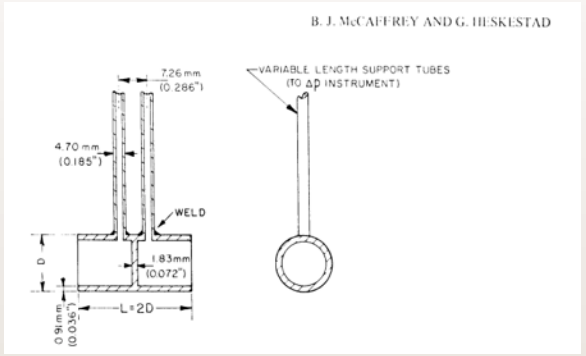
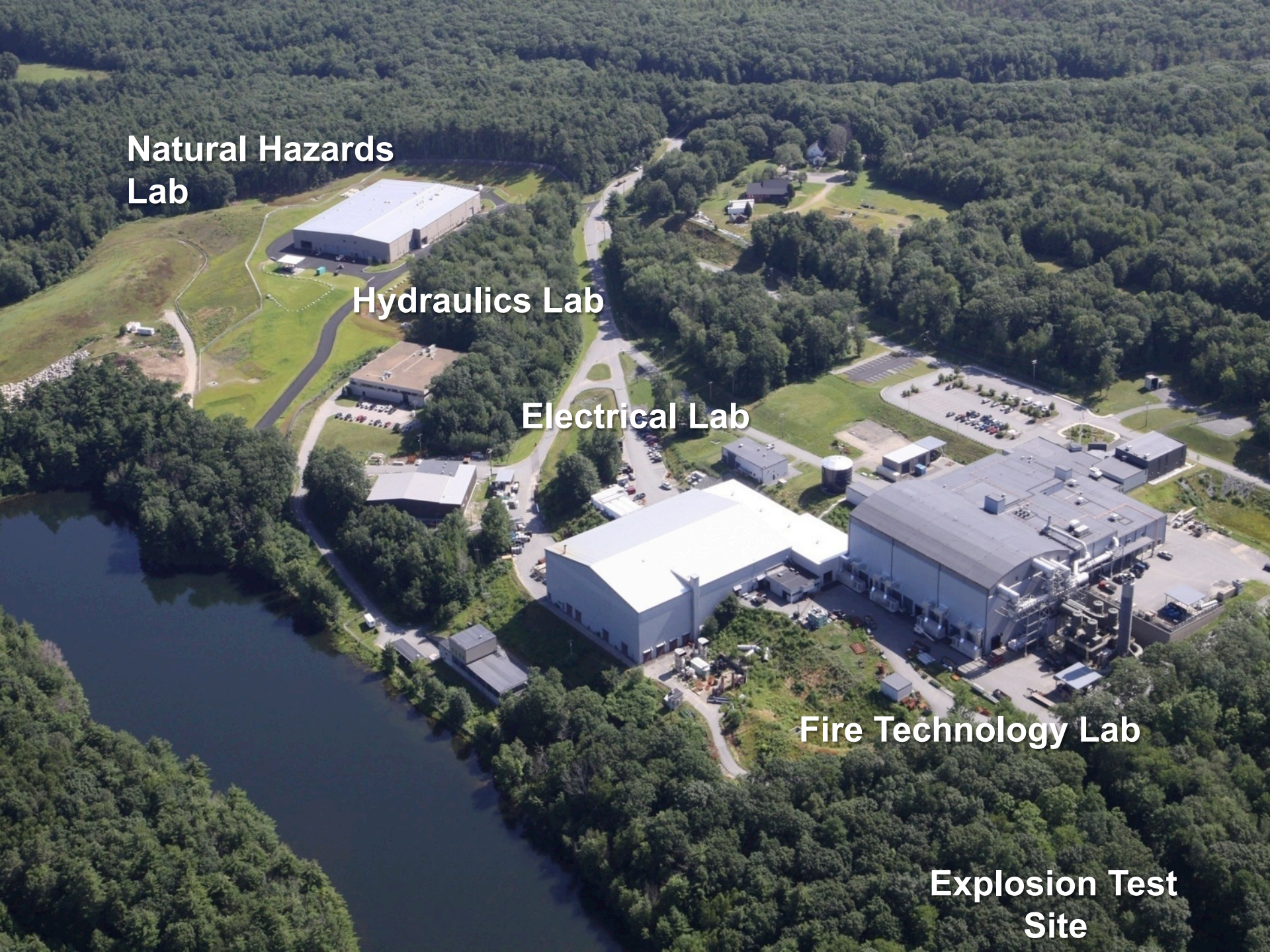
Fire modeling strategy

Louis Gritzo, Ph.D.
Vice President, Research

40 Years Ago

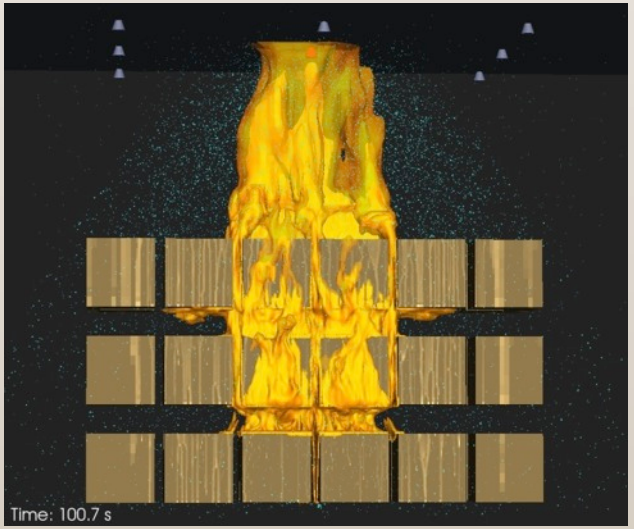



Natural Hazards Lab
Hydraulics Lab
Electrical Lab
Fire Technology Lab
Explosion Test Site

Fire Protection Today

Drivers

- Perform Better Tests
  - Quality
  - Scope
- Provide Deeper Knowledge
- Engage and Advance the Community
- Provide Better Protection



Fire modeling program

- Initiated in 2008
- Investment in staff and scientific computing*
- Five-year objective
  - modeling capabilities to reduce the number of large scale tests required for sprinkler protection of storage applications
- Strategic goal
  - Predictive fire modeling capabilities for some applications

