Moore’s Law and Robotics

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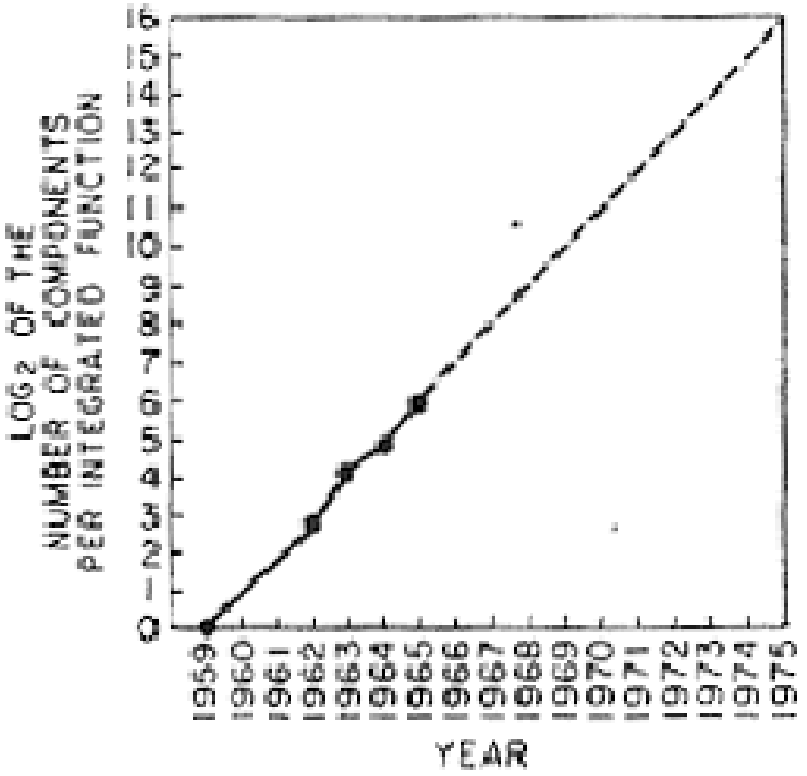
Moore's Original Law

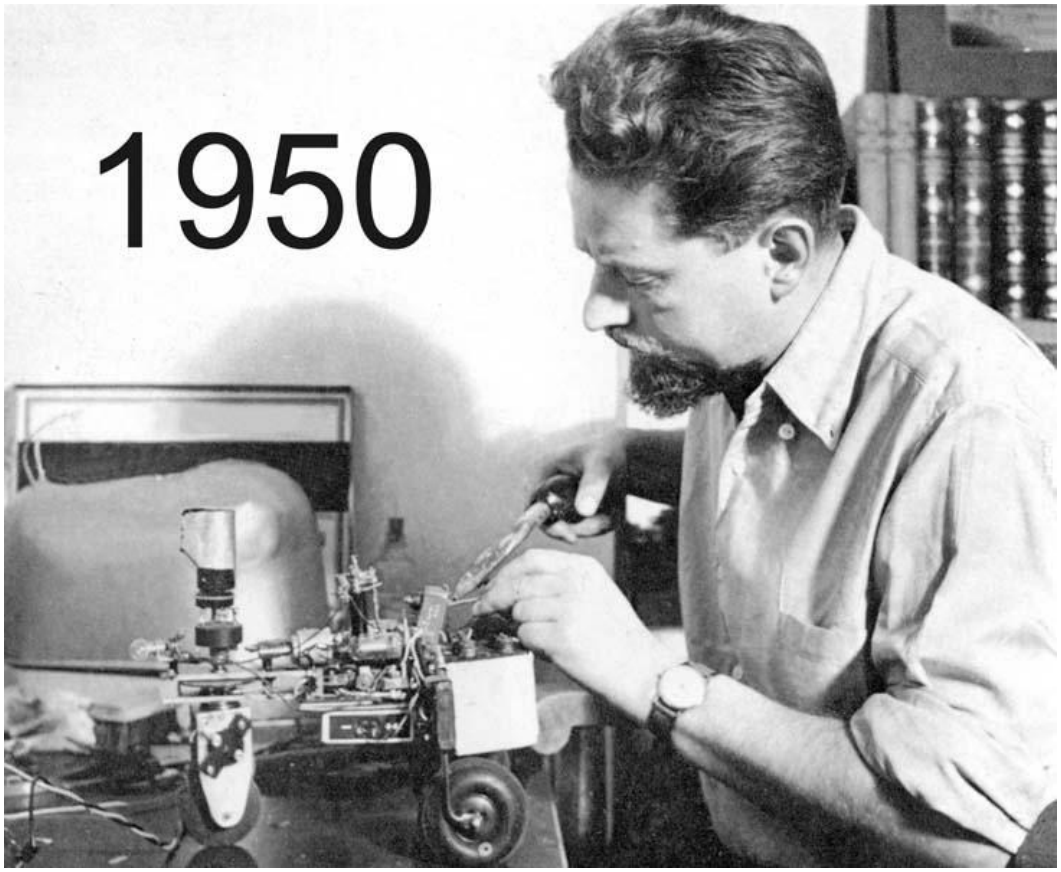
- Transistor density doubles every 1 year

