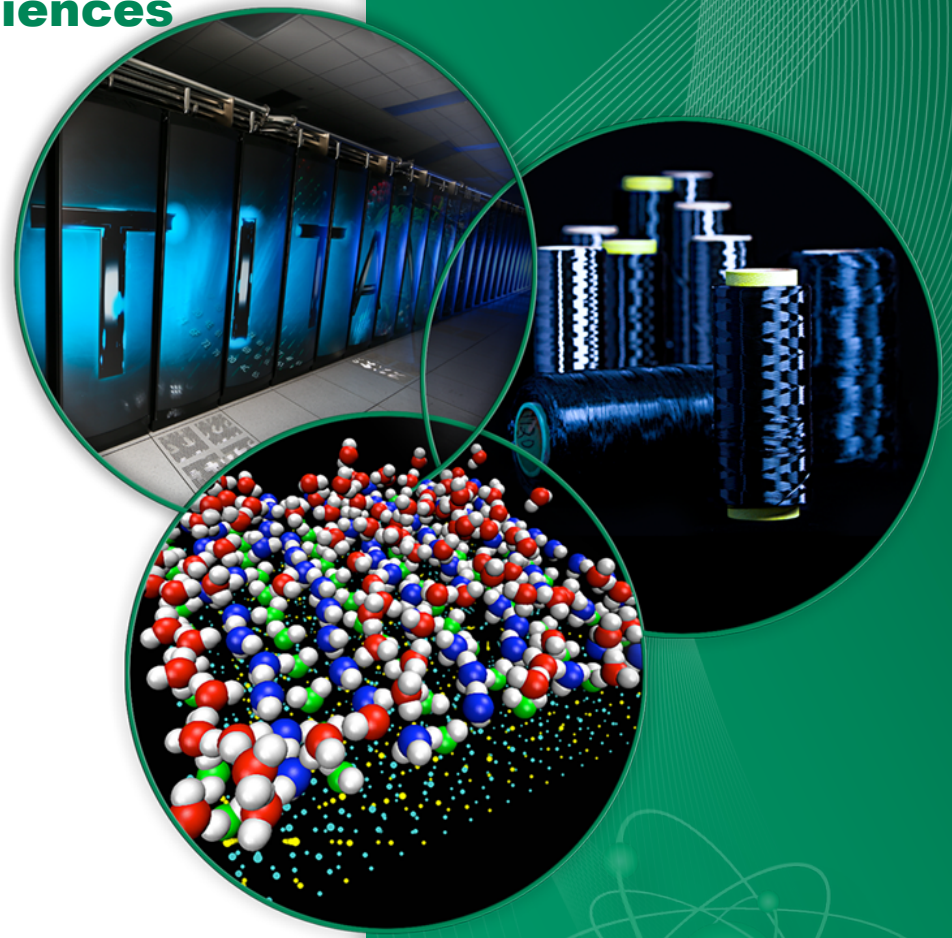
Oak Ridge National Laboratory
Computing and Computational Sciences



EE-HPC-WG Workshop, SC13

Data Motion projects at ESSC

Presented by:

Stephen Poole
Chief Scientist – CSM
Director of Special Programs/ESSC

Currently deployed in Research at the DoD.

