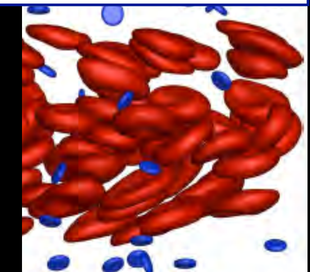
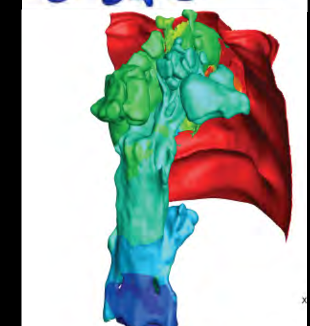
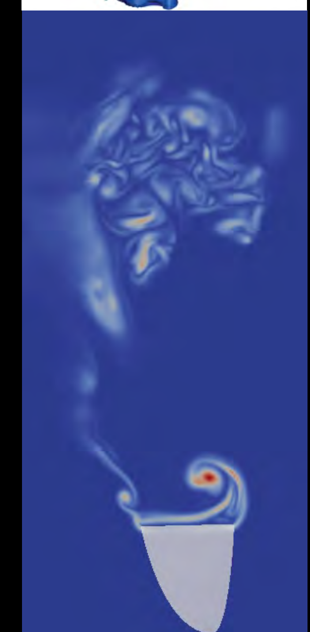


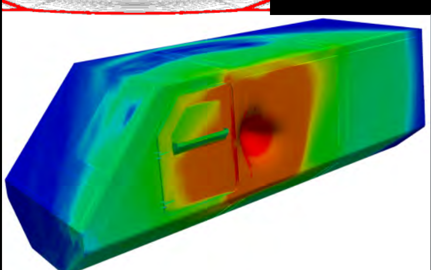
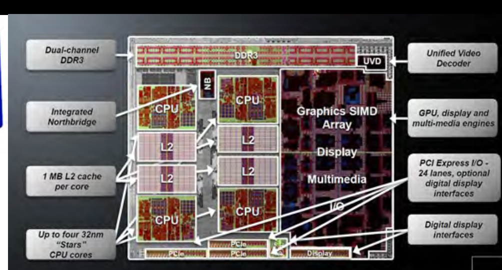





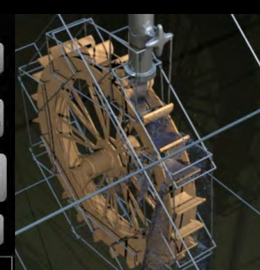
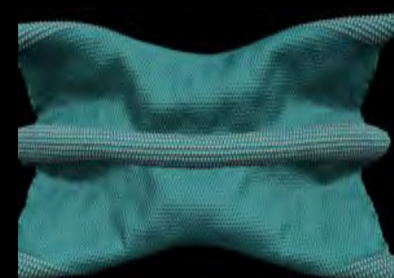
The Army High Performance Computing Research Center

