Parallel Programming:
Moore's Law and Multicore

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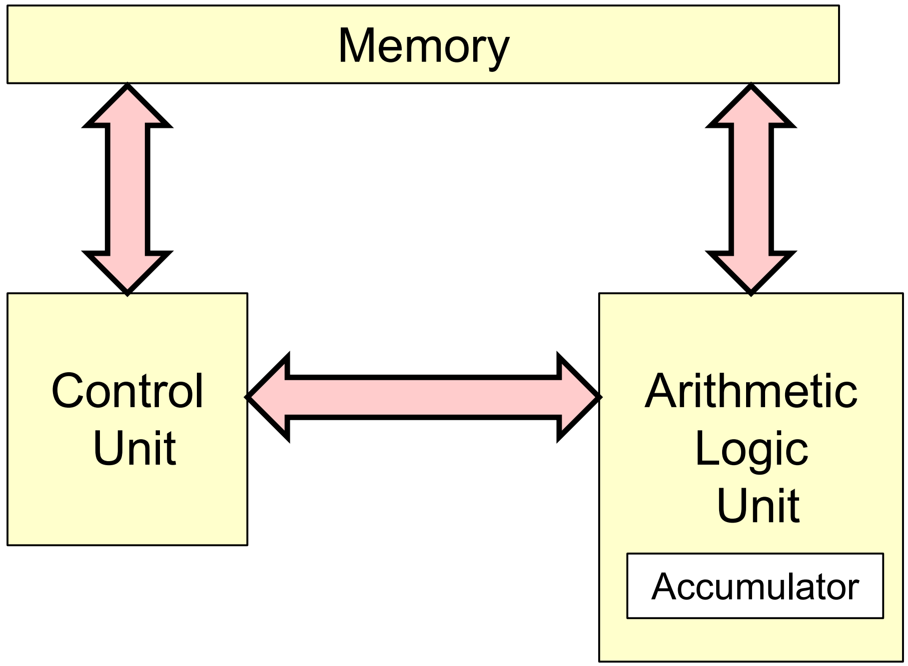
Von Neumann Architecture: Basically the fundamental pieces of a CPU have not changed since the 1960s



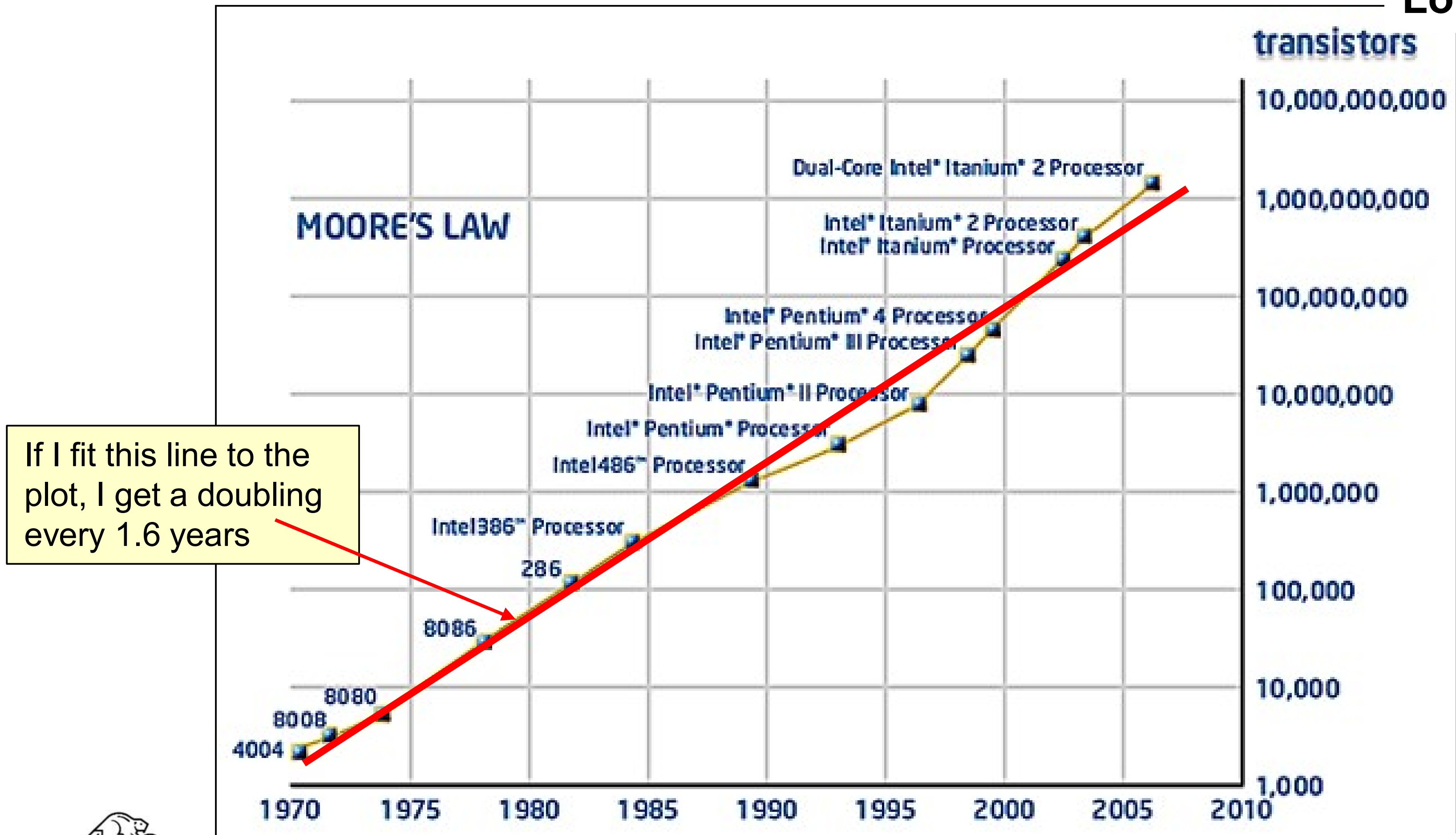
Other elements:

