
# Los procesadores y la computación en el final de la ley de Moore

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- Motivación
- Evolución, tendencias y límites
- Ley de Moore, Escalado de Dennard y Microarquitectura
- Después de la Ley de Moore

# Motivación

- Predecir el futuro es un ejercicio arriesgado

"Hacer predicciones es muy difícil, especialmente sobre el futuro"
Niels Bohr

"No existe ninguna razón para tener un computador en casa".
Ken Olsen, 1977, co-fundador y CEO de DEC (Digital Equipment Corporation),

"Las máquinas serán capaces, en los próximos veinte años, de hacer cualquier trabajo que una persona pueda hacer"
Herbert Simon, 1965, Premio Novel Economía 1978, Premio Turing 1975

# Motivación

- Algunos aciertan

**The future of integrated electronics** is the future of electronics itself. The advantages of integration will bring about a proliferation of electronics, pushing this science into many new areas.

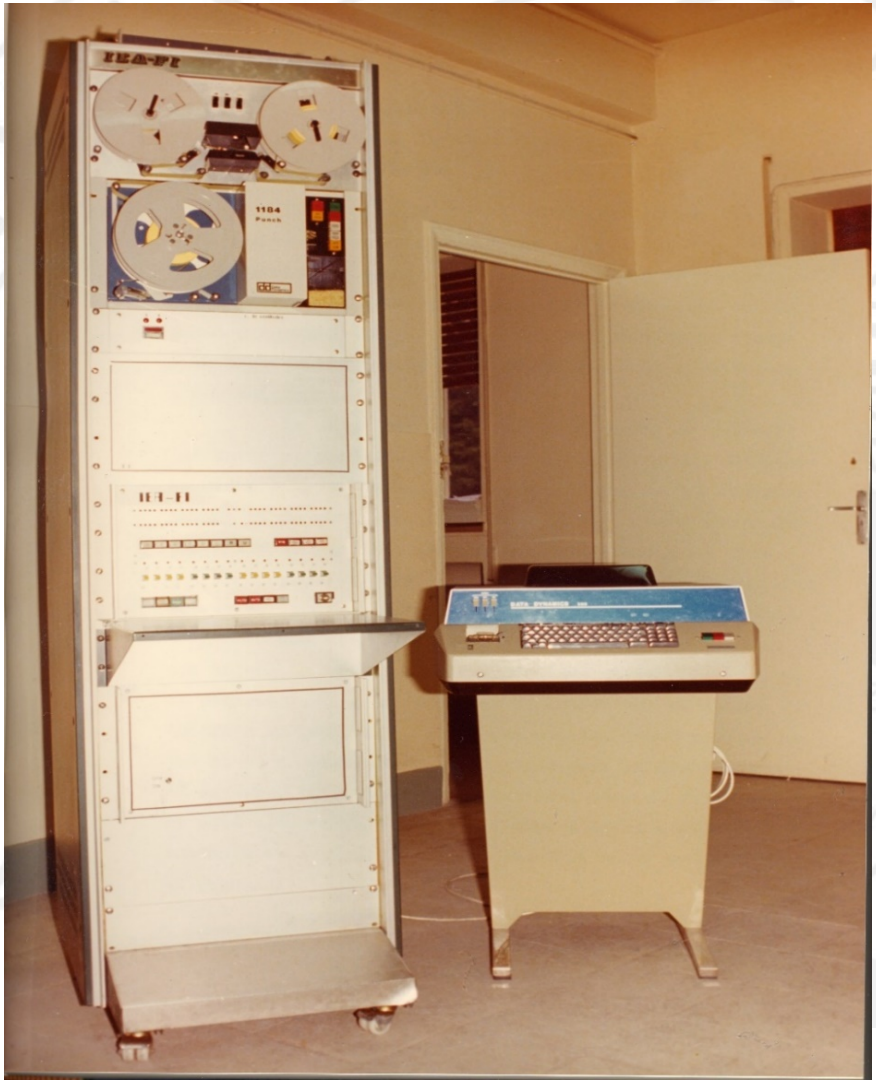
Integrated circuits will lead to such wonders as **home computers** - **or at least terminals connected to a central computer** - **automatic controls for automobiles**, and **personal portable communications equipment**.