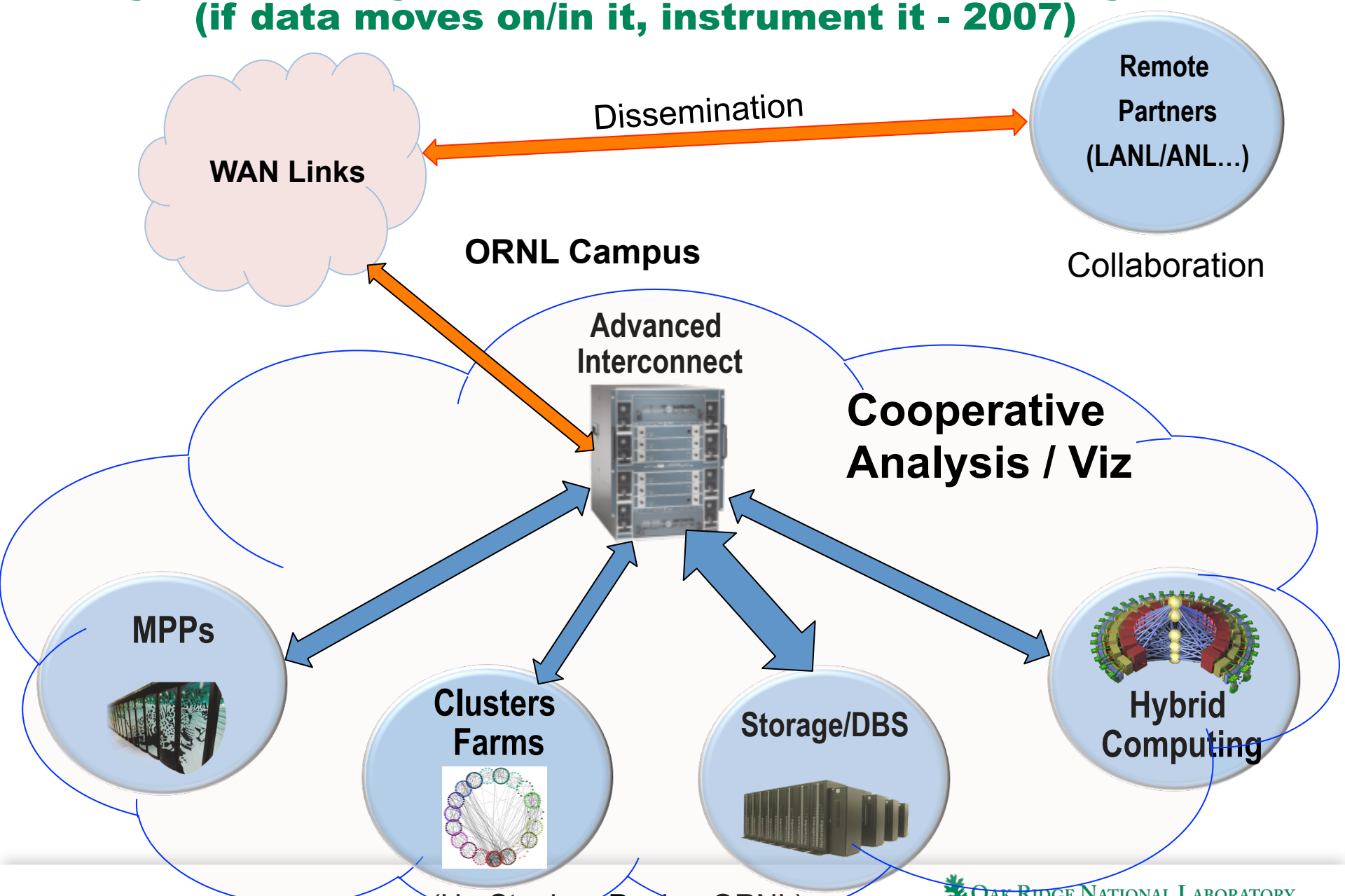
The ESSC Team

- **ORNL**
  - **Stephen Poole**
  - Joshua Lothian
  - **Chung-Hsing Hsu**
  - Jonathan Schrock
  - **Brad Settlemyer**
  - Greg Koenig
  - **Pavel Shamis / Pasha**
  - **Manjunath Venkata / Manju**
  - **Oscar Hernandez**
  - Matthew Baker
  - Sarah Powers
  - Nina Imam
  - Tiffany Mintz
  - OLCF/NCCS (Jim Rogers, Don Maxwell)
- **Partners**
  - **UofH (many interns, Sidhartha)**
  - DoD (SME's) (CC)
  - Sonoma State University
  - Link Analytics
  - Colorado State Univ.
  - LANL / SNL / ANL
  - UTK
  - NMI – (Steve Hodson)
  - NCSU (Blair Sullivan)
  - QRI, Inc. (Jeff Kuehn)
  - SDSC
  - **Natalie Bates**

Outline

- Where did we start and why ? (2006)
- What did we want and why ? (Goals/Ideas/Vision)
- What tools do we have now ? (Benchmarks, Libraries…)
- New Benchmark
- How are we enabling these new tools/capabilities ?
- How do we make data available and where ?

A System of Systems focused on Data Analytics
(if data moves on/in it, instrument it - 2007)



