Porting and Performance of the Community Climate System Model (CCSM3) on the Cray X1

CUG05

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Albuquerque, NM

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Overview

- CCSM3 Introduction
- Cray X1 Introduction
- An Orientation to the Port and Evaluation Process
- Status of the Validation Process
- Future Activities

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CCSM Introduction

- CCSM, the Community Climate System Model, is a coupled model for simulating the earth's climate system.
  - Developed at NCAR with significant collaborations with DOE, NASA and the university community
- Components in CCSM3 include
  - Atmospheric Model – CAM 3.0

    T31: (48 x 96 x 26) **T42**: (64 x 128 x 26) **T85**: (128 x 256 x 26)
  - Ocean Model – modified version of POP 1.4.3

    3 degree: (100 x 116 x 25) **1 degree**: (320 x 384 x 40)
  - Sea Ice Model – CSIM5 - grid matches ocean
  - Land Model – CLM3 - grid matches atmosphere
  - Coupler - CPL6

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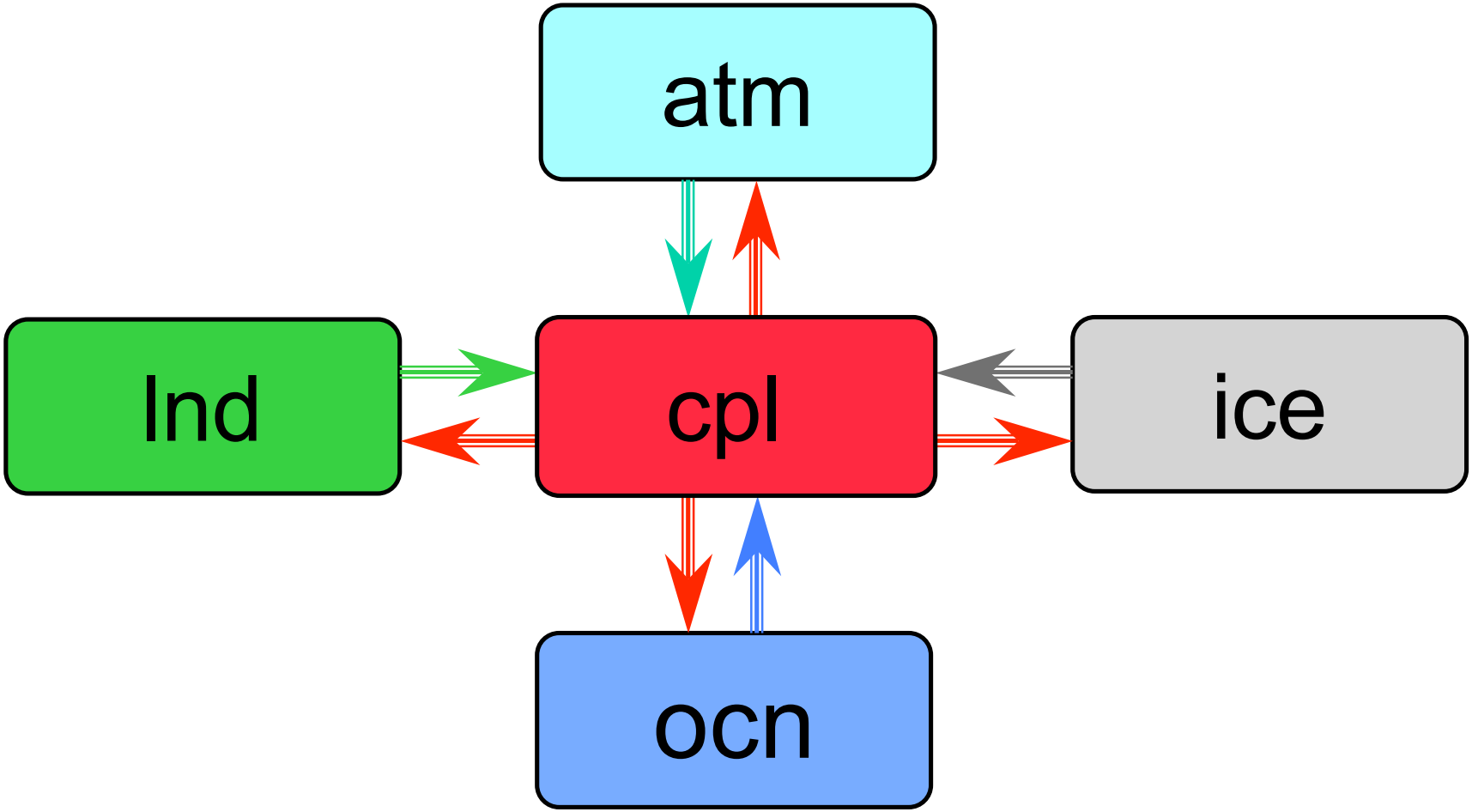
CCSM Hub and Spoke



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Supported Machines

- IBM Power3, Power4 - fully validated
- Xeon Linux Clusters (GigE and Myrinet) - validated T31x3
- Cray X1 - recently validated T31x3, just starting T85x1
- SGI Altix - baseline validation complete for T31x3
- Earth Simulator - fully validated on pre-release, update planned
- Opteron Linux Clusters (Myrinet) - work well underway
- Xeon Linux Clusters (InfiniBand) - work continuing
- Cray XT3 and XD1 - work begun

Approximate Timelines (1 of 2)

=> December 2003:

- Component model vectorization

=> April, 2004:

- Merge of vector versions into development branch, including basic support for the X1
- CAM/CLM2 standalone model (spectral Eulerian dycore) validated on the Earth Simulator and X1

=> June, 2004:

- CCSM validated on Earth Simulator and achieves required percentage of vectorization
- CCSM3 released, including basic support for X1

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Approximate Timelines (2 of 2)

=> October, 2004:

- Successful initial T31x3 X1 validation

=> March/April, 2005:

- Failed second T31x3 X1 validation

=> May, 2005:

