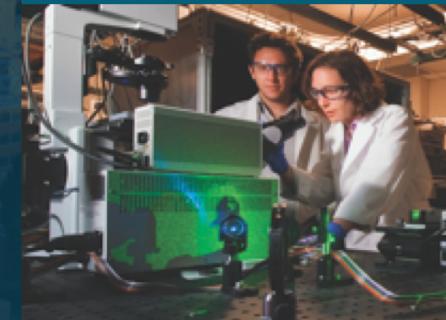


Guest Lecture Stanford ME469: High Performance Computing for CFD



*PRES*ENTED BY

Stefan P. Domino

Computational Thermal and Fluid Mechanics

Sandia National Laboratories SAND2018-4536 PE



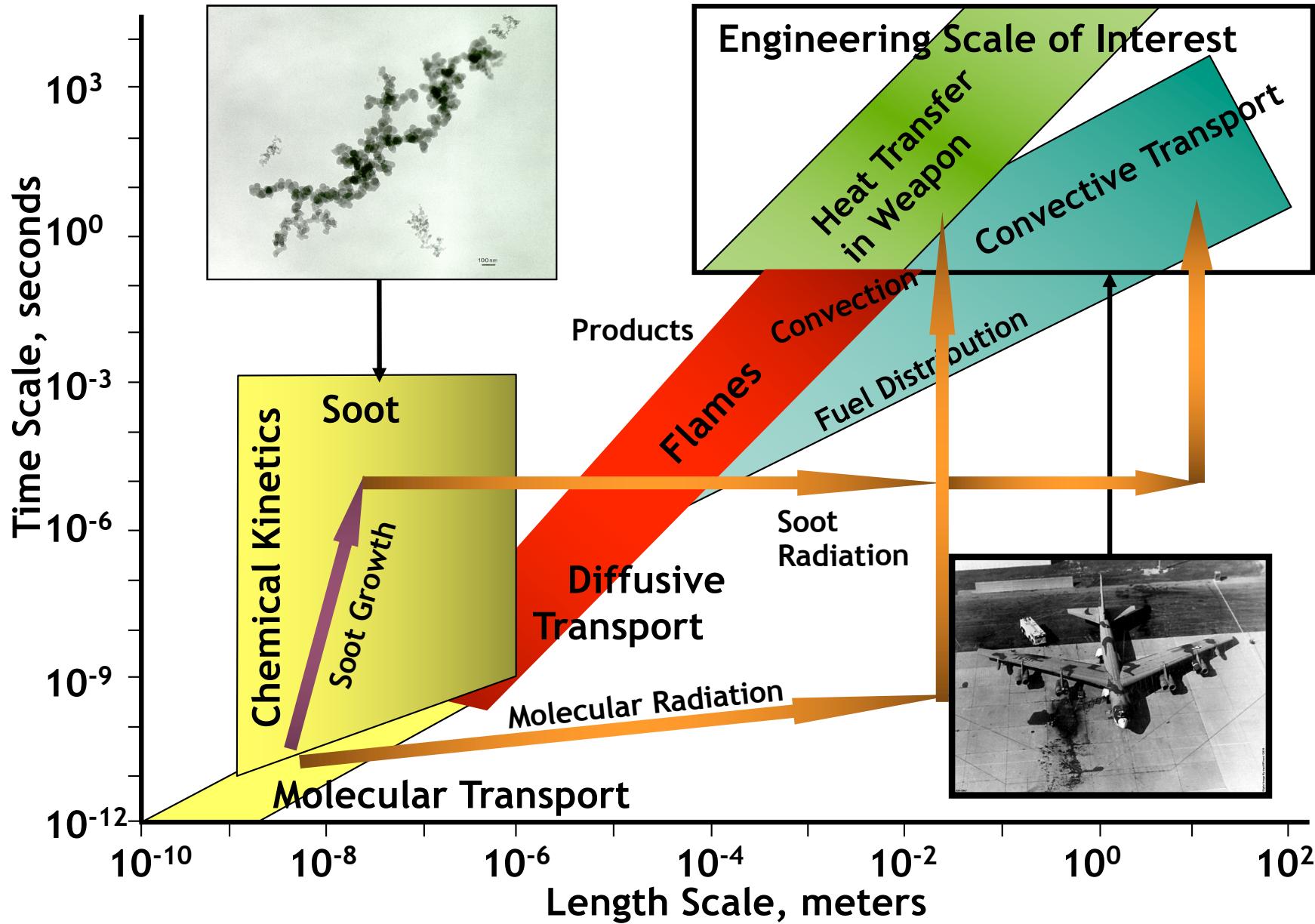
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High Performance Computing for CFD: Outline