Charbel Farhat

Director

Stanford University

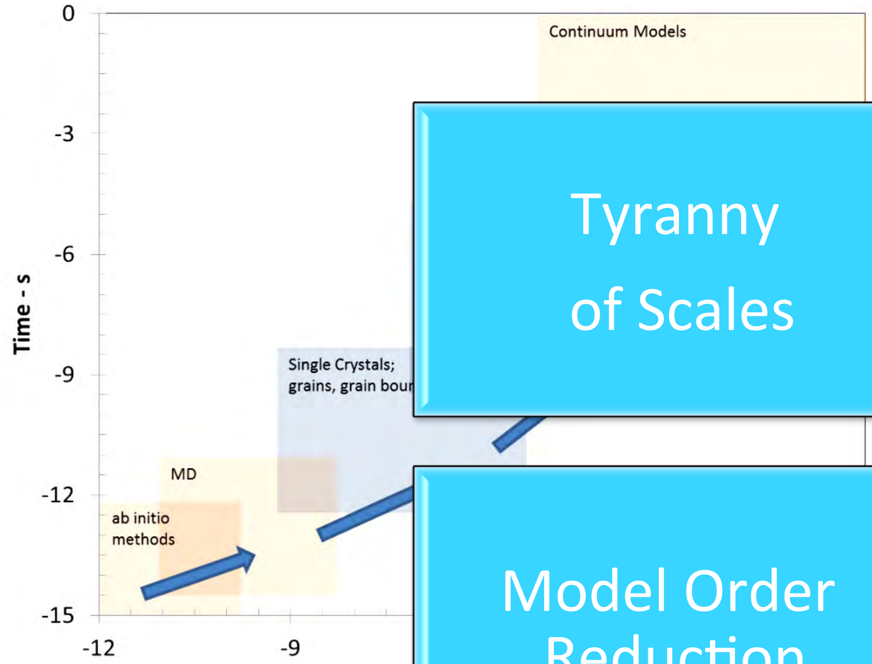



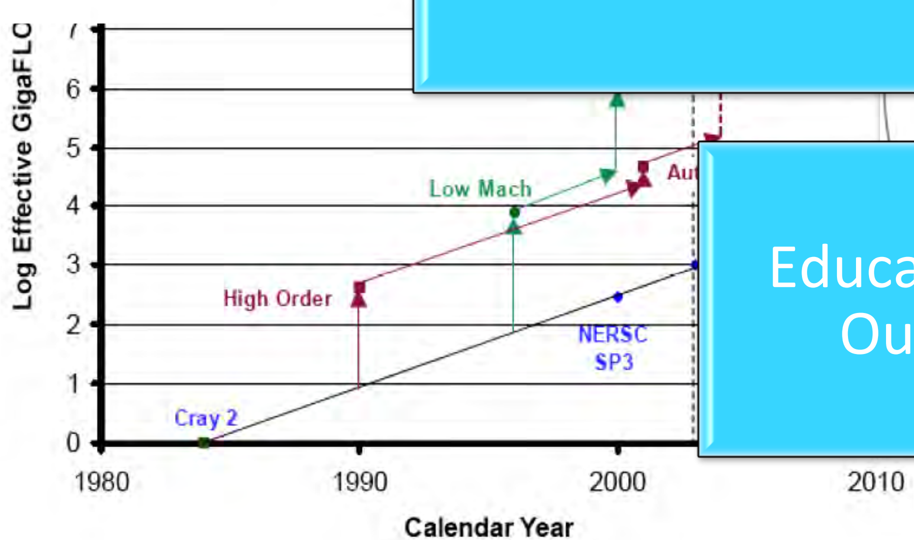
AHPCRC: OUR MISSION

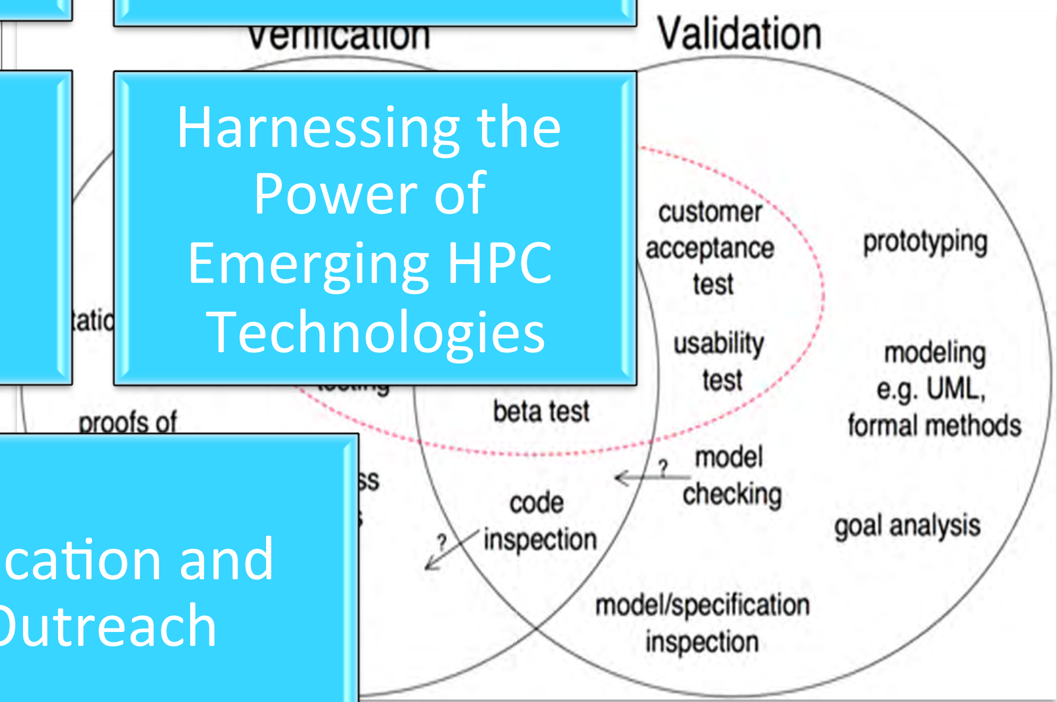
- ***Anticipate***, ***shape***, and ***develop*** the ***needs***, ***form***, and ***underpinnings*** of the ***next-generation*** Computational Science and Engineering (CSE)
  - advanced computational methods and numerical algorithms
  - emerging computing systems