- **Clock**
- Registers
- Program counter
- Stack pointer

Increasing Transistor Density -- Moore's Law

"Transistor density doubles every 1.5 years."

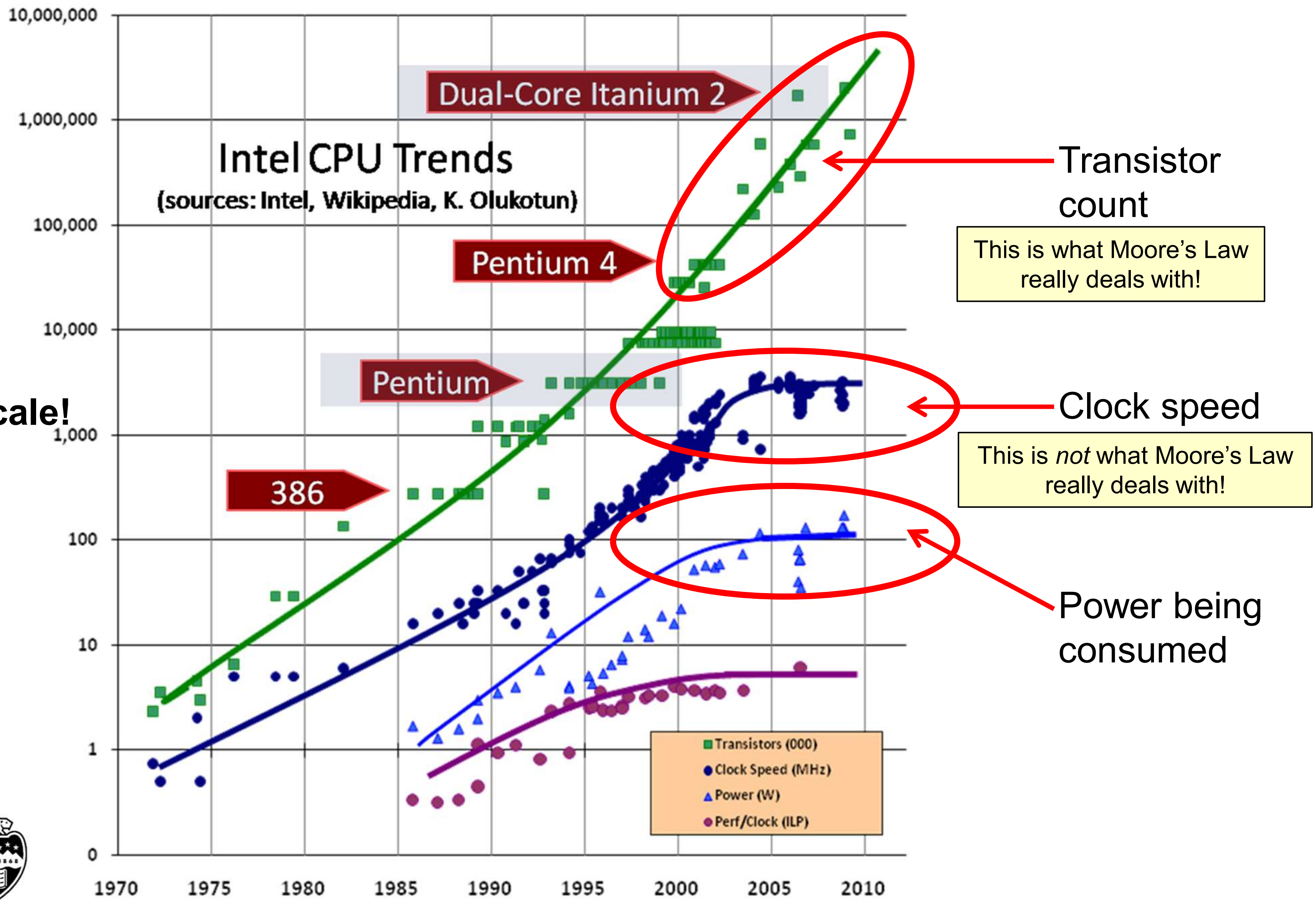
Note:
Log scale!



