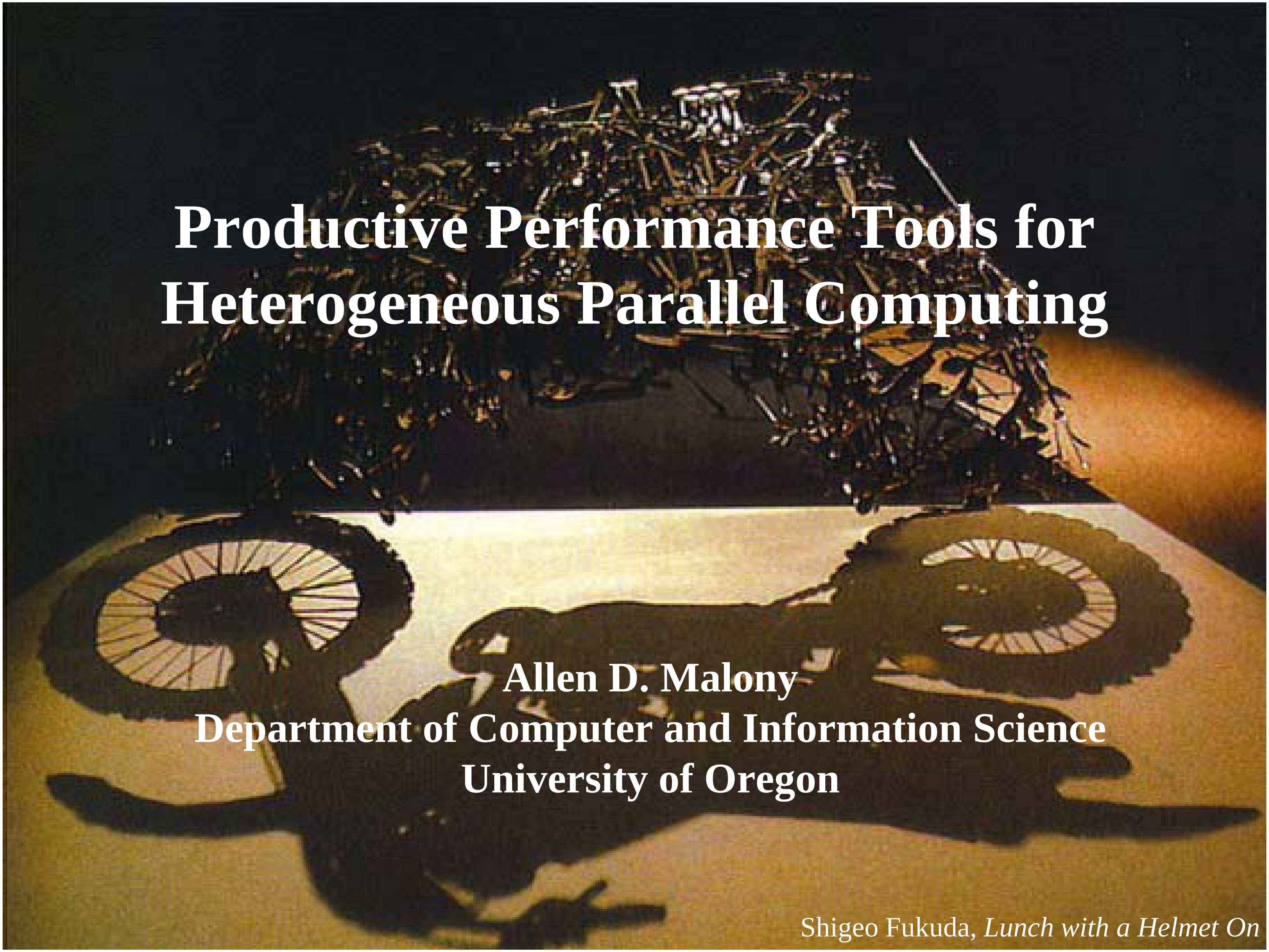
Productive Performance Tools for Heterogeneous Parallel Computing

