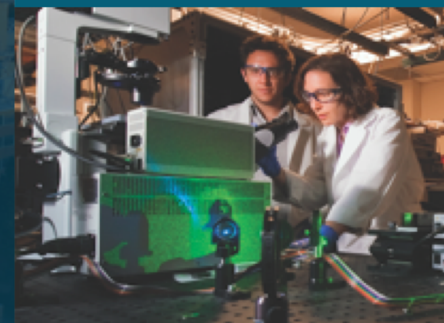
# Guest Lecture Stanford ME469: High Performance Computing for CFD




*PRESENTED BY*

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Computational Thermal and Fluid Mechanics

Sandia National Laboratories SAND2018-4536 PE



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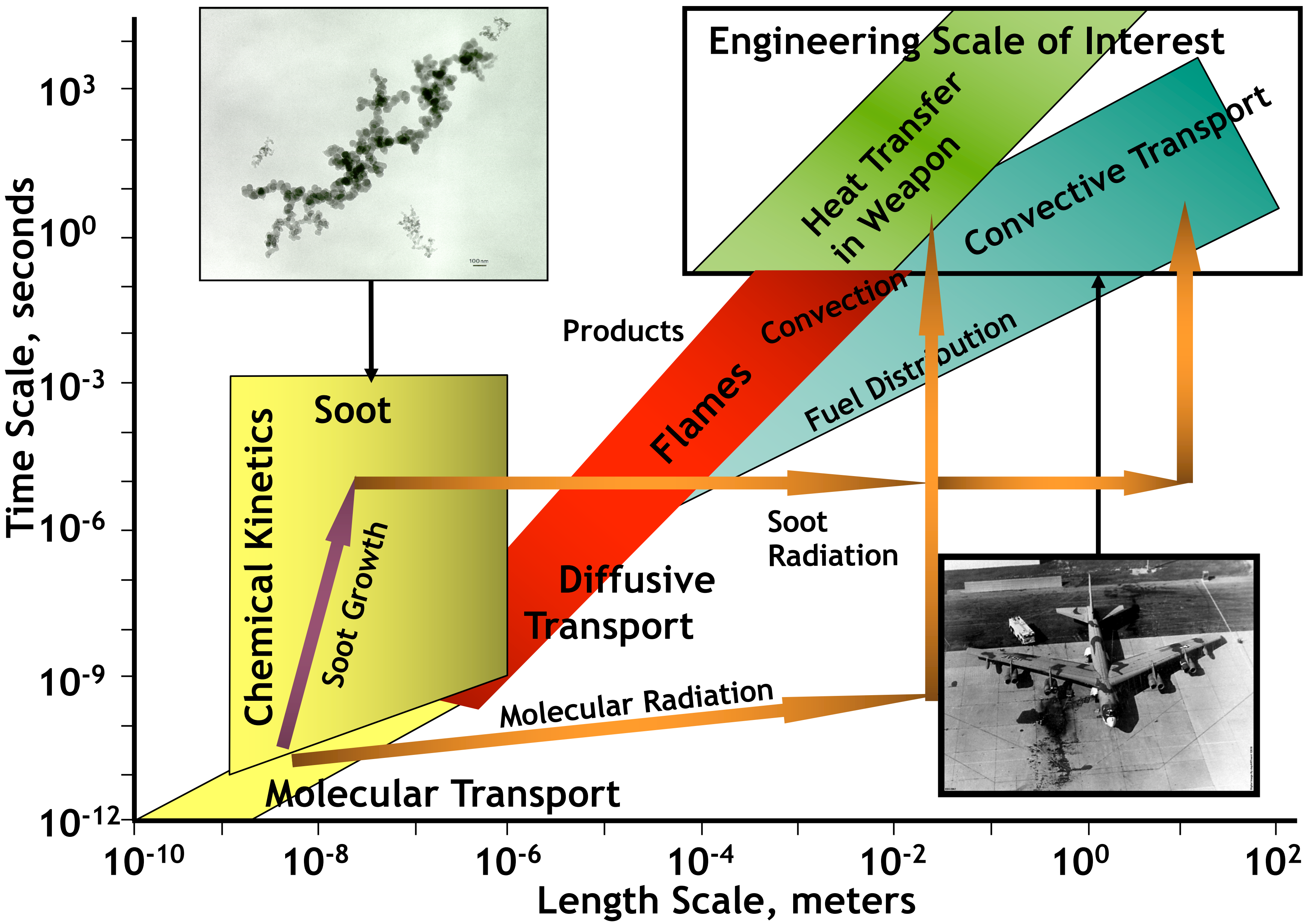
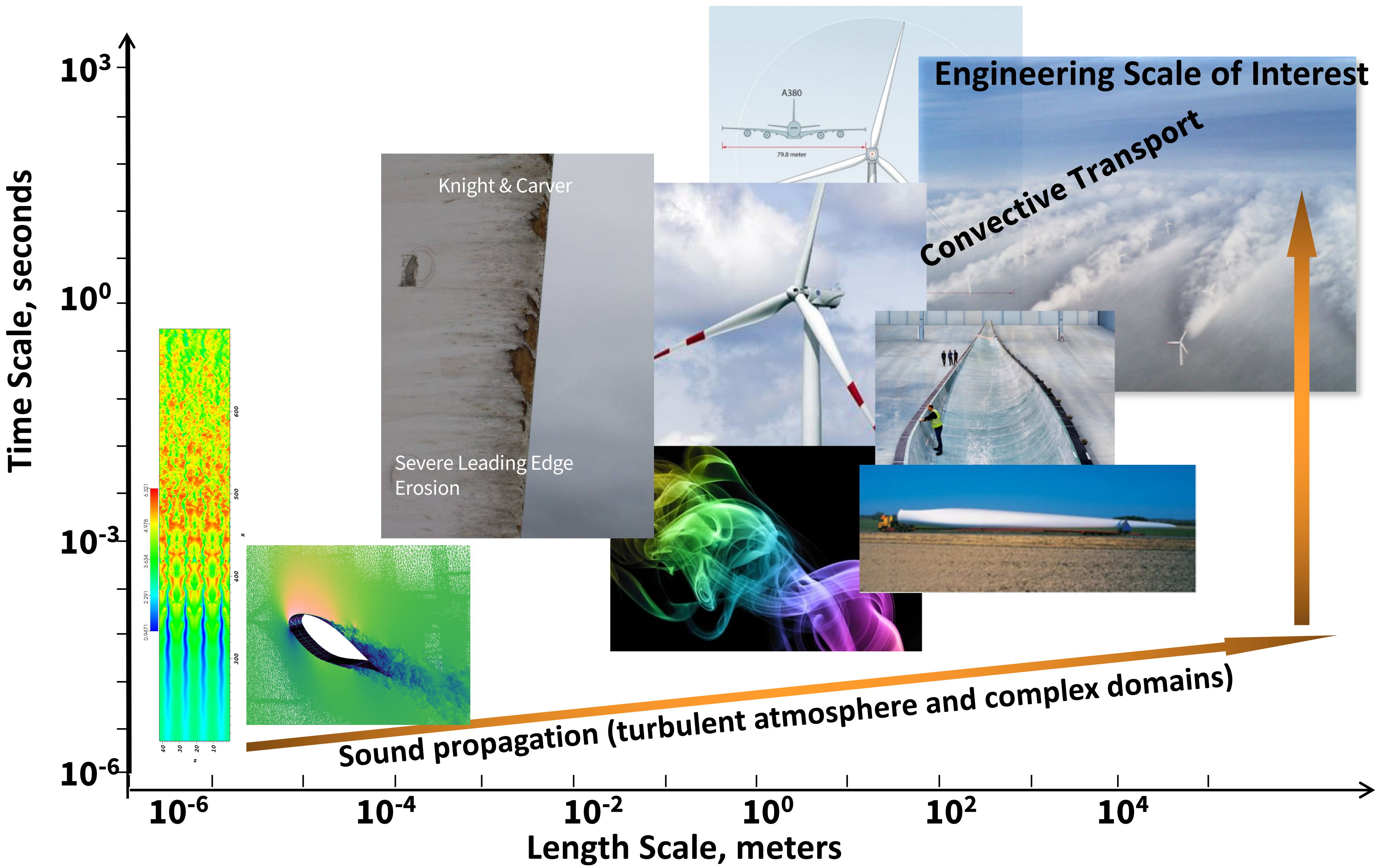
# High Performance Computing for CFD: Outline