- ***Foster better and faster scientific discovery*** of relevance to the Army
  - reduce design-cycle time, support tests, and improve system performance

AHPCRC: OUR CHALLENGES







Tyranny of Scales

Complexity of Multi-physics

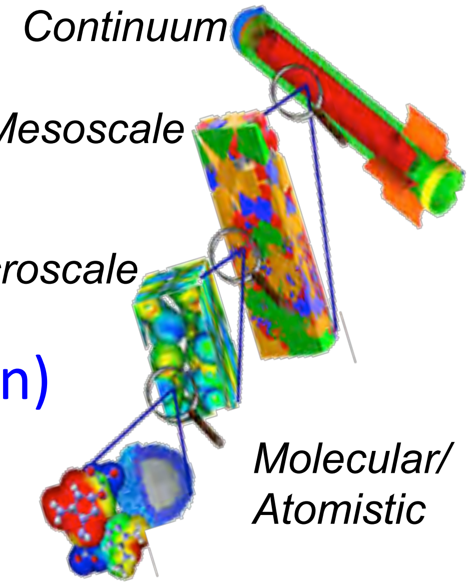
Model Order Reduction

Harnessing the Power of Emerging HPC Technologies

Education and Outreach

TYRANNY OF SCALES

- The ultimate roadblock for many applications including
  - computational nano-science and materials
  - molecular modeling of drugs and biological systems
  - failure analysis



- Most physical phenomena of interest today operate across large ranges of scale
  - spatial scales:
    - o 8 orders of magnitude (crack propagation)
    - o 10 orders of magnitude (protein folding)
  - temporal scales:
    - o 7 orders of magnitude (aerothermal heating)
    - o 12 orders of magnitude (protein folding)

→ ***renders conventional computational methods simply useless***

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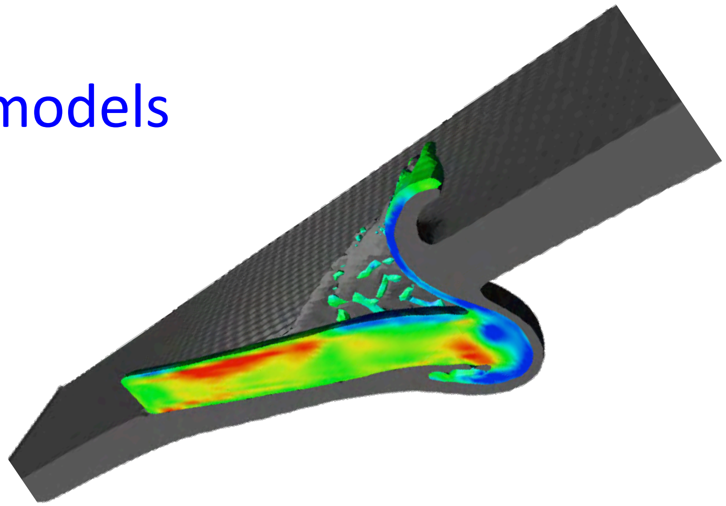
TYRANNY OF SCALES

- New approaches for
  - coupling atomistic and continuum models
  - averaging and homogenization
  - turbulence modeling

