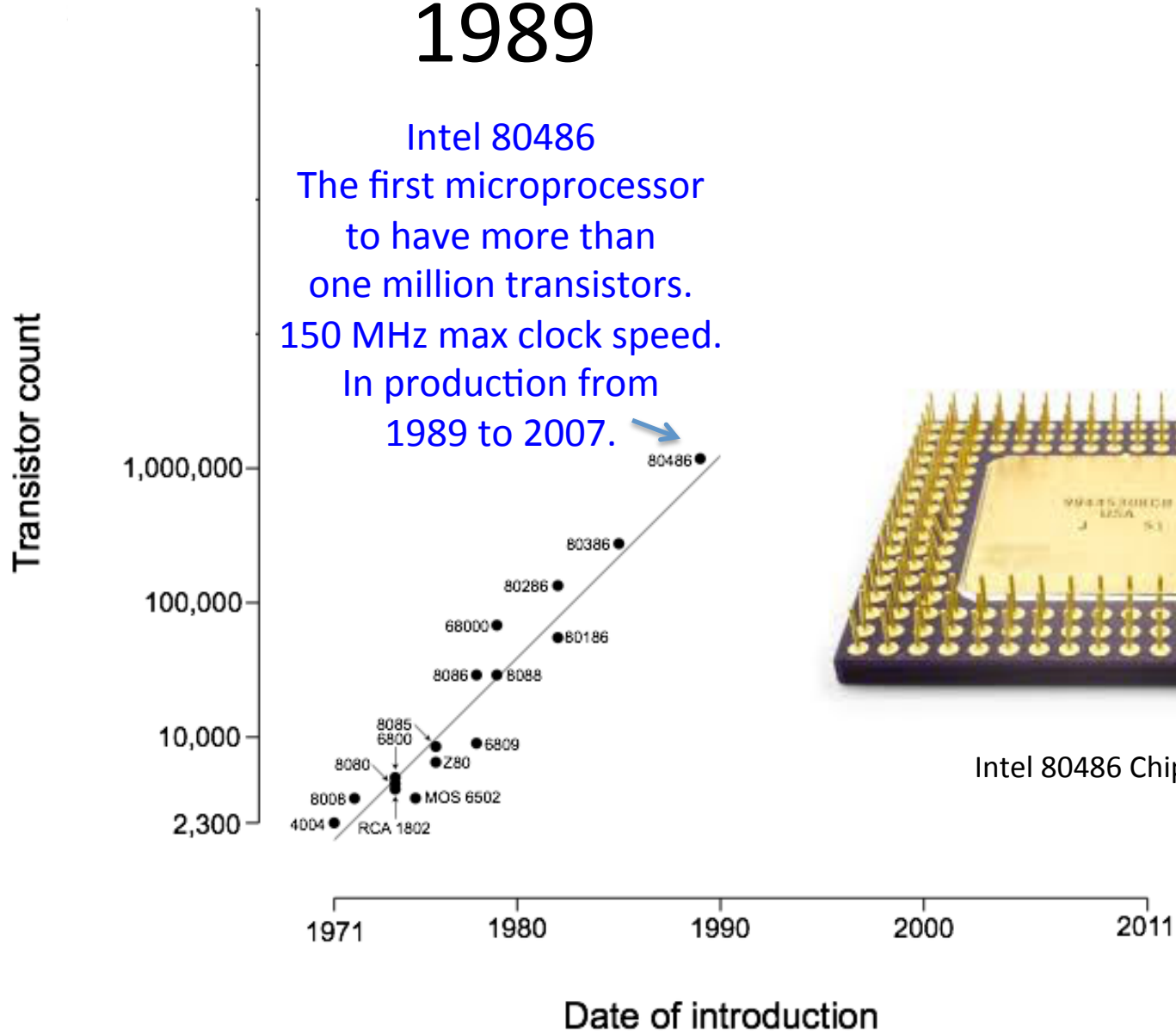
The Executive:

- weighed 100 times as much;
- occupied nearly 500 times the volume;
- cost approximately 10 times as much (inflation adjusted);
- and had a clock frequency 100 times slower than the smartphone's.