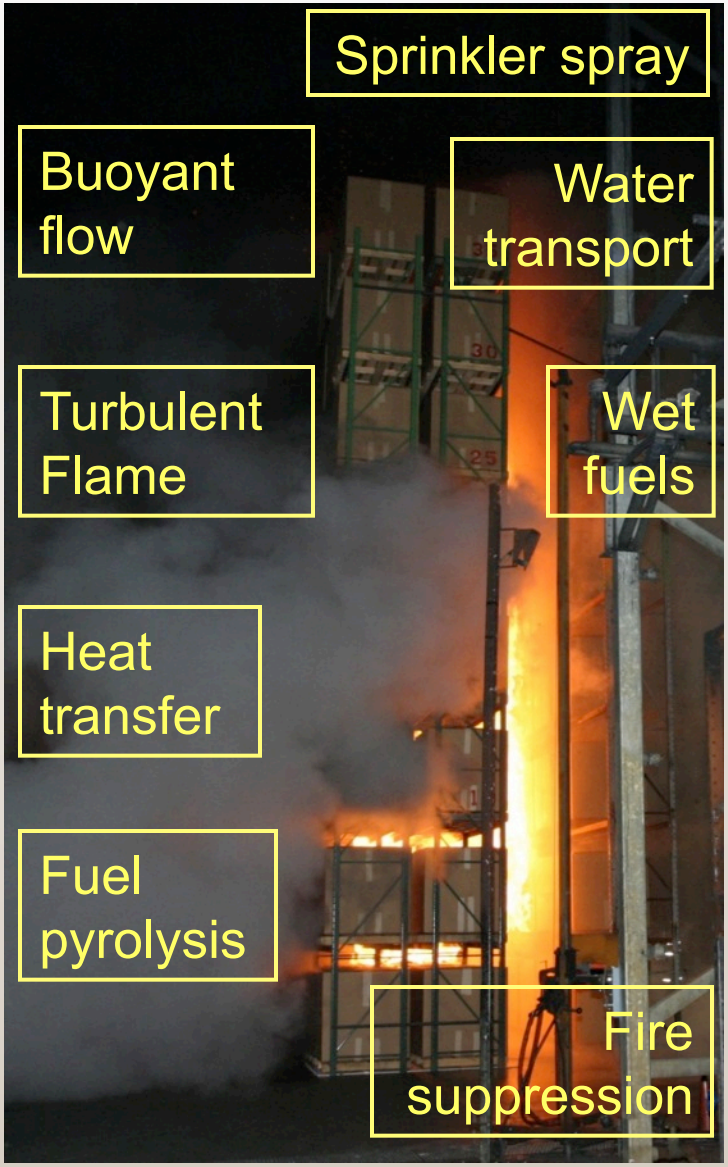
* 1280 cores cluster, 10 Teraflops

Modeling scope

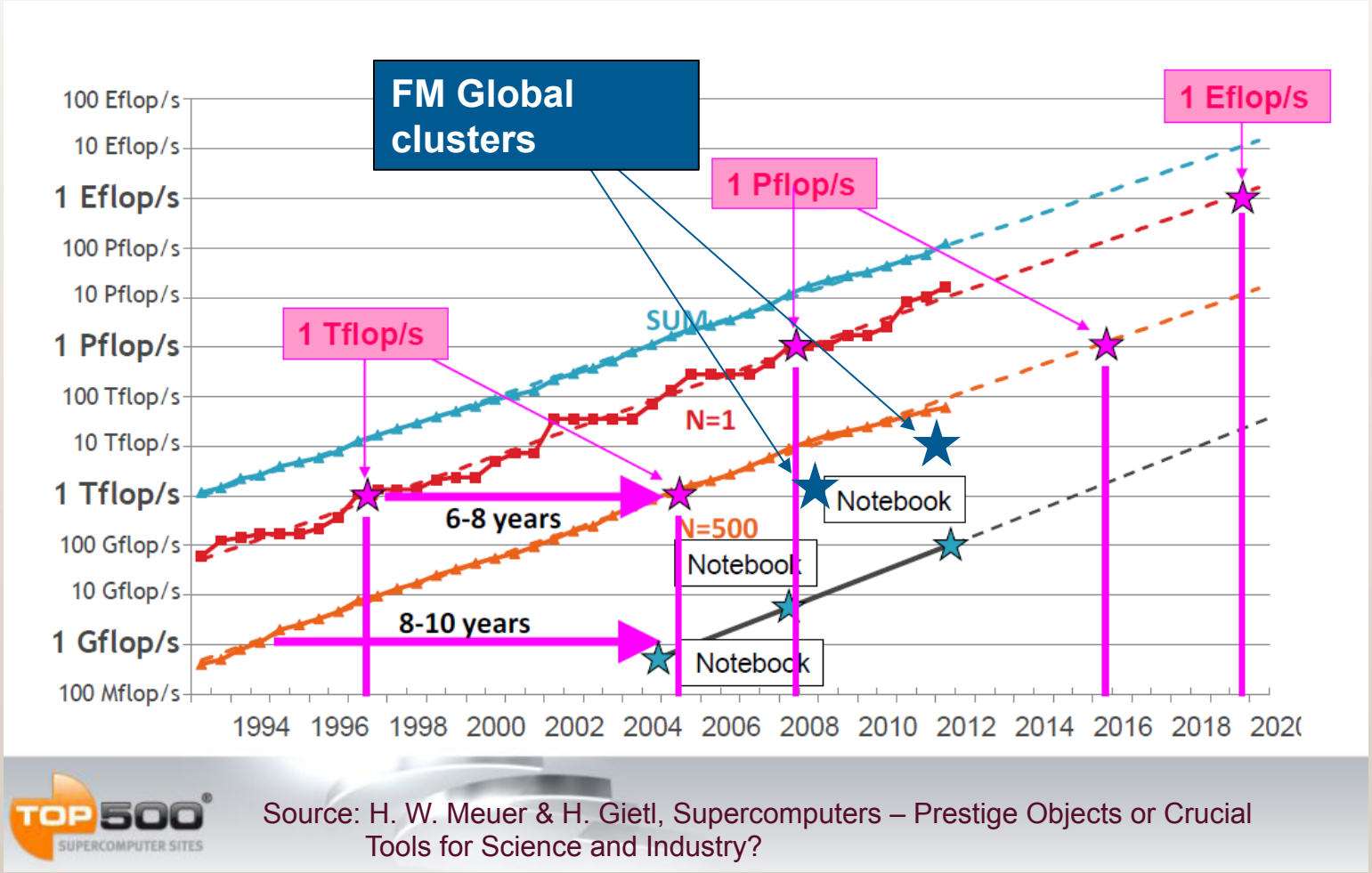
- Challenges
  - Multi-physics
  - Multi-scale

The Basics

- Growth
- Protection



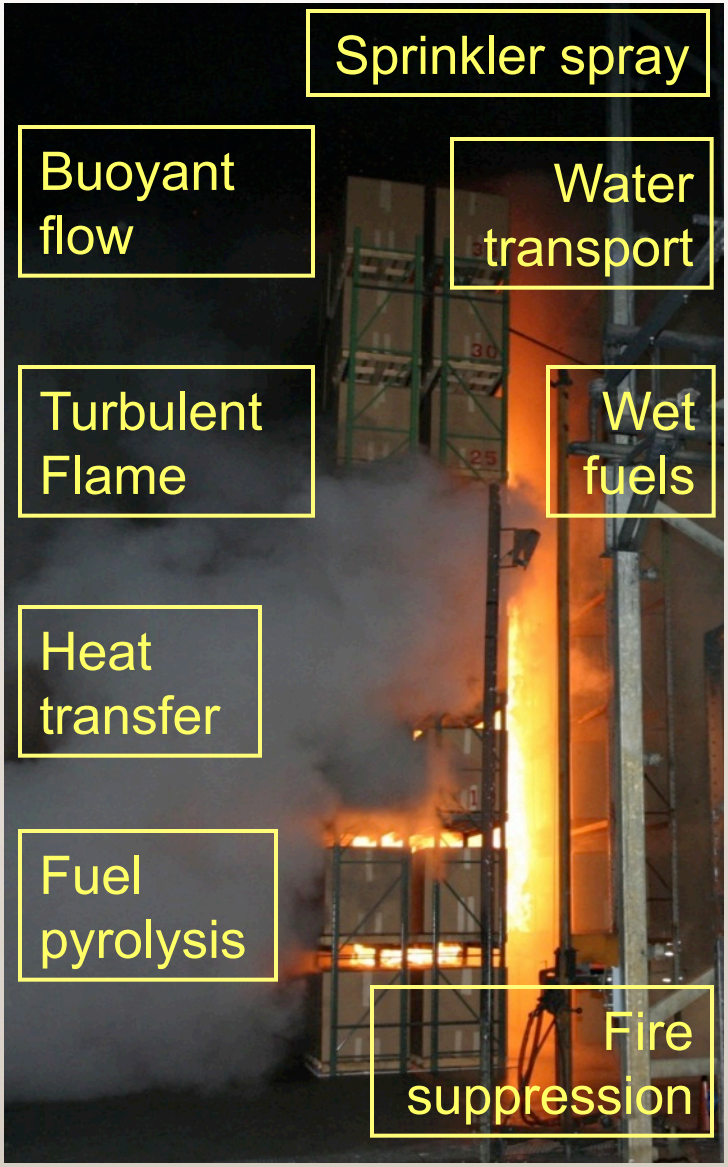
Computing Performance



Source: H. W. Meuer & H. Gietl, Supercomputers – Prestige Objects or Crucial Tools for Science and Industry?

Key Factors

- Complexity
- Scale
- Rigor



Efficient approach

- OpenFOAM toolbox
  - Imperial College
  - Supported by OpenCFD
- Develop only key models: FireFOAM
- Open source
  - Acceptance
  - Cooperation with academia and industry

Annual Workshops

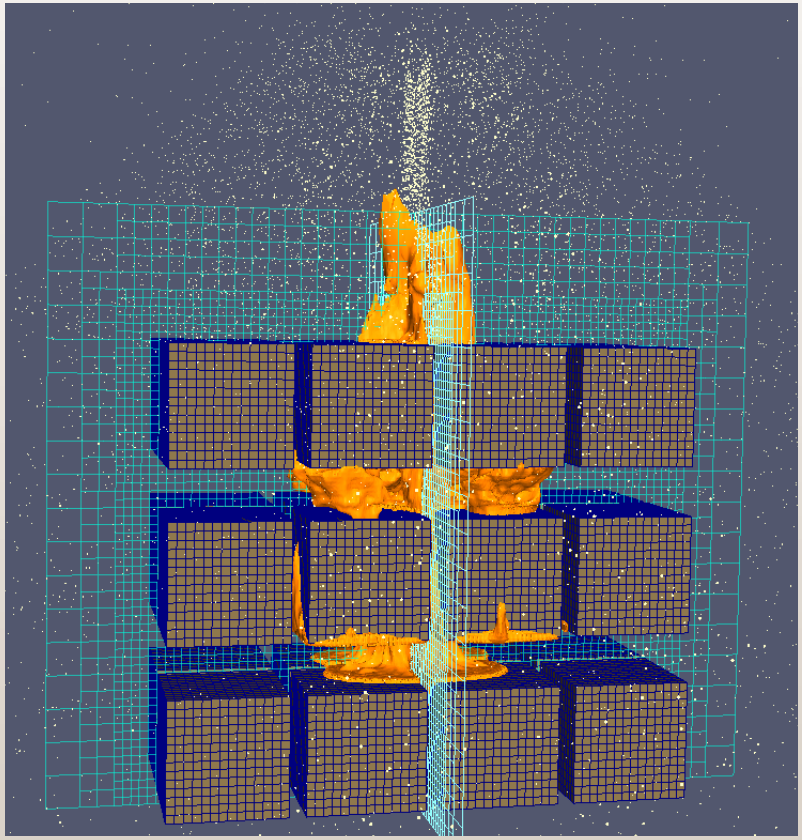
Program of FM Global Open Source CFD Fire Modeling Workshop 2014

15-May-2014			
Chair Person: Sergey Dorofeev			
8:30 – 8:45	Welcome and Introductions		
8:45 – 9:15	Vilfayeau, S., Ren, N., Wang, Y. and Trouvé, A.	University of Maryland	Numerical Simulation of Under-Ventilated Liquid-Fueled Compartment Fires With Flame Extinction and Thermally-Driven Fuel Evaporation
9:15 – 9:45	Daniel C. Haworth	Pennsylvania State University	OpenFOAM-Based Modeling of Multiphase Turbulent Reacting Flows with Radiative Heat Transfer
9:45– 10:15	C. Devaud	University of Waterloo	Developments of turbulent combustion models for fire modeling
10:15– 10:30 Coffee break			
Chair Person: Guillermo Rein			
10:30 – 11:00	Craig Weinschenk, Jason Floyd, Randall McDermott	NIST	A Partially-Stirred Batch Reactor Model for Under-Ventilated Fire Dynamics
11:00 – 11:30	Beth Weckman	University of Waterloo	An Overview of Experimental Pool Fire Data
11:30 – 12:00	Chatterjee, P., Wang, Y., Meredith, K.V., Dorofeev, S.B.	FM Global	Modeling Radiation Heat Transfer in a Medium-Scale Heptane Pool Fire
12:00 – 1:00			
Lunch			
Chair Person: Bart Merci			
1:00 – 1:30	Guillermo Rein	Imperial College	Transient radiation pyrolysis
1:30 – 2:00	David O. Lignell, Elizabeth I. Monson, Ryan Hintze, Mark A. Finney	Brigham Young University	LES, ODT, and experimental investigation of vertical ethylene wall fires
2:00 – 2:30	Dong Zeng and Marcos Chaos	FM Global	A Pyrolysis Model for Delaminating Material
2:30 – 3:00	Thomas H. Fletcher, Aaron D. Lewis, Dallan R. Prince	Brigham Young University	Chemical Structure-Based Pyrolysis Models of Wood and Biomass for Possible Use in CFD Fire Simulations
3:00 – 3:15Coffee break			
Chair Person: Arnaud Trouvé			
3:15 – 3:45	Georgios Maragkos and Bart Merci	Ghent University	Numerical simulations of upward flame spread with fireFOAM
3:45– 4:15	Yibing Xin, Yi Wang, Marcos Chaos, Sergey B. Dorofeev	FM Global	A Characteristic Fuel Unit approach for the study of complex fuel burning behavior
4:15– 4:40	Andre D. Da Vitoria, Ali S. Rangwala, Liang Zhou, Dong Zeng, Marcos Chaos,	WPI	An Experimental Study on Flammability of Roll Paper
4:40– 5:05	Vilfayeau, S., White J., Sunderland P., Marshall A., and Trouvé, A.	University of Maryland	Large Eddy Simulation of Extinction Limits In Two-Dimensional Plane Turbulent Diffusion Flames
5:05– 5:30	Bjarne Husted and Vivi Rygnestad Helgesen	Lund University	Simulation of the activation of pressure line detectors placed under roof eaves and comparison with experimental data

