Parallel Computing
&
Accelerators

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Purpose of this talk

This is the 50,000 ft. view of the parallel computing landscape. We want to orient you a bit before parachuting you down into the trenches to deal with OpenACC. The plan is that you walk away with a knowledge of not just OpenACC, but also where it fits into the world of High Performance Computing.

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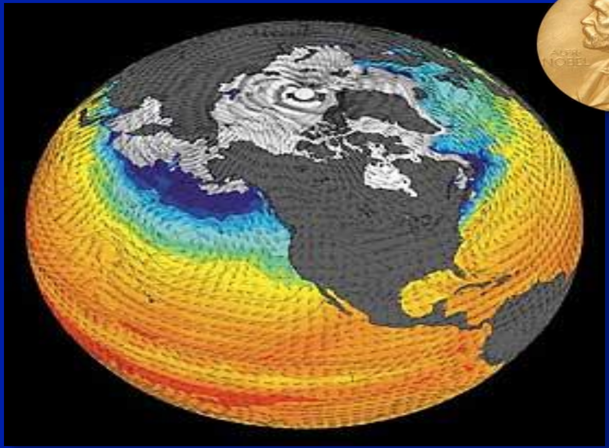
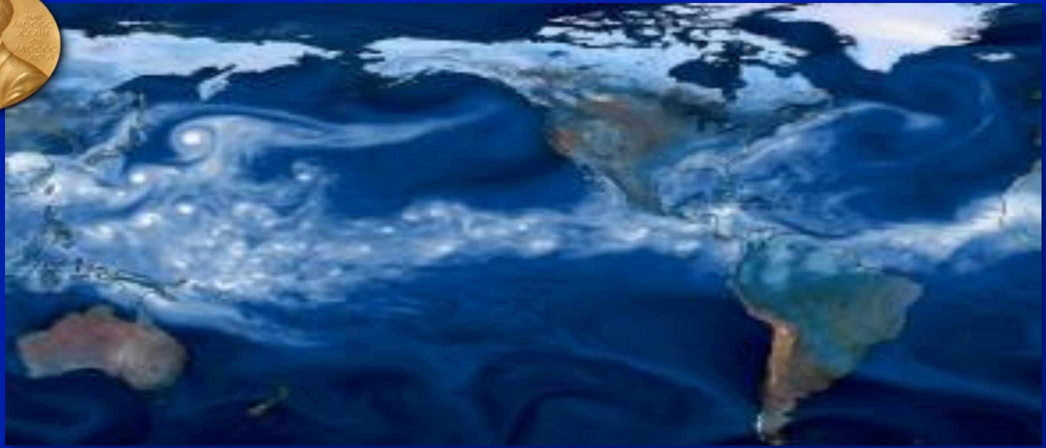
FLOPS we need: Climate change analysis





Simulations

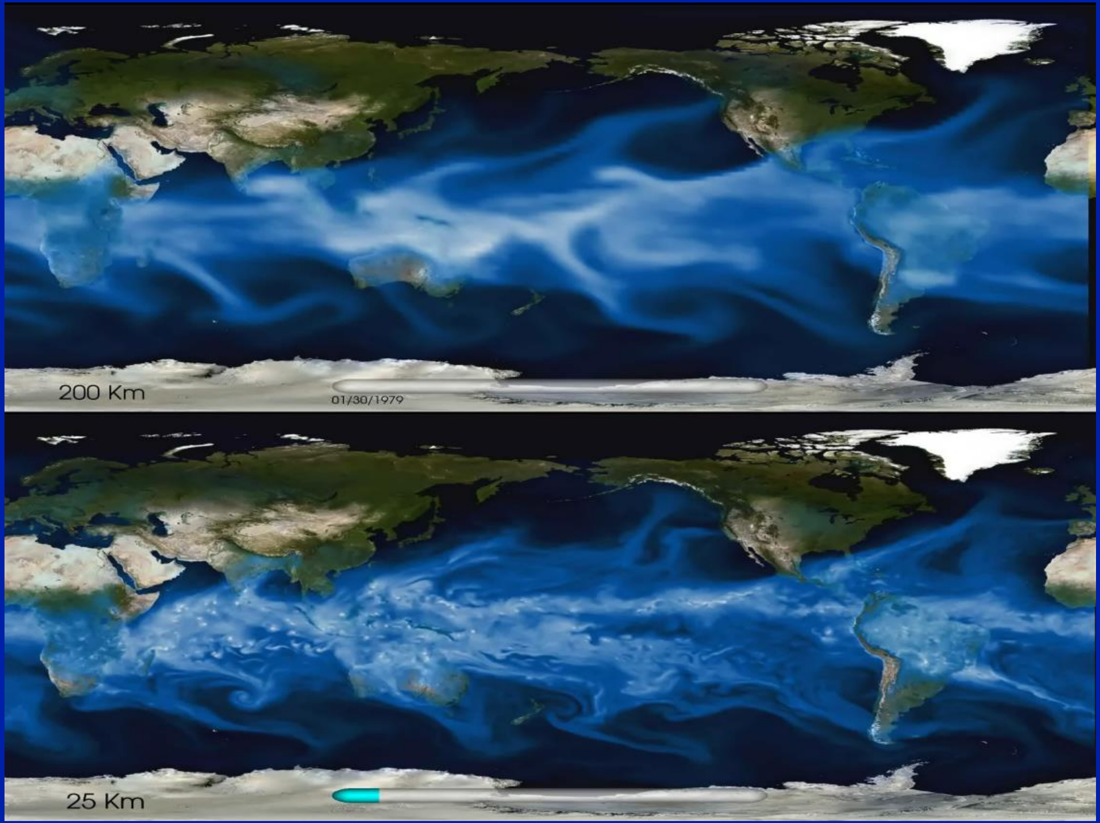
- Cloud resolution, quantifying uncertainty, understanding tipping points, etc., will drive climate to exascale platforms
- New math, models, and systems support will be needed