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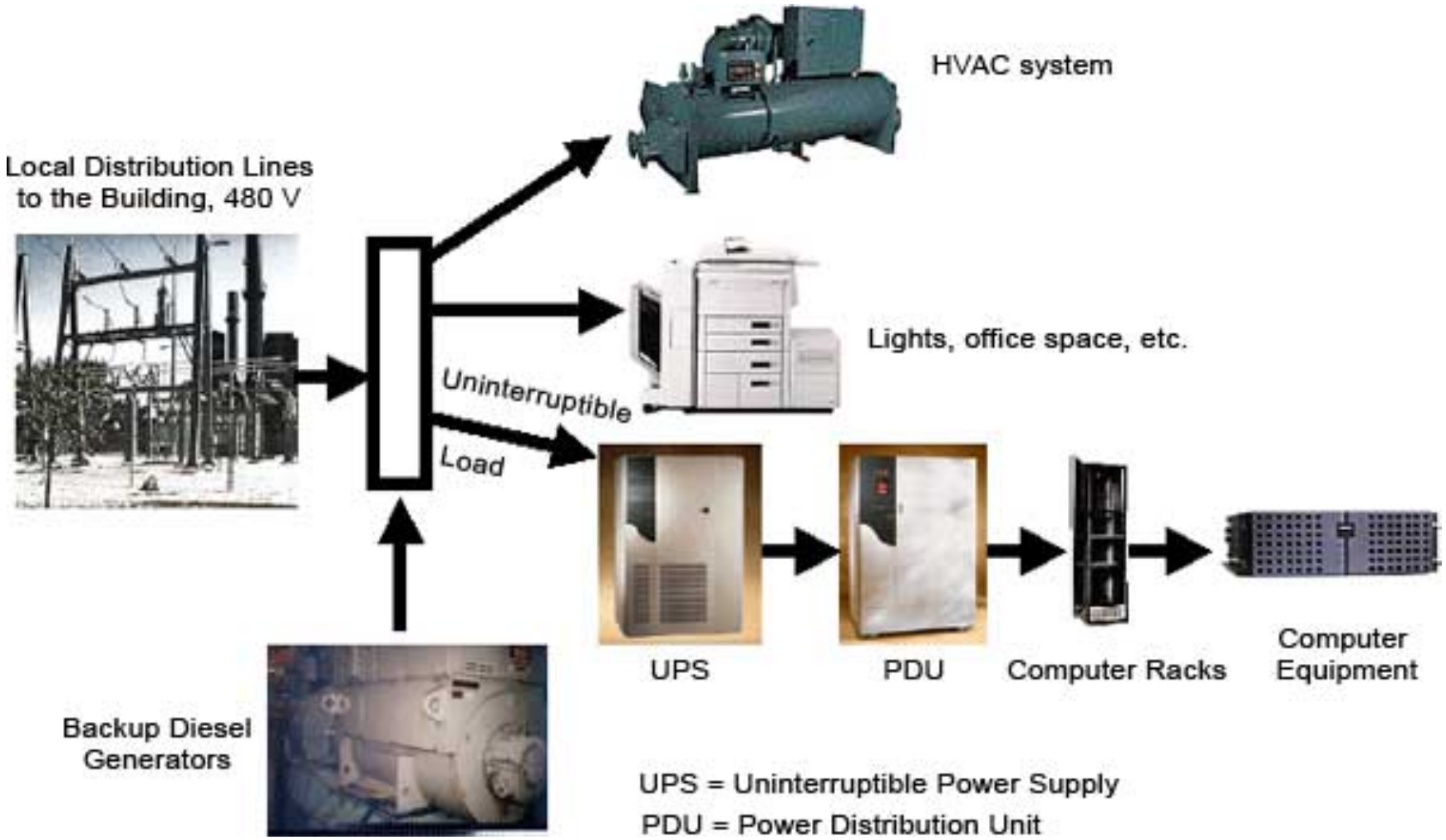
Hierarchical Measurement Domains

ORNL has lots of power, *BUT* money=people/projects.



How to help the procurement and facilities folks get a better handle on real costs

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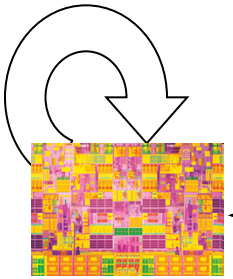
System Analytics
(overall system approach - 2007)

- External sensors
  - Networking (LAN/WAN)
  - Environment
- Internal sensors
- Collection SW
- Networking (LAN/WAN)
- Storage
- Benchmarks
- Math Tools
  - Statistical tools
  - Graph theory tools



What will fit on a chip?

What useful information can we extract?

System, Environmental, Power, Networking, Benchmarks, I/O **Data Collections**

Sun SPOT

IPMI Baseboard Management Controller (BMC)

w83627hf-isa-0290 **LM-sensors**
Adapter: ISA adapter
VCore 1: +3.90 V (min = +1.34 V, max = +1.49 V)
VCore 2: +3.79 V (min = +1.34 V, max = +1.49 V)
+3.3V: +3.82 V (min = +3.14 V, max = +3.46 V)
temp3: -48.0°C (high = +80°C, hyst = +75°C)
sensor = thermistor
vid: +1.419 V (VRM Version 11.0)