On April 19, 1965 Electronics Magazine published a paper by Gordon Moore in which he made a prediction about the semiconductor industry



Size vs. vost

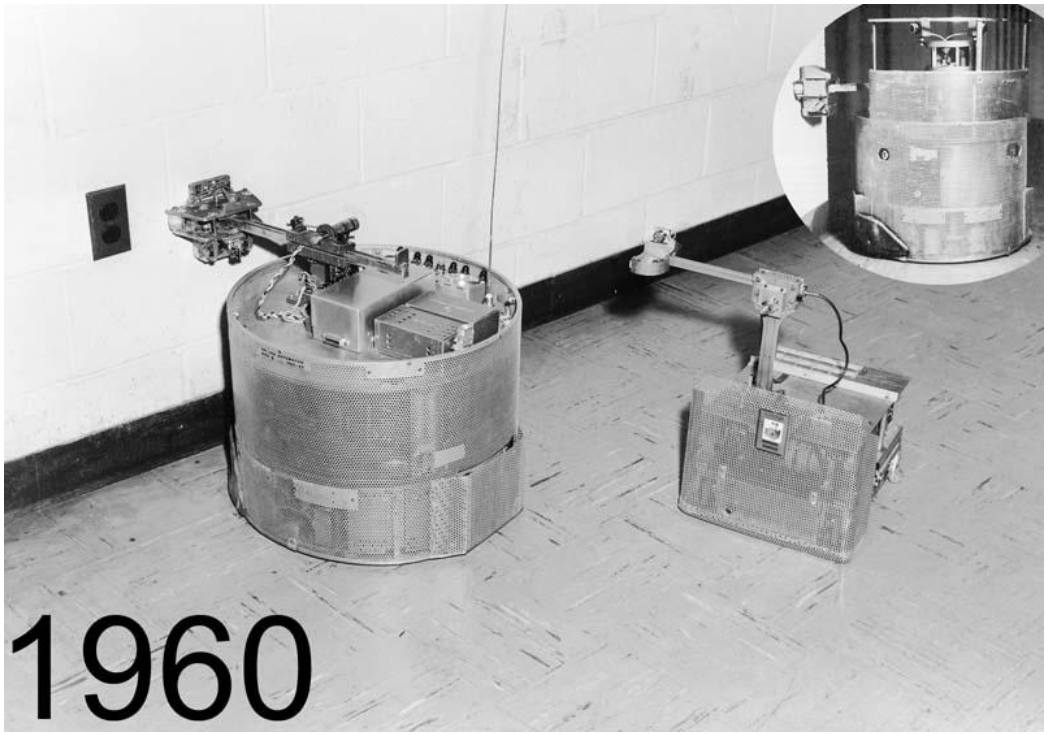
Grey Walter Tortoise, Elsie



One of eight built, with phototube eye and two vacuum tube amplifiers driving relays that controlled steering and drive motors. Elsie's shell, removed for surgery, can be seen in the background. The tortoises exhibited very lively behavior, for instance dancing near a lighted recharging hutch until their battery ran low, then enter. Their simple tropisms resemble bacterial "intelligence".