- Recast second T31x3 X1 validation attempt
- CAM T170 runs begun

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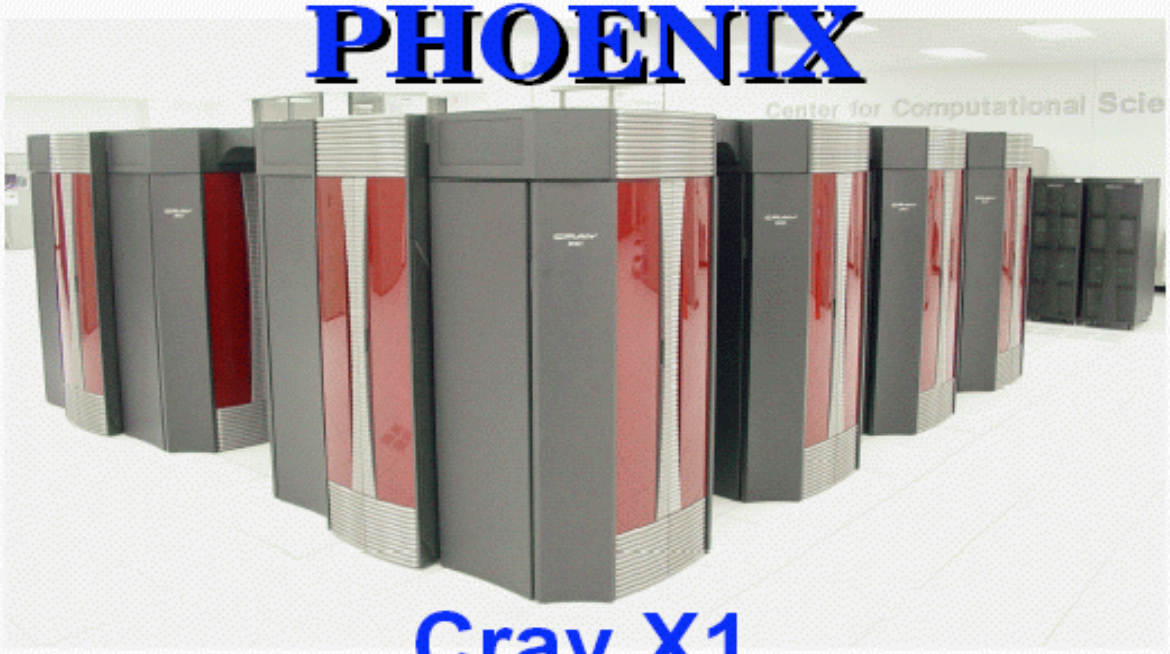

Cray X1

- 128 SMP nodes
- 4 Multi-Streaming Processors (MSPs) per node
- 4 Single Streaming Processors (SSPs) per MSP
- Two 32-stage, 64-bit wide vector units running at 800 MHz and one 2-way superscalar unit running at 400 MHz per SSP
- 2 MB E-cache per MSP
- 16 GB of memory per node

512 processors (MSPs), 2048 GB of memory, and 6400 GFlop/s peak

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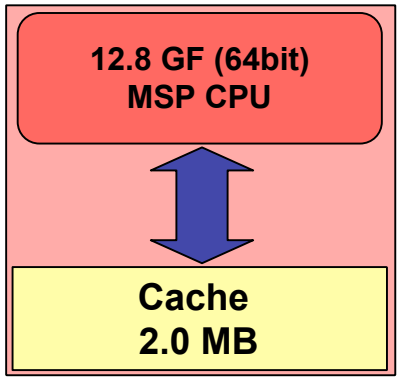
Multistreaming Processor



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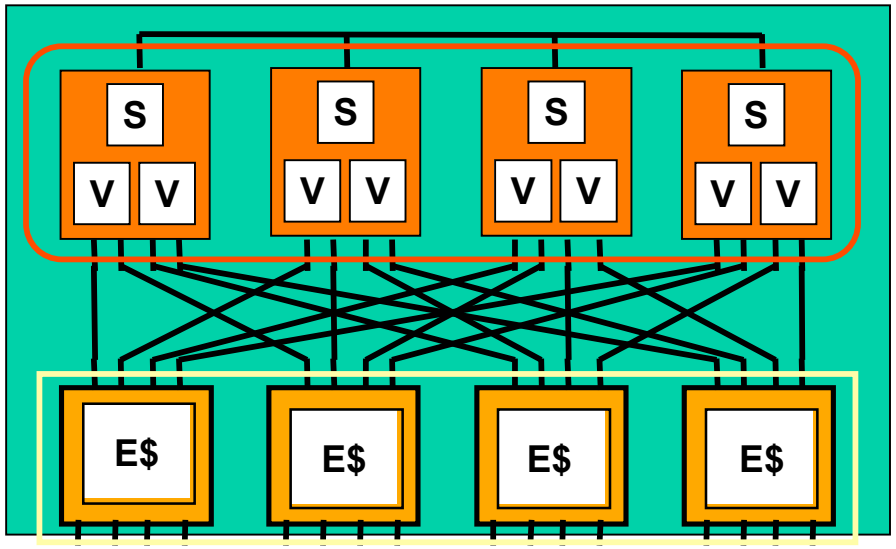

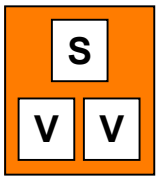

SSP – Single-Streaming Processor

- Two vector pipe units
- One 4-way superscalar processor

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CCSM Validation Process

- Get code to build and run
- CAM Perturbation Growth test (PERGRO)
- Atmospheric Diagnostics test on CAM and/or CCSM CAM history files
- CCSM 100 year statistical test
- Harden the scripts and do CCSM component load balancing

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CAM PERGRO

- Establish known baseline
- Perturb initial data
- Roundoff errors:
  - Within PERGRO limits: great
  - Close to PERGRO: probably ok
  - Way off: reject

- PERGRO is a simple two simulation day run for each configuration being tested.
- See http://www.ccsm.ucar.edu/models/atm-cam/port/

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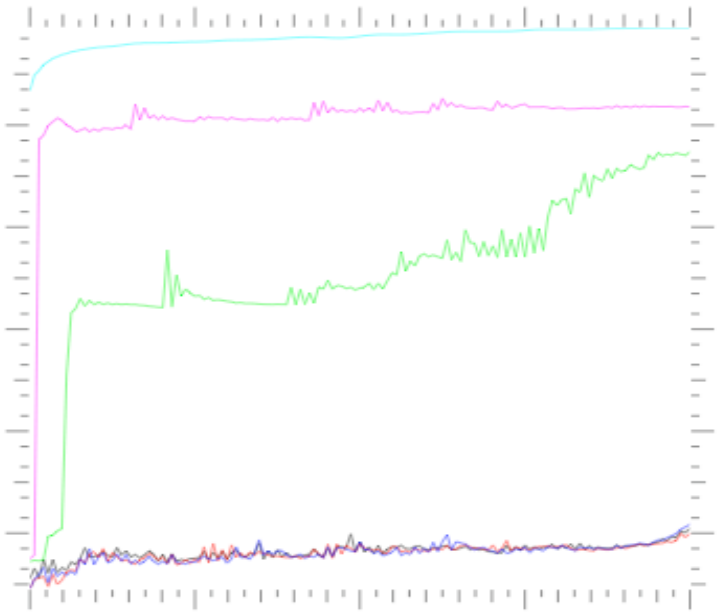
CAM PERGRO Example



Days

perturbation (ibm–P4)
difference: ibm – sgi–O3800
difference: ibm – x86(lf95)
difference: ibm – x86(pg–513 –O1)
difference: ibm – amd64(pg64–524 –O1)
difference: ibm – amd64(pg64–524 –O0)