Extreme data

- “Reanalysis” projects need 100× more computing to analyze observations
- Machine learning and other analytics are needed today for petabyte data sets
- Combined simulation/observation will empower policy makers and scientists

Courtesy Horst Simon, LBNL

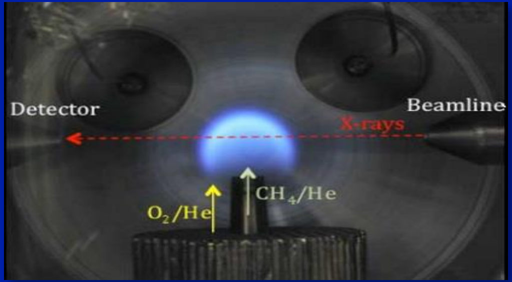
Qualitative Improvement of Simulation with Higher Resolution (2011)

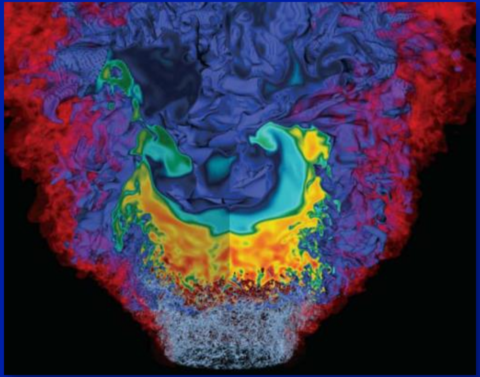


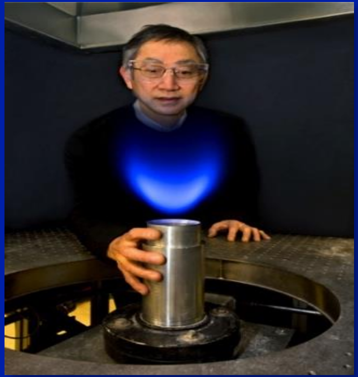
Michael Wehner, Prabhat, Chris Algieri, Fuyu Li, Bill Collins, Lawrence Berkeley National Laboratory; Kevin Reed, University of Michigan; Andrew Gettelman, Julio Bacmeister, Richard Neale, National Center for Atmospheric Research

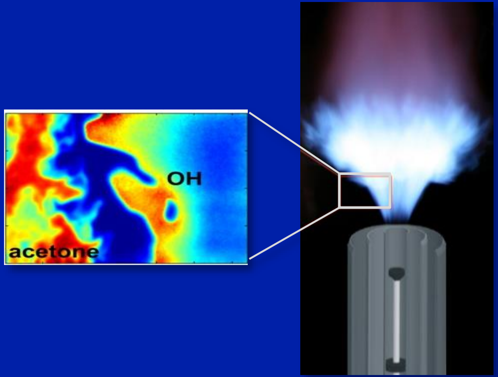
Exascale combustion simulations

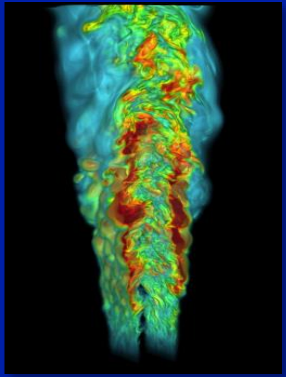
- Goal: 50% improvement in engine efficiency
- Center for Exascale Simulation of Combustion in Turbulence (ExaCT)
  - Combines M&S and experimentation
  - Uses new algorithms, programming models, and computer science