Allen D. Malony
Department of Computer and Information Science
University of Oregon



Shigeo Fukuda, *Lunch with a Helmet On*

Heterogeneous Implications for Performance Tools

- Tools should support parallel computation models
- Current status quo is comfortable
  - Mostly homogeneous parallel systems and software
  - Shared-memory multithreading – OpenMP
  - Distributed-memory message passing – MPI
- Parallel computational models are relatively stable (simple)
  - Corresponding performance models are relatively tractable
  - Parallel performance tools are just keeping up
- Heterogeneity creates richer computational potential
  - Results in greater performance diversity and complexity
- Performance tools have to support richer computation models and broader (less constrained) performance perspectives

Heterogeneous Performance Perspective

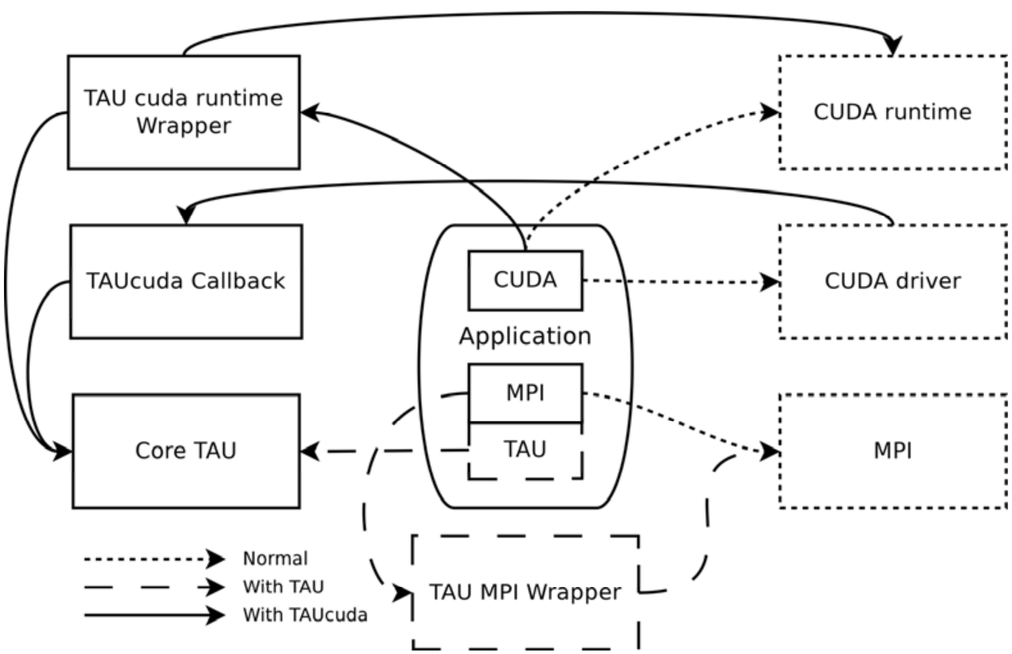
- Want to create performance views that capture heterogeneous concurrency and execution behavior
  - Reflect execution logic beyond standard actions
  - Capture performance semantics at multiple levels
- Heterogeneous applications have concurrent execution
  - Want to capture performance for all execution paths
- Consider "host" path and "external" paths
- What perspective does the host have of the external entity?
  - Determines the semantics of the measurement data
- Existing parallel performance tools are CPU(host)-centric
  - Event-based sampling (not appropriate for accelerators)
  - Probe-based measurement