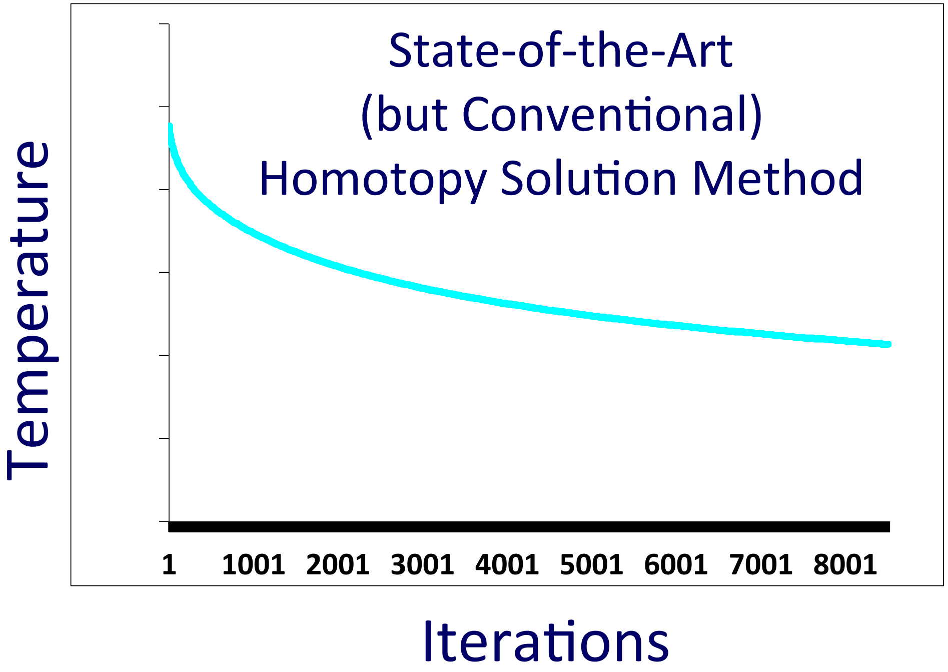


- Innovative discretization methods
  - non-polynomial enrichment functions rather than ansatz functions for representing operators that vary rapidly on microscopic scales
  - adaptive multi-resolution methods

- Revolutionary numerical algorithms
  - asynchronous approaches
  - fast low rank approximation solvers

TYRANNY OF SCALES - EXAMPLE

- Aerothermal heating of an AHW-like system



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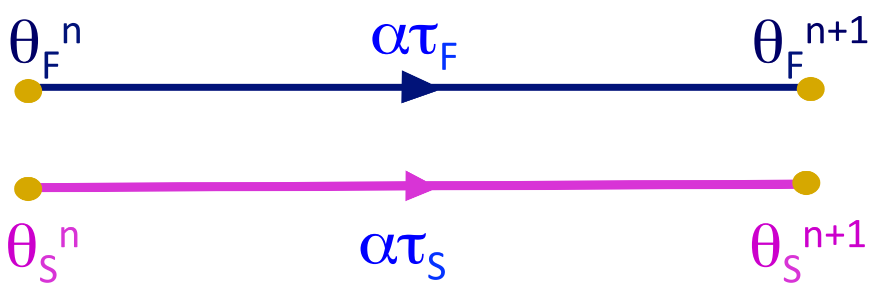
TYRANNY OF SCALES - EXAMPLE

- Two very different scales

$$\tau_S = \frac{\rho c_p L^2}{k} \sim 10^5 \text{ sec} \qquad \tau_F = \frac{L}{U_\infty} \sim 10^{-2} \text{ sec}$$