ESSC/Scheduler **Database(s)**

PDU

Graph Theory
Graffiti.sc
conjectures

Data Analysis

Collect, Trace, Model, System Replay, Simulate…

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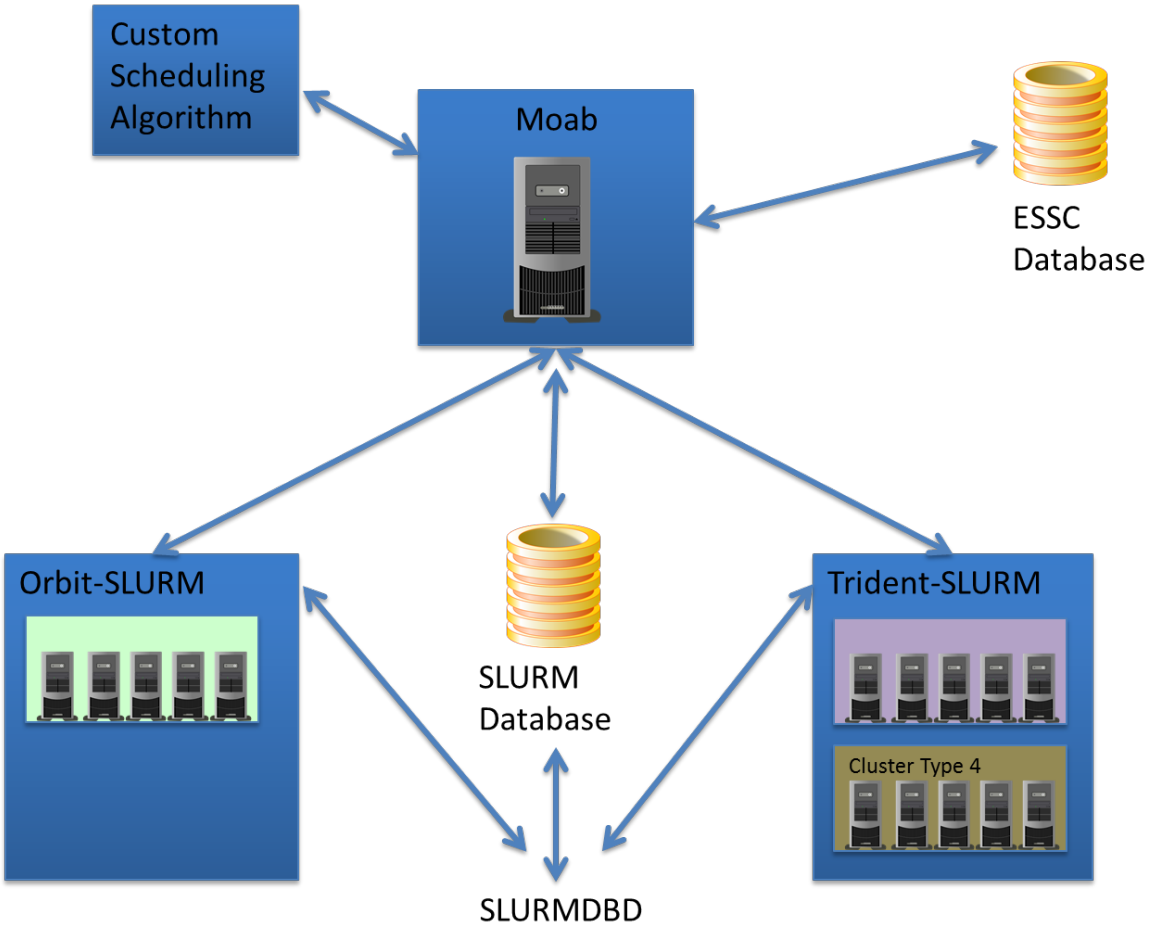
Customizing Scheduling Algorithm via ESSC-DB



Design of a system to integrate several systems together with a customized scheduling algorithm inside Moab using SLURM as the resource manager, and the ESSC database as a repository of disparate sensor information for forensic analytics and all jobs. (Job, Machine type, Cost, Location, constraints…

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Some of what we have used

- HPL
  - High-Performance Linpack (HPL) is the de-facto standard for FP-Dense (~Z)
  - Great historical data base
- Graph500 / Green Graph500
  - Data Intensive HPC Benchmark
- SPEC
  - SSJ2008 (Java)
- XDD / IOR (Instrumented File I/O, LAN/WAN)
- GUPS/Guppie, Random Access (Other DoD kernels)
- DOE-SC Apps, DOE-NNSA public Kernels

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Some of what we currently use (cont)

- SystemBurn
  - Systemburn allows us to emulate different application behavior profiles within a single framework (LOADS/Hybrid LOADS)
  - Used in DOE and DoD procurement process and machine diagnostics
  - Integrated performance data derived from PAPI or est. op counts
  - Development of infrastructure for automatic maximization of power draw
  - Tight integration of SystemBurn with ESSC DB
  - Some existing loads (others can be written, roll your own)
    - Memory loads: LSTREAM, DSTREAM, DSTRIDE, LSTRIDE, GUPS
    - I/O Loads : WRITE, Scenarios (1-12), Networking(LAN/WAN)
    - “Power Virus”: PV1, PV2, PV3 streaming computation
    - Mixed Loads: CBA, ISORT, TILT
    - CUDA/OpenCL/OpenACC Loads: DGEMM, BLAS
    - SLEEP – a dummy do nothing load
    - PCI Bus Load