Thanks to Hans Morevac

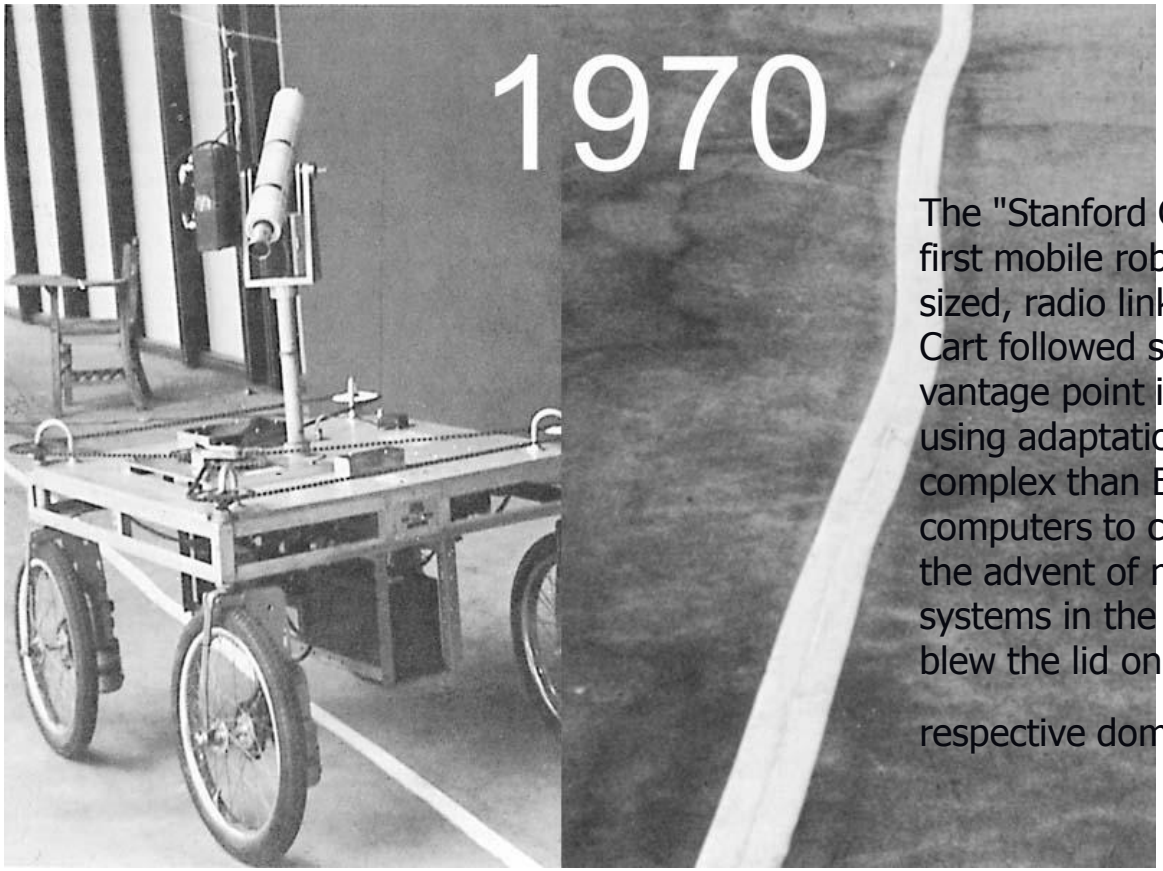
The Hopkins Beast



Thanks to Hans Morevac

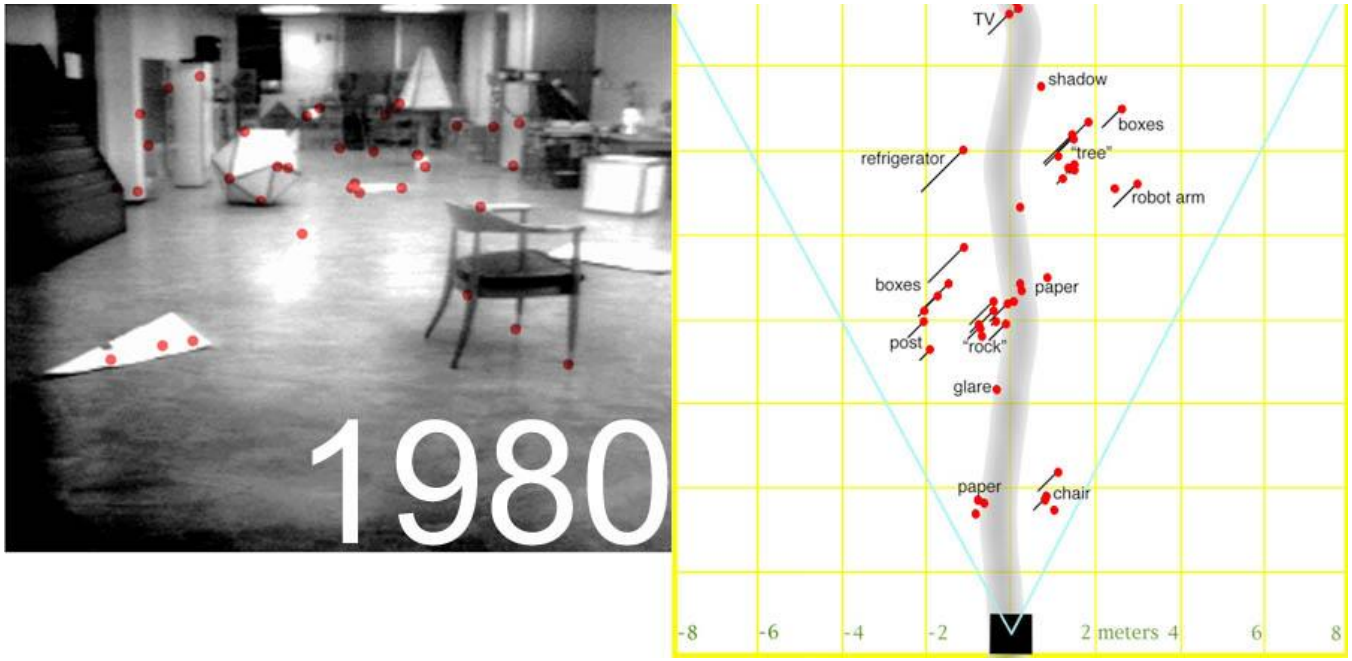
Controlled by dozens of transistors, the Johns Hopkins University Applied Physics Lab's "Beast" wandered white hallways, centering by sonar, until its batteries ran low. Then it would seek black wall outlets with special photocell optics, and plug itself in by feel with its special recharging arm. After feeding, it would resume patrolling. Much more complex than Elsie, the Beast's deliberate coordinated actions can be compared to the bacteria hunting behaviors of large nucleated cells like paramecia or amoebae.