Source: http://www.intel.com/technology/mooreslaw/index.htm

Oftentimes people have (*incorrectly*) equivalenced this to:
"Clock speed doubles every 1.5 years."

Increasing Clock Speed?



Note:
Log scale!

Source: Intel

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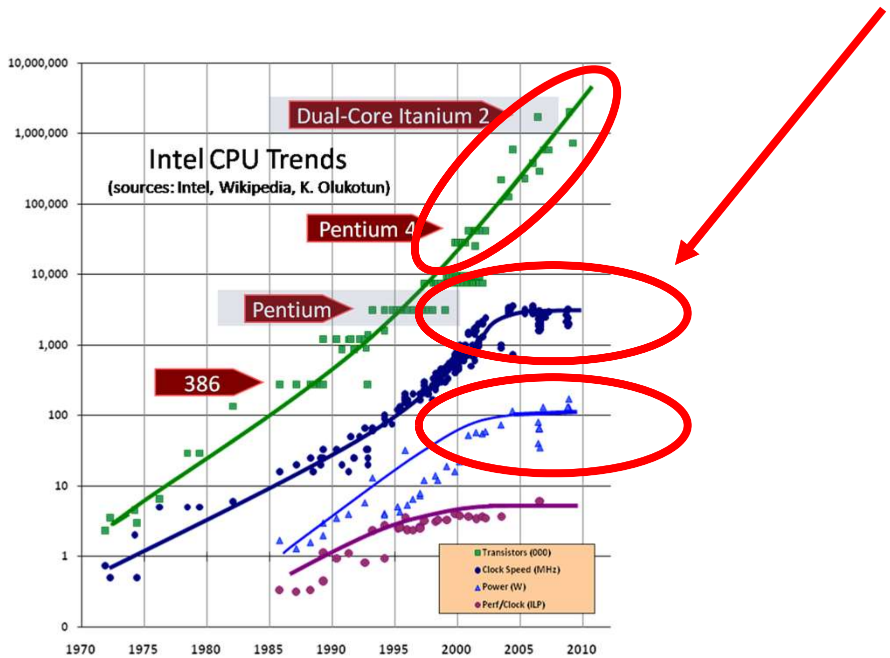
Moore's Law

- Fabrication process size ("gate pitch") has fallen from 65 nm, to 45 nm, to 32 nm, to 22 nm, to 16 nm, to 11 nm, to 8 nm. This translates to more transistors on the same size die.

- From 1986 to 2002, processor performance increased an average of 52%/year, but then virtually plateaued.



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Clock Speed and Power Consumption

1981	IBM PC	5 MHz
1995	Pentium	100 MHz
2002	Pentium 4	3000 MHz (3 GHz)
2007		3800 MHz (3.8 GHz)
2009		4000 MHz (4.0 GHz)

Clock speed has hit a plateau, largely because of power consumption and power dissipation.