16-May-2014			
Chair Person: Yi Wang			
8:30 -9:00	J.P. White, E.D. Link, A.W. Marshall, P.B. Sunderland, A.C. Trouvé, J.A. Sheffel, M.B. Colket	University of Maryland	Oxidizer Dilution Effects in a Turbulent Slot Burner
9:00 – 9:30	Kazui Fukumoto and Jennifer Wen	University of Warwick	Large eddy simulation of upward flame spread along a PMMA wall with consideration for variations in pyrolysis gas composition
9:30– 10:00	Changjian Wang, Jennifer Wen, Yanming Ding, Qize He and Shouxiang Lu	University of Science and Technology of China	An efficient EDC based approaches for modeling soot formation and oxidation in fires
10:00 – 10:15 Coffee break			
Chair Person: André Marshall			
10:15 – 10:45	Changjian Wang and Jennifer Wen	University of Warwick	Further improvement of the multi-component EDC and WSGGM radiation model in FireFOAM
10:45 – 11:15	O.A. Ezekoye and V. Raman	University of Texas at Austin	Applications of Statistical Moment Methods to Simulate Population Evolution in Fire Scenarios
11:15– 11:45	Xiaoyang Zhao and James S. T'ien	Case Western Reserve University	A Numerical Model for Flame Growth and Extinction in Concurrent Flows
11:40 – 12:05	Stanislav I. Stoliarov, Fernando Raffan, Xi Ding, Roland Kraemer	University of Maryland	Flaming Combustion Calorimetry: A New Tool for Flammability Assessment using Mg-sized Samples
12:05 – 1:00 Lunch			
Chair Person: Karl Meredith			
1:00 – 1:30	E. D. Link, P. B. Sunderland, and A. W. Marshall	University of Maryland	Momentum Based Criteria for Fire Sprinkler Selection
1:30 – 2:00	Xiangyang Zhou	FM Global	Velocity and Droplet Size Measurements of Interactions Between Hot Air Plumes and Water Sprays
2:00 – 2:30	S. J. Jordan and A. W. Marshall	University of Maryland	Spatially-resolved Spray Scanning System (4S) Sprinkler Measurements
2:30 – 3:00	T. M. Myers, H. R. Baum, and A. W. Marshall	University of Maryland	A Potential Flow Model of a Fire Sprinkler Head
3:00 – 3:15 Coffee break			
Chair Person: Jennifer Wen			
3:15 – 3:45	Alexander L. Brown, Flint Pierce, John C. Hewson	Sandia National Labs	Suppression modeling adapted for the EDC model in Sierra/Fluid Mechanics/Fuego
3:45 – 4:15	Karl Meredith	FM Global	Application of Sprinkler Injection and Water Transport Modeling to In-Rack Sprinkler Protection
4:15 – 4:45	Ning Ren, Yi Wang, Karl Meredith, Marcos Chaos, Jaap de Vries and Xiangyang Zhou	FM Global	Modeling effect of wood pallets on fire growth and suppression of Standard Class 2 commodity
Discussion			
Chair Person: Sergey Dorofeev			
4:45 – 5:45	All		Discussion

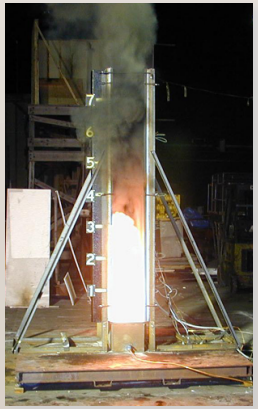
Modeling technique

- Equations solved on grids in multiple time steps
- Solid, liquid, gas phase grids and spray droplets
- Calculations
  - Days to run
  - Multiple possible