- 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

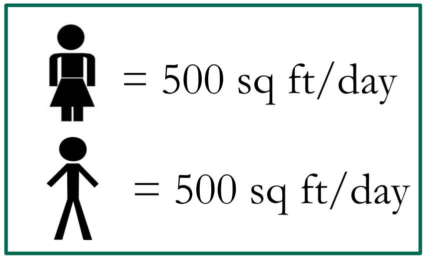
# Disparity in Time and Length Scales, Fire



# Disparity in Time and Length Scales, Wind



# Conceptual Scaling Exercise

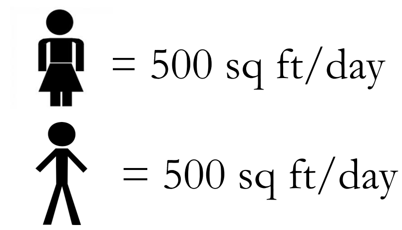



Painting Rate Legend

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

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

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




Painting Rate Legend

- Goal: Paint a house in one day
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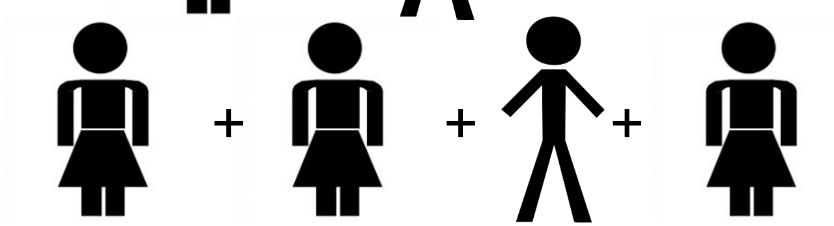
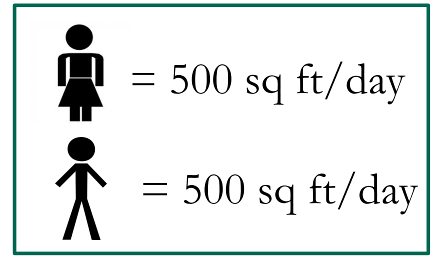


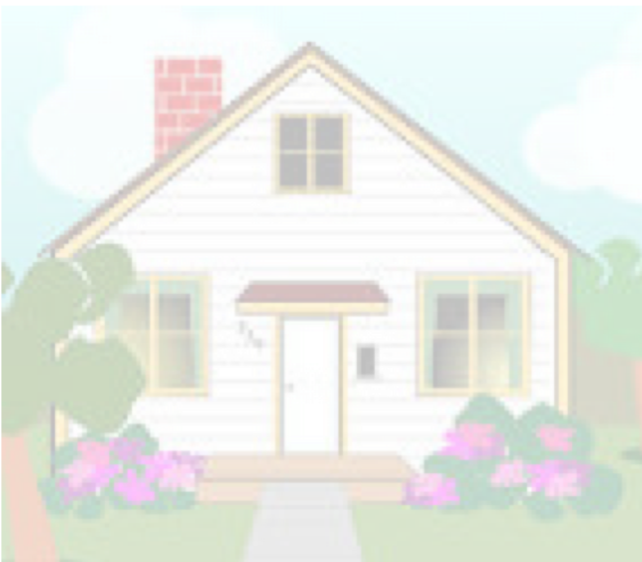

= Faster Completion; Half day (each person 250 sq ft)

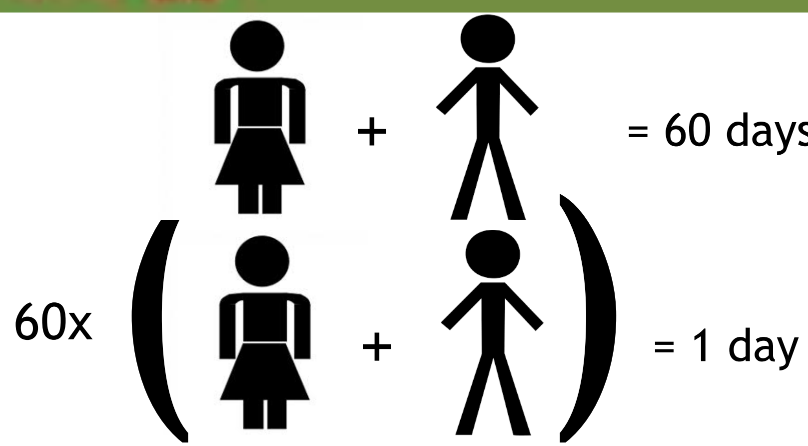
# Single House, More People (with shared load)