1989

Intel 80486

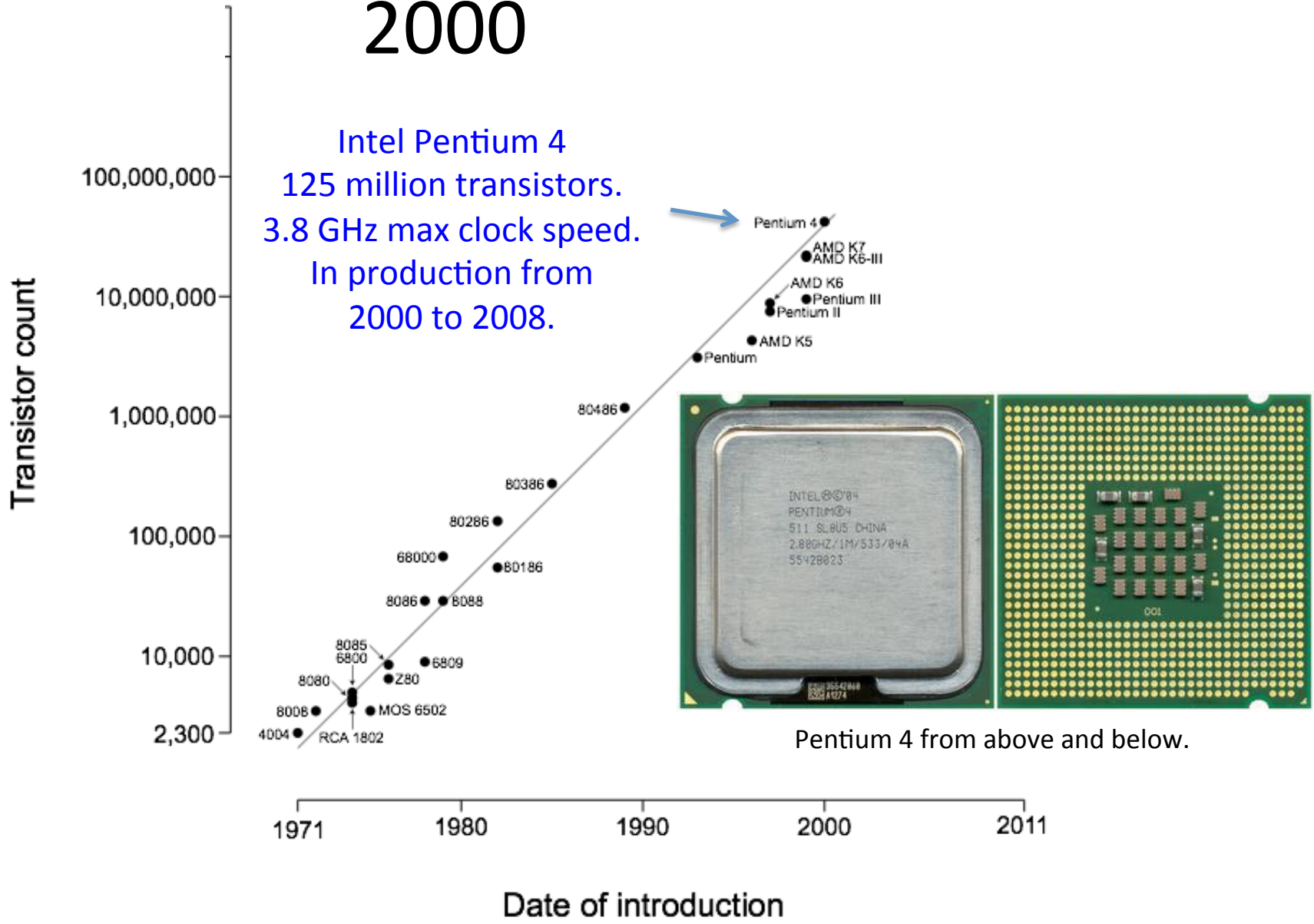
The first microprocessor to have more than one million transistors.
150 MHz max clock speed.
In production from 1989 to 2007.



Intel 80486 Chip

2000

Intel Pentium 4
125 million transistors.
3.8 GHz max clock speed.
In production from
2000 to 2008.



Pentium 4 from above and below.

What are the limits?