Program milestones

FireFOAM
2008



8’ Parallel Panel
Test 2009

2x4x3 rack
Free burn 2010

2x4x3 rack
Water application
2011

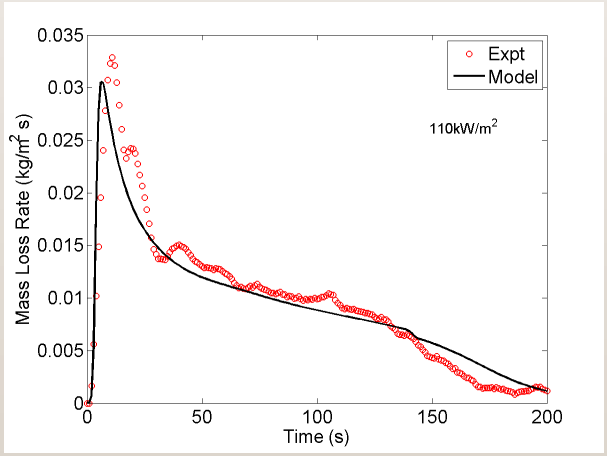
Rack storage
sprinkler
suppression
2012

Fire growth

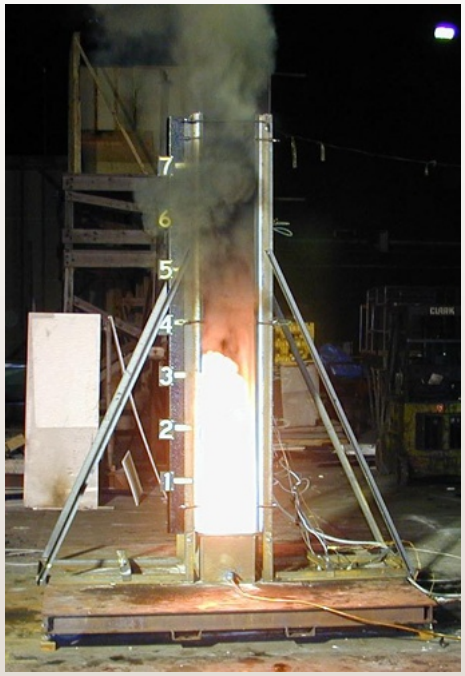
Fuel properties
from bench-scale

FPA apparatus

Material
decomposition model



8’ Parallel Panel Test



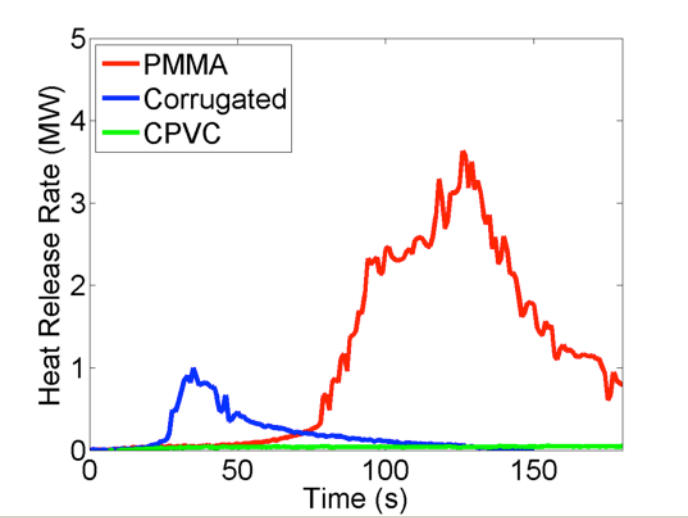
Validation

2x2x3; 2x4x3 Racks

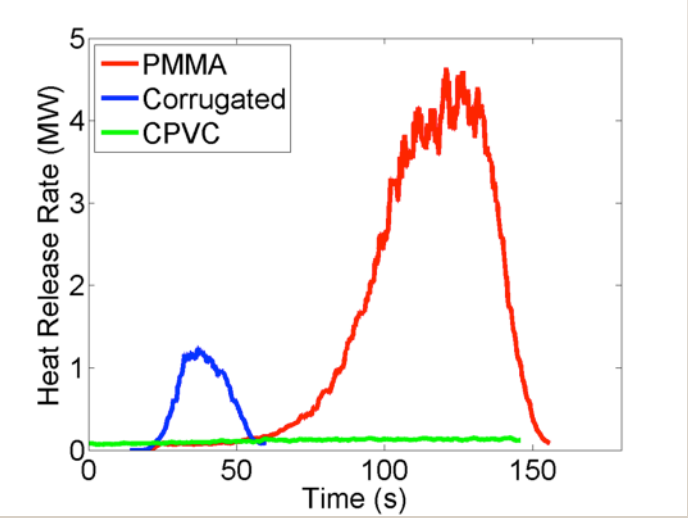
Fire growth: PPT

- Captured fire size and propagation behavior

Test



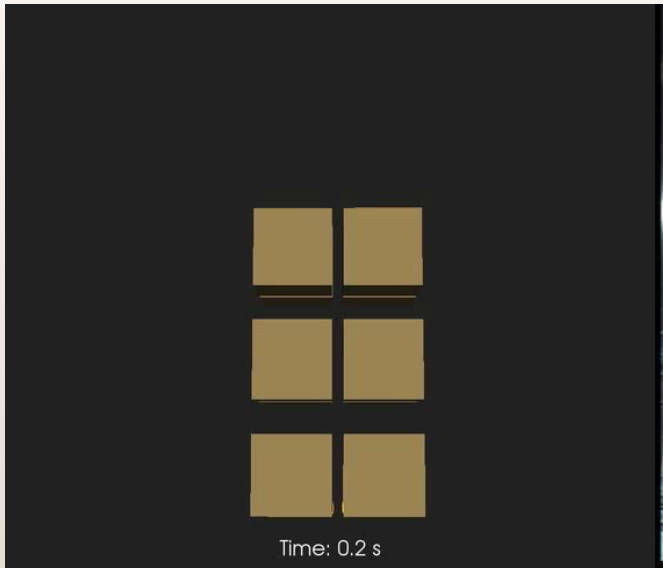
Model



Fire growth: rack storage

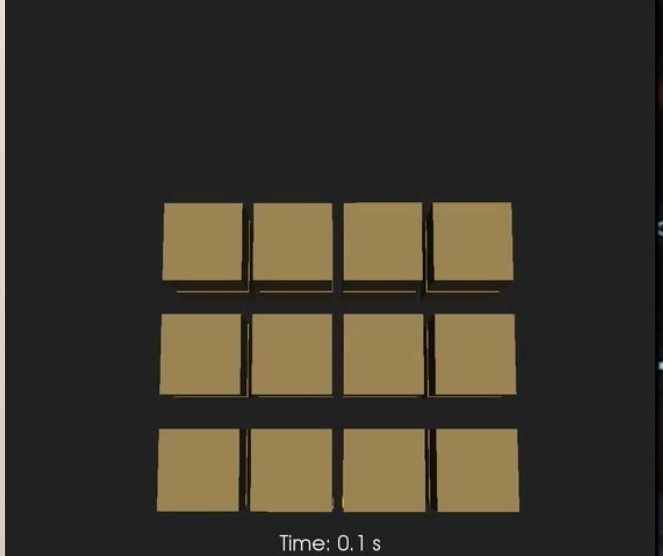
2x2x3

Model

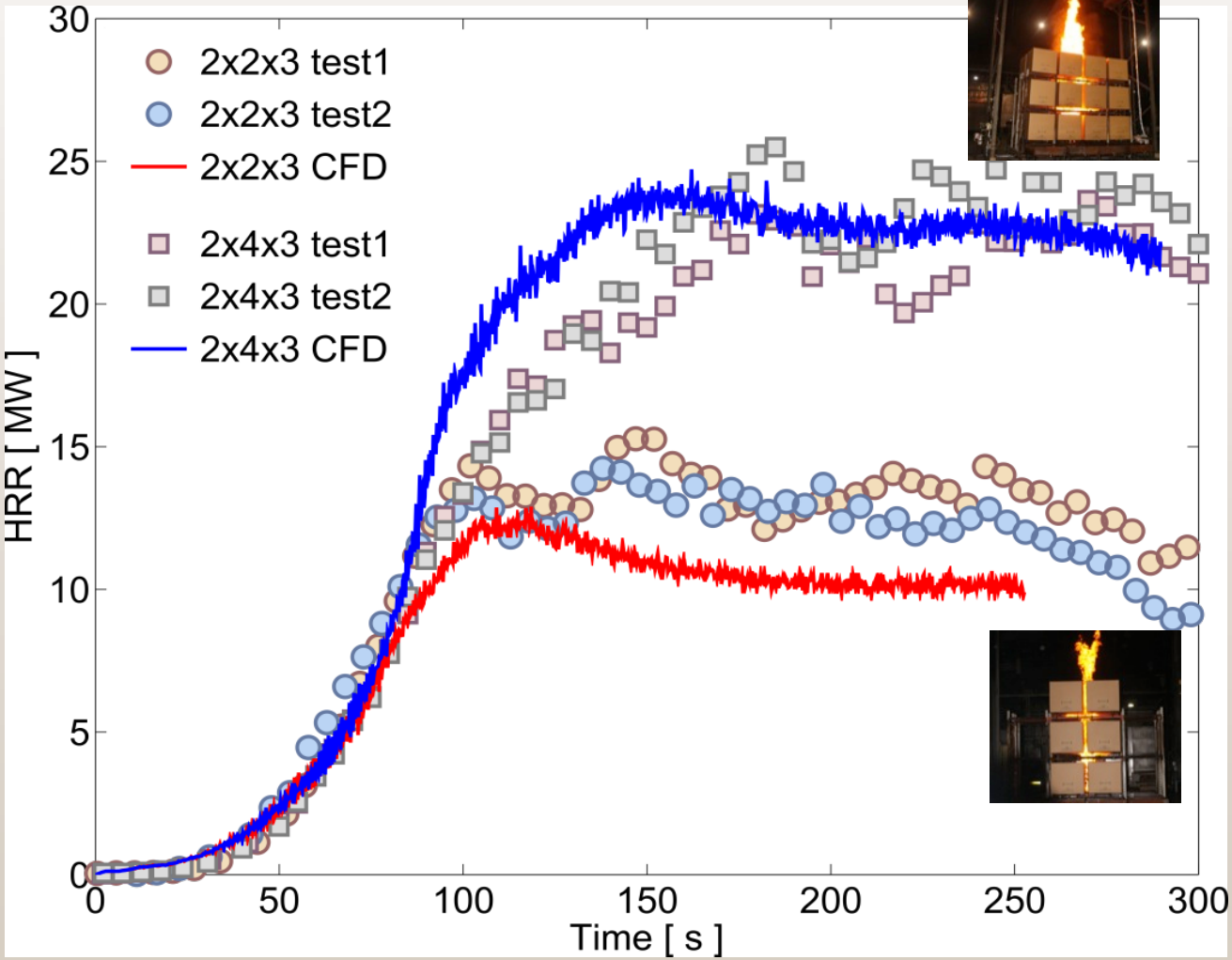


Tests

2x4x3



Fire growth validation

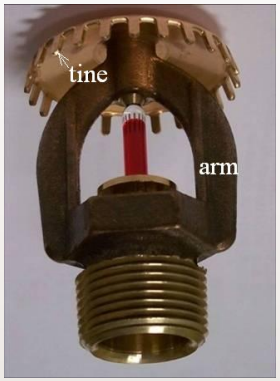


Fire growth: predictability

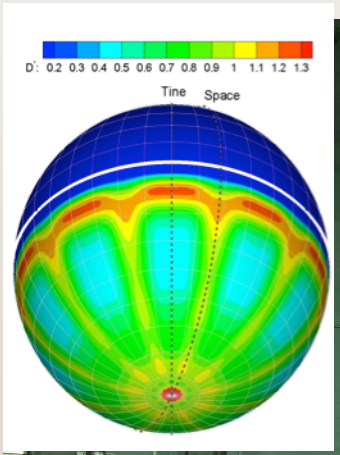
- Small to large scale

Water based suppression

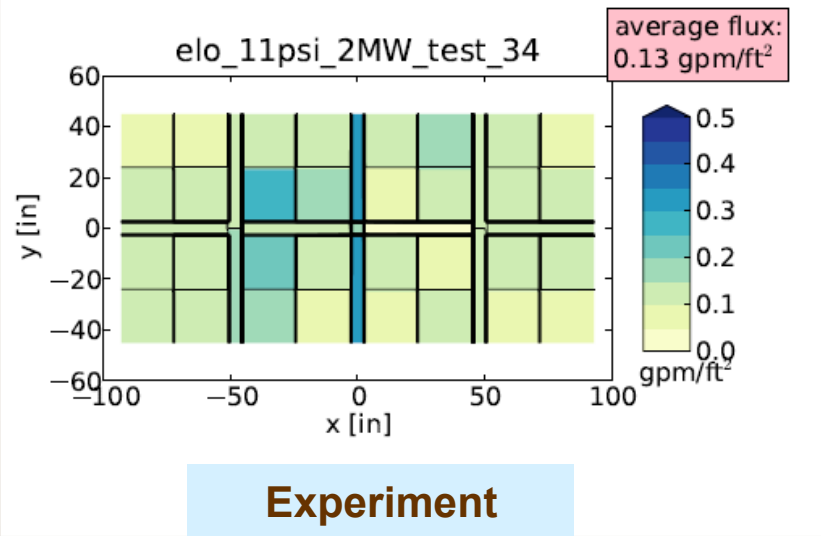
Sprinkler spray modeling

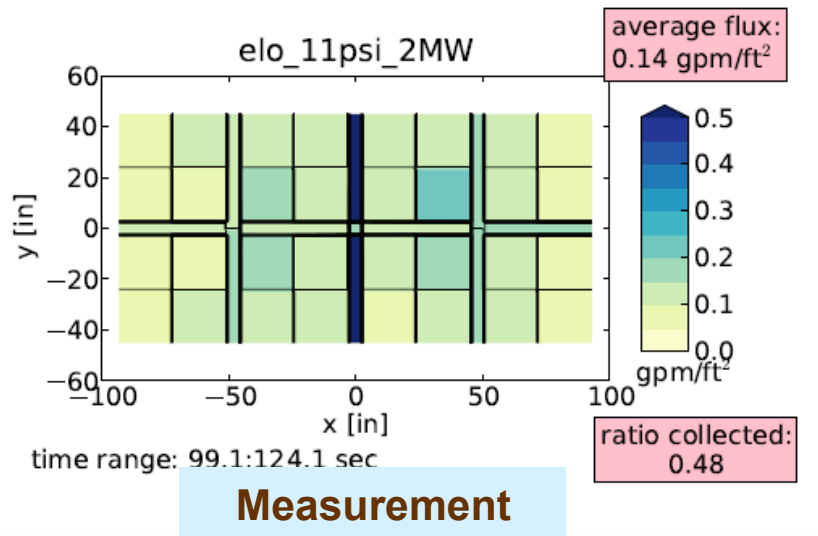


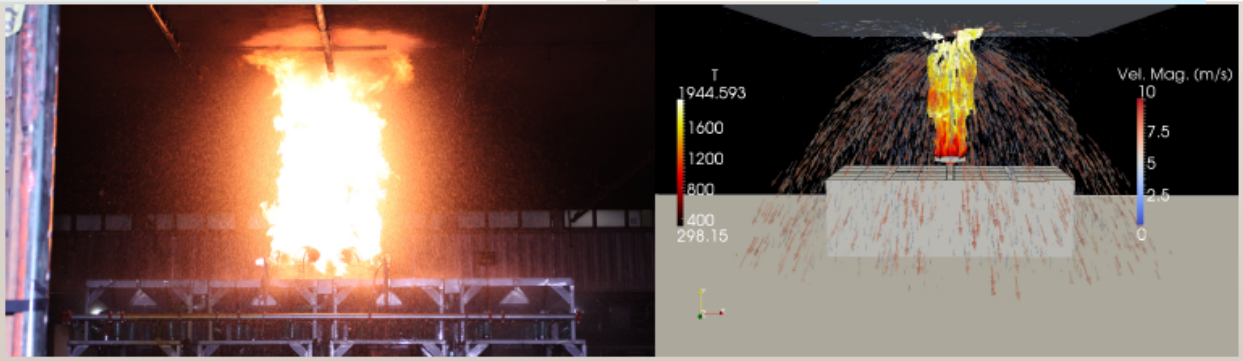
- Characterize selected sprinklers
  - Water flux
  - Droplet sizes
  - Number density
- Spray model track droplets