- Innovative asynchronous thinking



- Equivalent transmission conditions

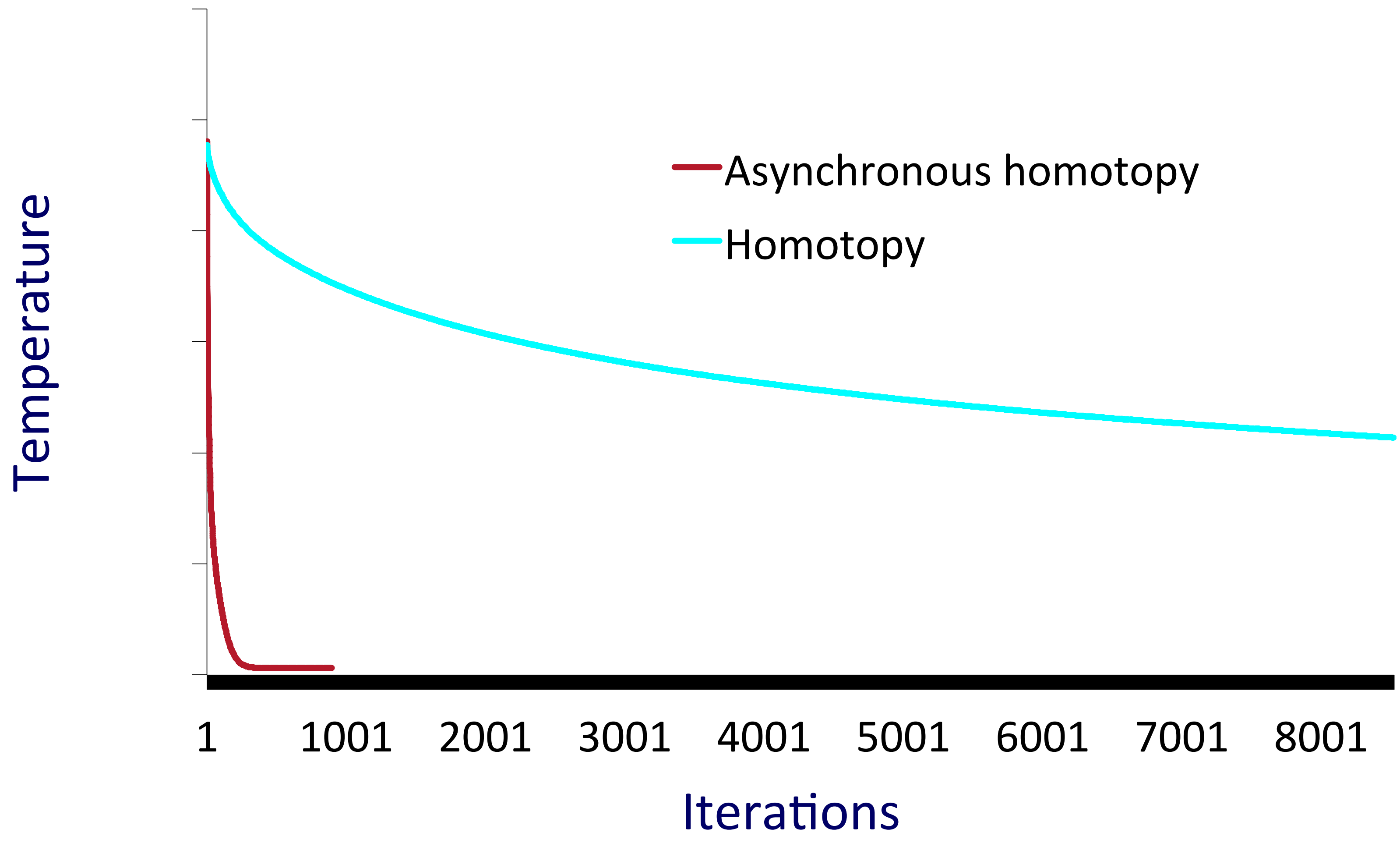
$$\kappa_S \, r \, \theta_S n + h \, \theta_S = \kappa_F \, r \, \theta_F n + h \, \theta_F$$

$$\theta_S = \theta_F$$

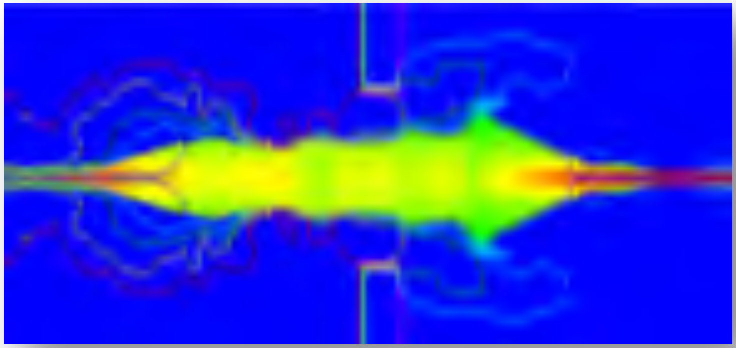
- h is determined from a stability analysis

TYRANNY OF SCALES - EXAMPLE

- Acceleration of convergence



COMPLEXITY OF MULTI-PHYSICS



- Problems of interest to the Army
  - multi-phase
  - multi-discipline
  - highly nonlinear
  - evolving domains and interfaces

- Call for a new generation of computational methods
  - higher-order embedded boundary methods
  - universal mesh concepts
  - advanced partitioned analysis procedures
  - advanced mathematical frameworks for stability, accuracy, and convergence analyses

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MODEL ORDER REDUCTION

- Model reduction will soon become an indispensable tool for
  - computational-based design and optimization
  - statistical analysis
  - embedded computing
  - real-time optimal control
- The ultimate form of HPC
  - bridges "big iron" and mobile computing

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MODEL ORDER REDUCTION

- ***Foster better and faster scientific discovery*** of relevance to the Army
- Current generation of most sophisticated sensors
  - measures what has ***already*** (albeit just) happened
- Next-Gen sensors will
  - measure what ***is about to*** happen
  - incorporate a real-time predictive capability called a ***ROM***
  - Next-Gen CSE, hardware and software