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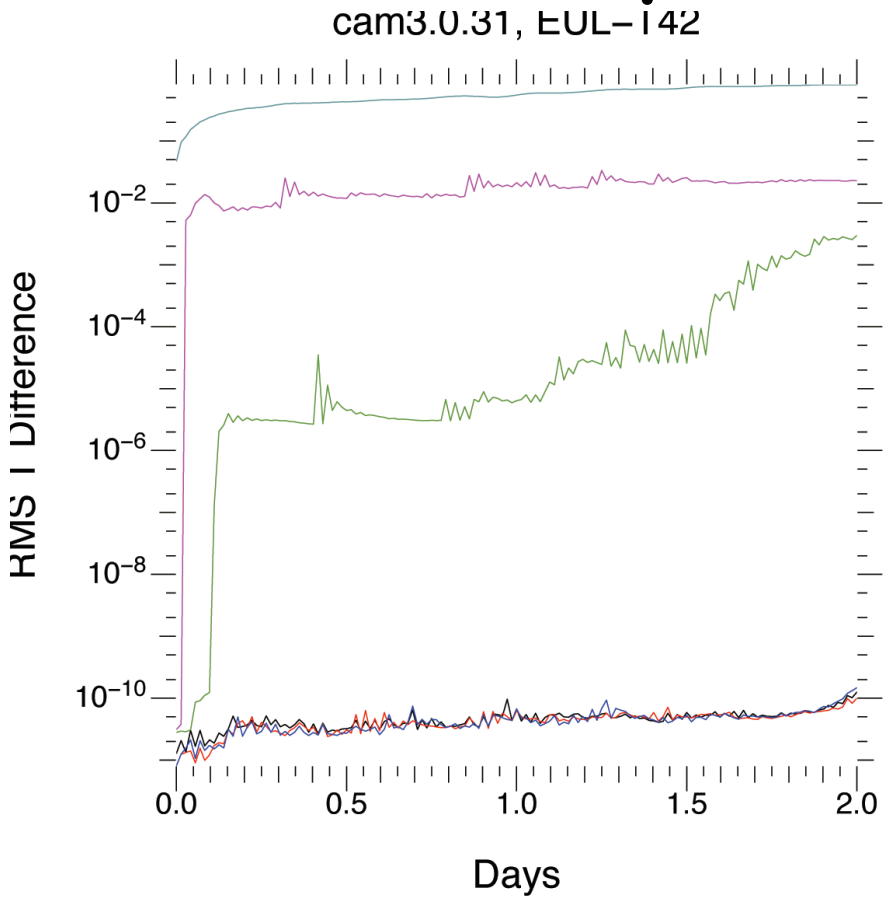
CAM PERGRO Example



perturbation (ibm–P4)
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difference: ibm – x86(pg–513 –O1)
difference: ibm – amd64(pg64–524 –O1)
difference: ibm – amd64(pg64–524 –O0)

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Atmospheric Diagnostic Tests

- Compare 5-100 years of test configuration to 100 years of accepted baseline
- Computes monthly averages for test and baseline
- Monthly averages used to generate large number of plots and graphs
- Find Oracle to perform evaluation

- See http://www.ccsm.ucar.edu/models/atm-cam/port/

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CCSM Statistial Test

- Requires 100 years of baseline
- Requires 100 years of test configuration
- Set of rigorous statistical analysis of the two data sets

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Two Kinds of "Load Balancing"

- CCSM load balancing: assigning right number of processors for each component
- Classic load balancing: moving processing around to even out execution times

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The CCSM MPMD Balancing Act

- Each component has different scaling attributes in part based on different grid sizes
- System architecture/configuration constraints

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Load Balancing Example - X1

T31x3	OCN	ATM	ICE	LND	CPL	Tot	Yrs/Day
Case 1	4	16	8	8	4	40	20.76
Case 2	2	16	2	8	8	36	22.12

Case 2 used fewer processors and got better performance

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Current X1 Validation Activities

- Move to PE5302 and minimal change set (nomodinline) and addition of fp1 - validated
- Add CAM physics load balance option changes - ok
- Better CAM vector length ("pcols") - ok
- Better CLM vector length ("clump" or CSD) - must choose
- CLM use of vector3, scalar3, stream3 appears ok
- CAM limited use of vector3, scalar3, stream3 might be ok, may not be ok for CAM as a whole
- Change to ice_transport_remap postponed

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Performance Metrics

- Simulated years per wall clock day
  - Optimize for single job maximum performance (capability oriented)
- Simulated years per wall clock day per "cpu"
  - Optimize for system aggregate performance (capacity oriented)

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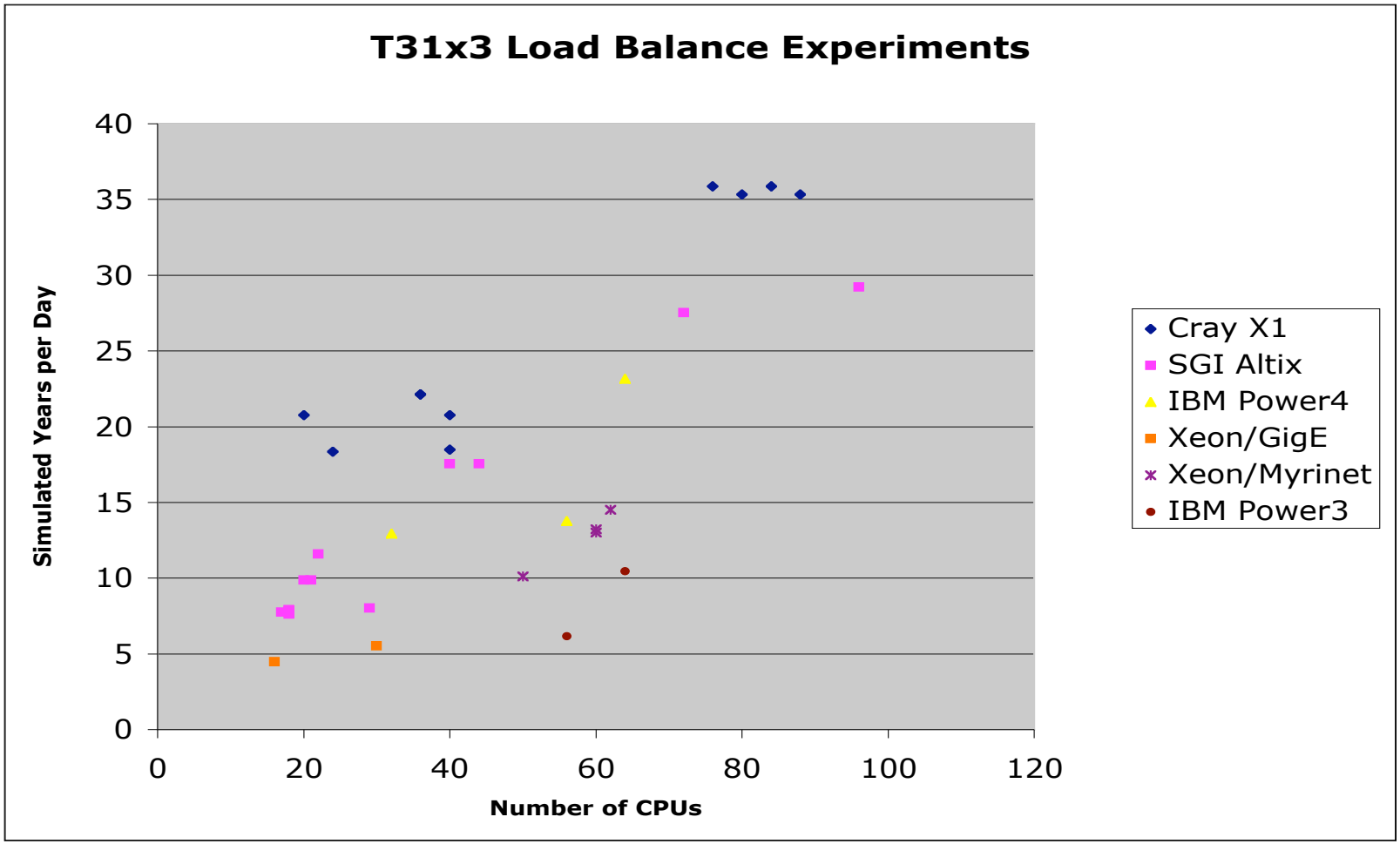
T31 Performance