Spray transport validation: ADD

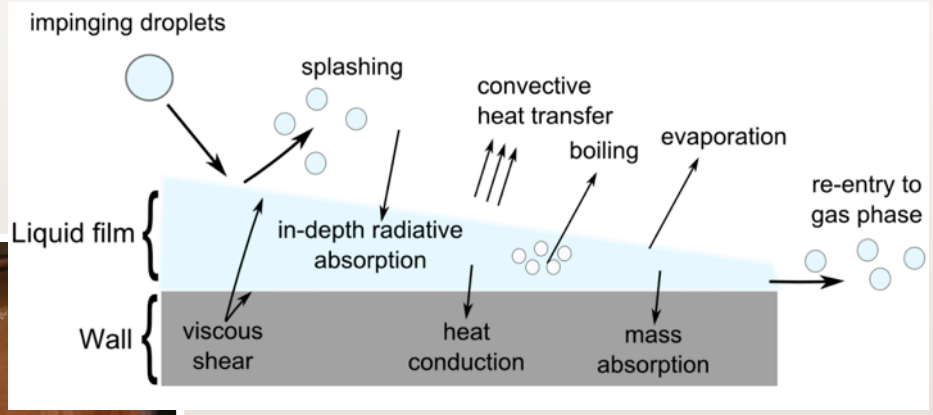


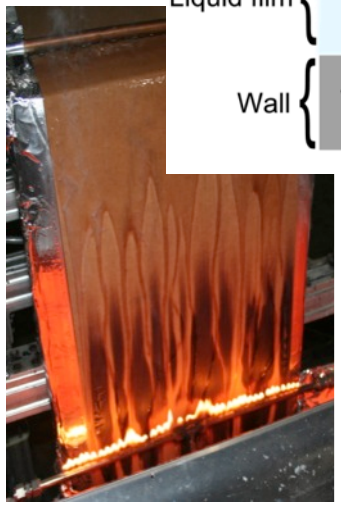




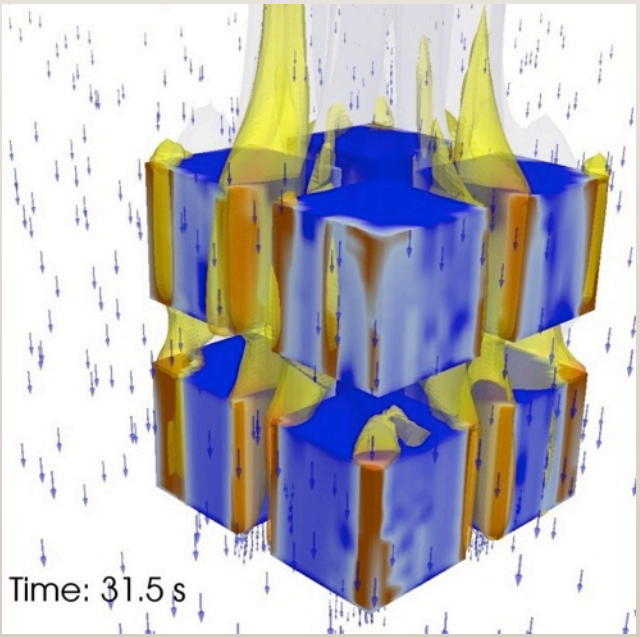
Water transport modeling

- Thin-film model
  - Partial wetting
  - Heat transfer





- Coupled with gas phase and solid fuel models

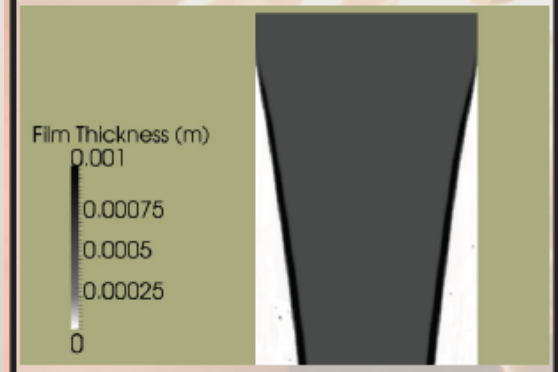


Experiments & Validations

Nusselt solution

Continuous film flow

- film thickness
- film velocity

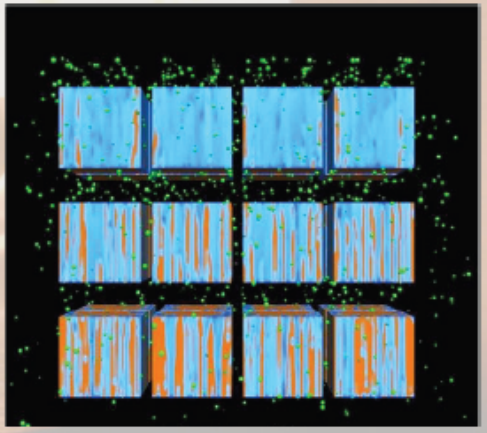


Partial wetting

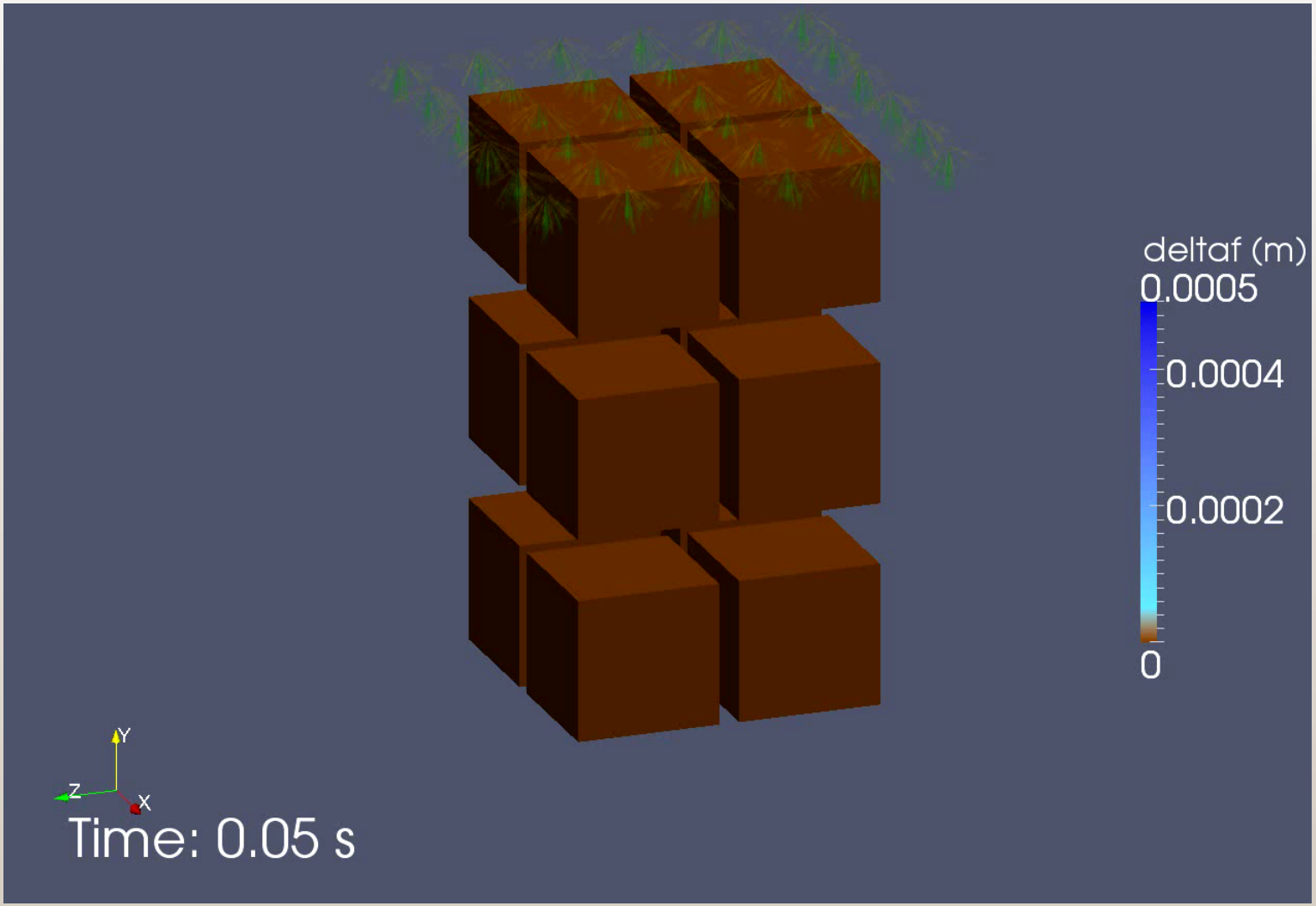
Wetted-area fraction for rivulet flow

Rack storage

Transient tier-to-tier water transport

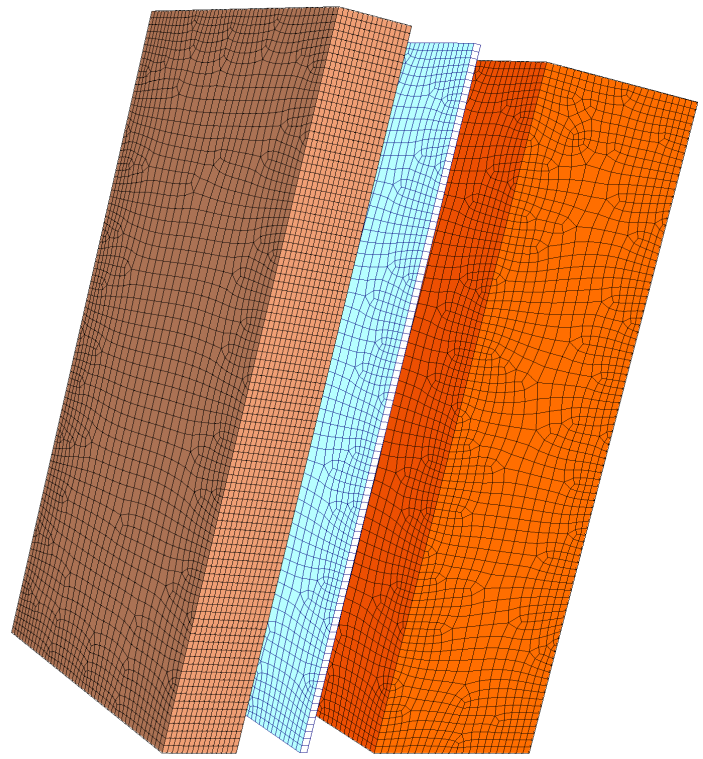


Water transport validation



Coupling fire growth & suppression

– Couple three phases through boundary conditions

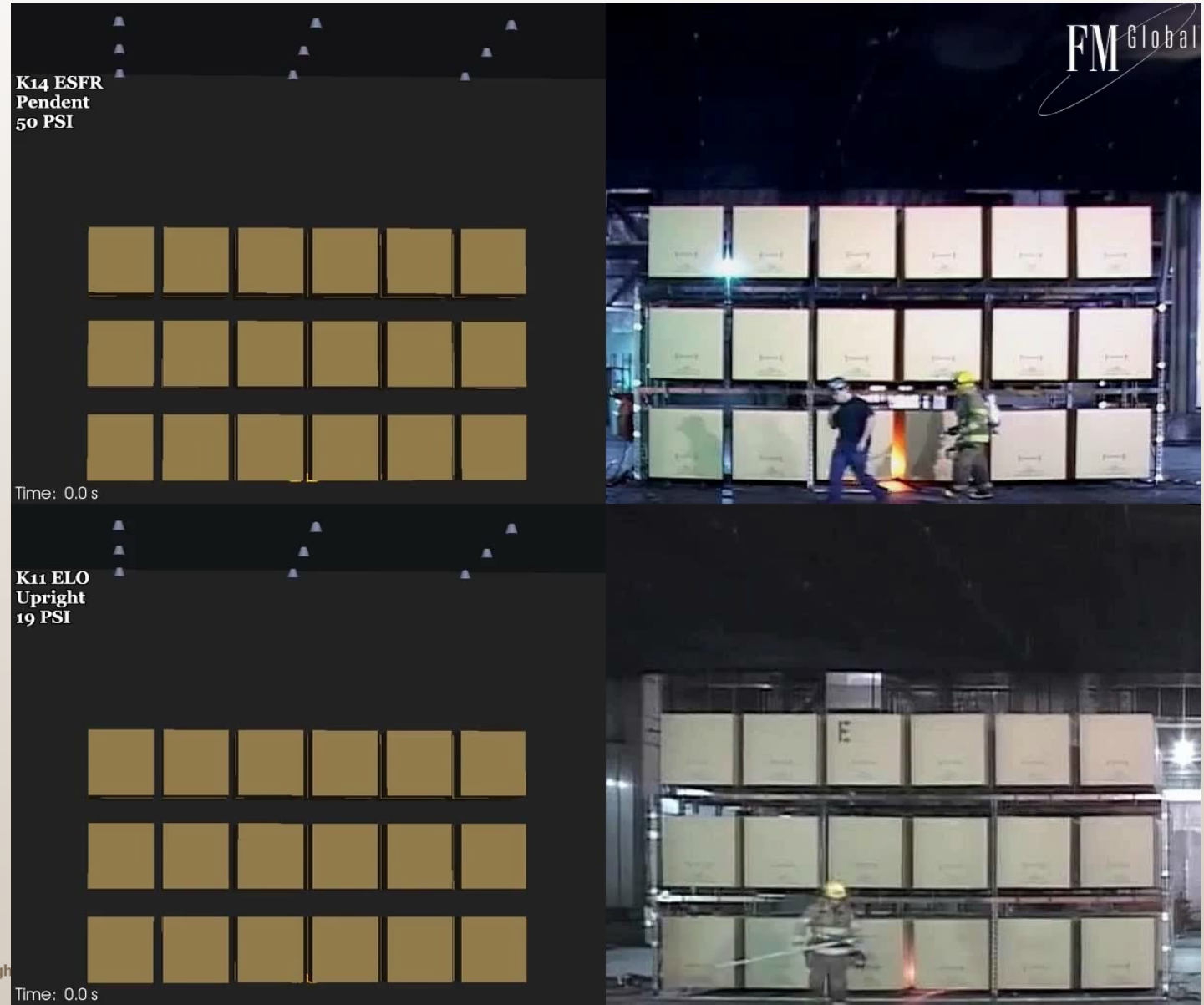


Solid Liquid Gas

• Meredith, Wang, et. al. 2013, *ISFEH*

Sprinkler tests and simulations

Model



Test

Cooperation

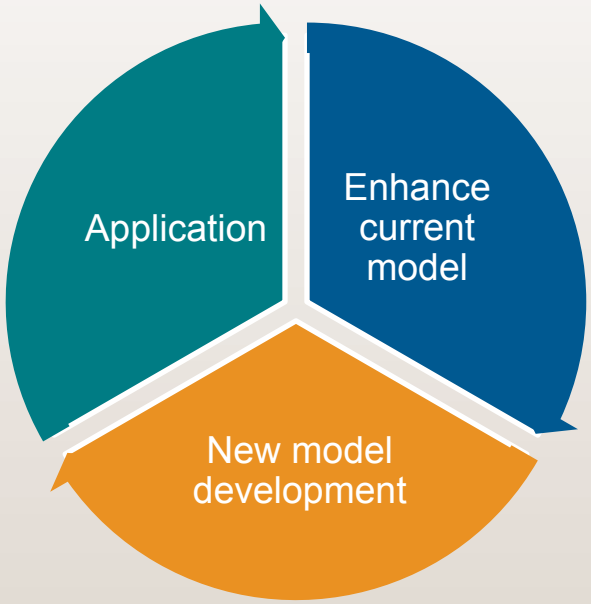
- Universities
  - Edinburgh, Ghent, Kingston, Maryland, WPI,USTC…
- Industry / Government
  - EdF, IRSN, NIST, Oak Ridge, OpenCFD, Sandia, UTRC,…
- FM Global Fire Modeling Workshops