Cramming more components onto integrated circuits, Electronics, Volume 38, Number 8, April 19, 1965.

*Gordon E. Moore, Co-founder Intel Corporation*

# Motivación

- Alguna experiencia desde 1973



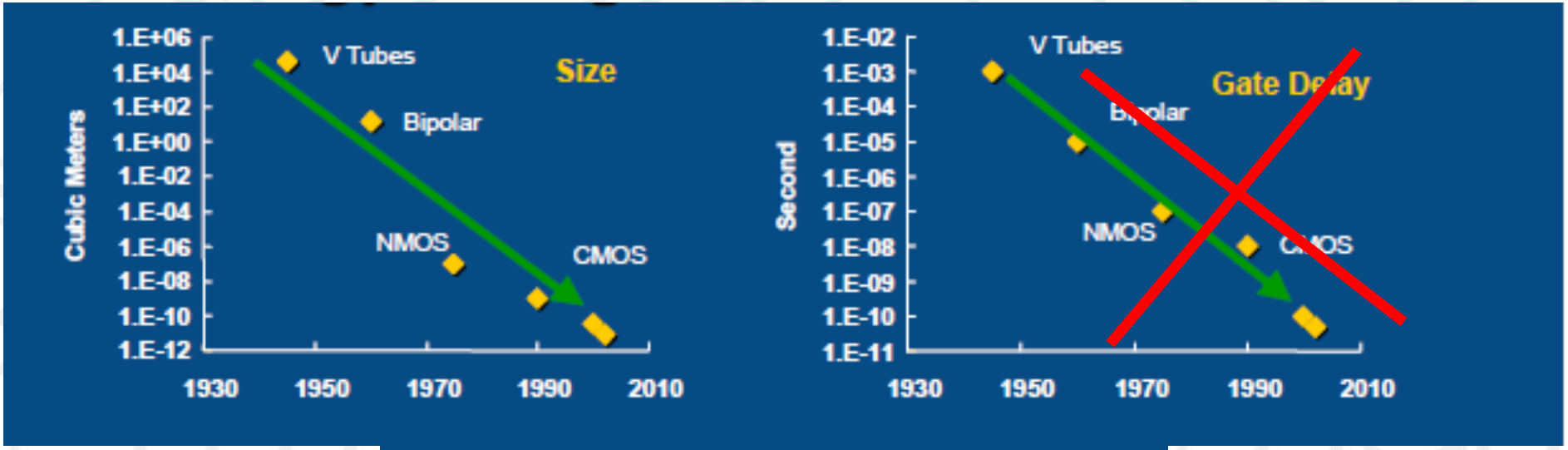

**MINICOMPUTADOR IEA-FI**

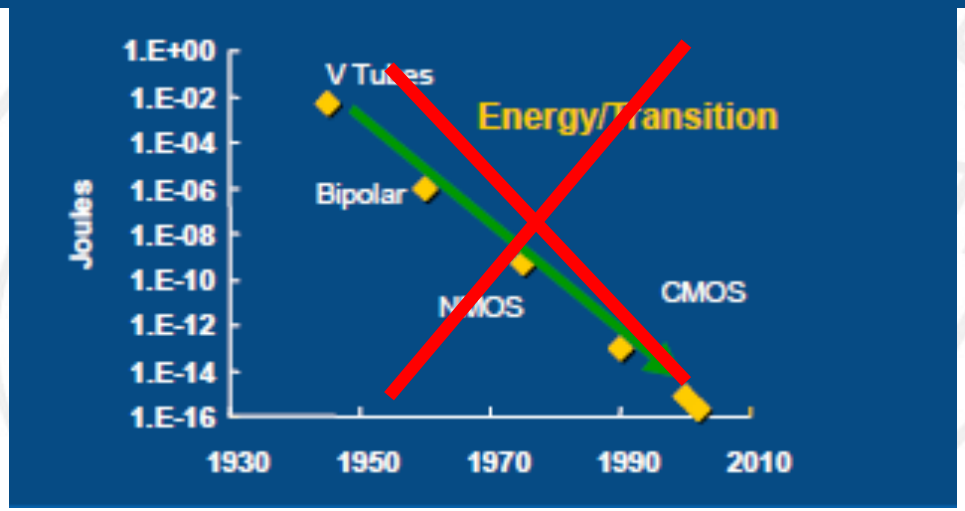
**PRIMER MINICOMPUTADOR CONSTRUIDO EN ESPAÑA**

# Evolución y Tendencias

¿ El escalado de la tecnología continua ?