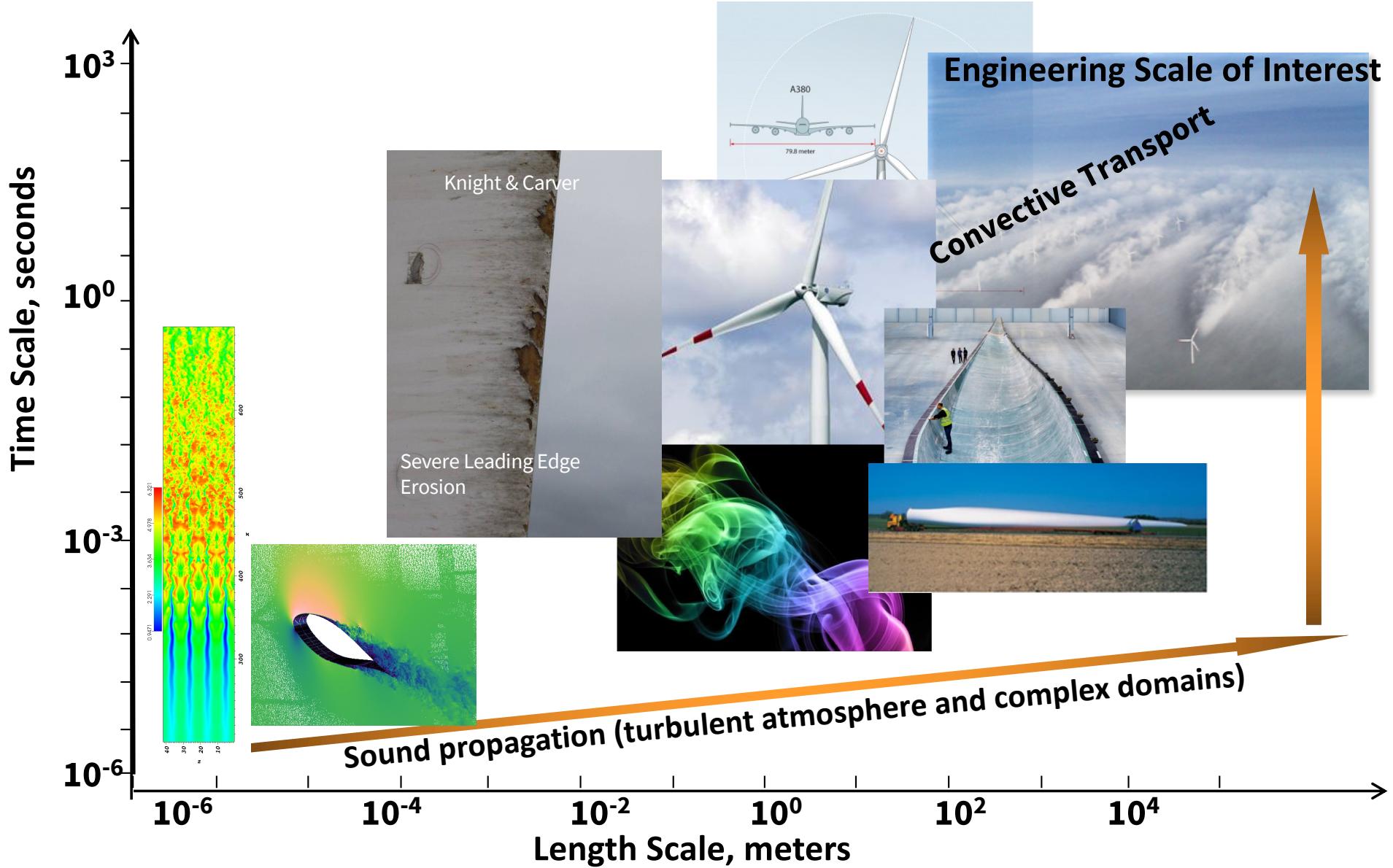


- Overview of Time and Length Scales
 - Fire
 - Wind
- Conceptual Parallel Computing Model
- Types of Scaling: Strong and Weak
- Examples of Scaling
- Next Generation Platform Exascale Drivers
- Conclusions

3 Disparity in Time and Length Scales, Fire



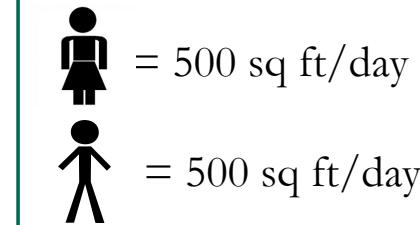