Courtesy Horst Simon, LBNL

Modha Group at IBM Almaden

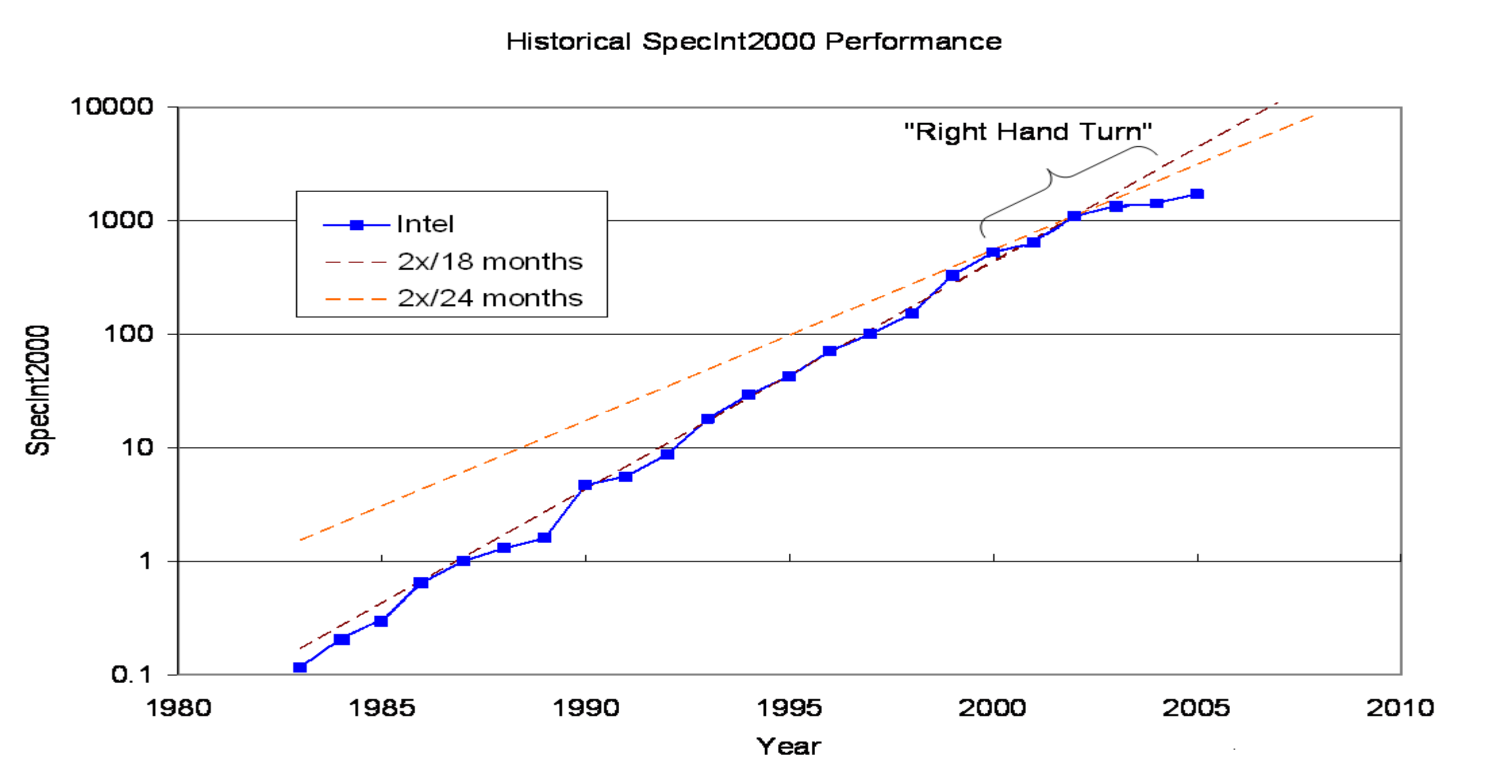
	Mouse	Rat	Cat	Monkey	Human
N:	16×10^{6}	56×10^{6}	763×10^{6}	2×10^{9}	22×10^{9}
S:	128×10^{9}	448×10^{9}	6.1×10^{12}	20×10^{12}	220×10^{12}

Recent simulations achieve unprecedented scale of $65*10^{9}$ neurons and $16*10^{12}$ synapses

Almaden	Watson	WatsonShaheen	LLNL Dawn	LLNL Sequoia
BG/L	BG/L	BG/P	BG/P	BG/Q
December, 2006	April, 2007	March, 2009	May, 2009	June, 2012

Courtesy Horst Simon, LBNL

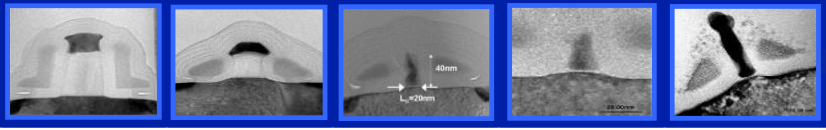
Waiting for Moore's Law to save your serial code start getting bleak in 2004



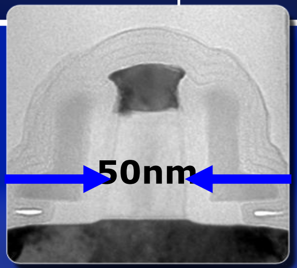
Source: published SPECInt data

Moore's Law is not at all dead…

Intel process technology capabilities

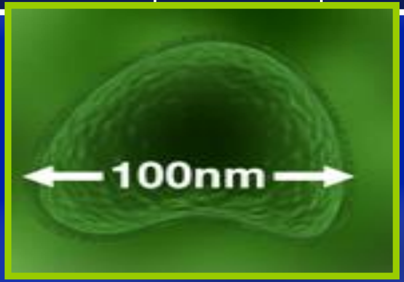


High Volume Manufacturing	2004	2006	2008	2010	2012	2014	2016	2018
Feature Size	90nm	65nm	45nm	32nm	22nm	16nm	11nm	8nm
Integration Capacity (Billions of Transistors)	2	4	8	16	32	64	128	256