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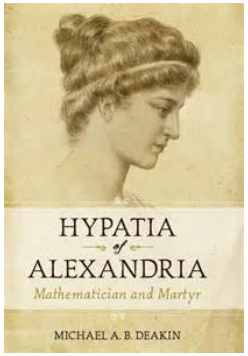
Proposed Capabilities of HIPATIA

- New Benchmark
  - **HI**gh **P**erformance **A**dap**T**ive **I**ntegrated Linear **A**lgebra Benchmark
    - HIPATIA (*hy-**pay**-shə*)
  - Scalable
  - Integer focused but will also evolve to use fixed point and others.
    - Not a lot of attention has been paid to non-FP problems (HW/SW)
  - User Configurable (with fixed/required runs, ala. HPL, Graph500)
    - Graphs (input)
    - Defined Matrix Types
      - Sparse, Dense, Structured, User defined (rules)
  - Fully Instrumented for Power and Performance (Data Motion costs)
  - Toolkits / Libraries available for HPL and others
    - Graph Generator(s)
    - Selected matrices



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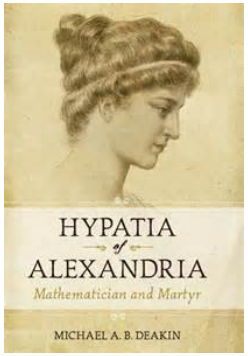
Proposed Capabilities (cont)

- Multiple implementations
  - C, OpenSHMEM, UPC, MPI, (Fortran, Cuda, OpenCL, ??)
- Additional areas
  - Will be incorporated into SystemBurn as a load module
    - So you can select between R, C Z, Fixed Point…
  - Will incorporate UCCS
    - With Power/Flow/Comms… tracing and cost models
  - Will incorporate signatures into DB (ESSC-DB)
  - Will be used by DoD/DOE (Applicable to: Oil, Informatics…)
- Hypatia
  - http://en.wikipedia.org/wiki/Hypatia
  - babelniche.wordpress.com for the image



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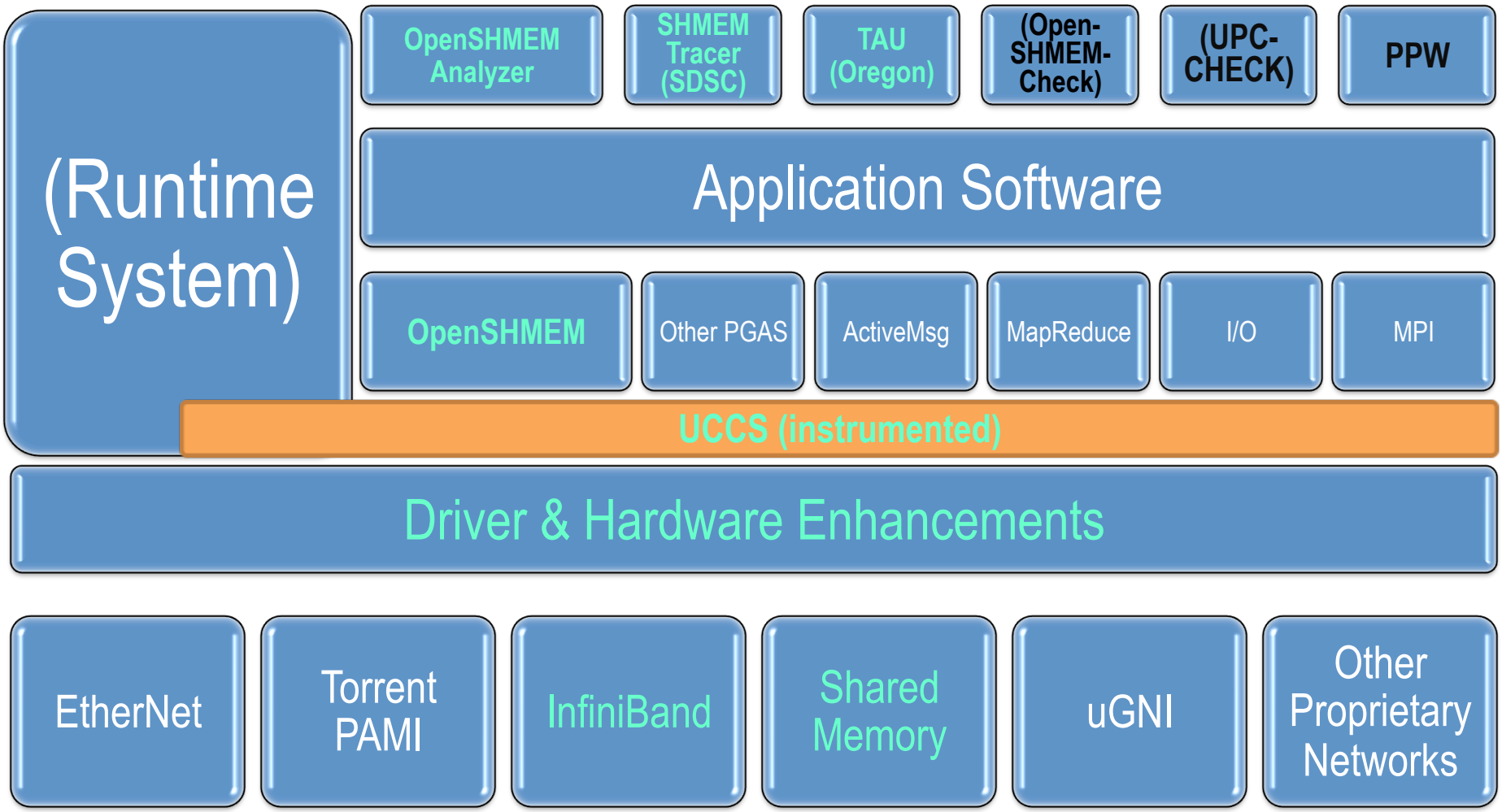
UCCS
(Universal Common Communication Substrate)