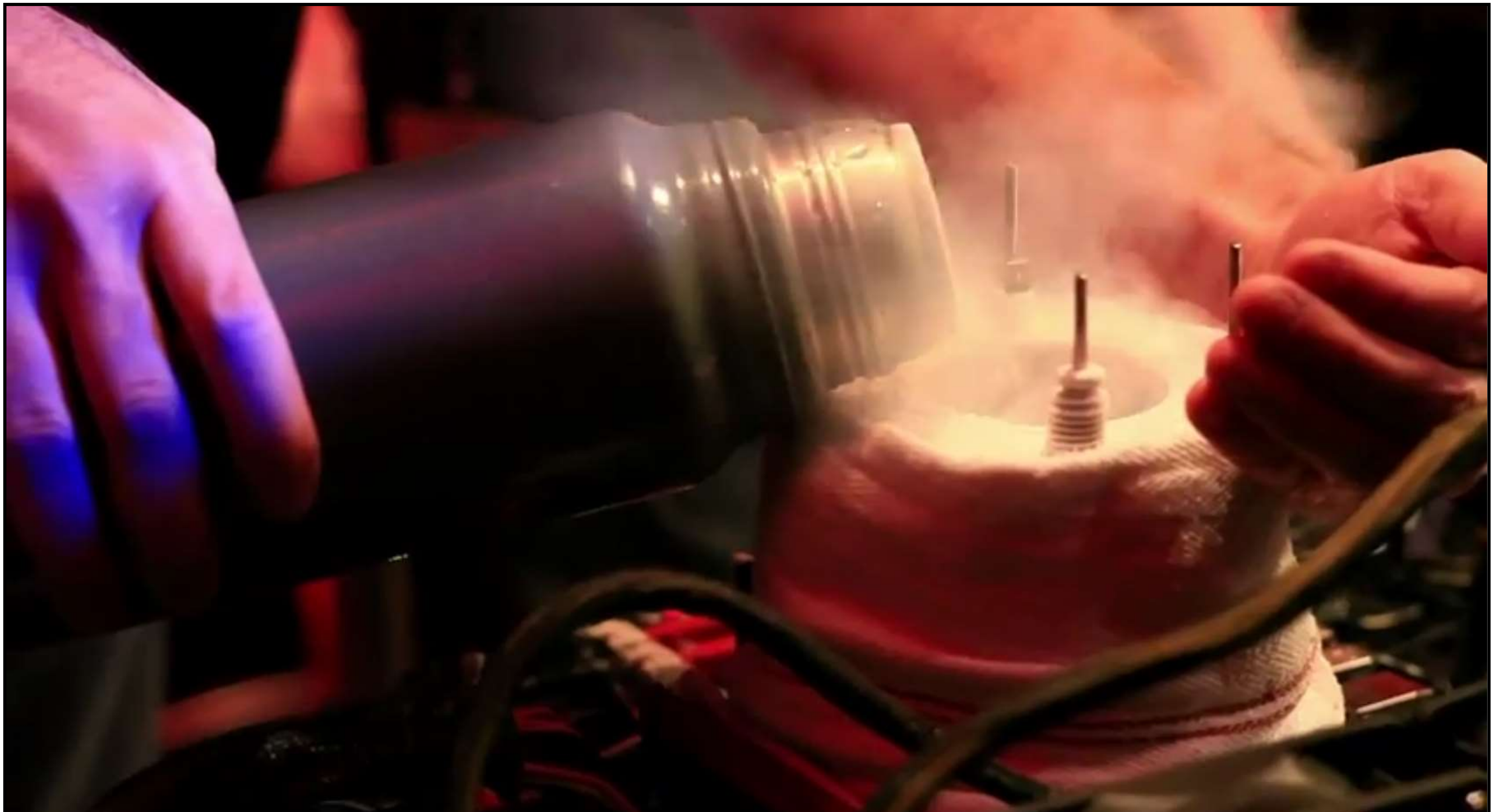
$$PowerConsumption \propto ClockSpeed^2$$

Yikes!