The Stanford Cart



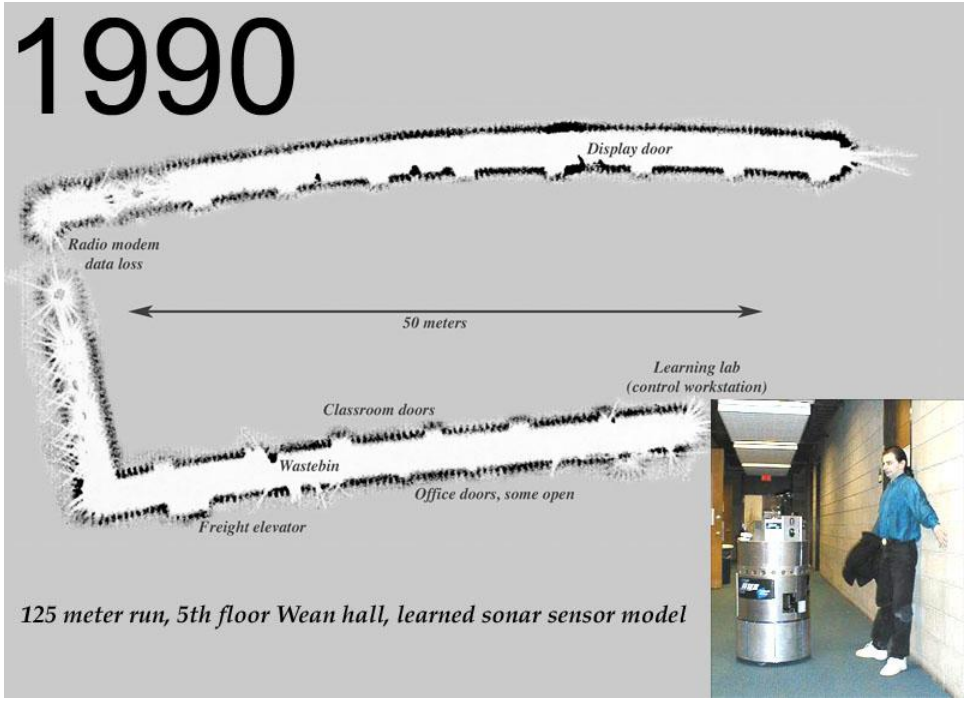
The "Stanford Cart" and SRI's "Shakey" were the first mobile robots controlled by computers (room-sized, radio linked). Both saw with TV cameras. The Cart followed smudgy white lines seen from a high vantage point in variable illumination quite reliably using adaptation and prediction methods far more complex than Elsie's or the Beast's. The use of computers to control robots can be compared to the advent of multicellular animals with nervous systems in the Cambrian explosion: both events blew the lid on behavioral complexity in their respective domains.

Mapping of 3D obstacles



A million calculation per second computer and more complex program allowed the Cart to sparsely map and negotiate obstacle courses, taking five hours to cover 30 meters, a sluglike performance