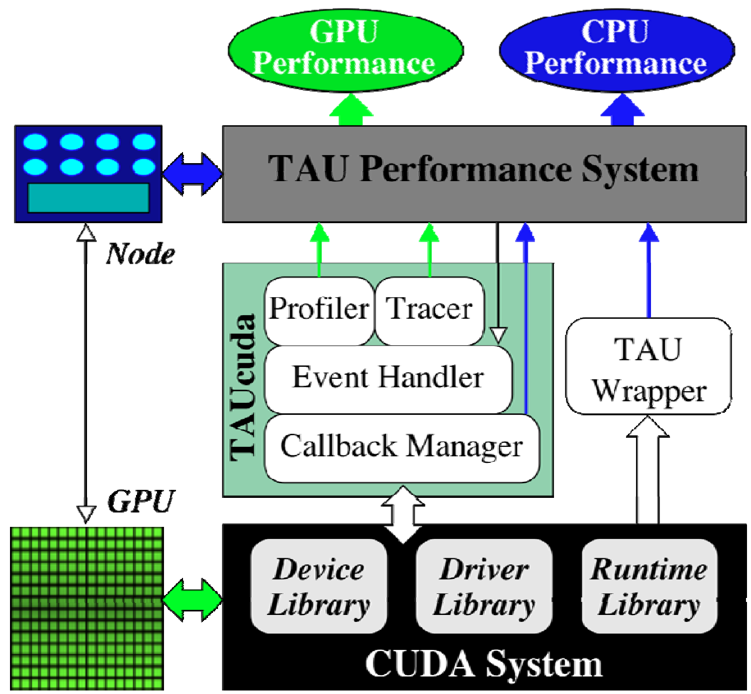
Heterogeneous Performance Complexity Issues

- Asynchronous execution (concurrency)
- Memory transfer and memory sharing
- Interactions between heterogeneous components
- Interference between heterogeneous components
- Different programming languages/libraries/tools
- Availability of performance data
- ...

TAUcuda Performance Measurement

- CUDA performance measurement
- Integrated with TAU performance system
- Built on experimental Linux CUDA driver (R190.86)
  - Captures CUDA device (*cuXXX*) events
  - Captures CUDA runtime (*cudaYYY*) events