Transistor for 90nm Process

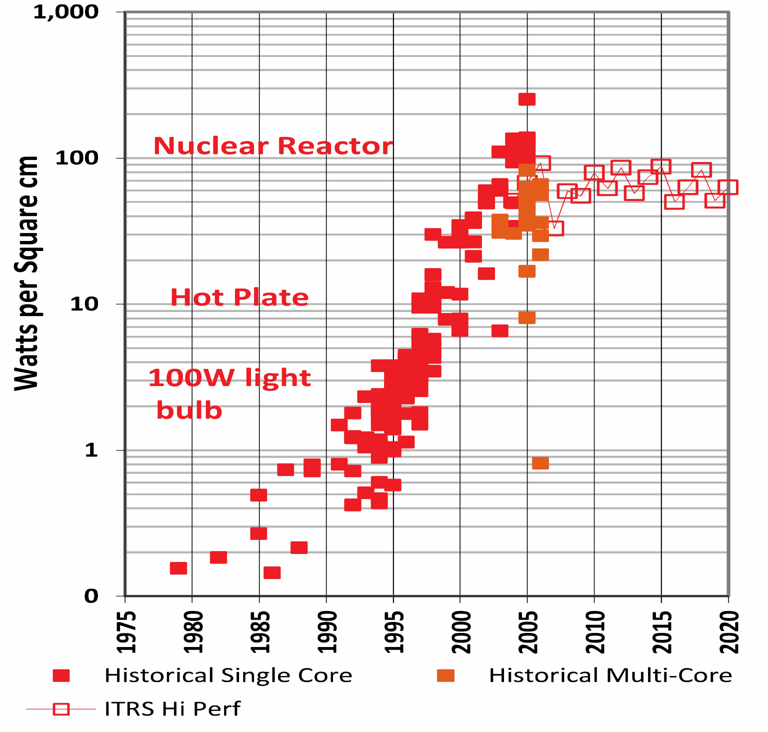
Source: Intel

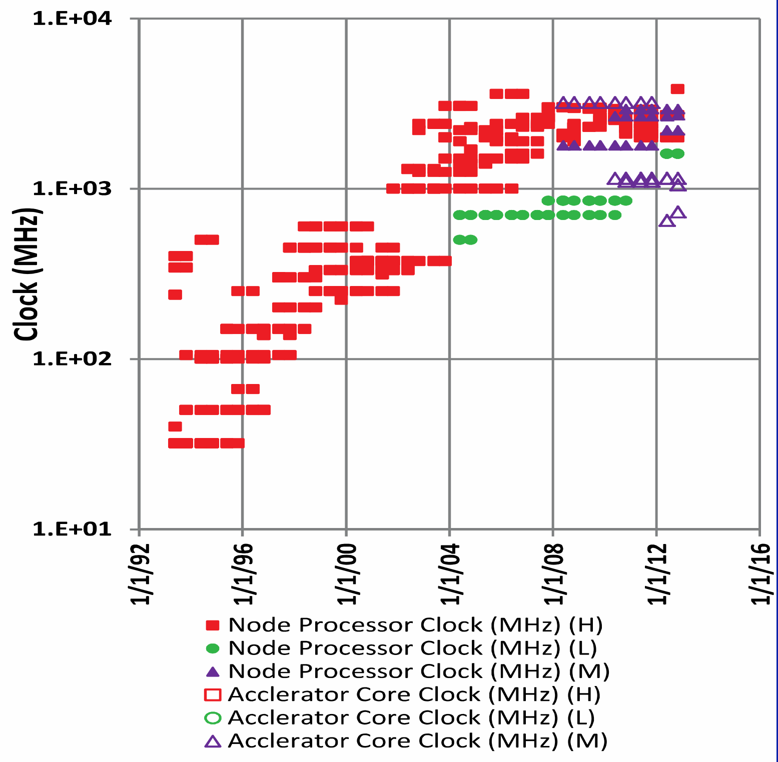


Influenza Virus

Source: CDC

That Power and Clock Inflection Point in 2004… didn't get better.