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Graph Generators Progress

Initial	• **Identify limits of current generators (internal report)**
	  • **Classical/Theoretical/Random, Internet, Real World Network, Geometric**
	• **Generate synthetic data set (we need useful sized ones)**
	  • **Of great computational and learning value**

Current	• Complete down selection process (implementations varied) • Implement final set of scalable generators in OpenSHMEM , UPC, MPI • Algorithm-optimized data structures for best performance
Next	• Implement pluggable generator(s) for HIPATIA integration

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Power Studies for OpenSHMEM

- Assume you have a network with reasonable latency/BW (not MPI centric)
- Power is very sensitive on how we effectively use caches.
  - Small/medium message sizes tend to be more cache friendly.
  - Small fragmentation of messages is good for power
- Memory accesses are expensive
  - More for medium and large message
- Barriers (HW/SW) are expensive in terms of power
  - They raise the power states of CPUs if they spin
  - Alternative implementations are needed
- Polling for messages is expensive
  - RDMA hardware for PGAS may improve this.
- We need to explore event-based execution models to save power

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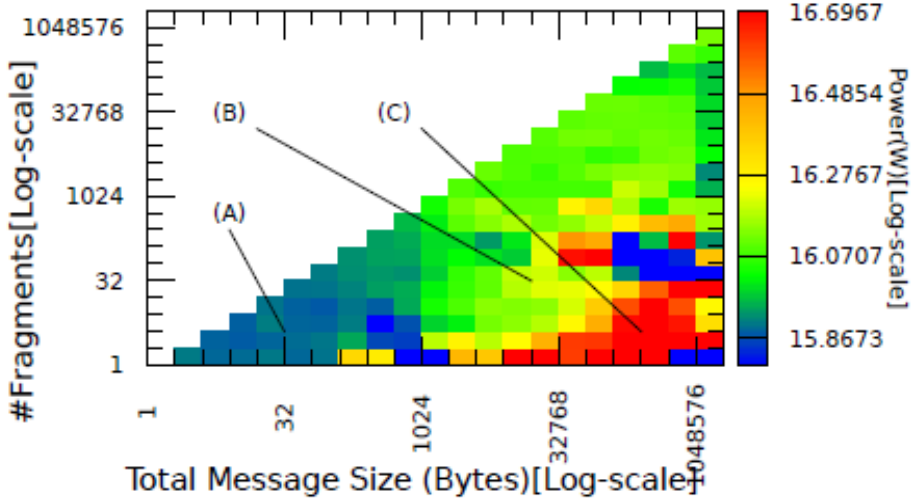
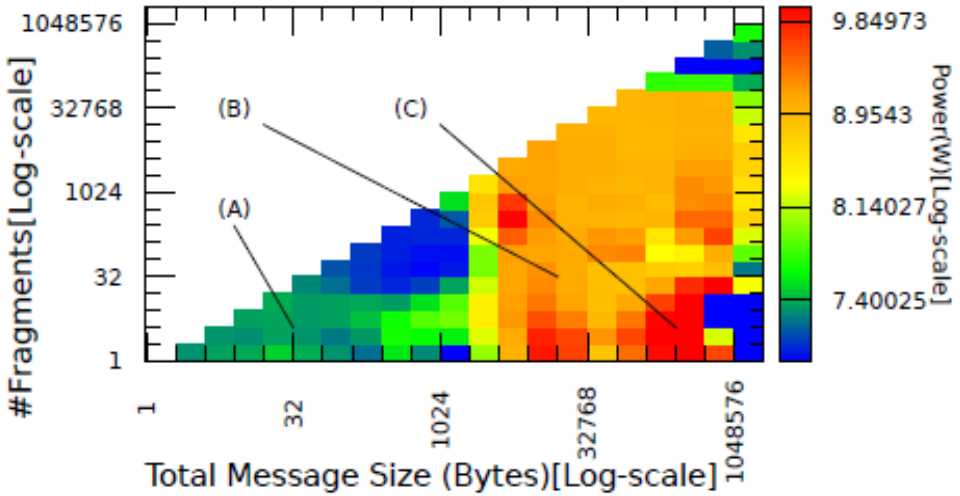
OpenSHMEM Power Studies
Power v/s Cache Misses for shmem_putmem()
(Mellanox SHMEM)