is-proportional-to

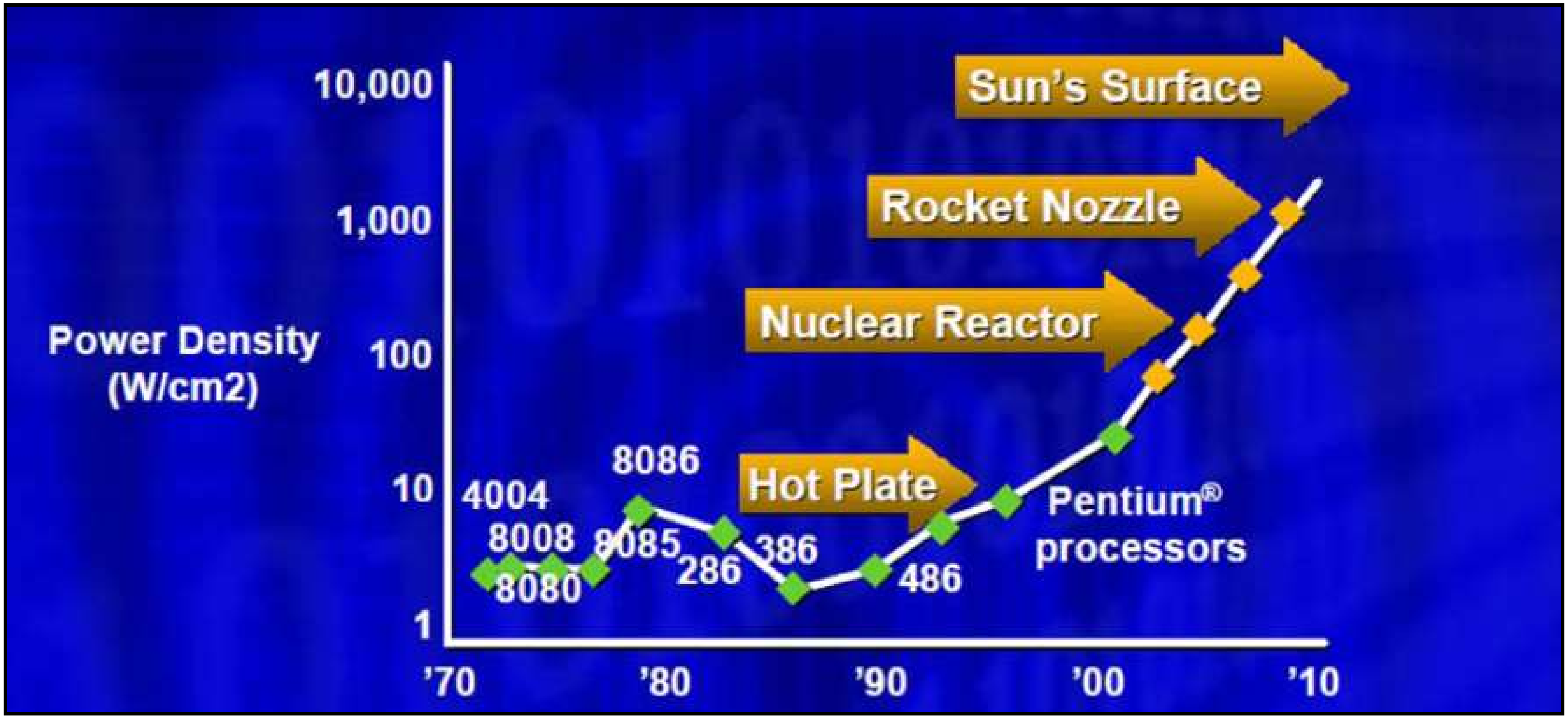
Once consumed, that power becomes *heat*, which much be dissipated somehow. In general, compute systems can remove around 150 $^{watts}/_{cm}$ without resorting to exotic cooling methods.

And, speaking of “exotic”, AMD set the world record for clock speed (8.429 GHz) using a Liquid Nitrogen-cooled CPU



Source: *AMD*

What Kind of Power Density Dissipation Would it Have Taken to Keep up with Clock Speed Trends?



Source: Intel

MultiCore -- Multiprocessing on a Single Chip

So, to summarize:

Moore's Law of transistor density is still going, but the "Moore's Law" of clock speed has hit a wall. Now what do we do?

We keep packing more and more transistors on a single chip, but don't increase the clock speed. Instead, we increase computational throughput by using those transistors to pack multiple processors onto the same chip.

This is referred to as ***multicore***.