MODEL ORDER REDUCTION

- ***Army leadership!***

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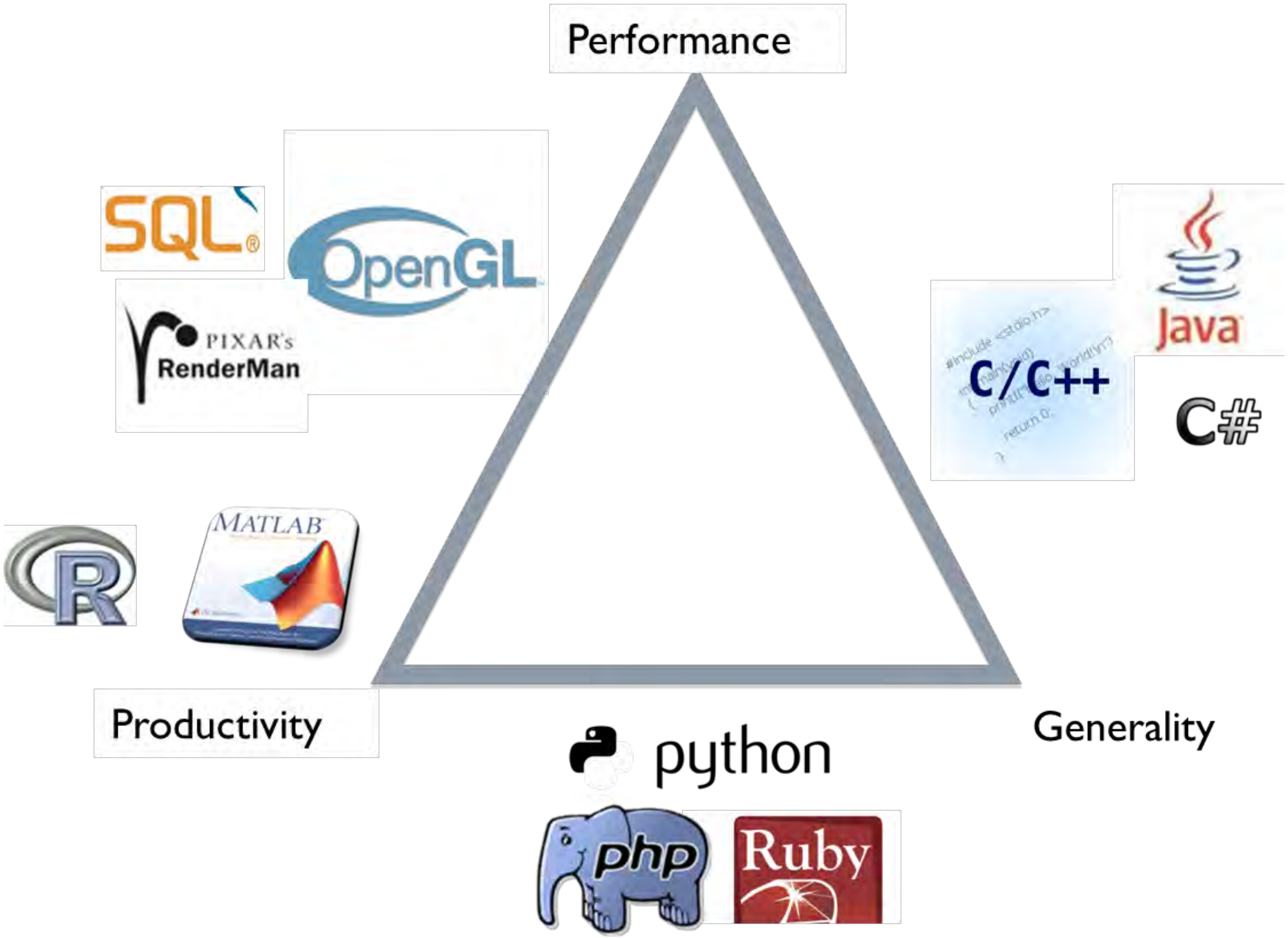
EMERGING HPC TECHNOLOGIES