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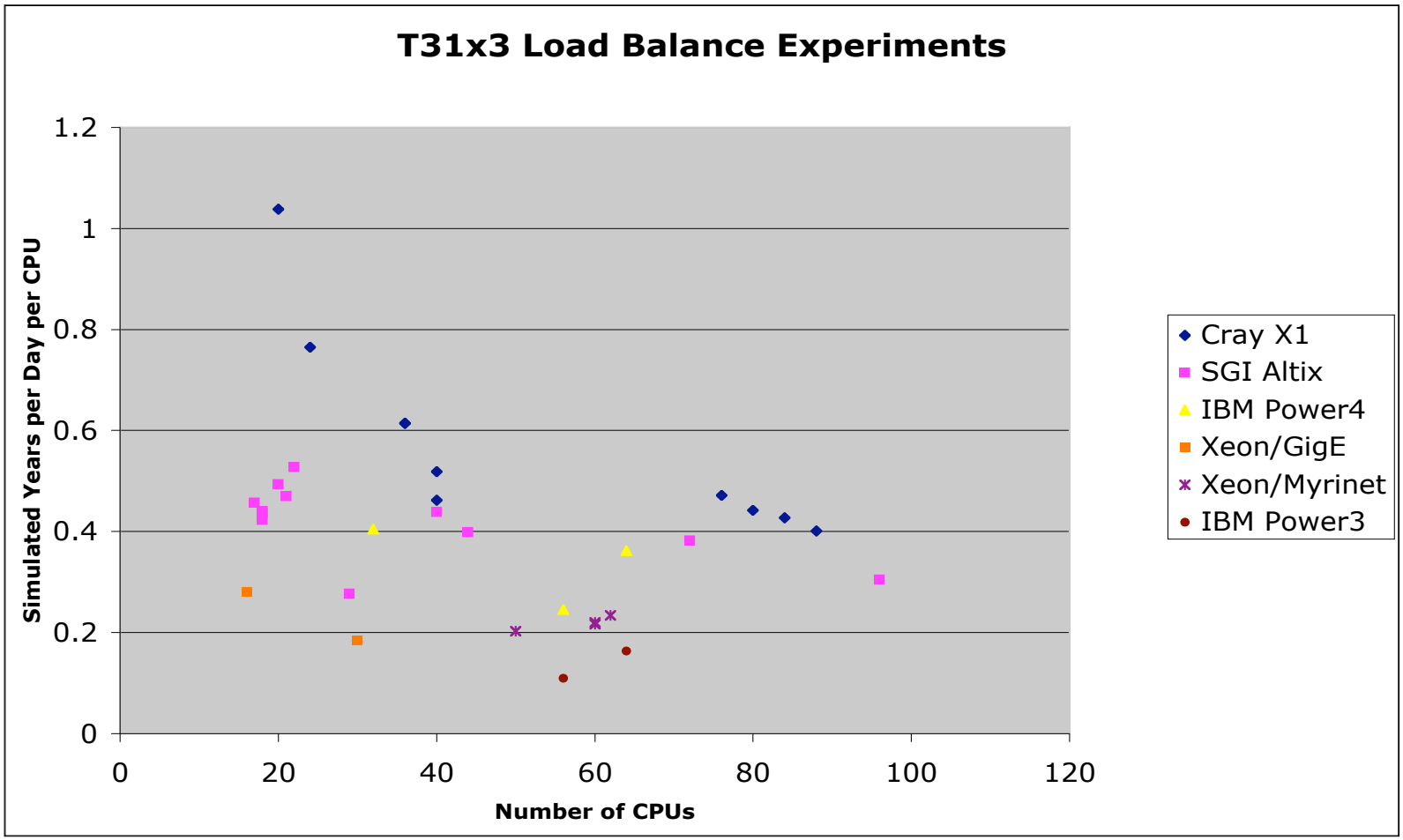
T31 Efficiency