Disparity in Time and Length Scales, Wind



Conceptual Scaling Exercise



- Goal: Paint a house in one day
 - My House: 1000 sq ft
 - WH: 60,000 sq ft



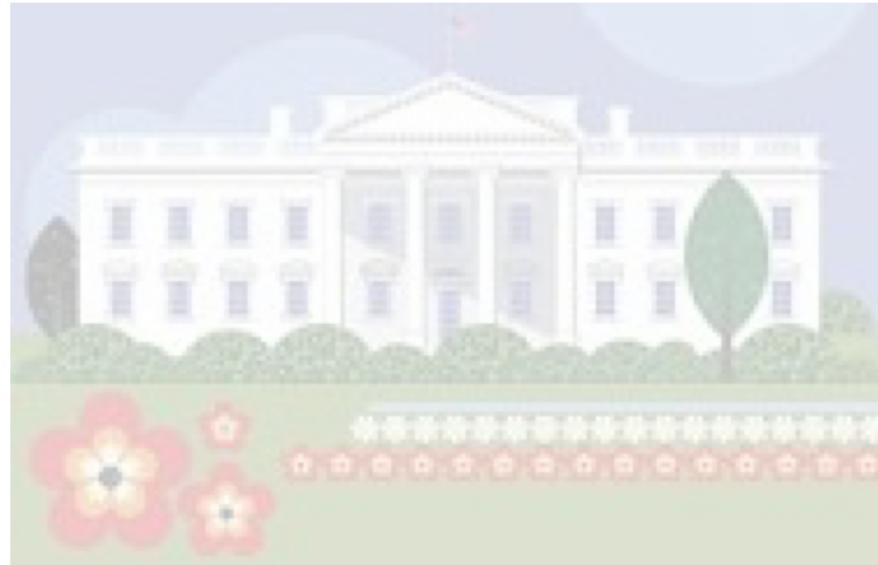
Painting Rate Legend

- One person would paint my house in two days (!!)
- The white house will require one person 120 days (!!)