Painting Rate Legend

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

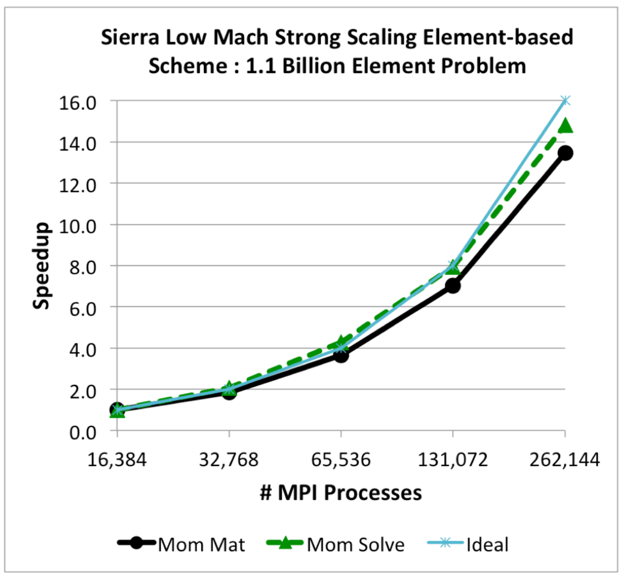




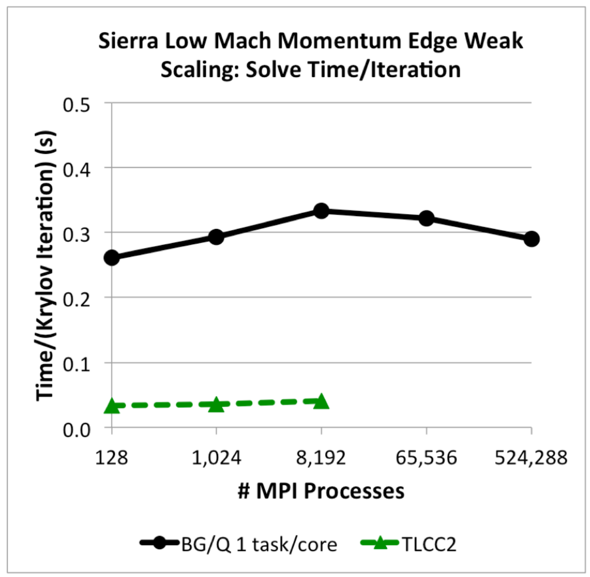

Time to completion is one day. Everyone involved provided 500 sq ft

# 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



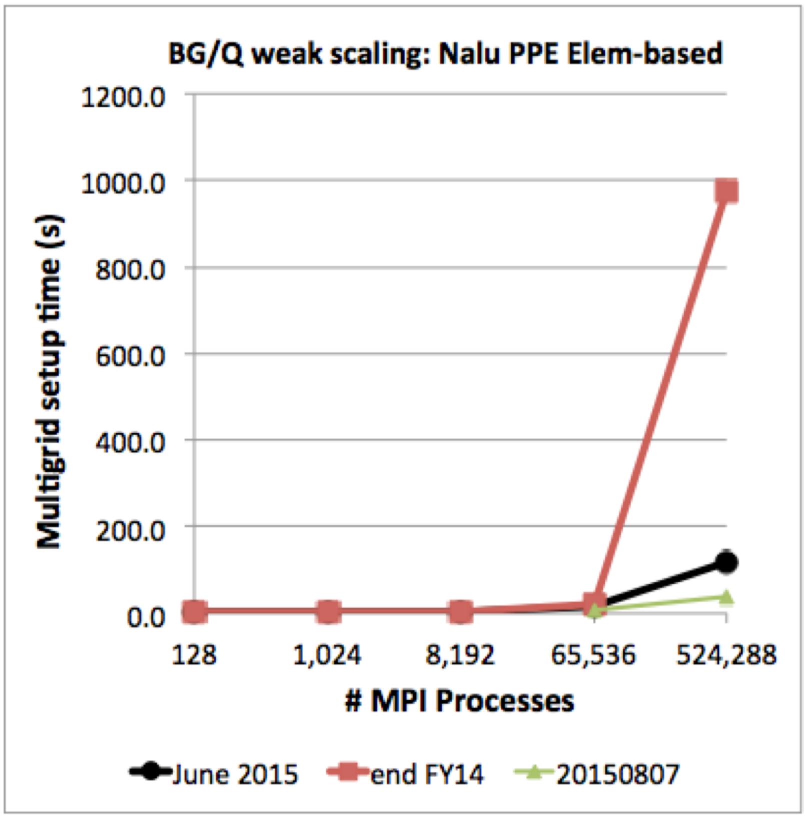

Strong Scaling