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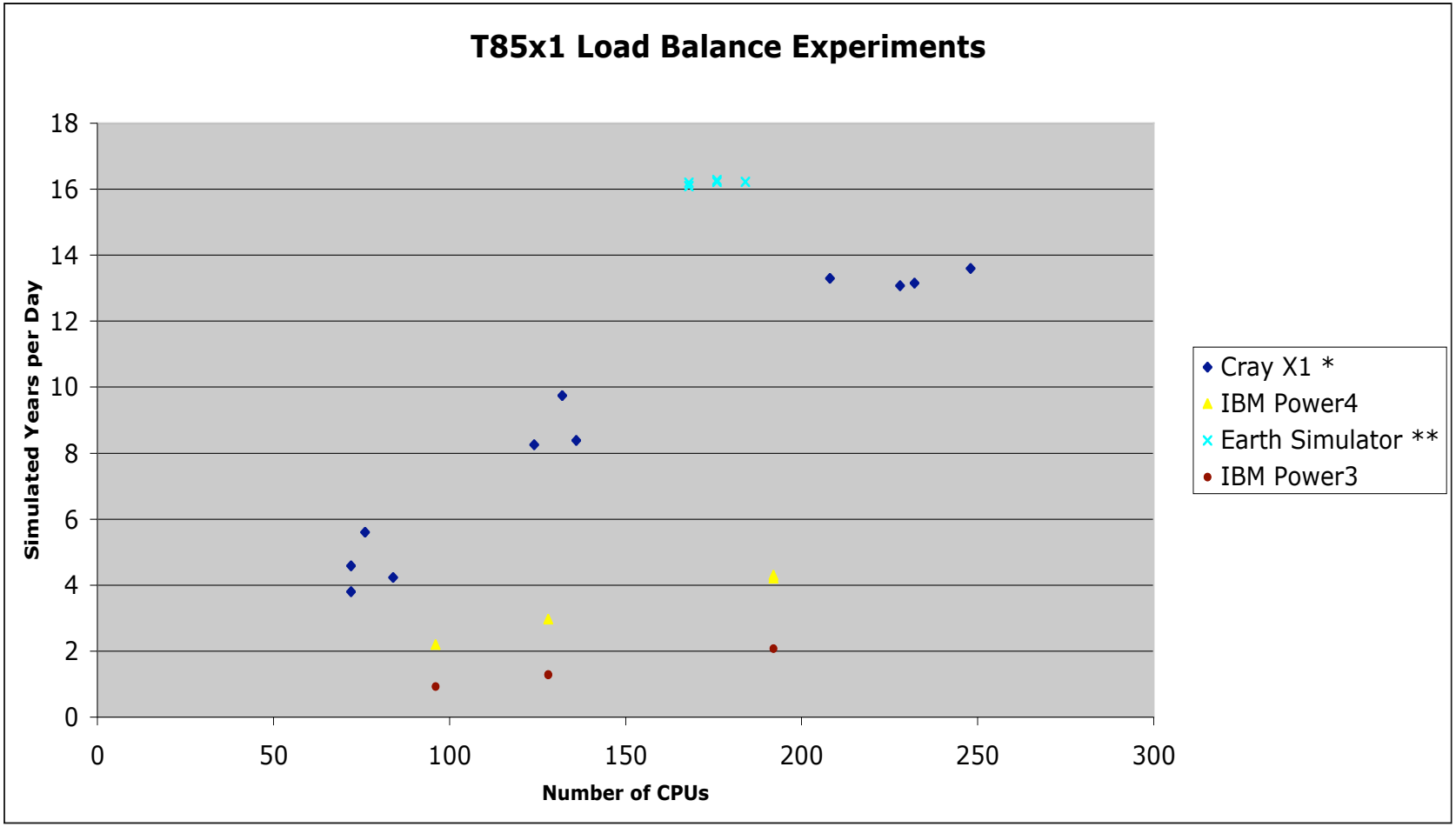
T85 Performance



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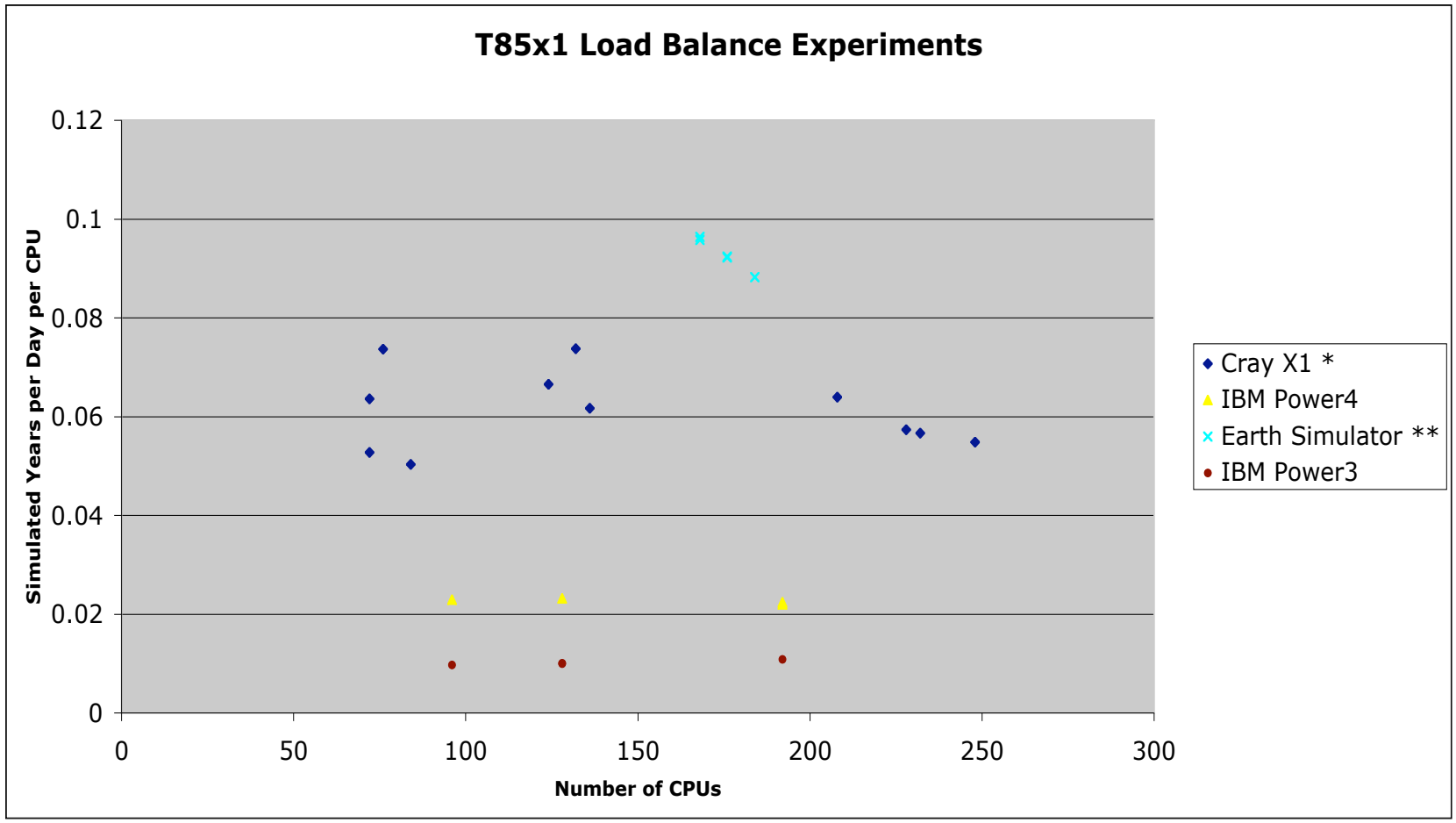
T85 Efficiency