6 Single House, More People (each person with reduced load)

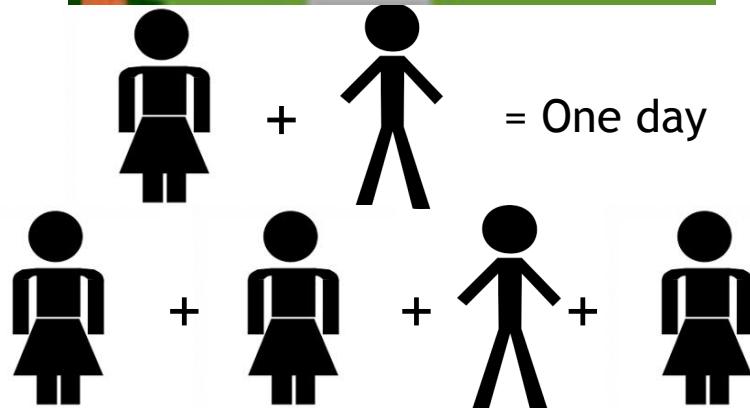


- Goal: Paint a house in one day
 - My House: 1000 sq ft
 - WH: 60,000 sq ft



	= 500 sq ft/day
	= 500 sq ft/day

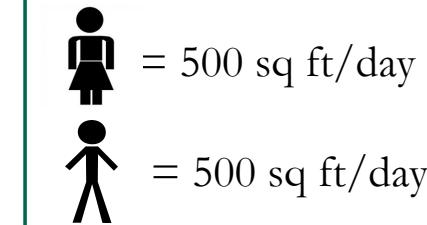
Painting Rate Legend



Single House, More People (with shared load)



- Goal: Paint a house in one day
 - My House: 1000 sq ft
 - WH: 60,000 sq ft



Painting Rate Legend

Time to completion is one day. Everyone involved provided 500 sq ft

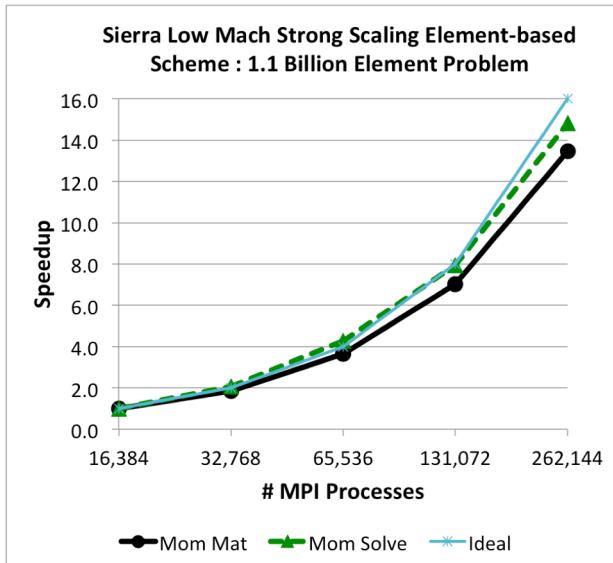
$$60 \times \left(\begin{array}{c} \text{Icon of a person with a skirt} \\ + \\ \text{Icon of a stick figure} \end{array} \right) = 60 \text{ days}$$

$$60 \times \left(\begin{array}{c} \text{Icon of a person with a skirt} \\ + \\ \text{Icon of a stick figure} \end{array} \right) = 1 \text{ day}$$

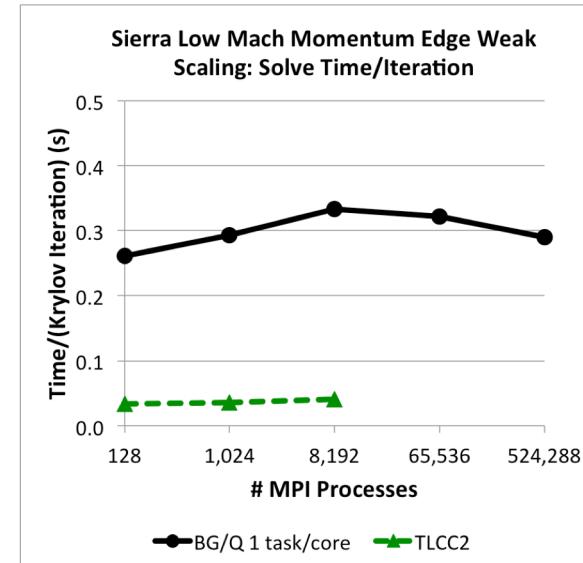
Types of Scaling



- Strong Scaling: How the solution time varies with increased computational resources (cores, threads, GPU/Warps) on a fixed-size problem
 - User Y has a mesh that is 1 billion elements and would like to minimize the time it takes to complete a simulation
- Weak Scaling: How the solution time varies with increased problem size on a fixed computational resource load (cores, threads, GPU/Warps)
 - User Y is conducting a validation study that includes three mesh resolutions, which were obtained by uniform mesh refinement, and would like to increase the computational resource appropriately