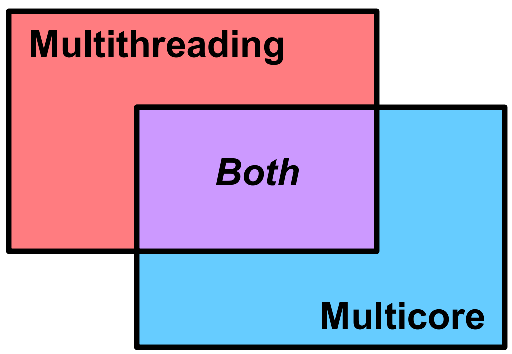
Vendors have also reacted by adding SIMD floating-point units on the chip as well. We will get to that later.

MultiCore and Multithreading

Multicore, even without multithreading too, is still a good thing. It can be used, for example, to allow multiple programs on a desktop system to always be executing concurrently.

Multithreading, even without multicore too, is still a good thing. Threads can make it easier to logically have many things going on in your program at a time, and can absorb the dead-time of other threads.

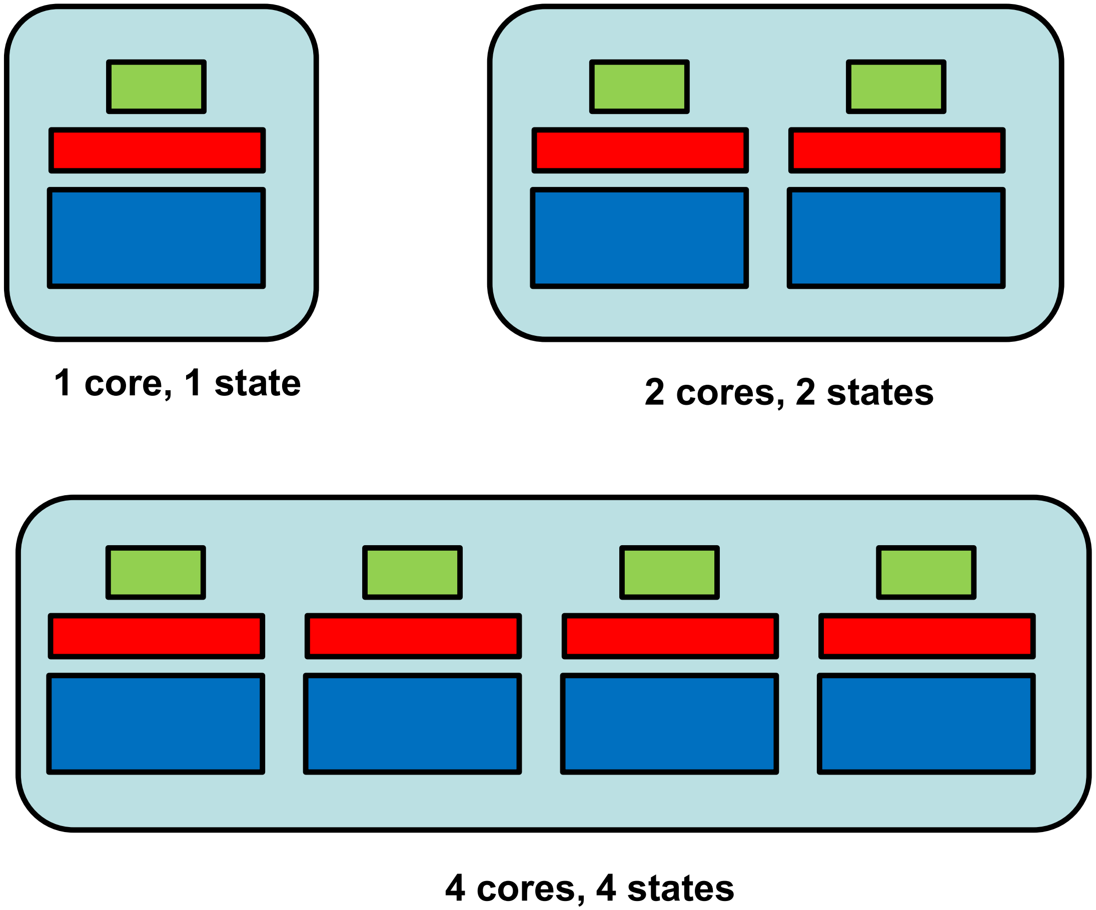
But, the big gain in performance is to use *both* to speed up a *single program*. For this, we need *a **combination of both multicore and multithreading***.