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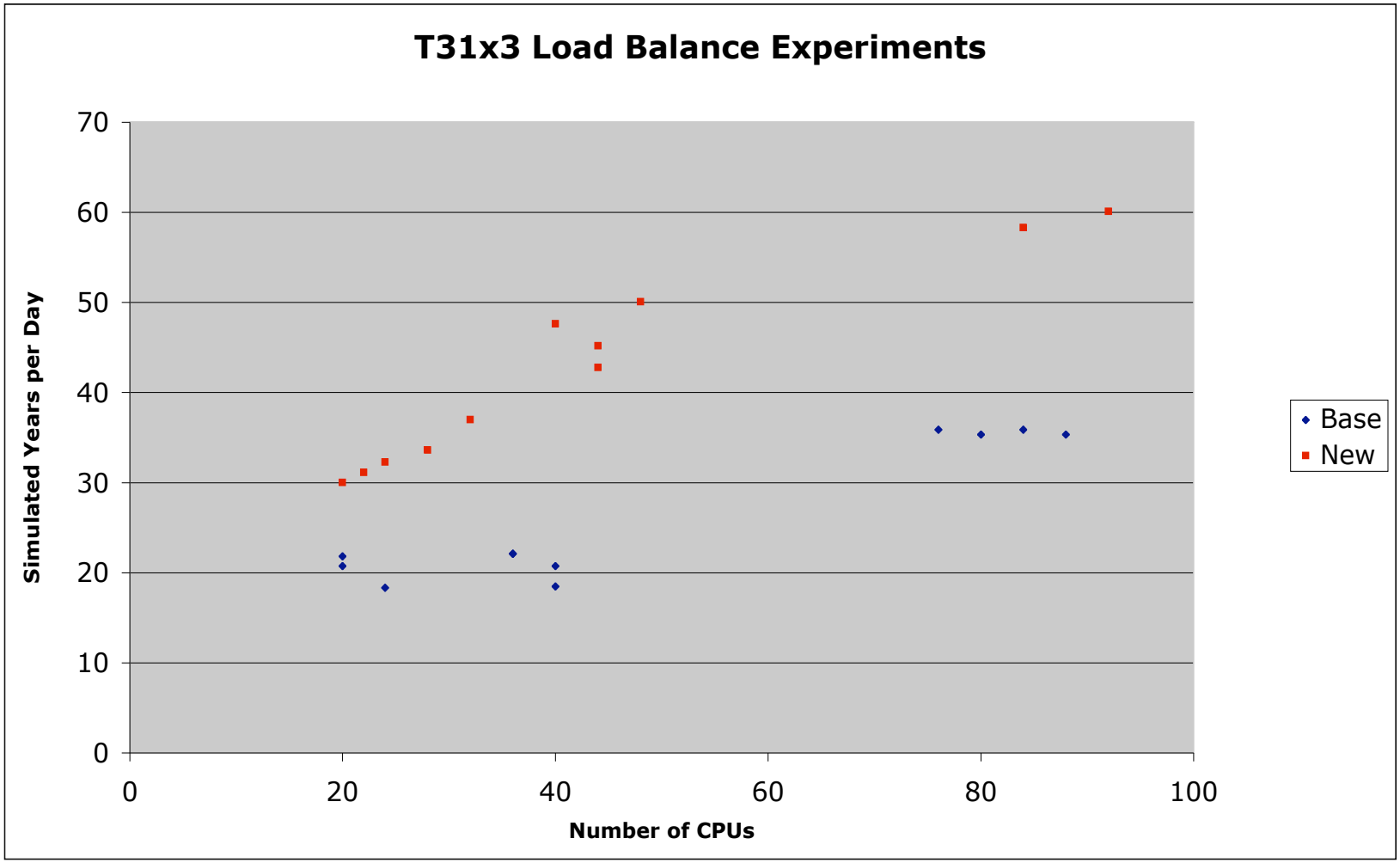
Anticipated T31x3 Improvement



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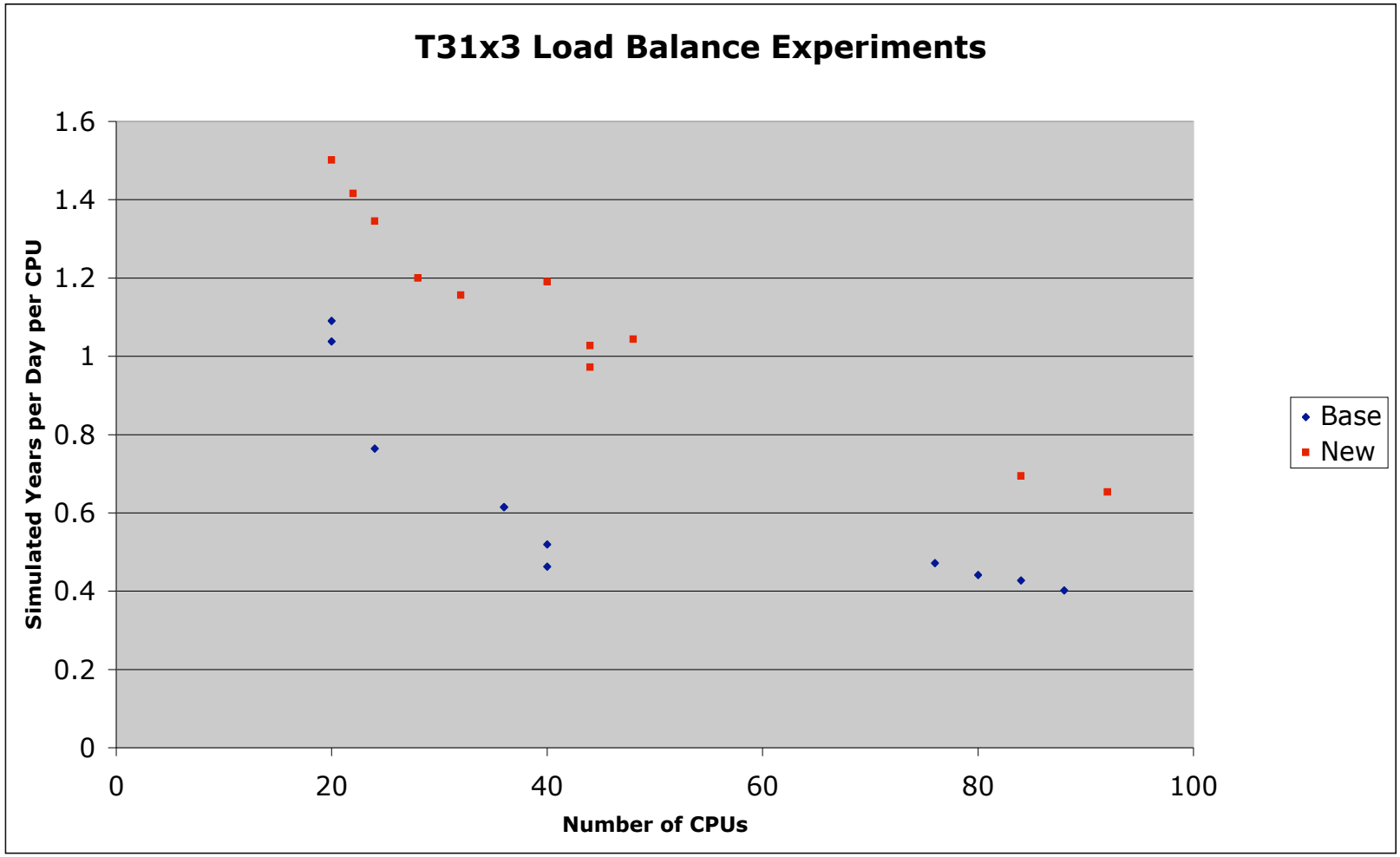
Anticipated T31x3 Efficiency