Después 2004

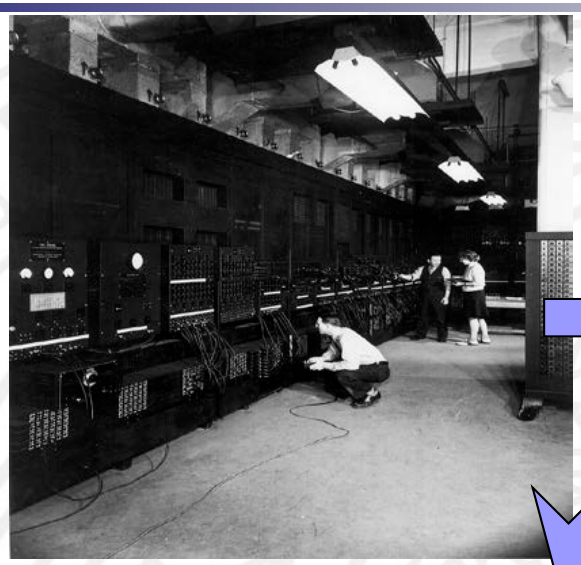


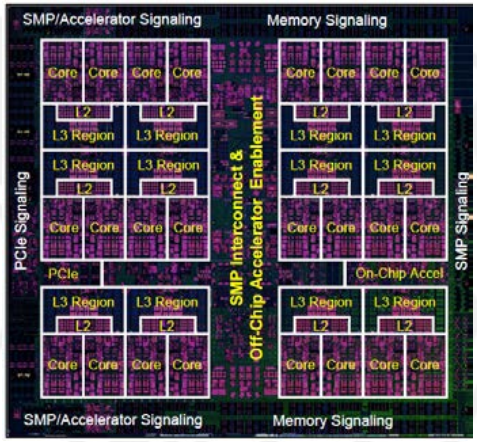




Fuente Intel

# Evolución y Tendencias

Eniac 1946
100 flops






**ASCI Red nº 1**
**1997-2000**
**1Tflops**
**7264 Pemtium Pro**

Mi teléfono