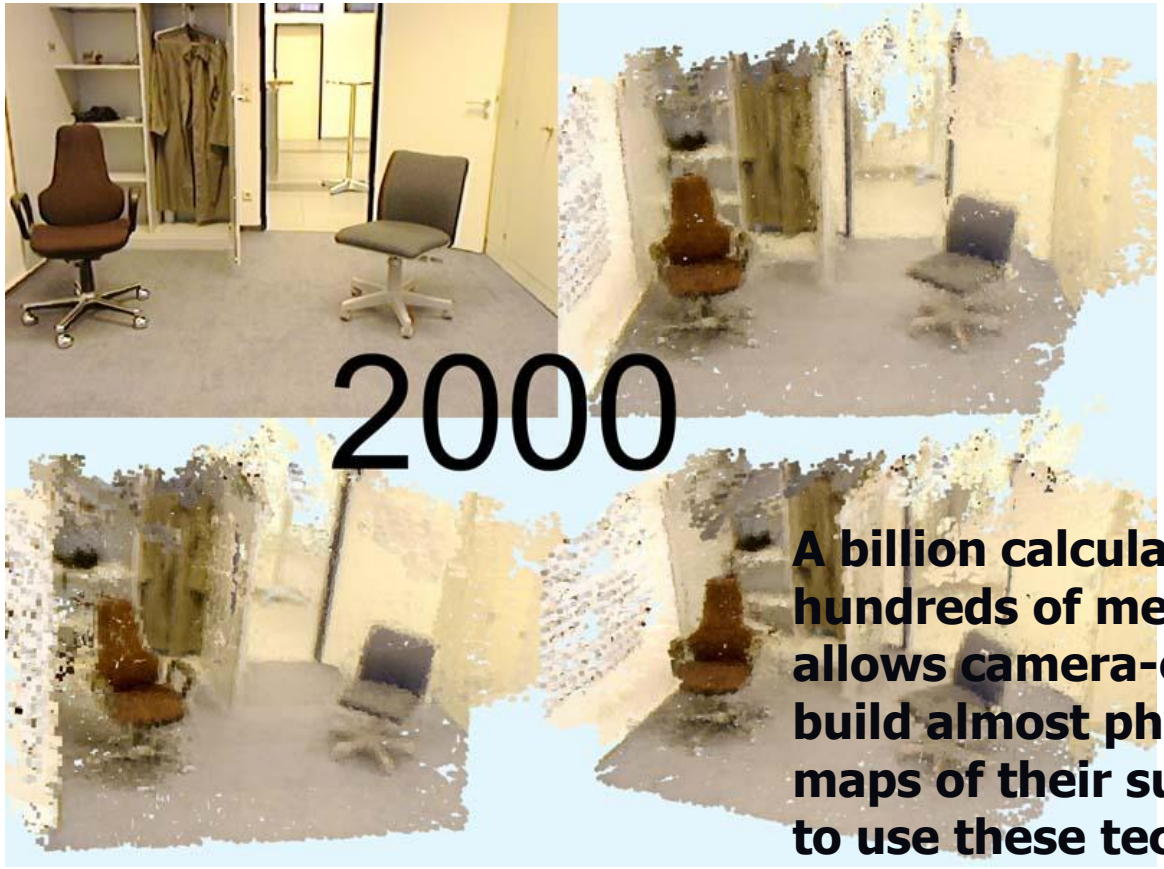
2D Mapping using Sonar Sensors



Ten million computations per second and a learned sensor model permitted quite reliable 2D mapping and navigation in real time from sonar range measurements, a performance comparable to the tiniest fish, or a medium insect.