- Generality-Performance-Productivity trade

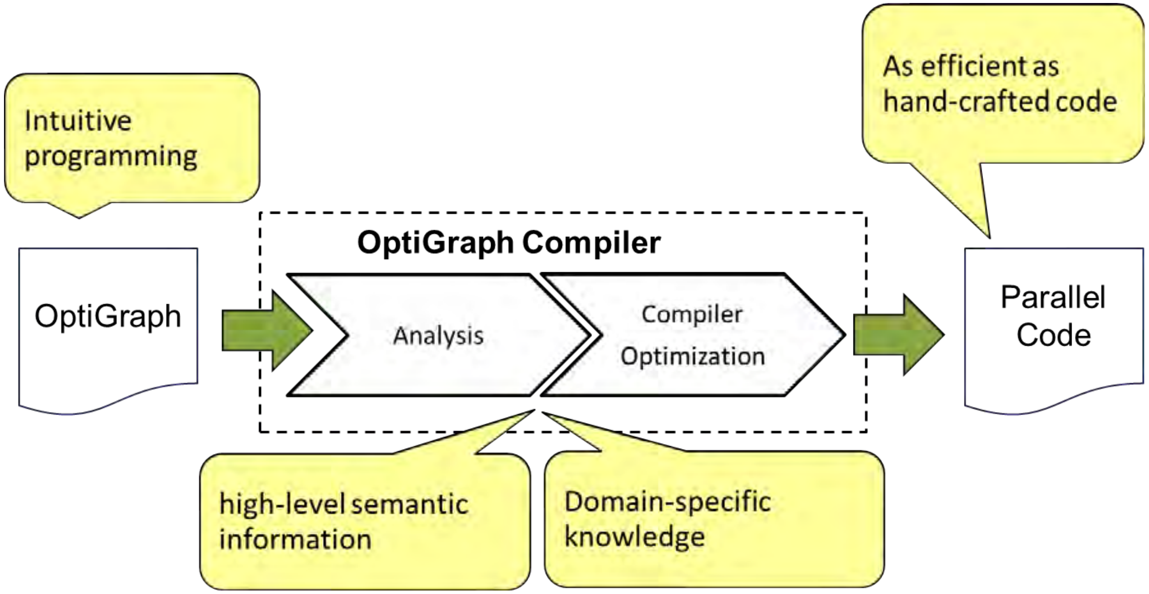


EMERGING HPC TECHNOLOGIES

- Basic research challenges
  - abstractions for classes of computations via Domain Specific Languages (DSLs)
  - compilation technology for high-level DSLs
  - exascale runtime systems
  - new algorithms for linear solvers

EMERGING HPC TECHNOLOGIES

- Big data analytics
  - DSLs for central problems in data analysis (such as analysis of large graphs)
    - o focus on high-level aggregate graph operations (e.g., depth or breadth-first search)
    - o transformation compositions of such high-level operations into efficient computations



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RESEARCH PROJECTS

Title	Performers	Core	Thematic
HPC-enabled parametric studies of under body blasts: From high-fidelity to reduced-order models	Stanford Berkeley UTEP and NMSU	70%	30%
Computational fluid dynamics for blood transfusion on the battlefield and inhalation of toxic agents in the lungs	Stanford	50%	50%
2D nano-electromechanical devices	Stanford	40%	60%
High-performance data analytics	Stanford	100%	0%

RESEARCH PROJECTS

Title	Performers	Core	Thematic
LisztFE: Finite element codes for exascale computers	Stanford	100%	0%
Scalable, shared and distributed memory algorithms for computational solids, fluids and geometry	Stanford	100%	0%
Towards enabling battlefield decision-making and planning through information processing in the DoD cloud	UTEP	100%	0%
Toward real-time computing for applications in the field	NMSU	100%	0%

EDUCATION AND OUTREACH

- AHPCRC Summer Institute
  - five years of success!

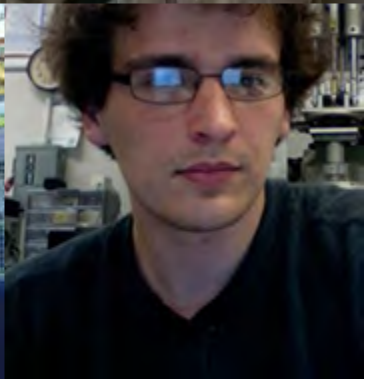
PROGRAM OBJECTIVES

- Train the next generation of scientists and engineers in CBES
- Provide students with early research experience to encourage them to pursue advanced degrees
- Provide students with Army relevant experience to encourage them to pursue careers in defense-related science and engineering

ARL INTERNSHIPS

- AHPCRC Summer Institute graduates regularly intern at ARL
  - 21 undergraduates since summer 2010