>200 Mflops

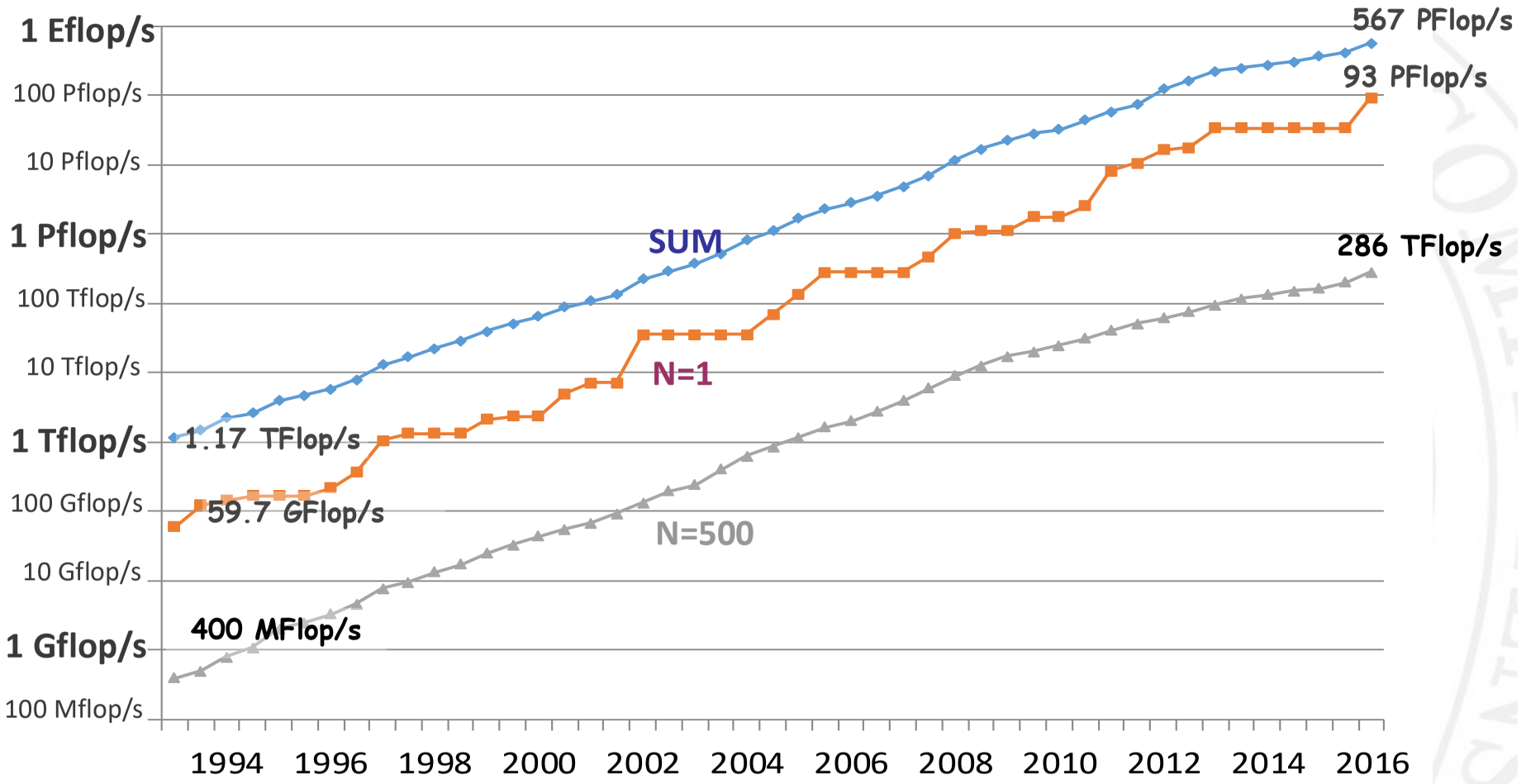
**1 Sunway, SW26010(280c, 1,45MHz), 10M cores , 93 Pflops ($10^{15}$ ), 1 PB, 14,5 MW**

IBM POWER9 12/24 cores (96Threads)
14nm. 650 mm2, 8000MTs, 4GHz,
120MB L3, 250w, 0.9Tflops