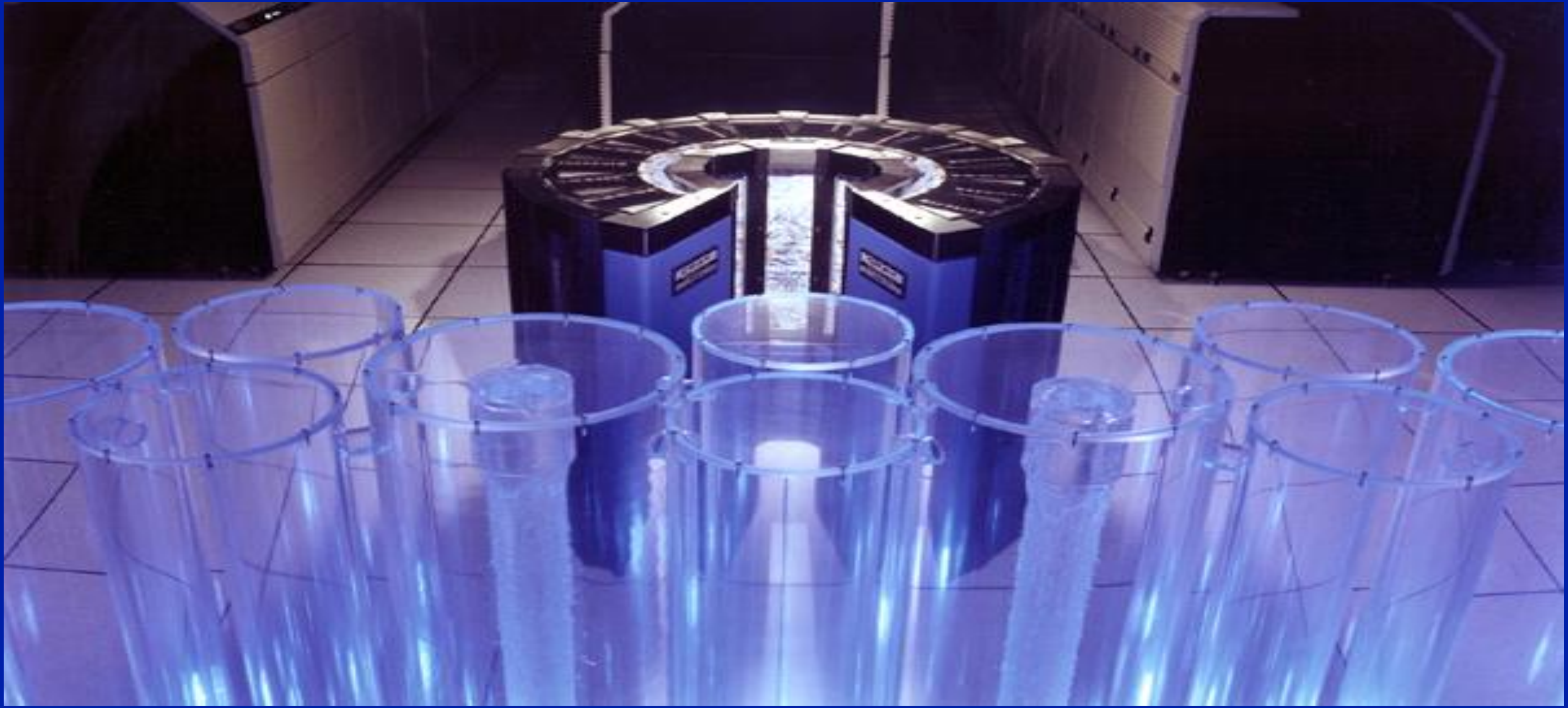




Source: Kogge and Shalf, IEEE CISE

Courtesy Horst Simon, LBNL

Not a new problem, just a new scale…



Cray-2 with cooling tower in foreground, circa 1985

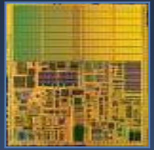
And how to get more performance from more transistors with the same power.

RULE OF THUMB

A 15% Reduction In Voltage Yields

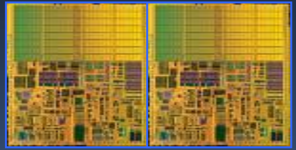
Frequency Reduction	Power Reduction	Performance Reduction
15%	45%	10%

SINGLE CORE



Area = 1
Voltage = 1
Freq = 1
Power = 1
Perf = 1

DUAL CORE



Area = 2
Voltage = 0.85
Freq = 0.85
Power = 1
Perf = ~1.8

Parallel Computing

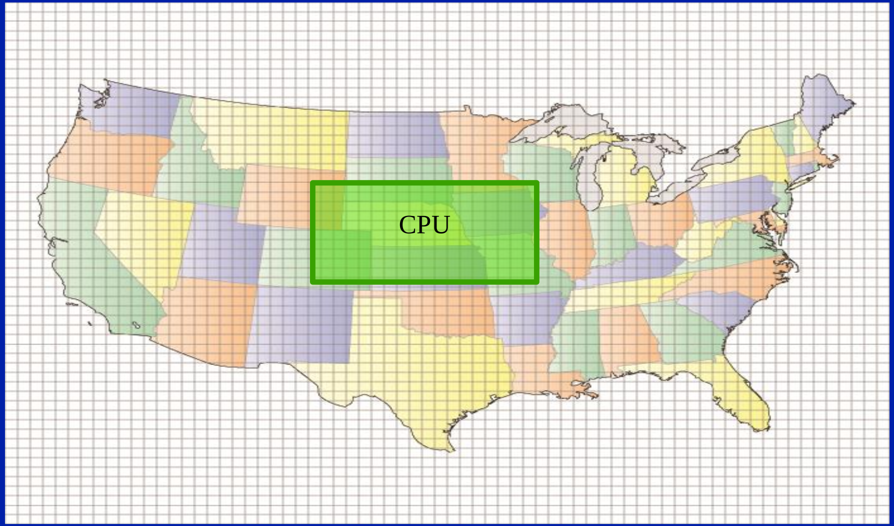
One woman can make a baby in 9 months.

Can 9 woman make a baby in 1 month?

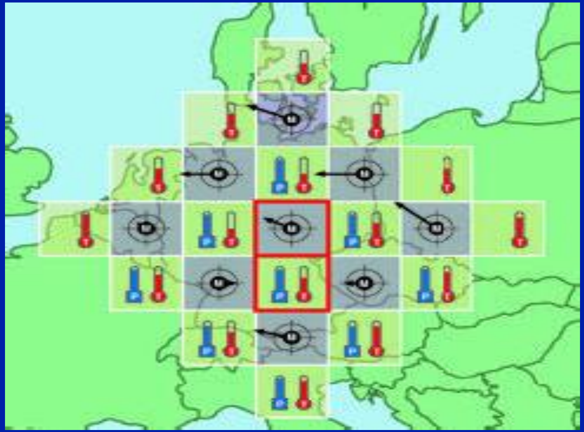
But 9 women can make 9 babies in 9 months.