As the cost of computer power to consumers falls,
the cost for producers rises.

Moore's second law, also called Rock's law,
was formulated in response to
rising cost of production:
*the capital cost of a semiconductor fab
increases exponentially over time.*

When will Moore's law collide with Rock's law
and progress cease?

Moore was also aware that exponential expansion can't continue forever. Exponentially expanding systems eventually collapse under their own weight.

Moore was also aware that transistor miniaturization would eventually reach the atomic level.

Krauss and Starkman announced in their 2004 paper
an ultimate limit
that will be reached in approximately 600 years.

They based their prediction on a rigorous estimation
of the total information-processing capacity
of any system in the Universe
which is limited by the
Bekenstein bound.

The Bekenstein bound, a Physics concept, denotes an upper limit on the entropy or information that can be contained within a given finite region of space which has a finite amount of energy—or conversely, the maximum amount of information required to perfectly describe a given physical system down to the quantum level.

Others argue we have nearly reached the limit.

Kaku (2011) and Kumar (2012) for example, in papers based on quantum theory and the laws of thermodynamics, predict that Moore's law will collapse in the next 20 to 40 years.

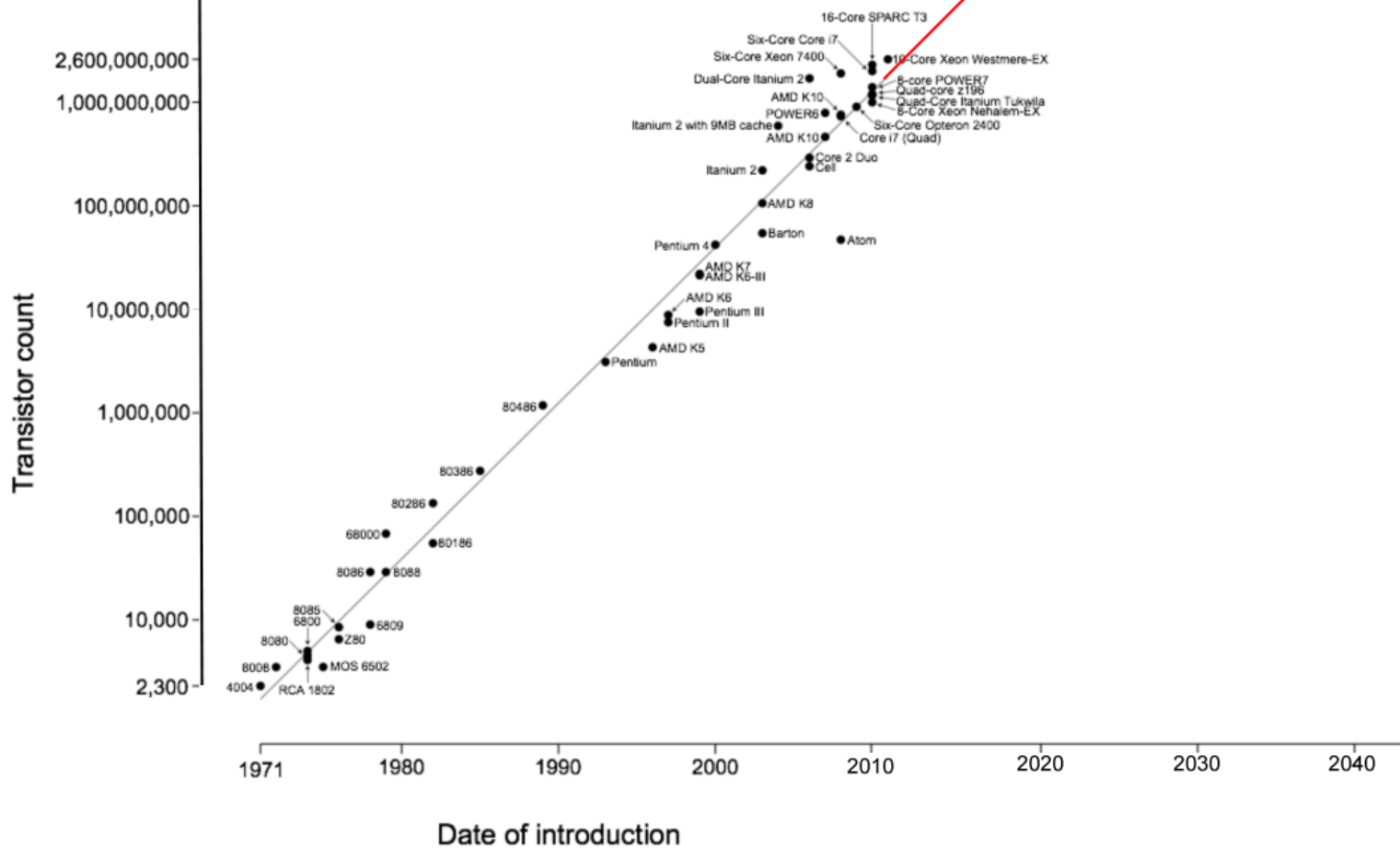
Moore's law has often met obstacles that at first appeared insurmountable, but were indeed surmounted soon afterwards.