# Evolución y tendencias

Top 500 jun 2015 a noviembre 2016 18 meses

Total de 363 Pflops a 567 Pflops, En último 166 Tflops a 286 Tflops




**Reto** el Exaflops ( $10^{18}$ ) < 20Mw

# Evolución y Tendencias

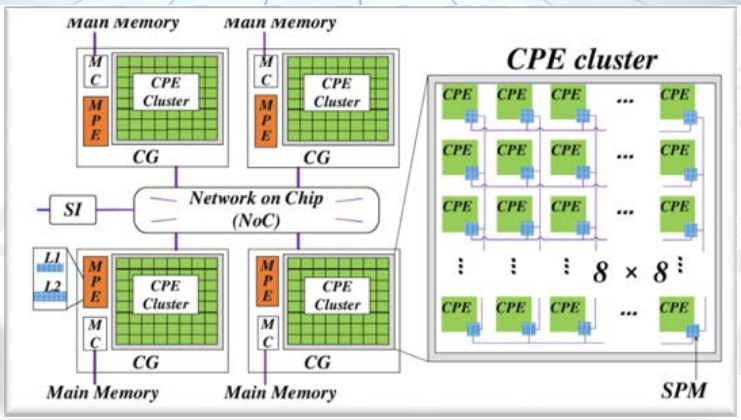
| Rank | Name | Site | Computer | Total Cores | Rmax | Rpeak | Power | Mflops/W |
|---|---|---|---|---|---|---|---|---|
| 1 | Sunway TaihuLight | National Supercomputing Center in Wuxi | Sunway MPP, Sunway SW26010 260C 1.45GHz, Sunway | 10649600 | 93014593,88 | 125435904 | 15371 | 6051,3 |
| 2 | Tianhe-2 (MilkyWay-2) | National Super Computer Center in Guangzhou | TH-IVB-FEP Cluster, Intel Xeon E5-2692 12C 2.200GHz, TH Express-2, Intel Xeon Phi 31S1P | 3120000 | 33862700 | 54902400 | 17808 | 1901,54 |
| 3 | Titan | DOE/SC/Oak Ridge National Laboratory | Cray XK7 , Opteron 6274 16C 2.200GHz, Cray Gemini interconnect, NVIDIA K20x | 560640 | 17590000 | 27112550 | 8209 | 2142,77 |
| 4 | Sequoia | DOE/NNSA/LLNL | BlueGene/Q, Power BQC 16C 1.60 GHz, Custom | 1572864 | 17173224 | 20132659,2 | 7890 | 2176,58 |
| 5 | Cori | DOE/SC/LBNL/NERSC | Cray XC40, Intel Xeon Phi 7250 68C 1.4GHz, Aries interconnect | 622336 | 14014700 | 27880653 | 3939 | 3557,93 |
| 6 | Oakforest-PACS | Joint Center for Advanced High Performance Computing | PRIMERGY CX1640 M1, Intel Xeon Phi 7250 68C 1.4GHz, Intel Omni-Path | 556104 | 13554600 | 24913459 | 2718,7 | 4985,69 |
| 7 | | RIKEN Advanced Institute for Computational Science (AICS) | K computer, SPARC64 VIIIfx 2.0GHz, Tofu interconnect | 705024 | 10510000 | 11280384 | 12659,89 | 830,18 |

En 2017-18
USA Aurora (Intel Xeon Phi 3ªG), Summit y Sierra ( IBM Pw9, Volta)
Japón PostK computer Fijitsu (ARM+SVE)
China Sunway-2

# Nº 1 Top 500

| | ORNL Titan | NUDT Tianhe-2 | Sunway TaihuLight |
|---|---|---|---|
| Theoretical Peak | 27 Pflop/s = (2.6 CPU + 24.5 GPU) Pflop/s | 54.9 Pflop/s = (6.75 CPU + 48.14 Coprocessor) Pflop/s | 125.4 Pflop/s = CPEs +MPEs<br>Cores per Node = 256 CPEs + 4 MPEs<br>Supernode = 256 Nodes<br>System = 160 Supernodes<br>Cores = 260 * 256 * 160 = 10.6M |
| HPL Benchmark Flop/s | 17.6 Pflop/s | 30.65 Pflop/s | 93 Pflop/s |

| | |
|---|---|
| CPU | Shenwei-64 |
| Developer | NRCPC |
| Chip Fab | CPU vendor is the Shanghai High Performance IC Design Center |
| Instruction set | Shenwei-64 Instruction Set (this is NOT related to the DEC Alpha instruction set) |
| Node Processor cores | 256 CPEs (computing processing elements) plus 4 MPEs (management processing elements) |
| Node Peak Performance | 3.06 TFlop/s |
| Clock Frequency | 1.45 GHz |
| Process Technology | N/A |




- 93 Pflops versus 30 Pflops
- 15,4MW versus 17,8MW, 6 Gflops/w
- 10Mcores versus 3Mcores
- 1.31 PB de memoria (DDR3).
- Water cooled
- 100% tecnología China
- USA y China comparten el TOP 500