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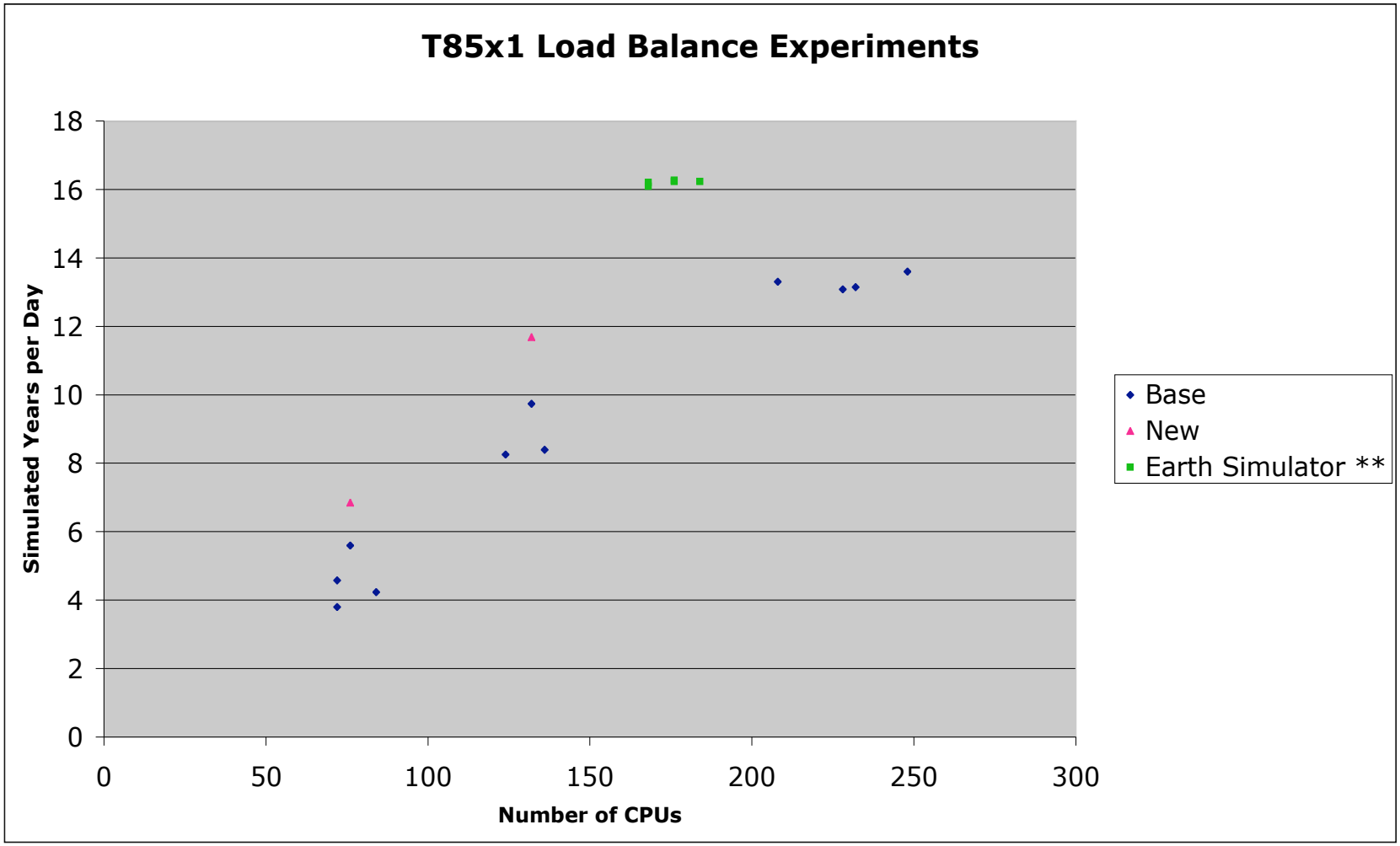
Anticipated T85x1 Improvement



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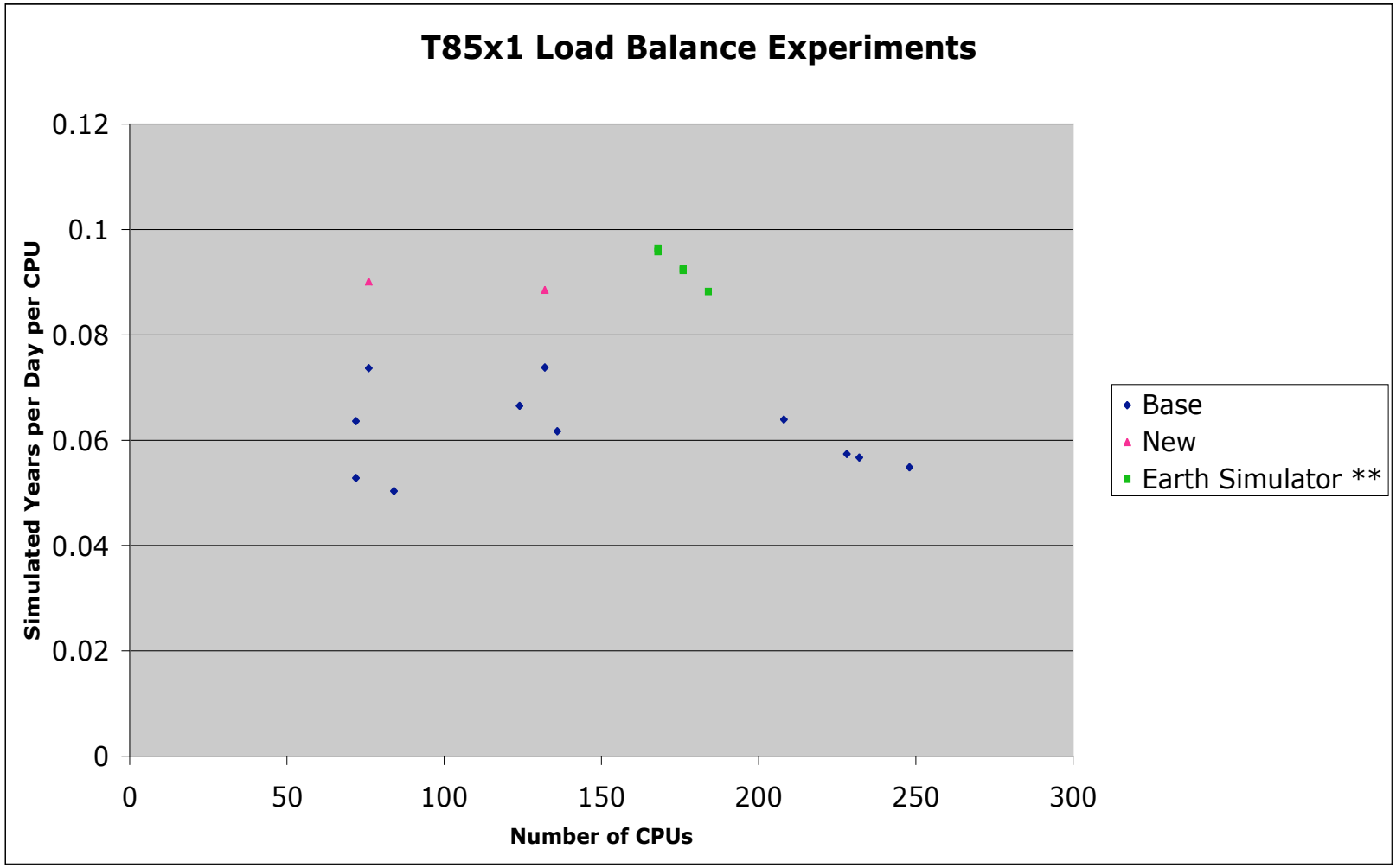
Anticipated T85x1 Efficiency