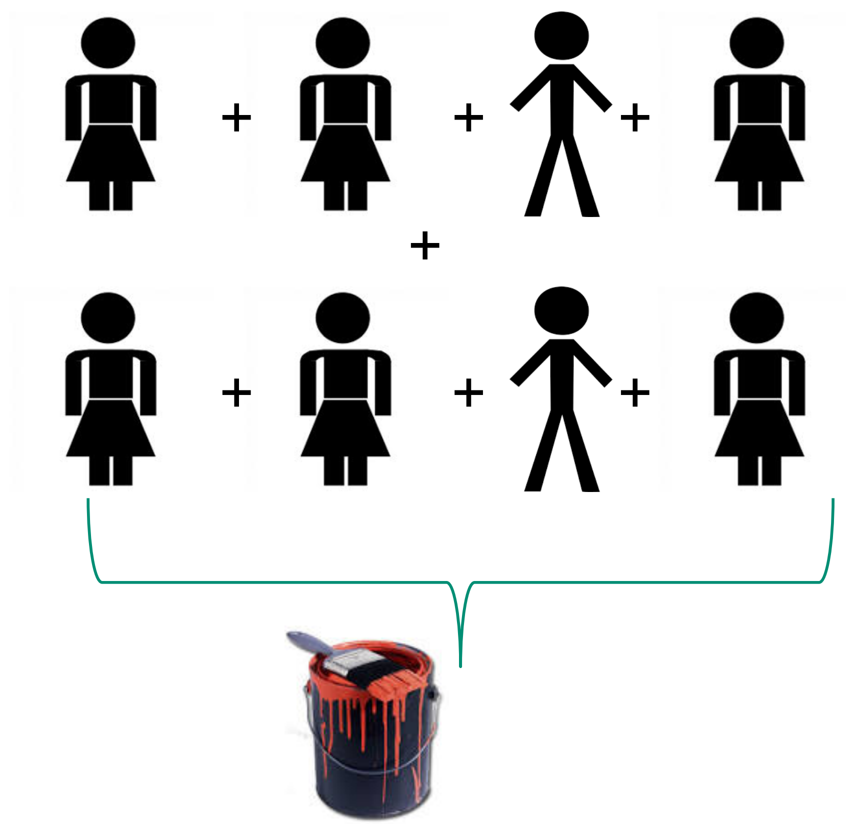



Weak Scaling

# Challenges Associated with Scaling

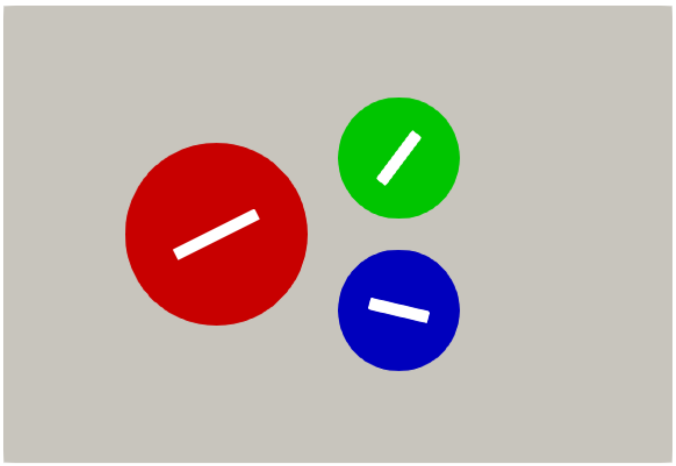
- Consider a communication-intensive code procedure: Algebraic Multigrid (AMG) preconditioner setup
- Like verification, the product of a first-time scaling study at a new production scale is generally met with work!