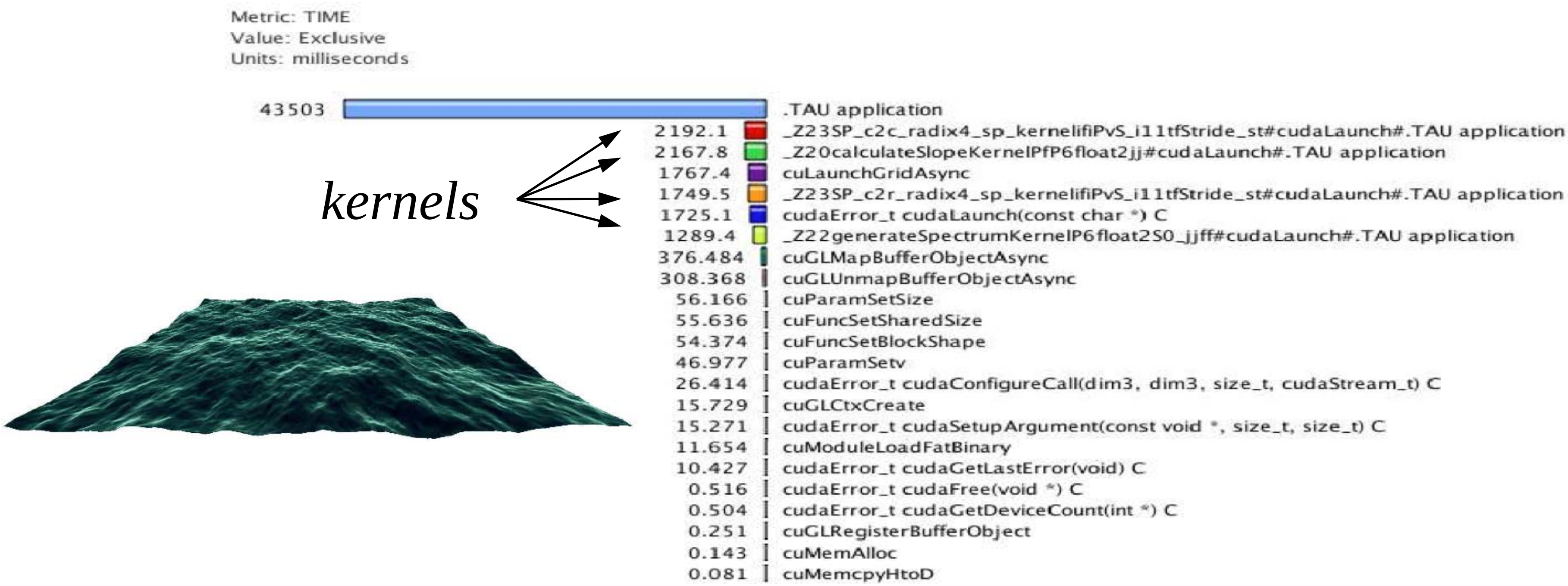


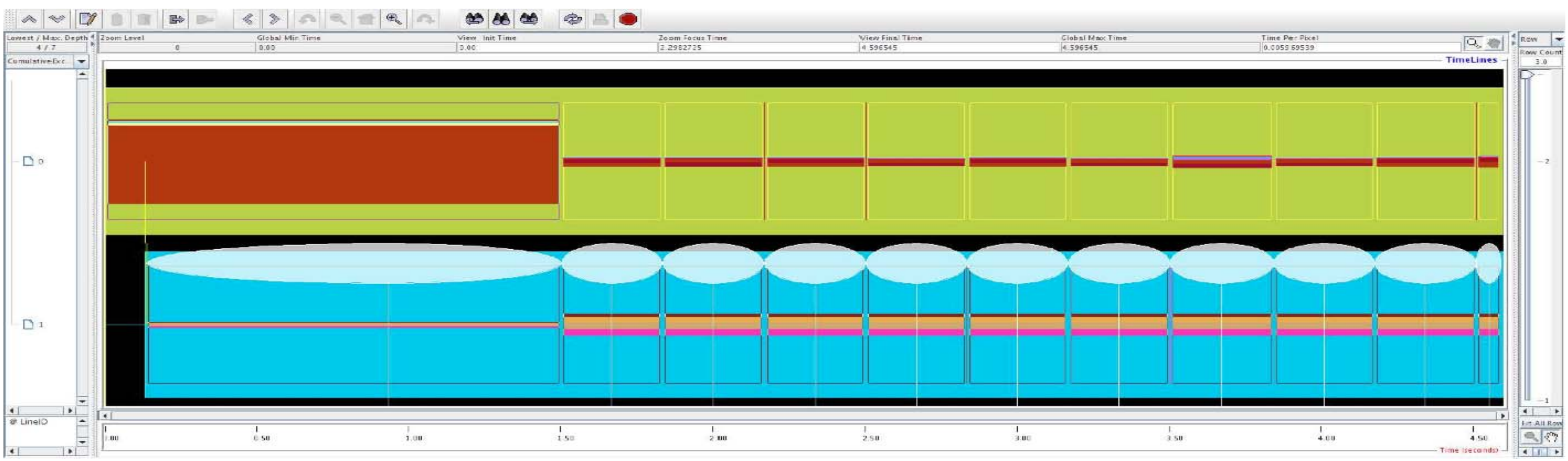


TAUcuda Experimentation Environment

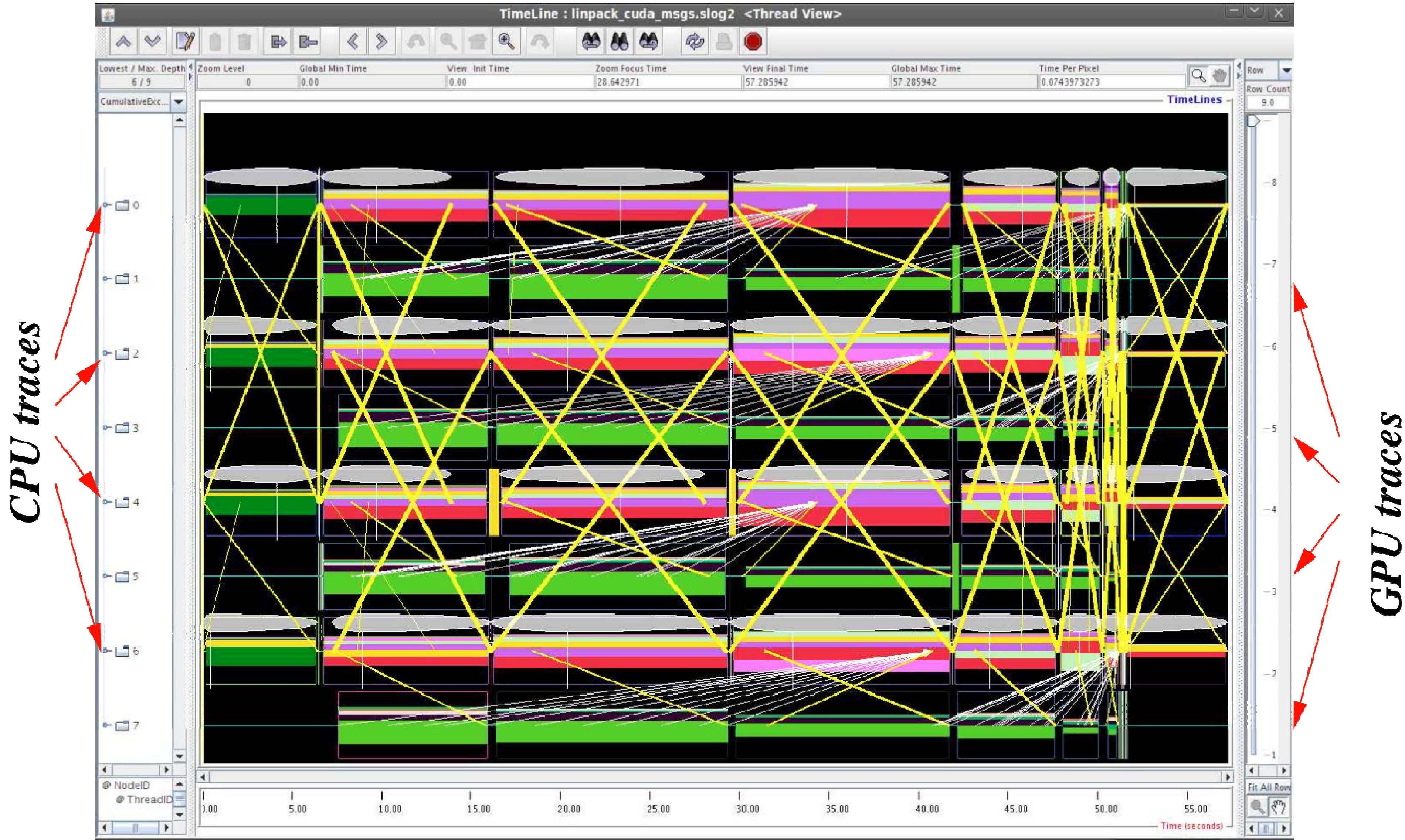
- University of Oregon
  - Linux workstation
    - Dual quad core Intel Xeon
    - GTX 280
  - GPU cluster (Mist)
    - Four dual quad core Intel Xeon server nodes
    - Two S1070 Tesla servers (4 Tesla GPUs per S1070)
- Argonne National Laboratory
  - 100 dual quad core NVIDIA Quadro Plex S4
  - 200 Quadro FX5600 (2 per S4)
- University of Illinois at Urbana-Champaign
  - GPU cluster (AC cluster)
    - 32 nodes with one S1070 (4 GPUs per node)