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Opteron Status

- NCAR has own Opteron/Myrinet cluster
- Work on XD1 and XT3 also begun
- Possible issues:
  - MPMD launch
  - Compiler questions
- None validated

Opteron Compiler Status

- PGI status (long term user)
  - Xeon clusters validated with 5.1-3 and 5.1-6 and -O1 (past -O2 issue)
  - Versions 5.2 and 6.0-2 fail PERGRO with -O1 and -O0
  - Bug identified. Bug fix released (6.0-4). Vendor testing with -fastsse (-O2++) shows promise.
- Pathscale status (very recent user)
  - Using latest 2.x version
  - Able to use -O2 to pass PERGRO and partial diagnostics
  - Identified byteswap bug impacts ability to complete validation and (if successful) support production

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Plans

- X1
  - Complete current validation
  - T85x1 validation leading to large number of production runs
  - Look at coupler performance
  - The next Programming Environments
  - Need to generalize vector length controls in scripts
- NCAR Opteron cluster
  - Test new PGI compiler
  - Begin first full validation attempt
- T1E/XT3/XD1 (all very important platforms)
  - Continue to work the validation process
- Improved timers (PAPI), CCSM performance characterization (Tau), performance regression testing
- CCSM entering time of massive changes: New Science
  - Change from Eulerian spectral dynamical core to Finite Volume
  - Bio-Geo-Chem changes
  - Increasing resolutions and time steps (T170, .1°, and more)

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Summary

- Significant speedup from initial baseline
- Entering significant X1 usage phase
  - CCSM3 official release use by community
  - New science development and experiments

- **Thanks** Cray and ORNL for great support!

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(that's a big thanks)

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For Further Information

- CCSM web pages
  - http://www.ccsm.ucar.edu/ccsm3
  - http://www.ccsm.ucar.edu/support_model
    - See CCSM User's Guide
    - See Scripts Tutorial
  - http://www.ccsm.ucar.edu/support_model/mach_support.html
- CCSM Bulletin Board
  - http://bb.cgd.ucar.edu
- ORNL X1 evaluation web pages
  - http://www.csm.ornl.gov/evaluation/PHOENIX
- gcarr@ucar.edu

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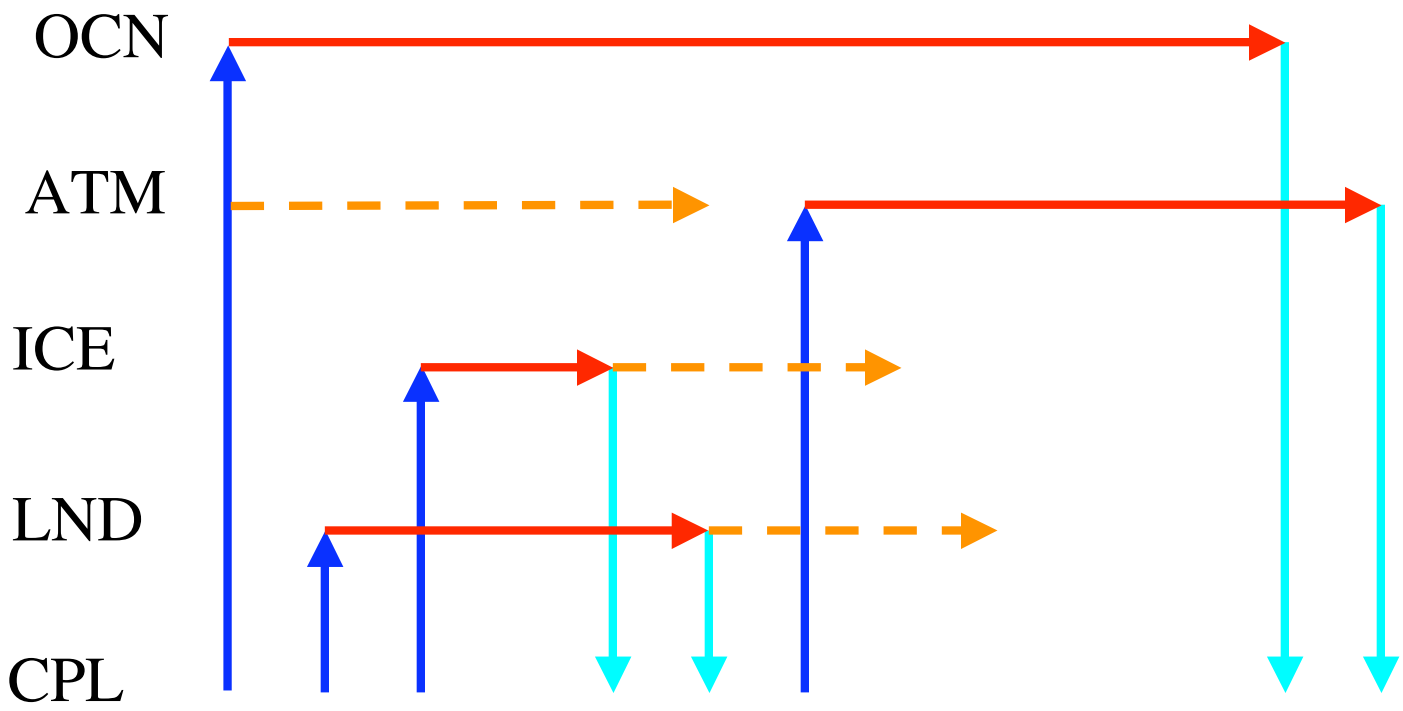
Supplemental Charts

CCSM3 Process Flow



CPL sending data to component (state 1)

CPL receiving data from component (state 3)

Component processing data (state 2)

Component processing (state 4)