# Nalu/reg_tests/test_files/dgNonConformalThreeBlade

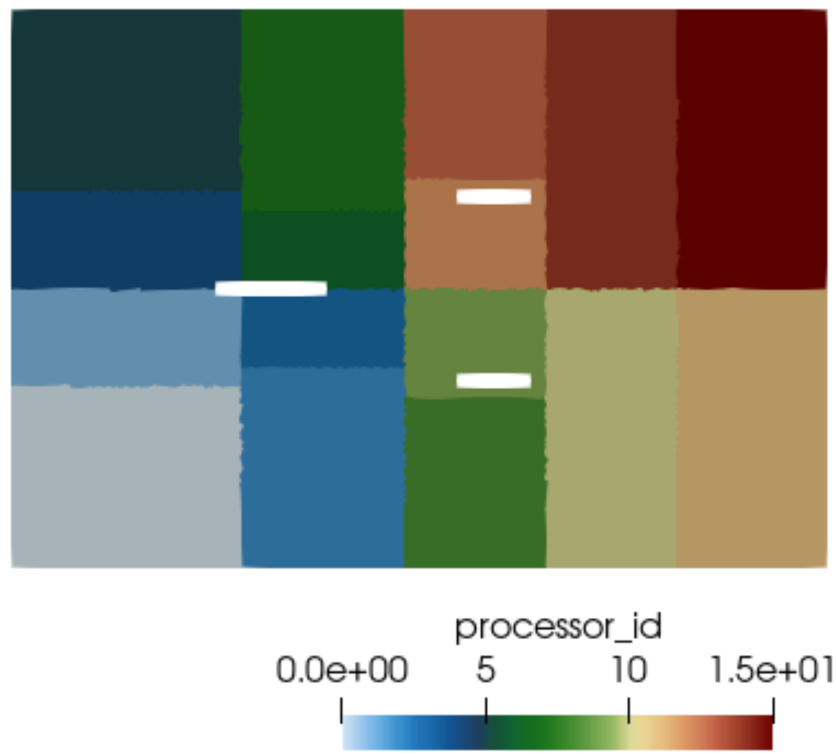
- Recall the first task assigned, dgNonConformalThreeBlade inclued the following line command within the input file:



Colored by block ID

Colored by core count (= 1)

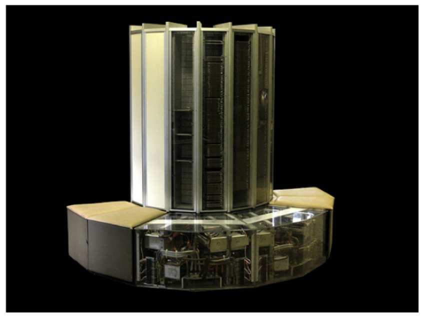
```
- name: realm_1
  automatic_decomposition_type: [type]
```



# Computing Performance: Through the Years

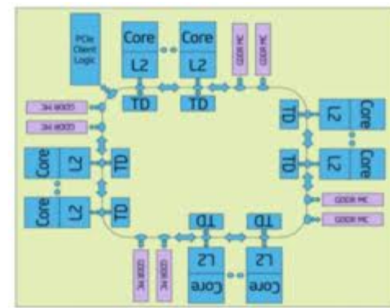
- HPC is facing a new disruption in technology