Strong Scaling



Weak Scaling

Computing Performance: Through the Years



- HPC is facing a new disruption in technology



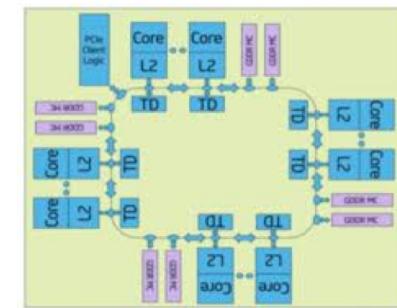
Mainframes
60's to 70's



Vector
Supercomputers
70's to early 90's



Massively parallel
processor (MPP)
systems with simple
nodes
1990's to 2010

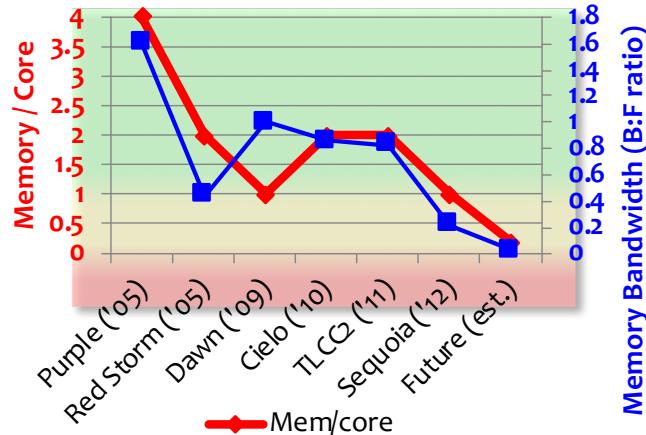
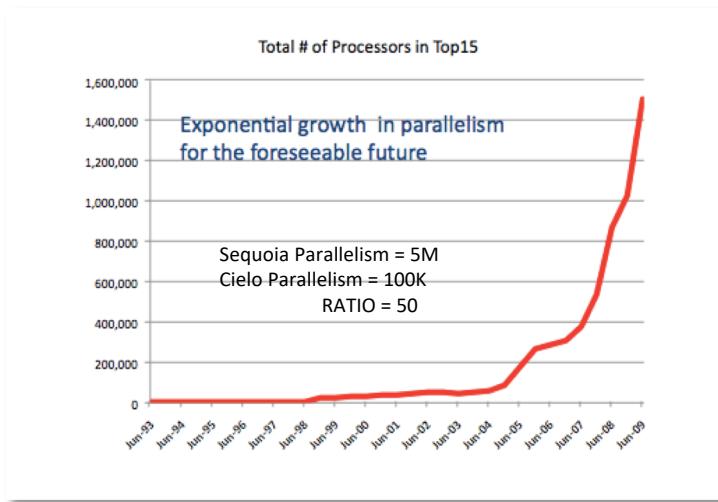


MPP w/ Advanced
Architecture nodes:
Multilevel,
heterogeneous,
energy and memory
constrained