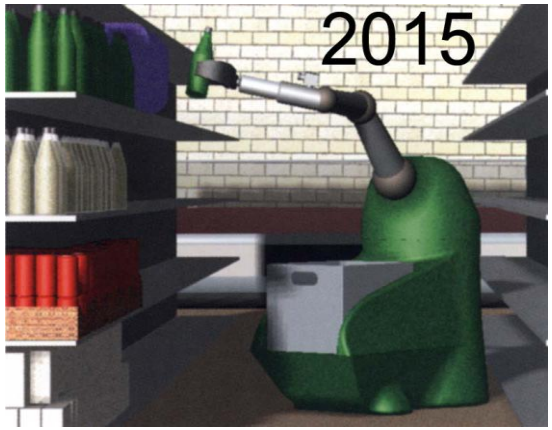
Thanks to Hans Morevac

3D Mapping and Vision

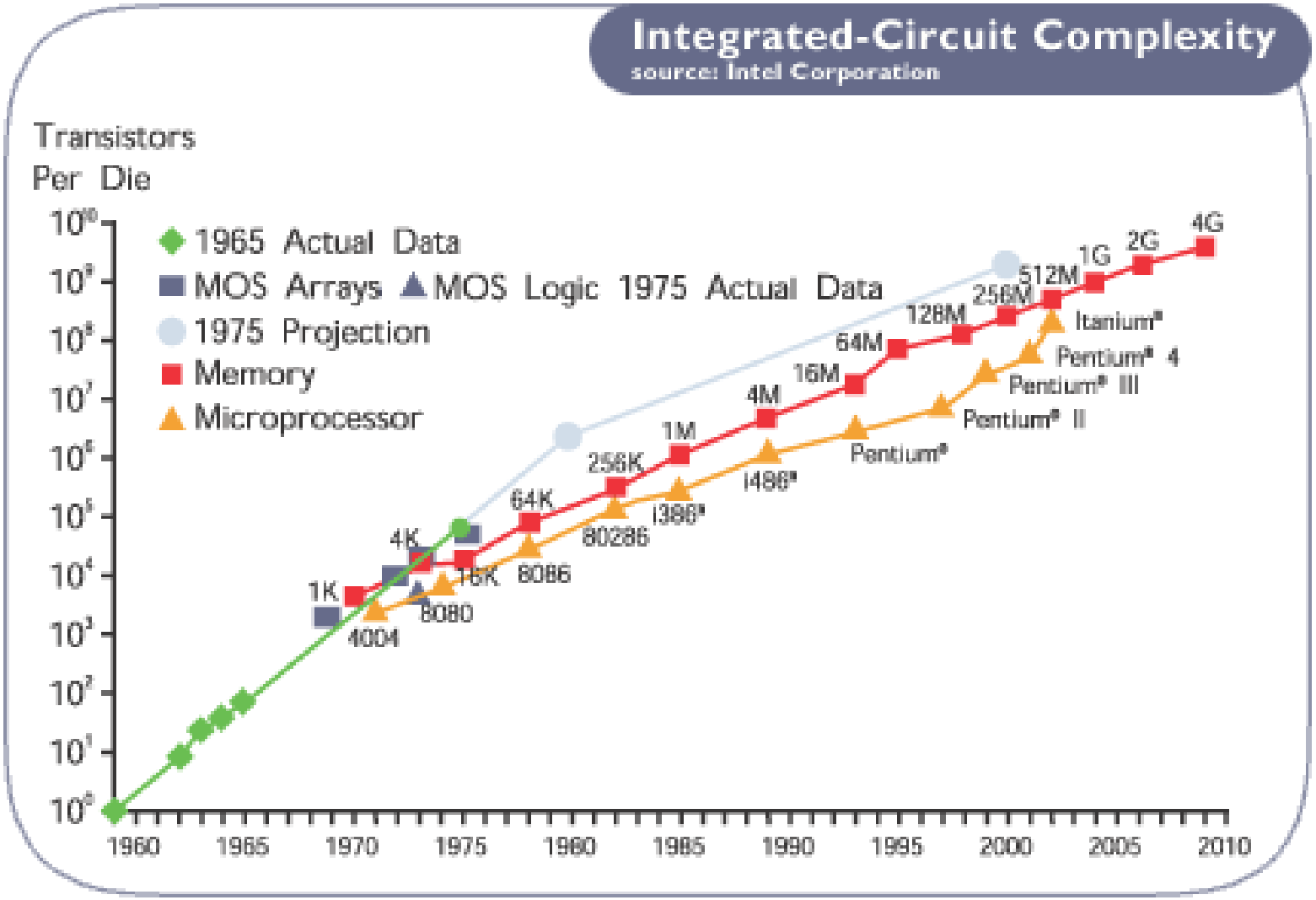


A billion calculations a second and hundreds of megabytes of memory allows camera-equipped robots to build almost photorealistic dense 3D maps of their surroundings. We expect to use these techniques in commercial robots that reliably transport or clean floors or guard routes they map themselves, with guppylike intelligence.