**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**

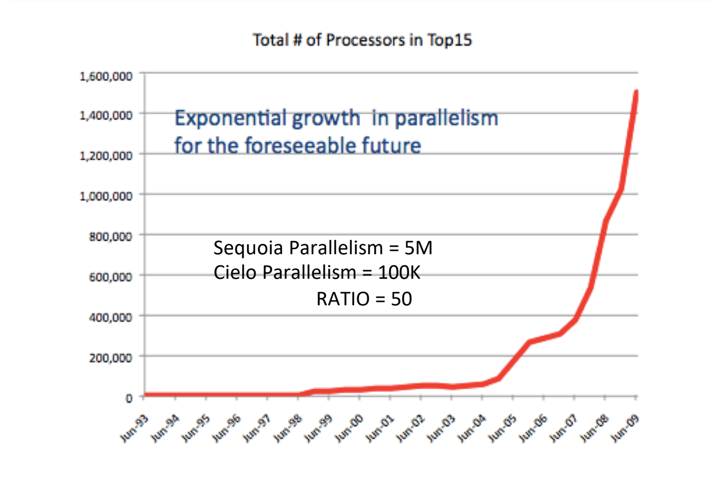
ROOM → MACHINE → CABINET → CHIP

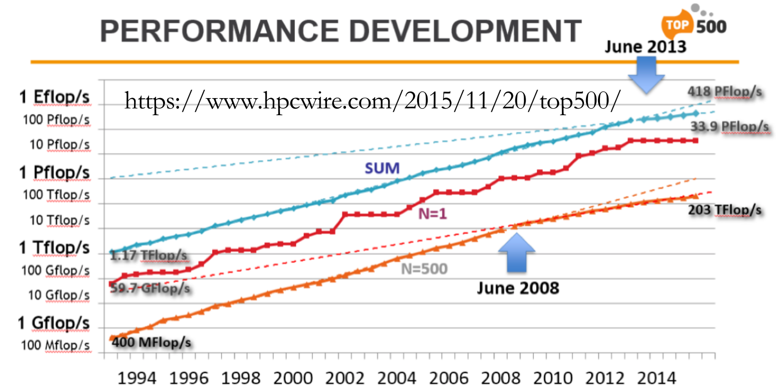
COMPLEXITY

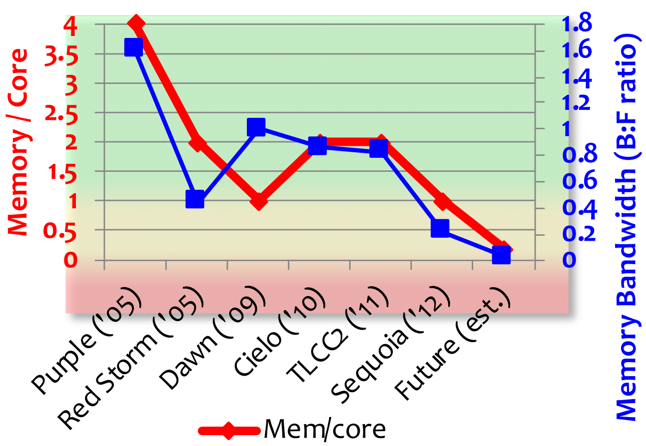
**Technology disruptions require a significant increase in complexity of our codes**

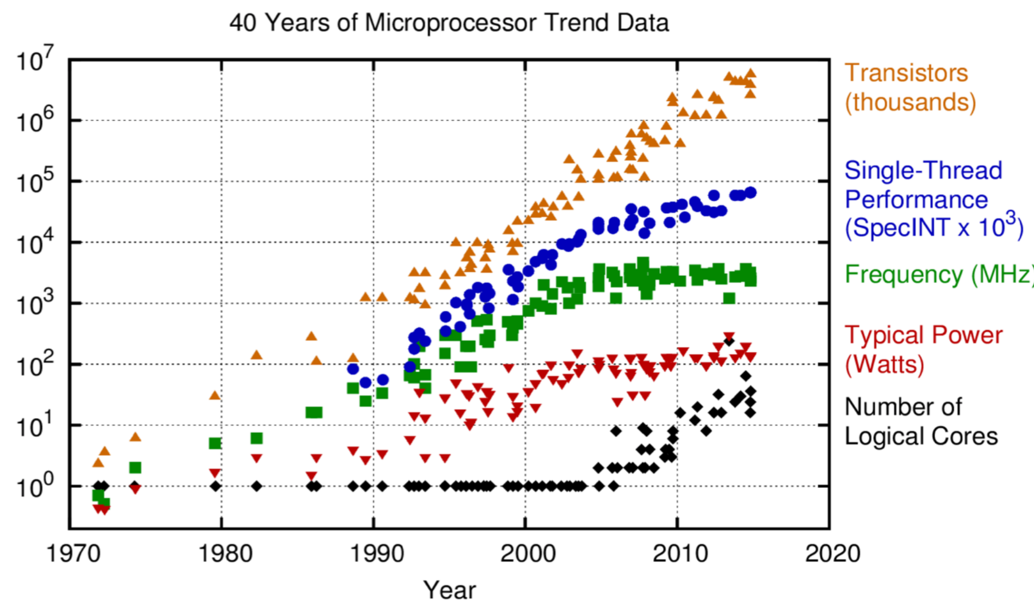
Slides courtesy of Mike Glass, Jim Ang, Rob Hoekstra, Si Hammond, Ron Brightwell, and Stephen Olivier.

# Drive Towards Next Generation Platforms




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

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

**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**

Slides courtesy of Mike Glass, Jim Ang, Rob Hoekstra, Si Hammond, Ron Brightwell, and Stephen Olivier.

# 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