1st workshop 2009

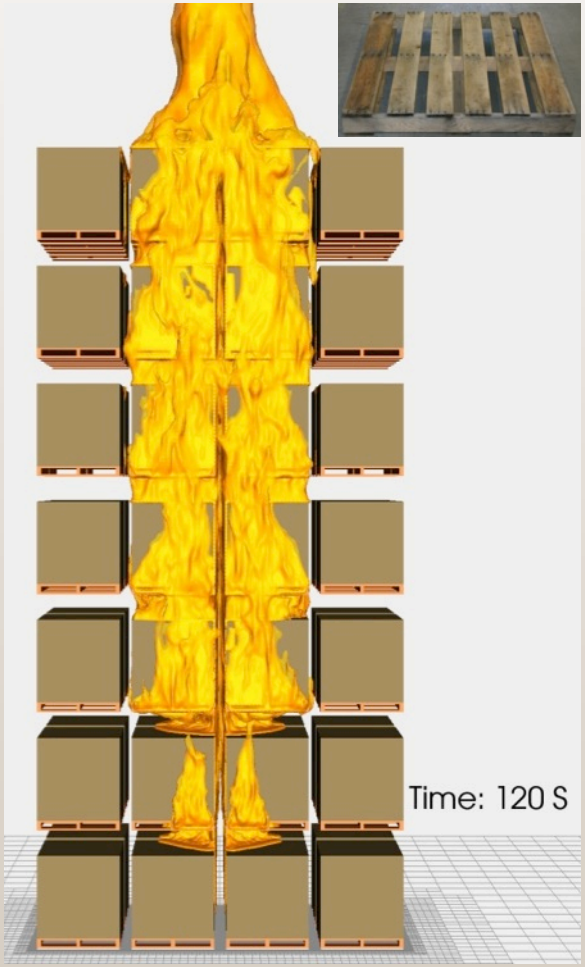
4th workshop 2012

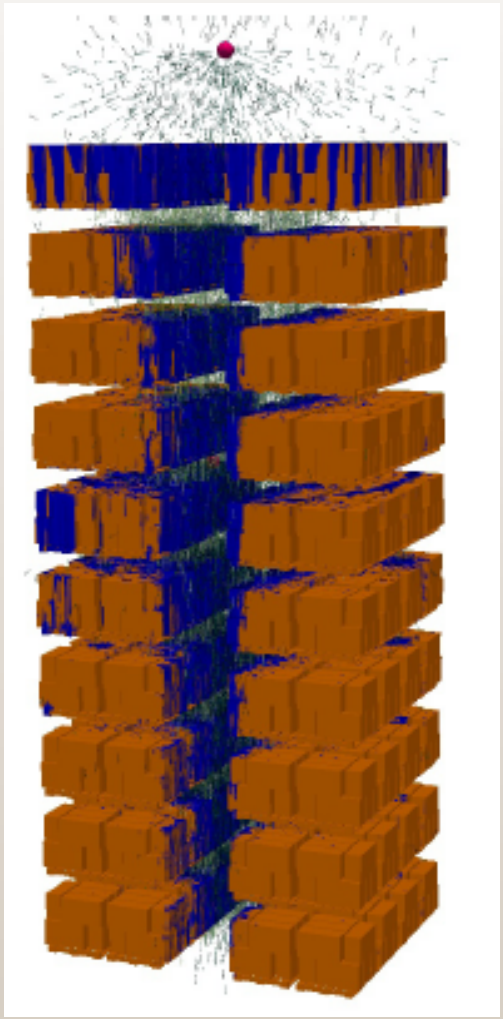
Fire modeling future

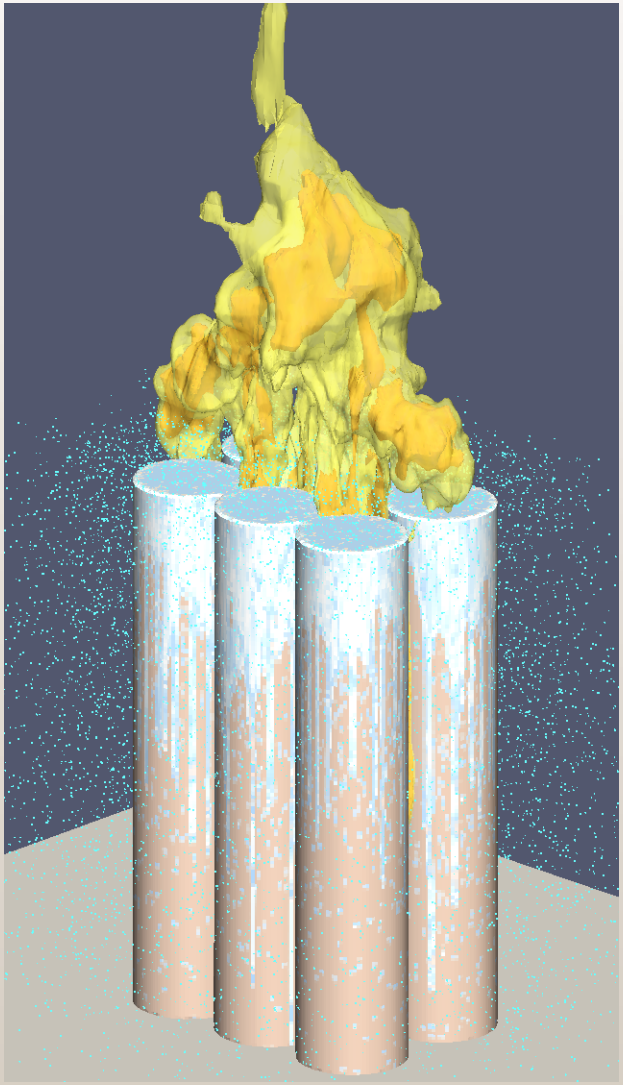
- Apply current model and continue FireFOAM development
  - Next 5-year roadmap