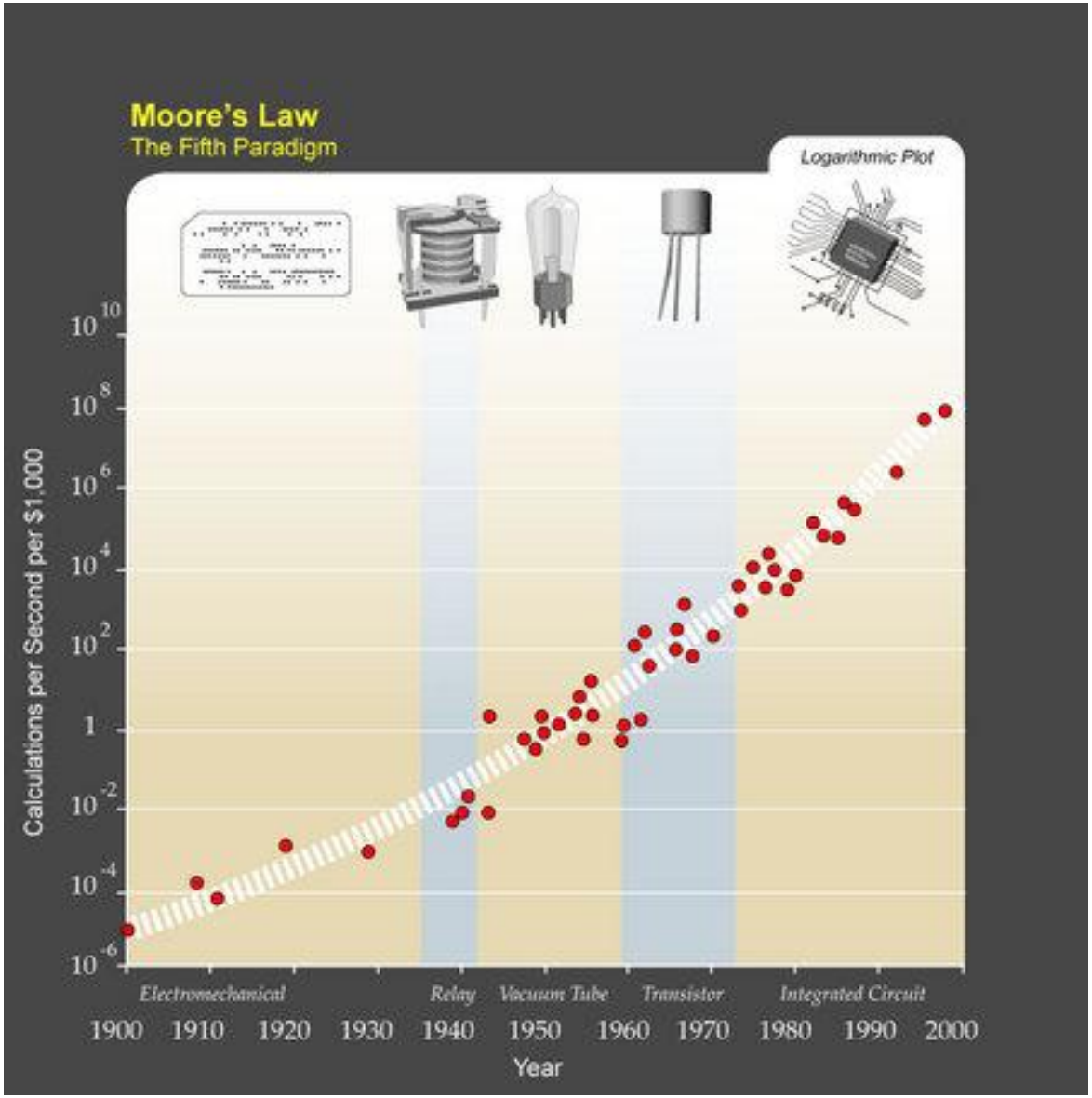
The near future



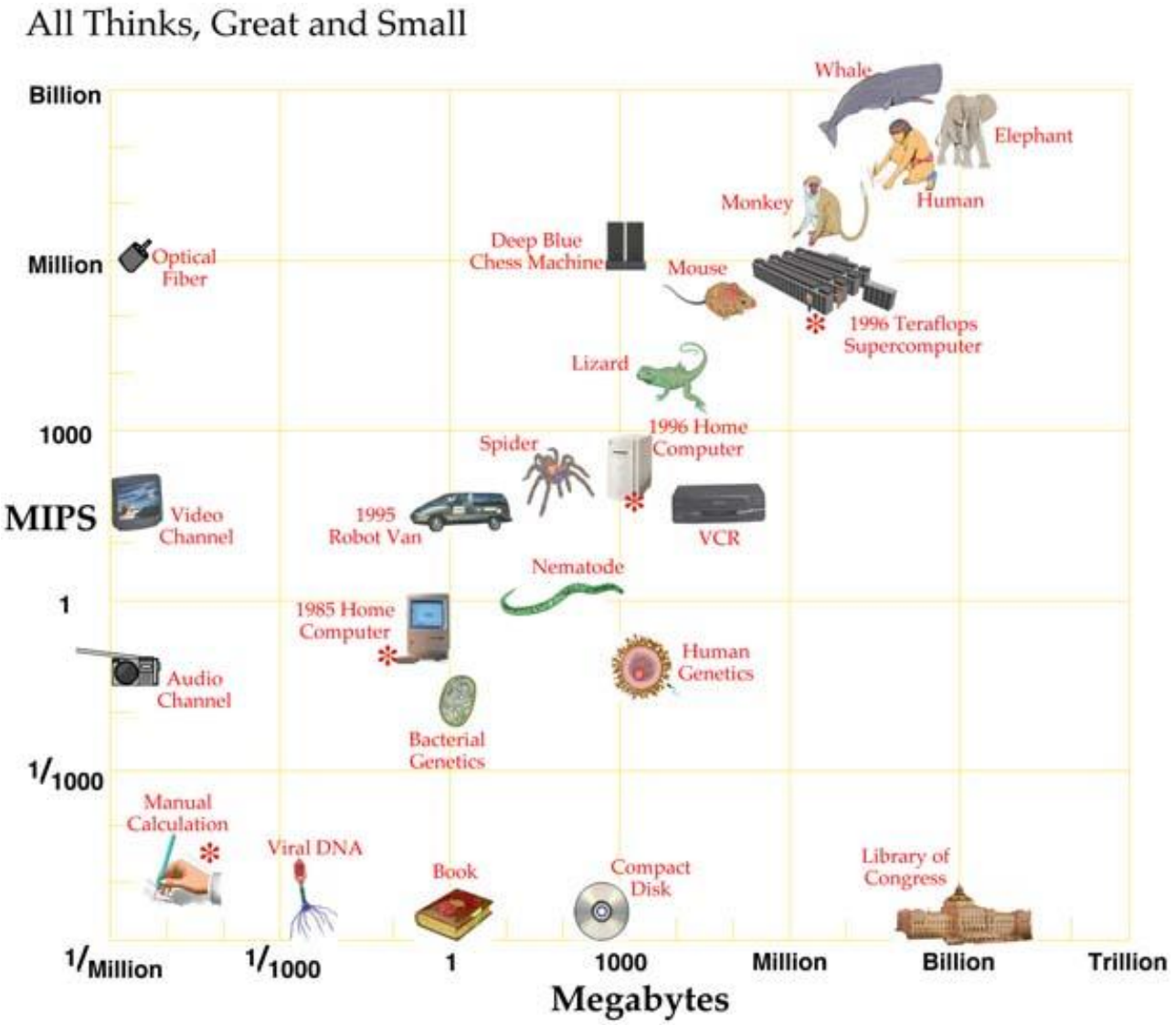
Moore's Law


Integrated-Circuit Complexity
source: Intel Corporation
Transistors
Per Die
1965 Actual Data
MOS Arrays
MOS Logic 1975 Actual Data
1975 Projection
Memory
Microprocessor
1K
4K
16K
64K
256K
1M
4M
16M
64M
128M
256M
512M
1G
2G