# Evolución y tendencias

## GREEN 500 noviembre 2016

| Green500 Rank | MFLOPS/W | Site | Computer |
|---|---|---|---|
| 1 | 9,462.09 | NVIDIA Corporation | NVIDIA DGX-1, Xeon E5-2698v4 20C 2.2GHz, Infiniband EDR, NVIDIA Tesla P100 |
| 2 | 7,453.51 | Swiss National Supercomputing Centre (CSCS) | Cray XC50, Xeon E5-2690v3 12C 2.6GHz, Aries interconnect , NVIDIA Tesla P100 |
| 3 | 6,673.84 | Advanced Center for Computing and Communication, RIKEN | ZettaScaler-1.6, Xeon E5-2618Lv3 8C 2.3GHz, Infiniband FDR, PEZY-SCnp |
| 4 | 6,051.30 | National Supercomputing Center in Wuxi | Sunway MPP, Sunway SW26010 260C 1.45GHz, Sunway |
| 5 | 5,806.32 | Fujitsu Technology Solutions GmbH | PRIMERGY CX1640 M1, Intel Xeon Phi 7210 64C 1.3GHz, Intel Omni-Path |
| 6 | 4,985.69 | Joint Center for Advanced High Performance Computing | PRIMERGY CX1640 M1, Intel Xeon Phi 7250 68C 1.4GHz, Intel Omni-Path |
| 7 | 4,687.99 | DOE/SC/Argonne National Laboratory | Cray XC40, Intel Xeon Phi 7230 64C 1.3GHz, Aries interconnect |
| 8 | 4,112.11 | Stanford Research Computing Center | Cray CS-Storm, Intel Xeon E5-2680v2 10C 2.8GHz, Infiniband FDR, Nvidia K80 |
| 9 | 4,086.82 | Academic Center for Computing and Media Studies (ACCMS), Kyoto University | Cray XC40, Intel Xeon Phi 7250 68C 1.4GHz, Aries interconnect |
| 10 | 3,836.65 | Thomas Jefferson National Accelerator Facility | KOI Cluster, Intel Xeon Phi 7230 64C 1.3GHz, Intel Omni-Path |

**Reto** el Exaflops ( $10^{18}$ ) < 20Mw

1º de Green 500 9,4 GFlops /w. Sunway 6,05 Gflop/w, Thiane-2 1,9Gflop/w

Necesitamos más de un orden de magnitud de incremento 100GFlops/w

# La ley de Moore

## Cramming More Components onto Integrated Circuits

GORDON E. MOORE, LIFE FELLOW, IEEE

*With unit cost falling as the number of components per circuit rises, by 1975 economics may dictate squeezing as many as 65 000 components on a single silicon chip.*

The future of integrated electronics is the future of

Each approach evolved rapidly and converged so that each borrowed techniques from another. Many researchers believe the way of the future to be a combination of the

Electronic- Abril1965


Fig. 2.

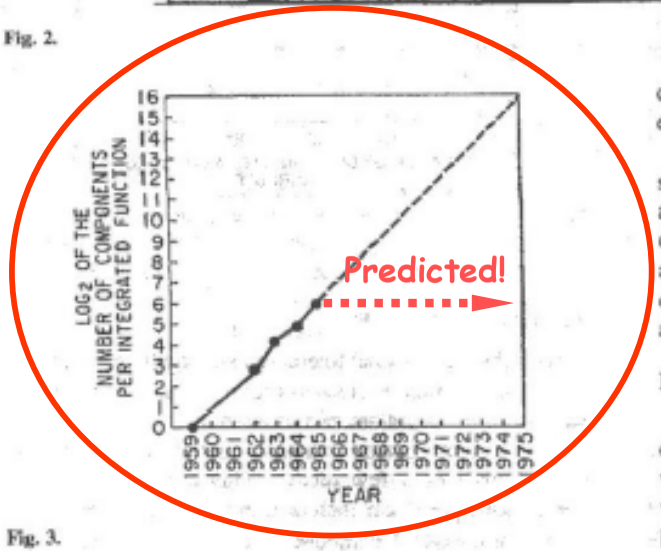



Fig. 3.

diagram to technological realization without any sp
engineering.

It may prove to be more economical to build
systems out of smaller functions, which are separately p
aged and interconnected. The availability of large funct
combined with functional design and construction, sh
allow the manufacturer of large systems to design
construct a considerable variety of equipment both ra
and economically.

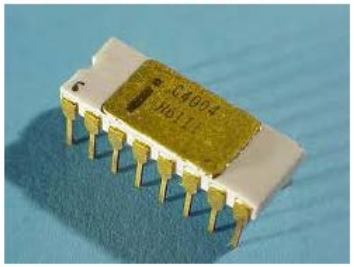
### IX. Linear Circuitry

Integration will not change linear systems as radical
digital systems. Still, a considerable degree of integr
will be achieved with linear circuits. The lack of l
value capacitors and inductors is the greatest fundam
limitation to integrated electronics in the linear area.