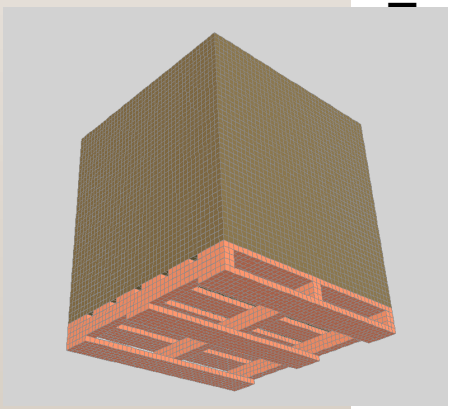
Engineering Impact

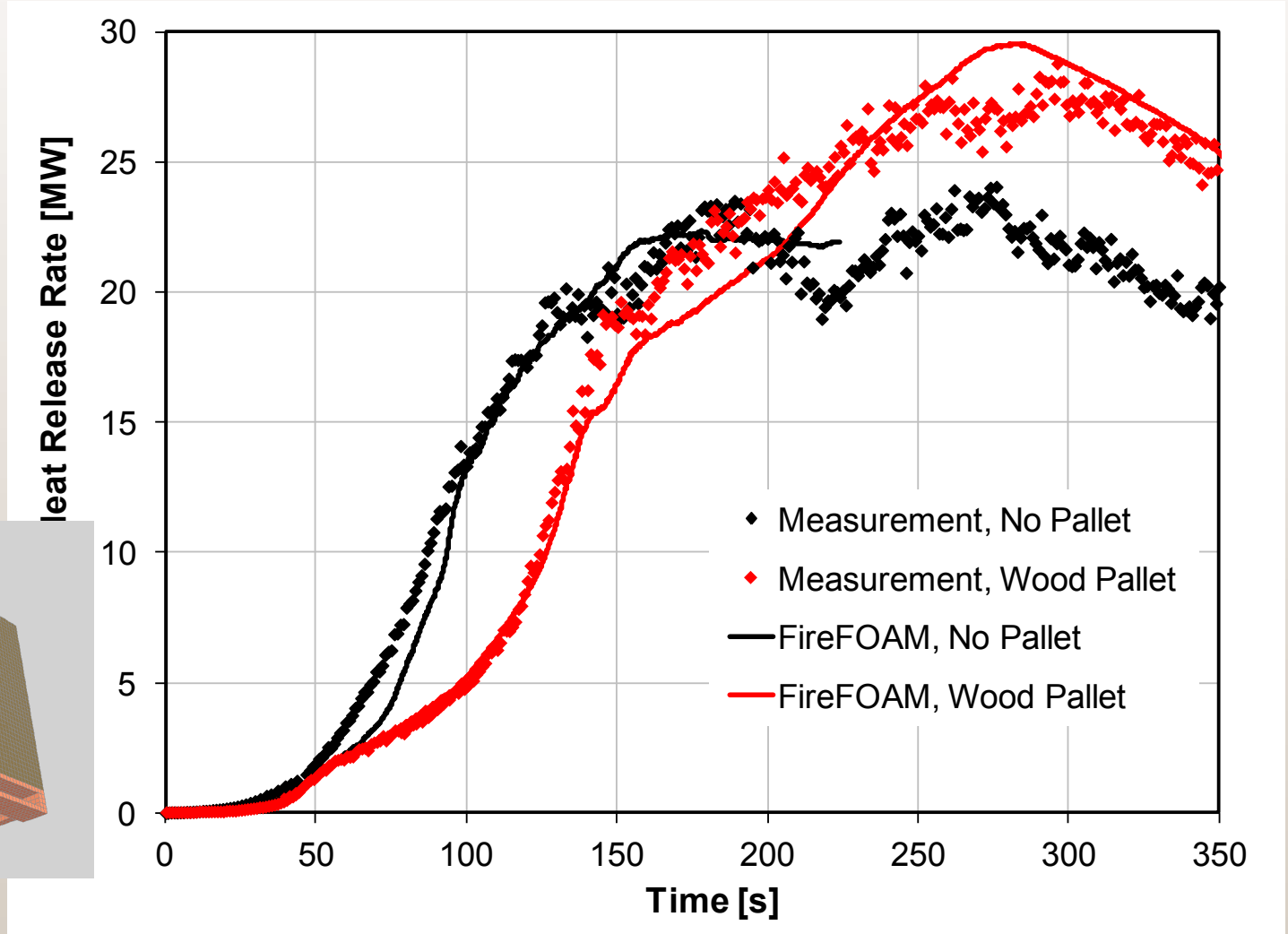




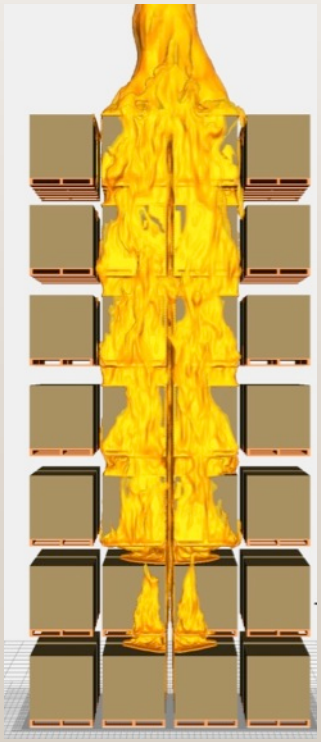


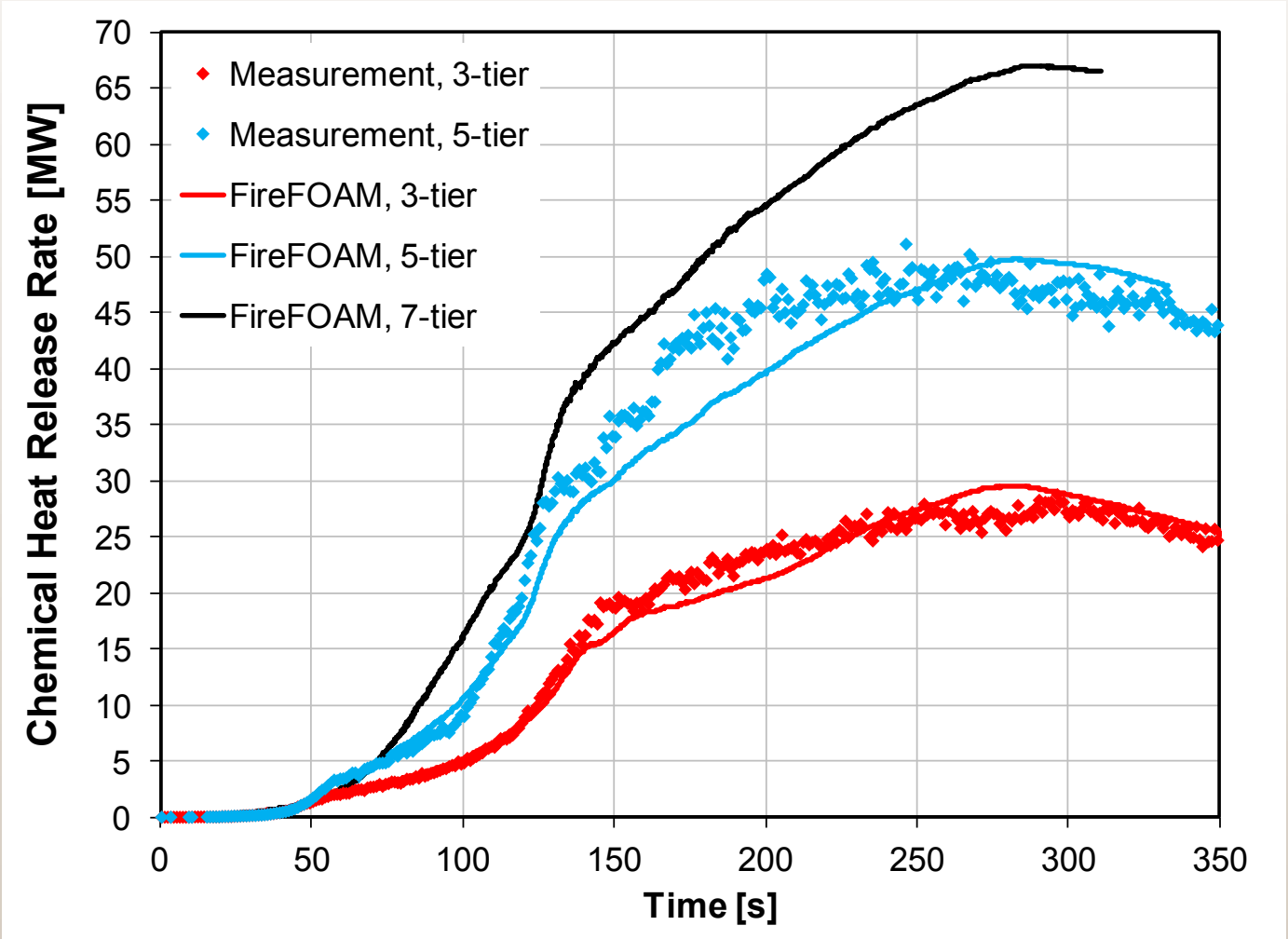
Effect of Wood Pallets



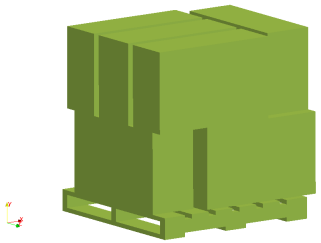


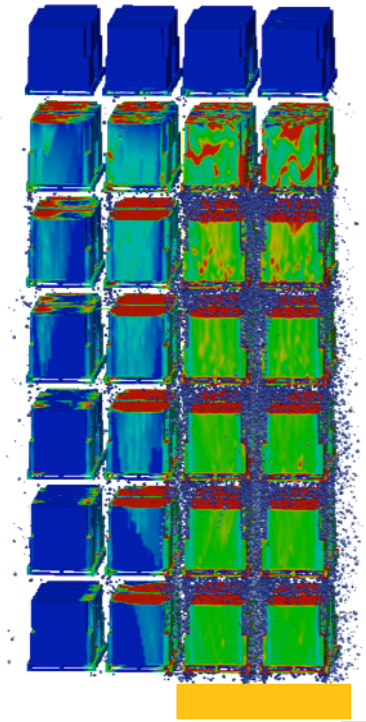
Higher Storage





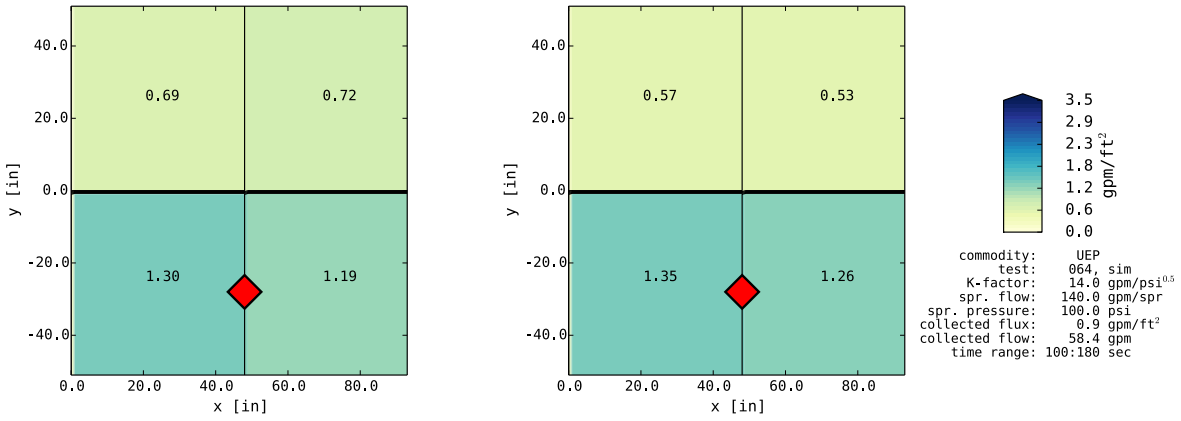
In-Rack Protection, UEP





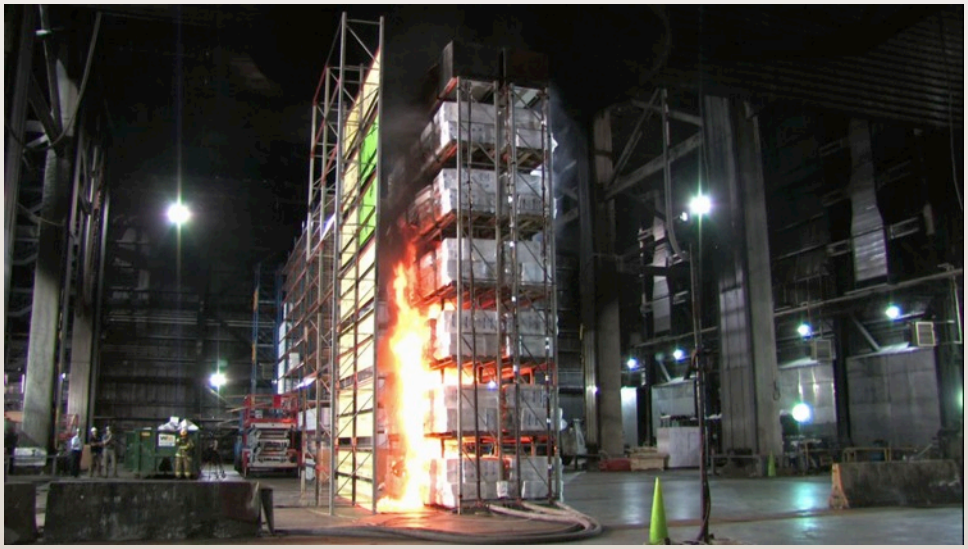
Simulation