First two bullets are Brook’s Law. From *The Mythical Man-Month.*

Prototypical Application: Serial Weather Model

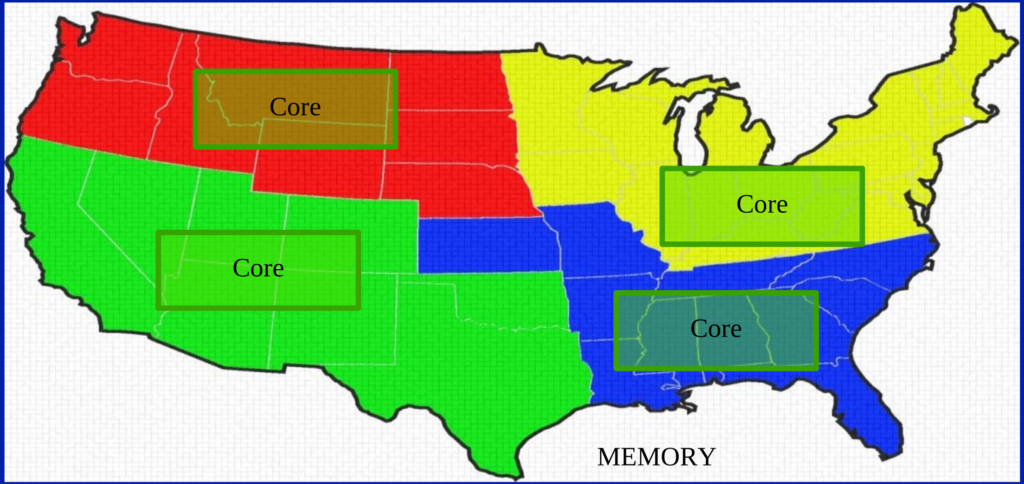


First Parallel Weather Modeling Algorithm: Richardson in 1917



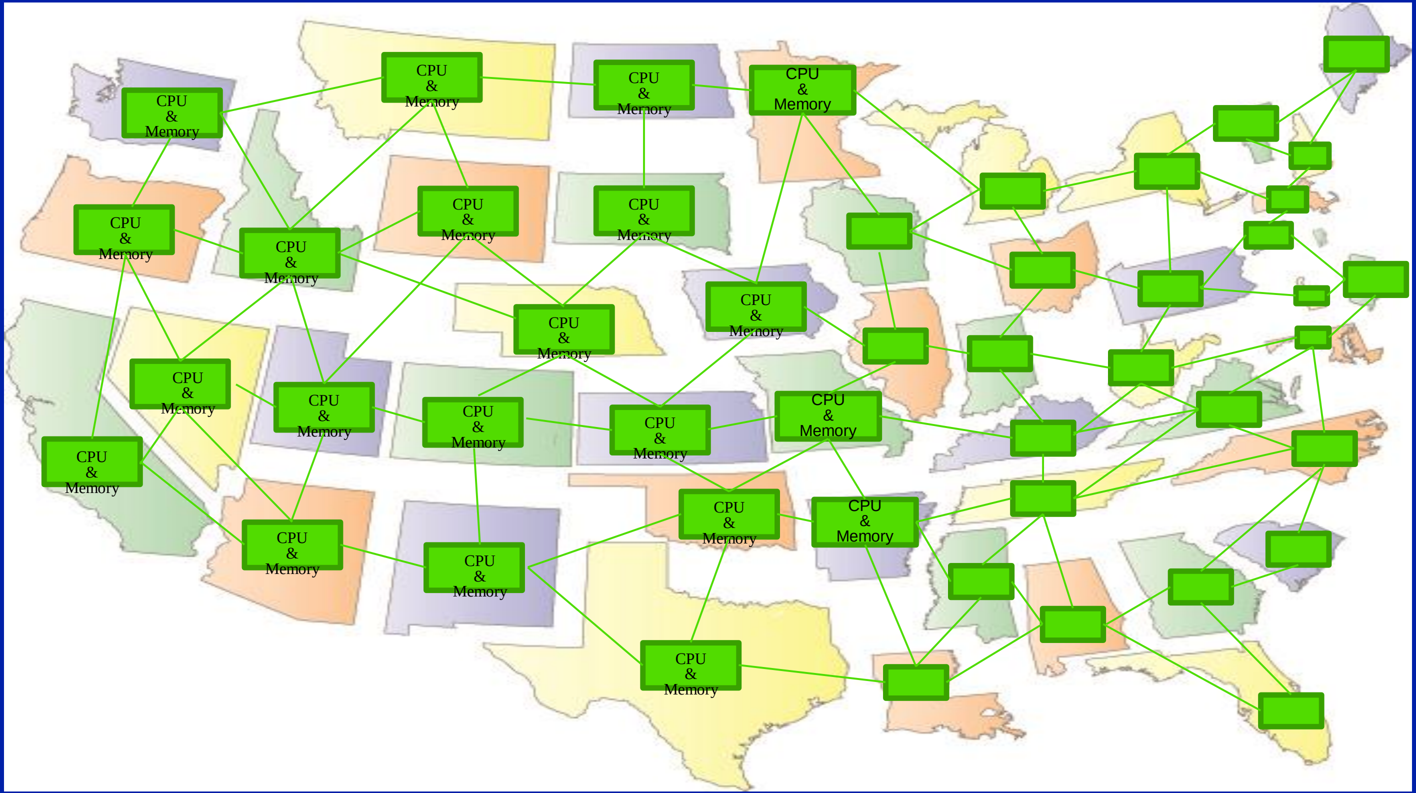
Courtesy John Burkhardt, Virginia Tech

Weather Model: Shared Memory (OpenMP)