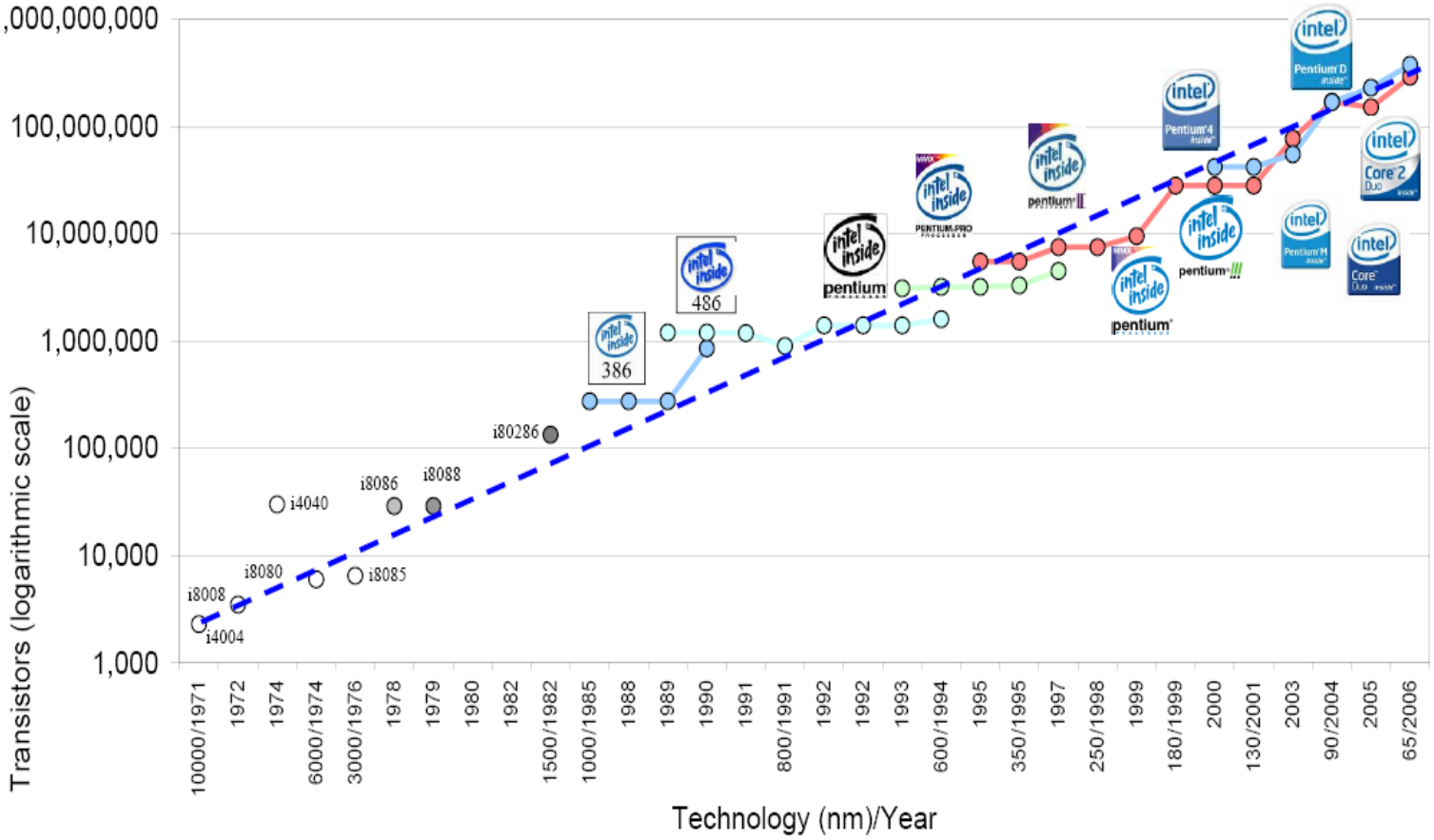
C Mead 1979

# La Ley de Moore se ha cumplido

Intel 4004, 1971