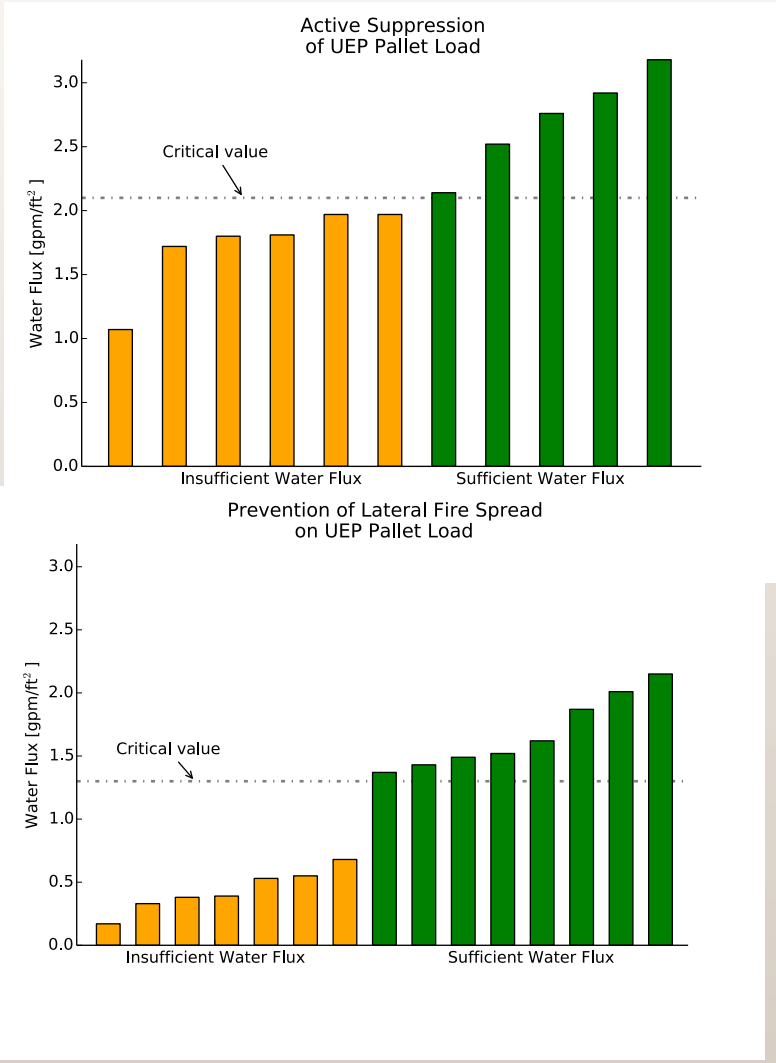
Test



In-Rack Protection, UEP

Protection Data Compared to
Water Transport Calculations



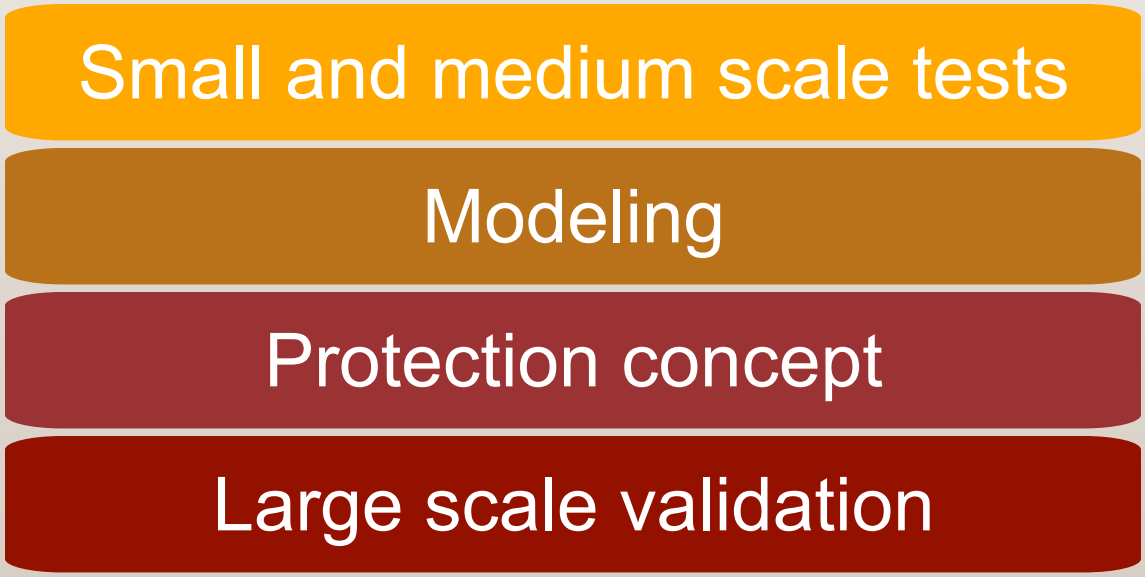


Benefits

- Reduced number of large scale tests for specific problem
- Better, more reliable, protection guidelines
- Faster turnaround of support projects
- Research Value

Fire modeling future

- Modeling will never replace testing
  - Complement test data
  - Design better tests



Questions?