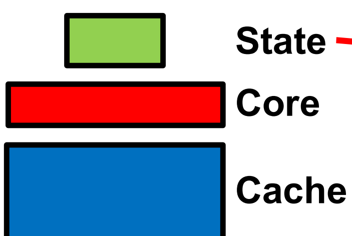


Multicore is a very hot topic these days. It would be hard to buy a CPU that doesn't have more than one core. We, as programmers, get to take advantage of that.

We need to be prepared to convert our programs to run on ***MultiThreaded Shared Memory Multicore*** architectures.

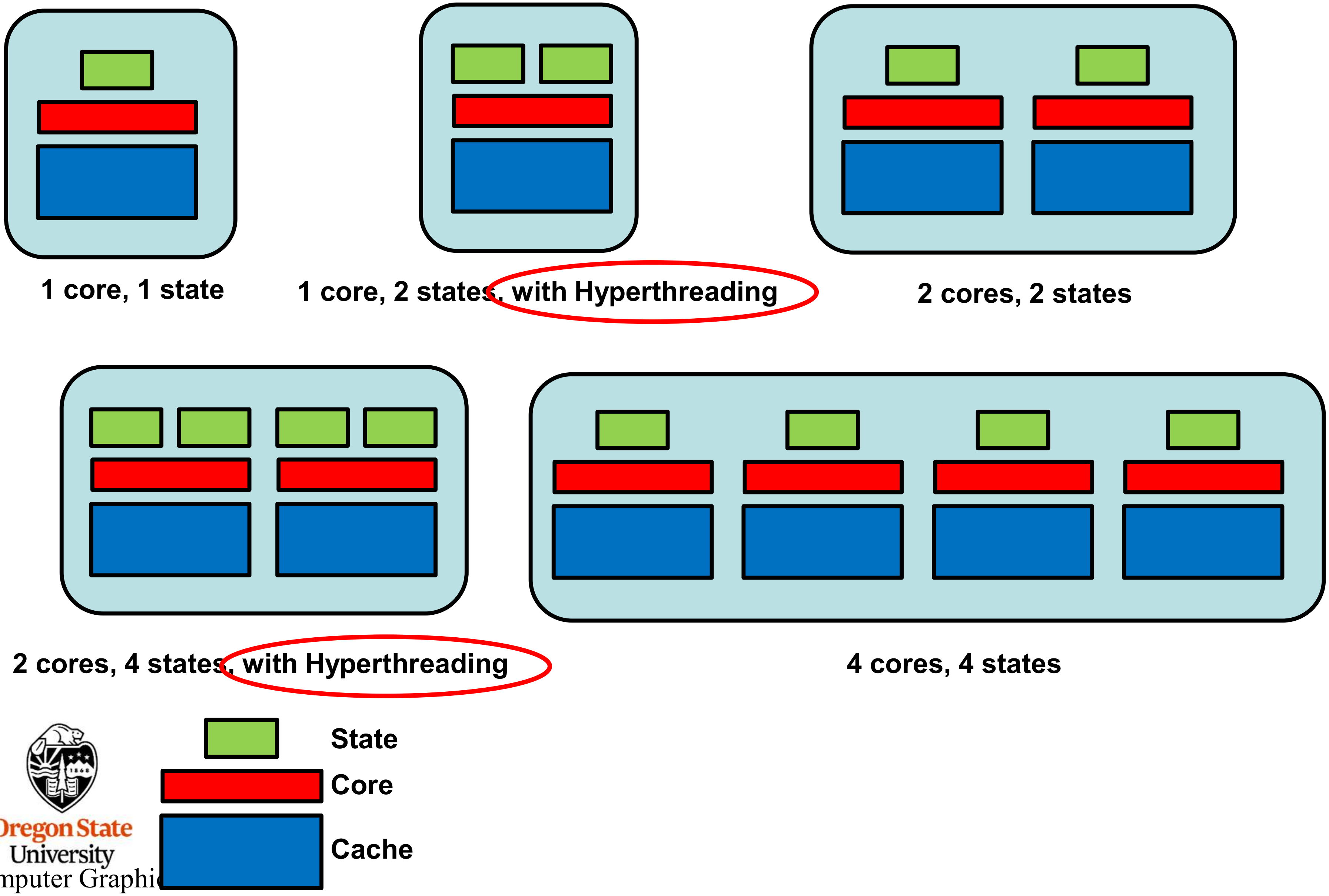
Each of the Multiple Cores keeps its own State





- Registers
- Program Counter
- Stack Pointer

So, if that's what Multicore is about, what is *Hyperthreading*?