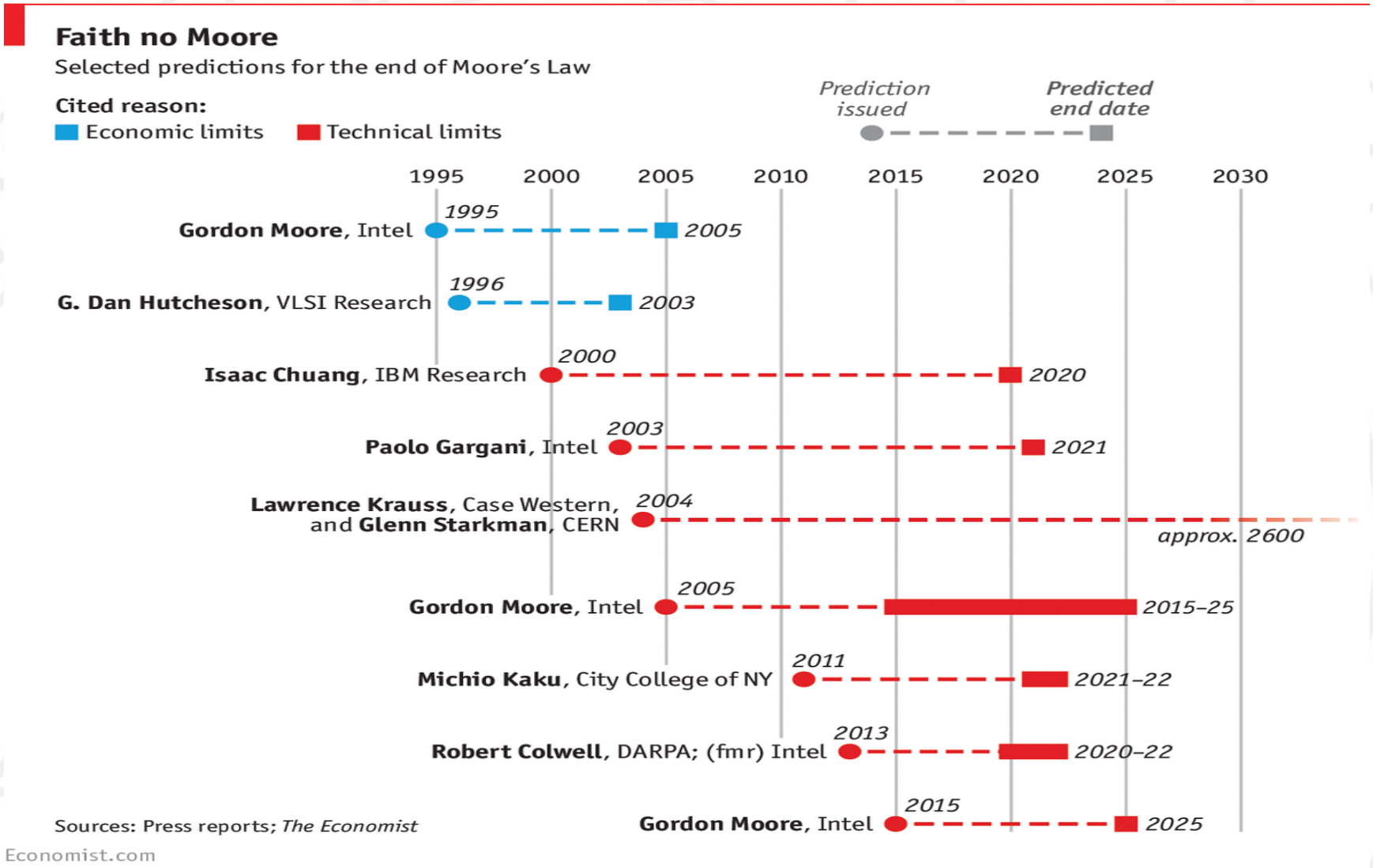
92,000 ops/sec


E5 22c ≈1Tflops

Fuente: Intel Corporation

# ¿Hasta cuando?




The Economist 2015