Moore says he now sees his law as more beautiful than he had realized:

"Moore's law is a violation of Murphy's law. Everything gets better and better."

Transistor counts will continue to double at two-year intervals for the next twenty to forty years...

...and perhaps for the next 600 years.



Wherever the limit lies, of this we can be sure:

over the course of our lives,
microprocessors and integrated circuits
will continue to get denser and faster.

Computers, tablets, phones, and media devices
will become more and more powerful
and do more and more things.

The devices we have today will look primitive
when we look back in ten years time
and devices we have not dreamed of
will then be commonplace.

The relentless pace of the digital revolution
is showing no signs of slowing down.

Enjoy the ride if you can!



Sources

Wikipedia Articles:

- Moore's Law
- Bekenstein Bound
- Intel 4004
- Motorola 68000
- Intel 80486
- Intel Pentium 4
- History of Personal Computers

Gordon Moore Photo

Steve Jurvetson (Wikipedia)

Moore's Law Graph

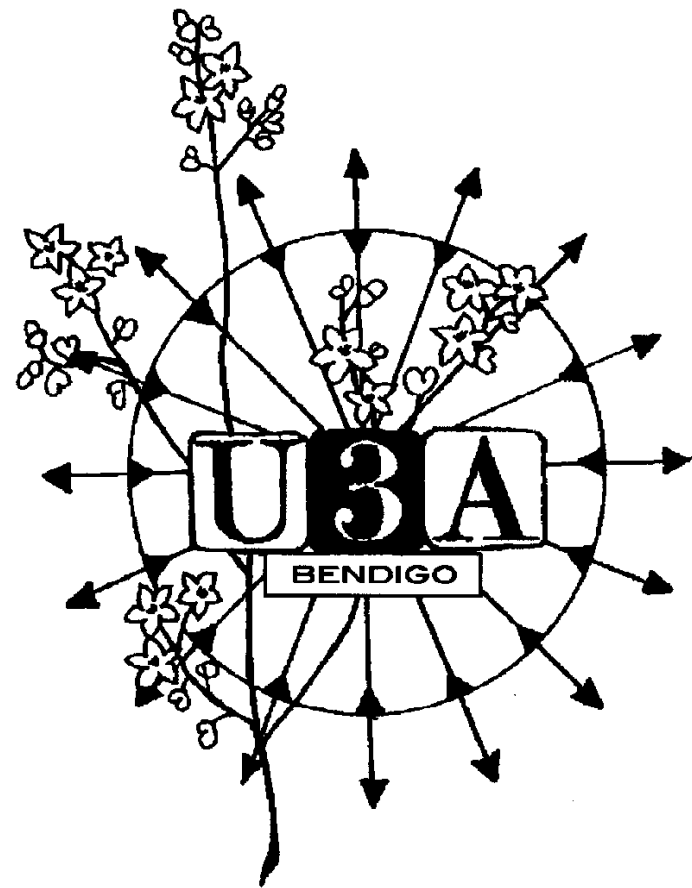
Wgsimon (Wikipedia)

Roller Coaster Graphic

www.clipartpanda.com

Microprocessor images

various websites



Michael Gallagher

U3A Bendigo

Technology Advisory Group Convener

20th November 2015