CUDA SDK OceanFFT



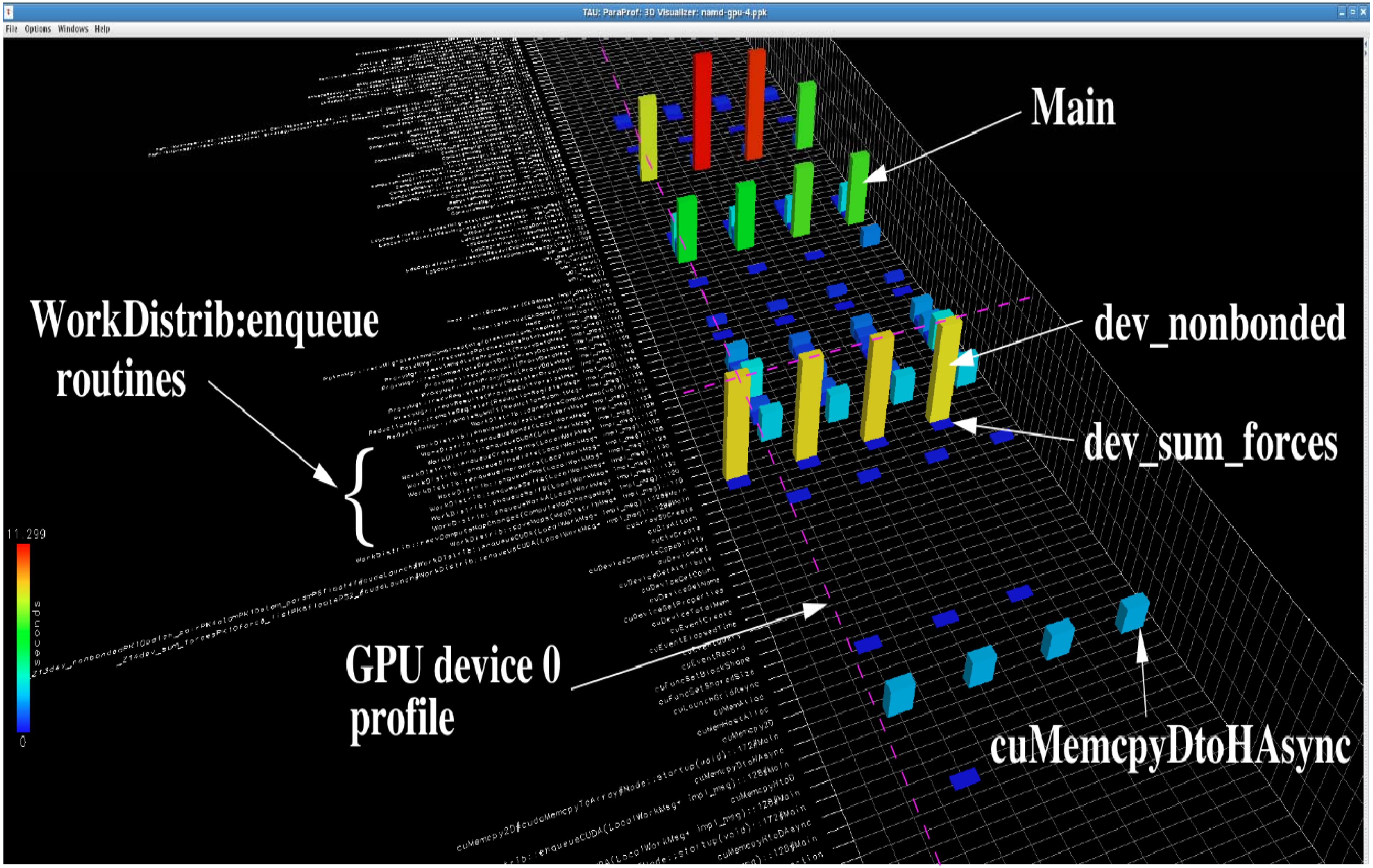


CUDA Linpack (4 process, trace)



CUDA memory transfer (white) *MPI communication (yellow)*

NAMD Performance Profile



Call for "Extreme" Performance Engineering

- Strategy to respond to technology changes and disruptions
- Strategy to carry forward performance expertise and knowledge
- Built on robust, integrated performance measurement infrastructure
- Model-oriented with knowledge-based reasoning
  - Community-driven knowledge engineering
  - Automated data / decision analytics
- Requires interactions with all SW stack components

Model Oriented Global Optimization (MOGO)

- Empirical performance data evaluated with respect to performance expectations at various levels of abstraction