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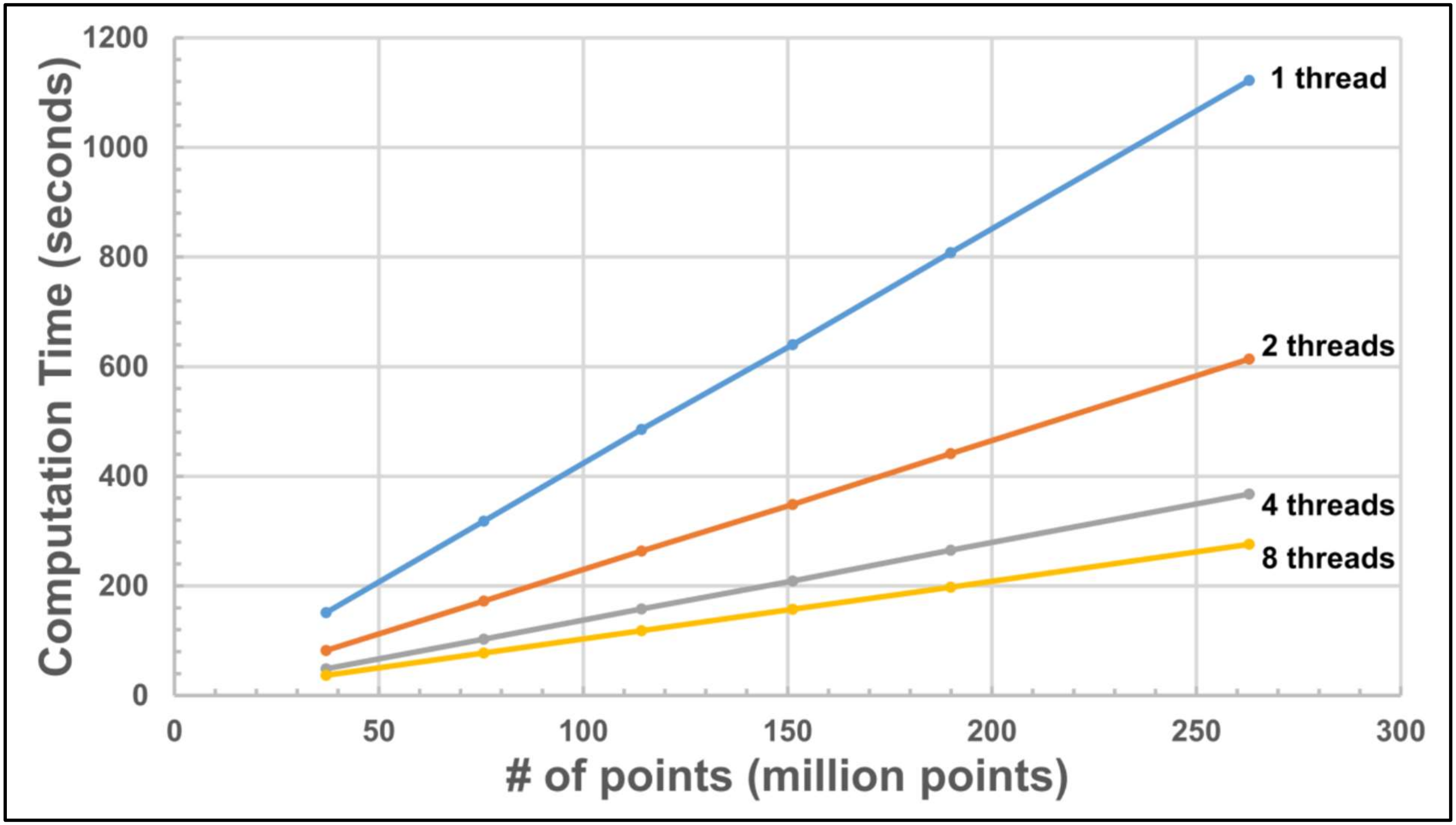
Four Cores with Two Hyperthreads per Core



Source: Erzhuo Che

Note that this is upside-down from our usual convention. Sorry. I got this from someone else.