ROOM → MACHINE → CABINET → CHIP

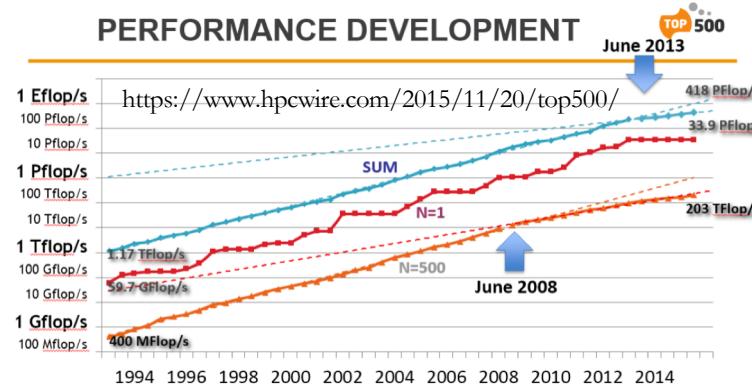
Technology disruptions require a significant increase in complexity of our codes

Drive Towards Next Generation Platforms

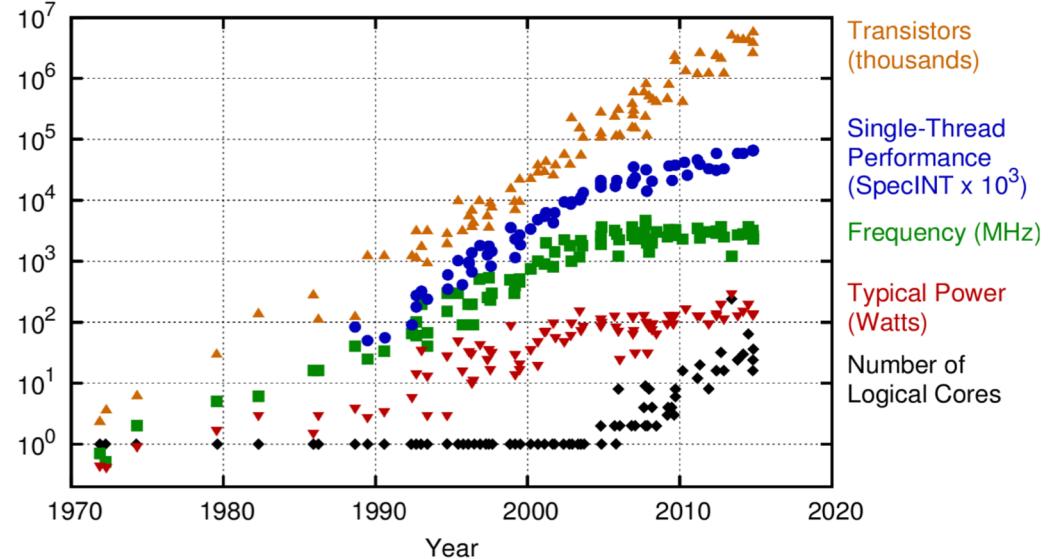


Dramatic increase in on-node parallelism and reduction in relative data movement is counter to our current code performance