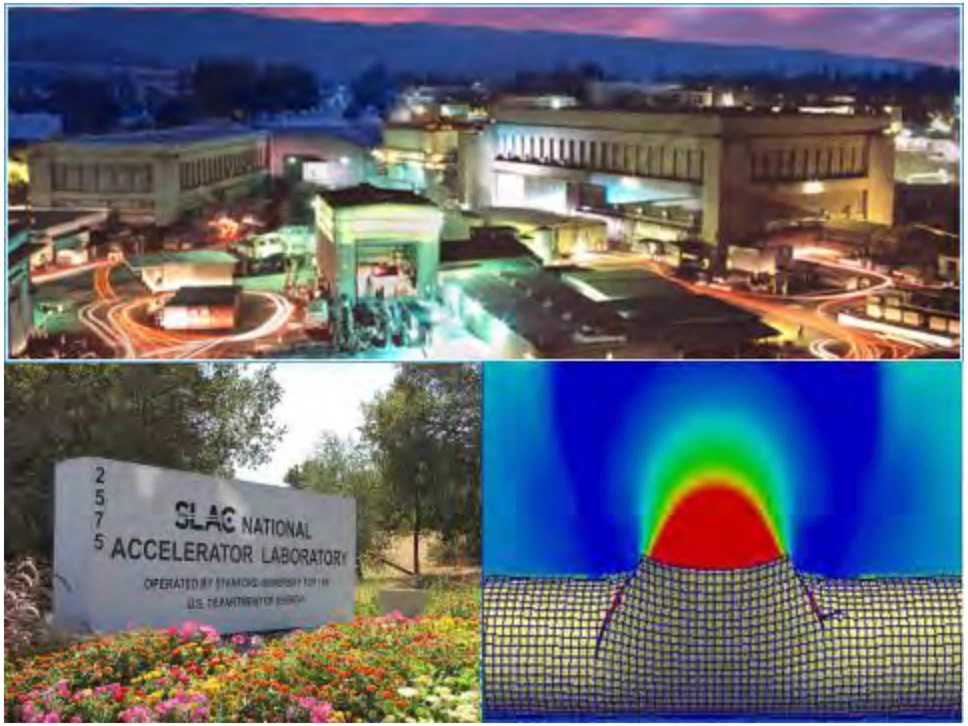
- AHPCRC graduates hired at ARL
  - David Powell (Ph. D.) hired at WMRD



- AHPCRC is currently promoting
  - long-term visits by graduate students
    - o Matthew Kury
    - o Alejandro Queiruga
  - post-doc hires
  - additional and longer faculty visits

INTERNATIONAL WORKSHOPS

- Workshop on Computational Methods for Problems With Evolving Domains and Discontinuities (December 3—5, 2013, Stanford)



- 25 leaders in the field from 7 different countries

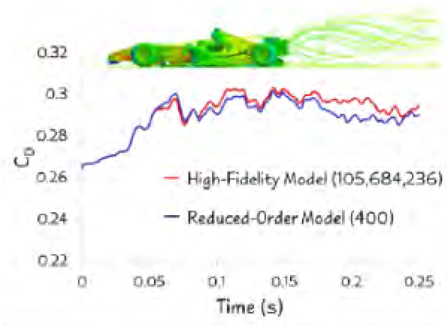
STANFORD CURRICULUM

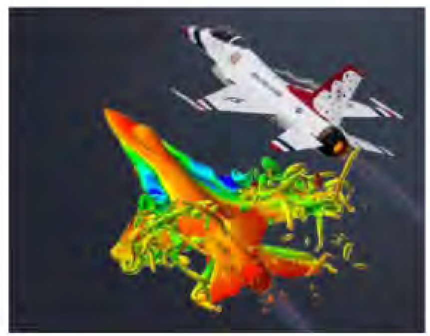
- CME (Computational Mathematics and Engineering) 345

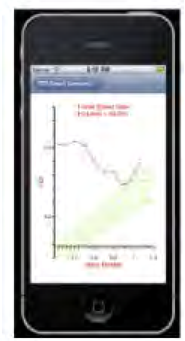
STANFORD
ENGINEERING

CME345: Model Reduction

Schedule: Spring 14, M-W-F (2 of 3) 9:30 am – 10:45 pm **Units** : 3
Venue : B160-323







Course Description
Model reduction is an indispensable tool for computational-based design and optimization, statistical analysis, embedded computing, and real-time optimal control. It is also essential for scenarios where real-time simulation responses are desired. This course presents the basic mathematical theory for projection-based model reduction. It is intended primarily for graduate students interested in computational sciences and engineering. The course material described below is complemented by a balanced set of theoretical, algorithmic, and Matlab computer programming homework assignments.

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- Next generation Computational Science and Engineering for and by our next generation leaders