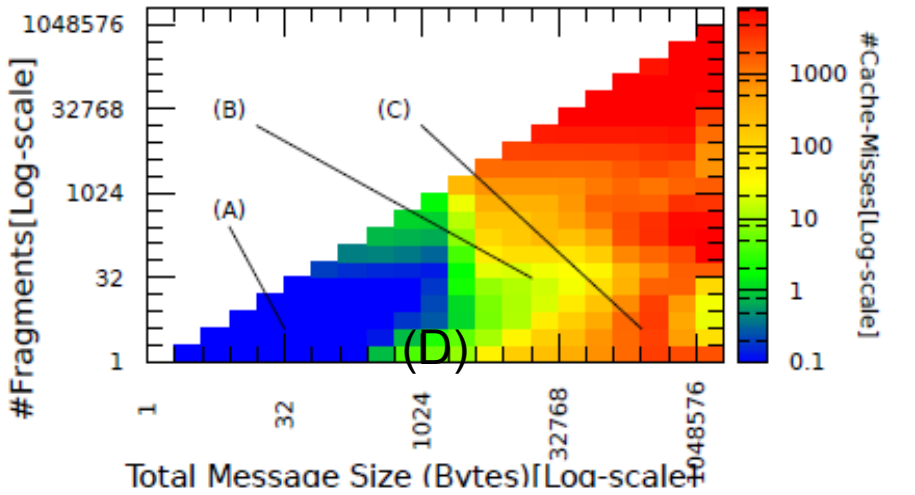
(I) Cores Power (Watts)



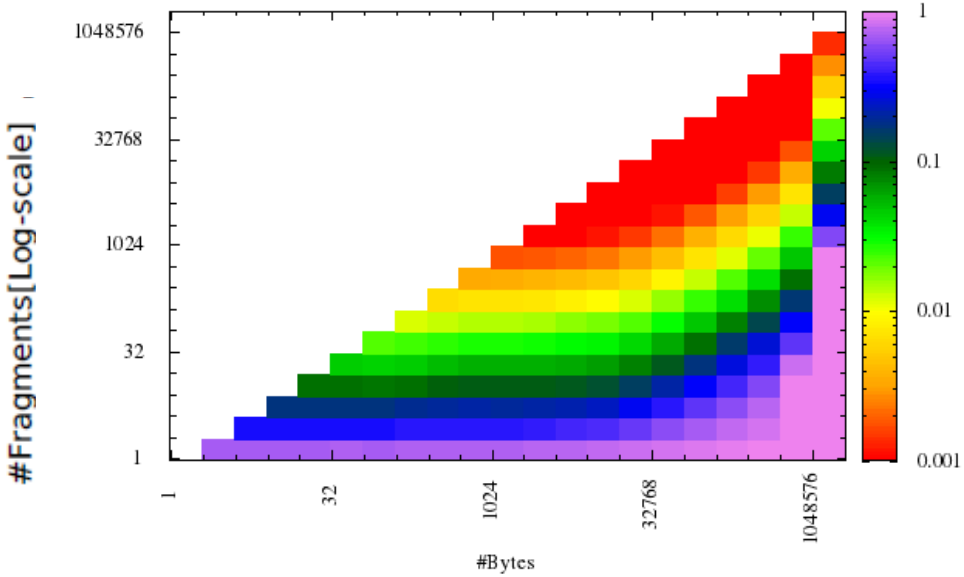
(II) DRAM Power (Watts)