PERFORMANCE DEVELOPMENT



40 Years of Microprocessor Trend Data



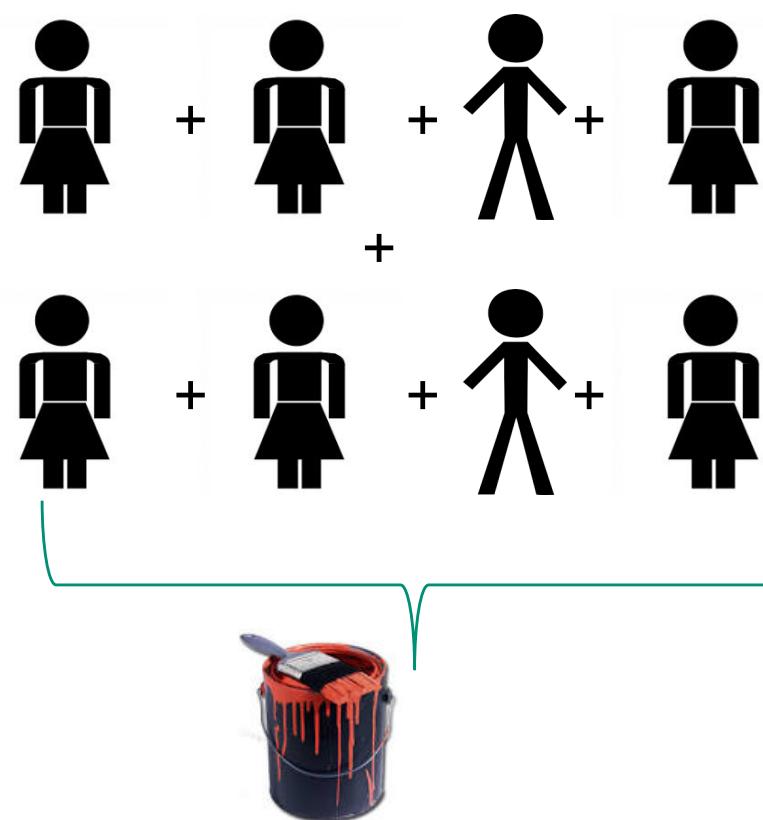
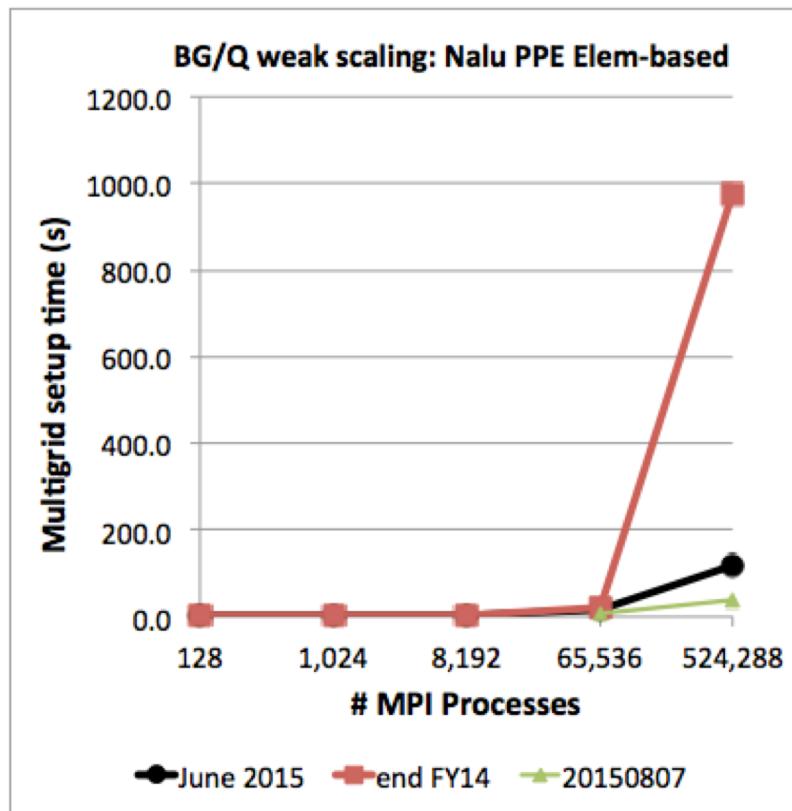
Original data up to the year 2010 collected and plotted by M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond, and C. Batten
New plot and data collected for 2010-2015 by K. Rupp

Power constraints are driving the rapid increase in on-node parallelism. However, per core memory bandwidth is decreasing making it extremely difficult to fully utilize additional cores

Challenges Associated with Scaling



- Consider a communication-intensive code procedure: Algebraic Multigrid (AMG) preconditioner setup
- Like verification, the product of a first-time scaling study at a new production scale is generally met with work!



High Performance Computing for CFD: Conclusions



- Several fluids applications found in the low-Mach application space require HPC
- Strong and weak scaling are of interest in engineering analysis
- Communication bottlenecks can affect scaling
- From a user-perspective, scaling is critical to efficiently deploying production simulation results
- Path towards NGP will require disruptive technology with significant code investments