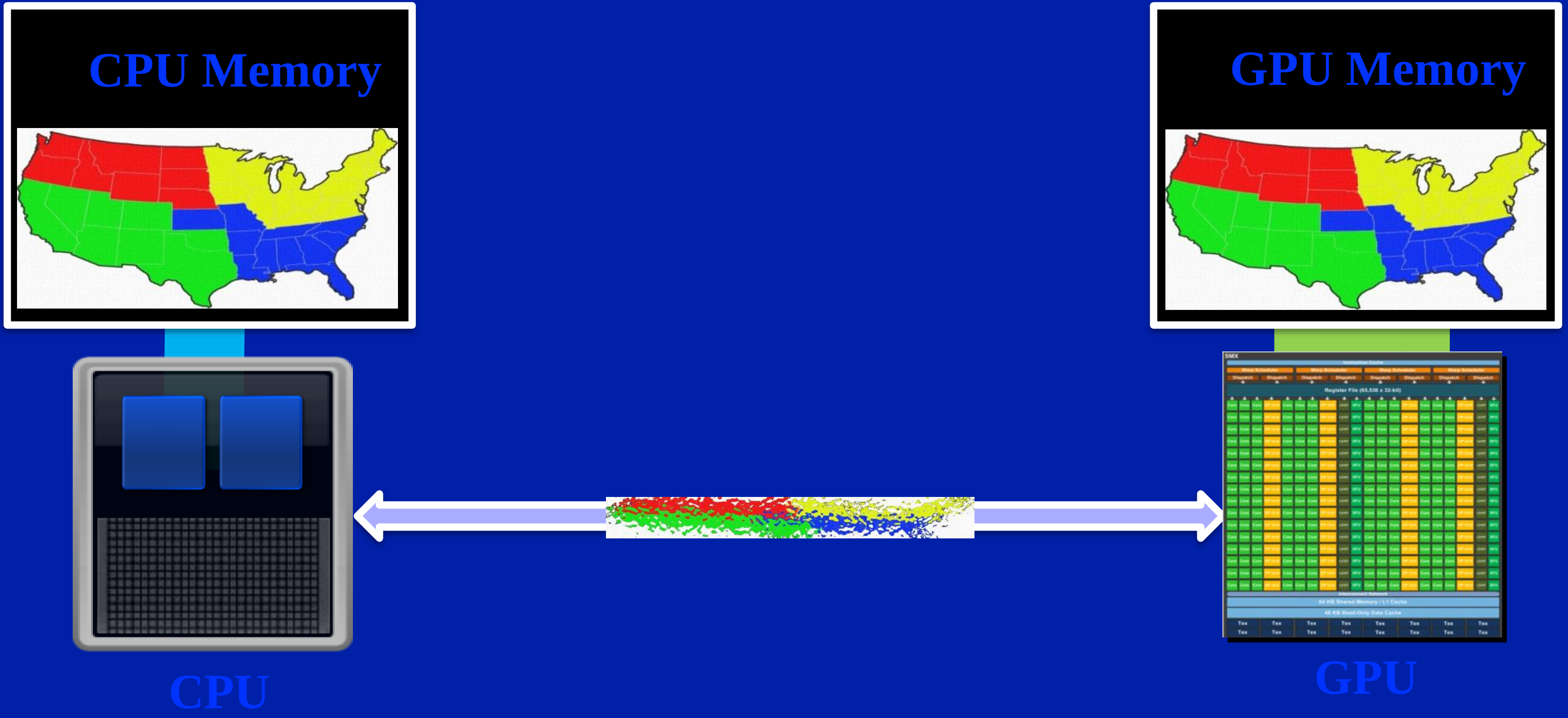
Four meterologists in the same room sharing the map.

Weather Model: Distributed Memory (MPI)