4G
4004
8080
8086
80286
I386
I486
Pentium®
Pentium® II
Pentium® III
Pentium® 4
Itanium®
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010

More Moore's Law



Moore's Law



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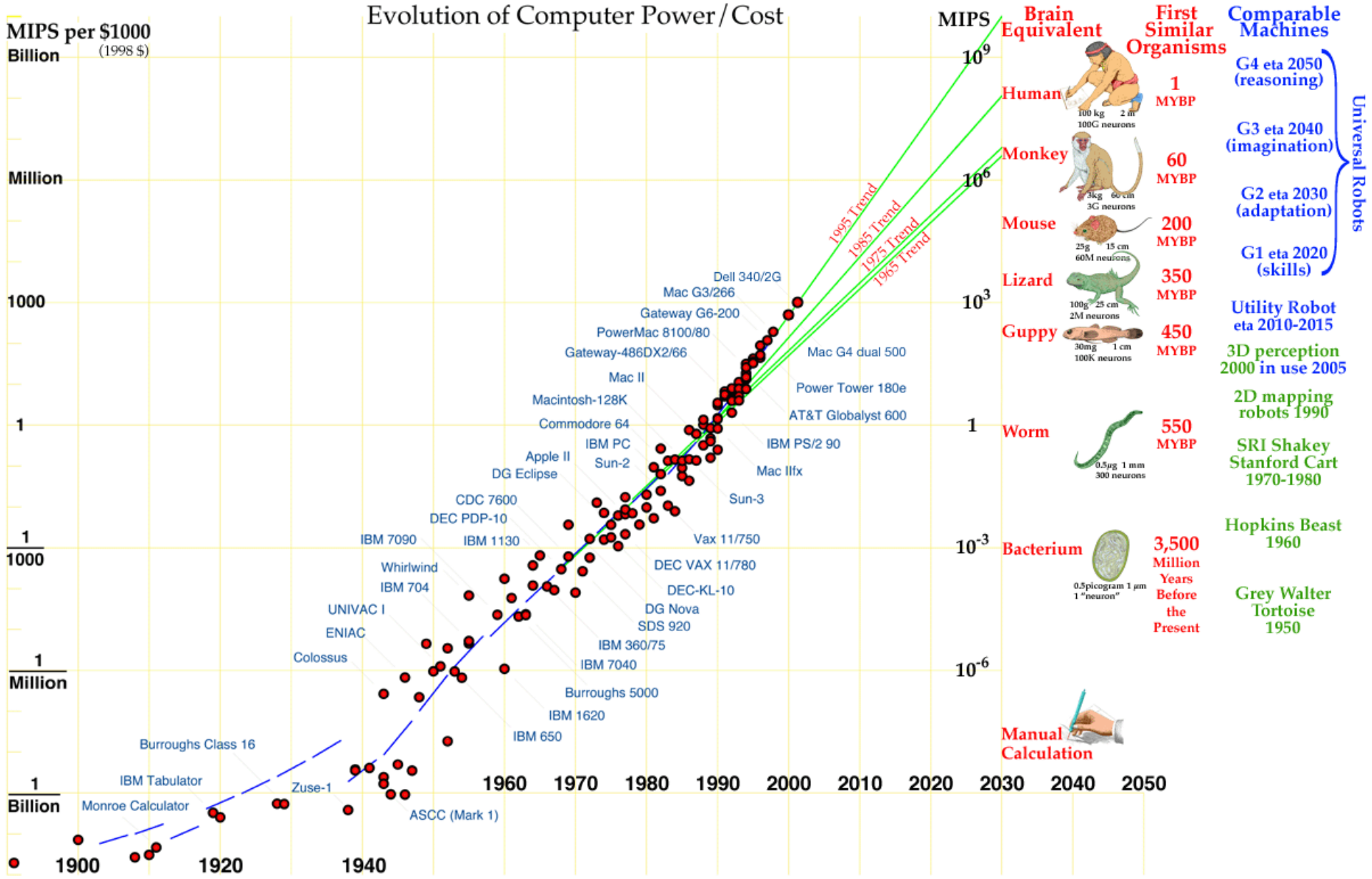
Evolution Overview



Historical Increase in Mechanical Complexity