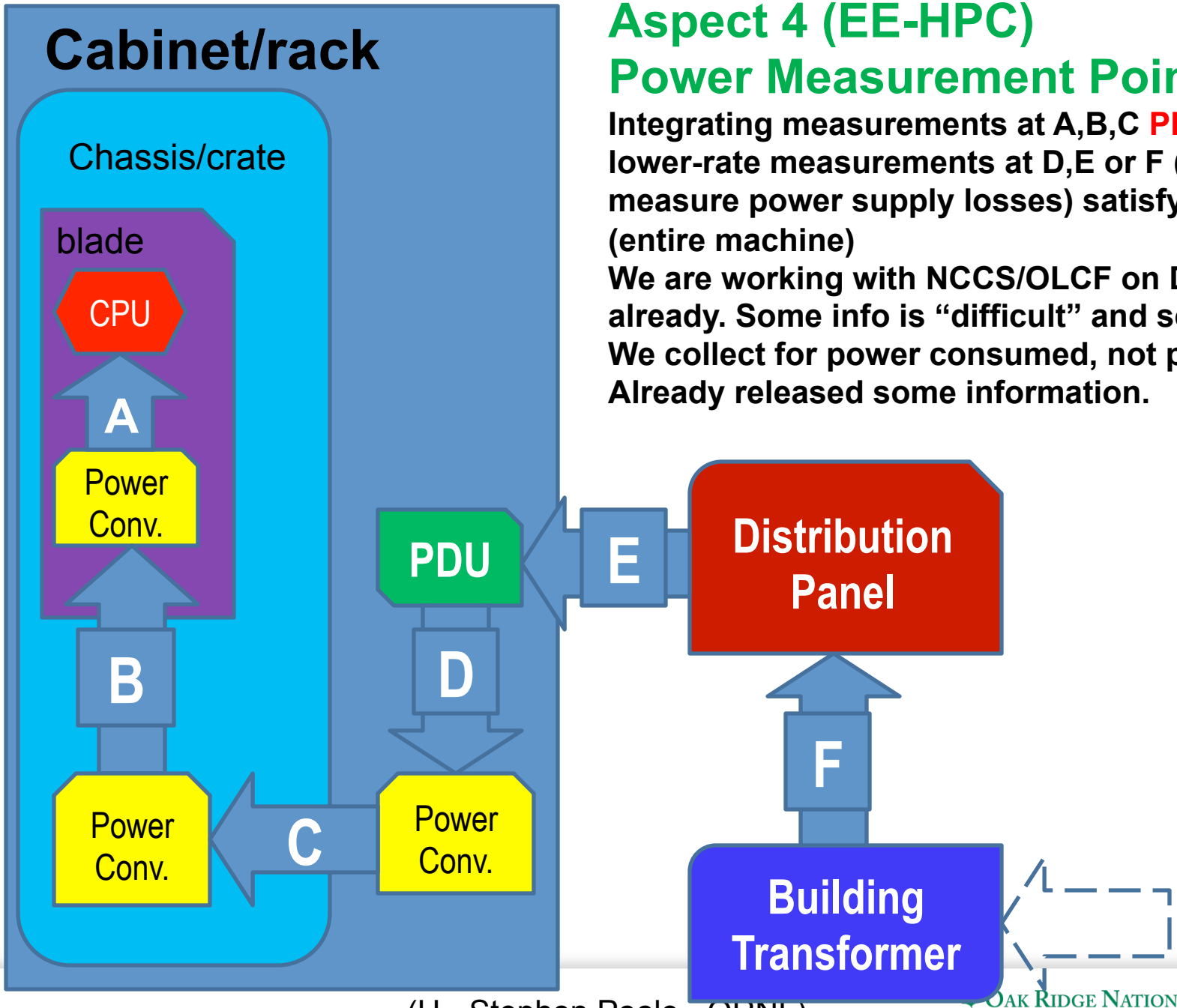


(III) L3 (shared) Cache Misses



(IV) Normalized (Bandwidth / Watt) per message size





Aspect 4 (EE-HPC) Power Measurement Point:

Integrating measurements at A,B,C PLUS lower-rate measurements at D,E or F (to measure power supply losses) satisfy L1-L3 (entire machine)

We are working with NCCS/OLCF on D/E/F already. Some info is "difficult" and sensitive.

We collect for power consumed, not peak.

Already released some information.

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What do we do with all of the data

- Repository for (sanitized) released data (LANL-Institutes?)
  - The IBM P7-IH (PERCS-DCIR) generates enormous data.
- Collecting a variety of system data is very important (Potential Predictors)
  - Application Signatures, Performance, Runtimes Traces
  - Power / Energy / Water (Cooling)
  - Resource Manager, Job Scheduler Information
  - Network (local / remote, HCA, Switch(s), Optics, Integrated NIC)
  - I/O (FileSystems)
- Helps guide system purchases and funding requirements
- Great feedback to the vendors and apps developers, compiler developers
- Helps determine power budgets
- A variety of machines/technologies (MPP, Clusters, …) All Vendors

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Talks at SC13 on these topics

- https://github.com/jlothian/systemburn
- http://openshmem.org -> Announcements -> SC13 Schedule
- http://www.csm.ornl.gov/cheetah/oshmem_event_schedule.pdf
- Power talks (Chung-Hsing)
- I/O talk Brad S.

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