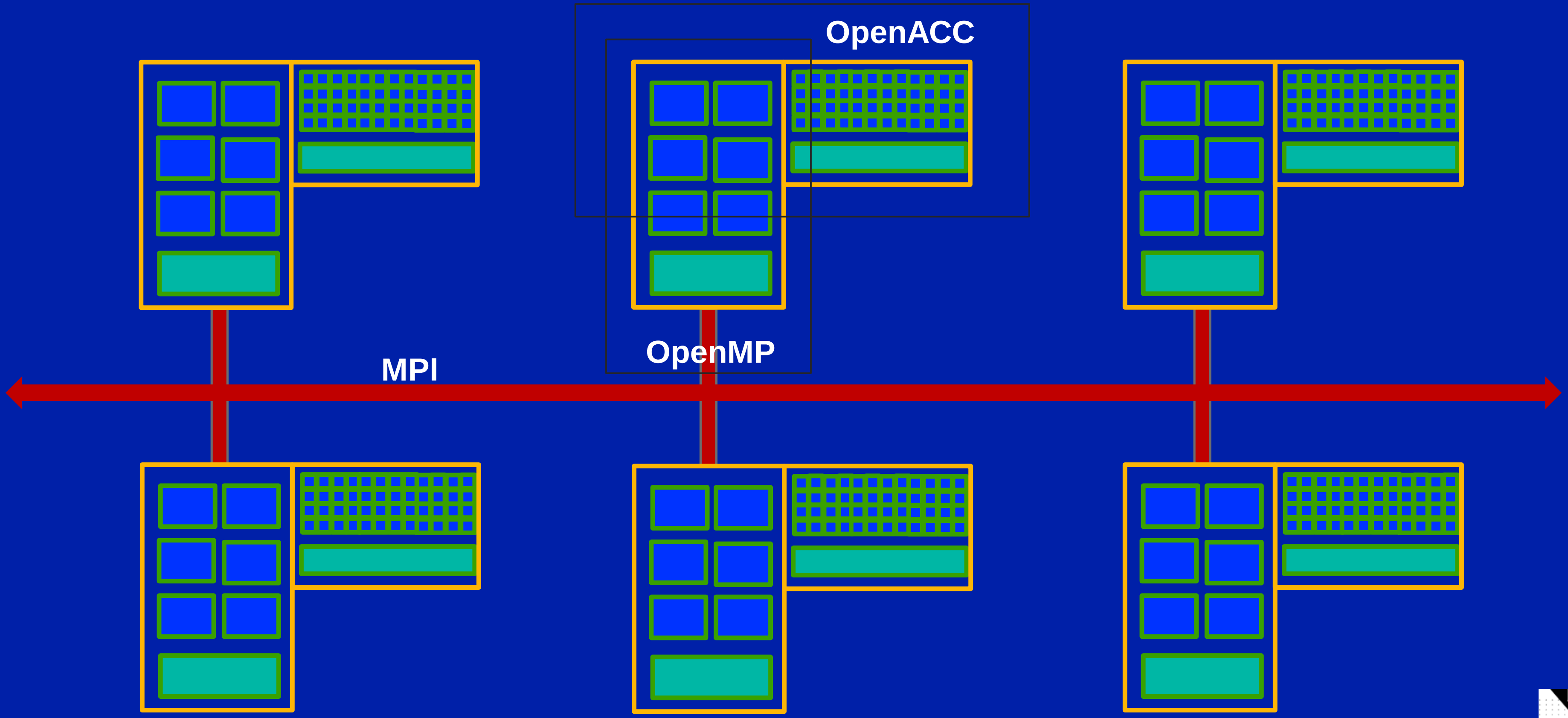
50 meterologists using telegraphs.

Weather Model: Accelerator (OpenACC)



1 meterologist coordinating 1000 savants using tin cans and a string.

The pieces fit like this…



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Top 10 Systems as of November 2017

#	Site	Manufacturer	Computer	CPU Interconnect [Accelerator]	Cores	Rmax (Tflops)	Rpeak (Tflops)	Power (MW)
1	National Super Computer Center in Guangzhou **China**	NRCPC	Sunway TaihuLight	Sunway SW26010 260C 1.45GHz	**10,649,600**	93,014	125,435	15.3
2	National Super Computer Center in Guangzhou **China**	NUDT	Tianhe-2 (MilkyWay-2)	Intel Xeon E5-2692 2.2 GHz TH Express-2 Intel Xeon Phi 31S1P	**3,120,000**	**33,862**	**54,902**	**17.8**
3	Swiss National Supercomputing Centre (CSCS) **Switzerland**	Cray	Piz Daint Cray XC50	Xeon E5-2690 2.6 GHz Aries NVIDIA P100	**361,760**	**19,590**	**25,326**	**2.2**
4	Japan Agency for Marine-Earth Science **Japan**	ExaScaler	Gyoukou	Xeon D-1571 1.3GHz Infiniband EDR	**19,860,000**	**19,135**	**28,192**	**1.3**
5	DOE/SC/Oak Ridge National Laboratory **United States**	Cray	Titan Cray XK7	Opteron 6274 2.2 GHz Gemini NVIDIA K20x	**560,640**	**17,590**	**27,112**	**8.2**
6	DOE/NNSA/LLNL **United States**	IBM	Sequoia BlueGene/Q	Power BQC 1.6 GHz Custom	**1,572,864**	**17,173**	**20,132**	**7.8**
7	DOE/NNSA/LANL/SNL **United States**	Cray	Trinity Cray XC40	Xeon E5-2698v3 2.3 GHz Aries Intel Xeon Phi 7250	**979,968**	**17,173**	**20,132**	**7.8**
8	DOE/SC/LBNL/NERSC **United States**	Cray	Cori Cray XC40	Aries Intel Xeon Phi 7250	**622,336**	**14,014**	**27,880**	**3.9**
9	Joint Center for Advanced High Performance Computing **Japan**	Fujitsu	Oakforest Primergy	Intel OPA Intel Xeon Phi 7250	**556,104**	**13,554**	**24,913**	**2.7**
10	RIKEN Advanced Institute for Computational Science (AICS)	Fujitsu	K Computer	SPARC64 VIIIfx 2.0 GHz Tofu	**705,024**	**10,510**	**11,280**	**12.6**

OpenACC is a first class API!

We can do better. We have a role model.

- **Straight forward extrapolation results in a real time human brain scale simulation at about 1 - 10 Exaflop/s with 4 PB of memory**
- **Current predictions envision Exascale computers in 2020 with a power consumption of at best 20 - 30 MW**
- **The human brain takes 20W**
- **Even under best assumptions in 2020 our brain will still be a million times more power efficient**

Courtesy Horst Simon, LBNL

Why you should be (extra) motivated.

- This parallel computing thing is no fad.
- The laws of physics are drawing this roadmap.
- If you get on board (the right bus), you can ride this trend for a long, exciting trip.

Let’s learn how to use these things!