Scientific Computing at SLAC

Richard P. Mount

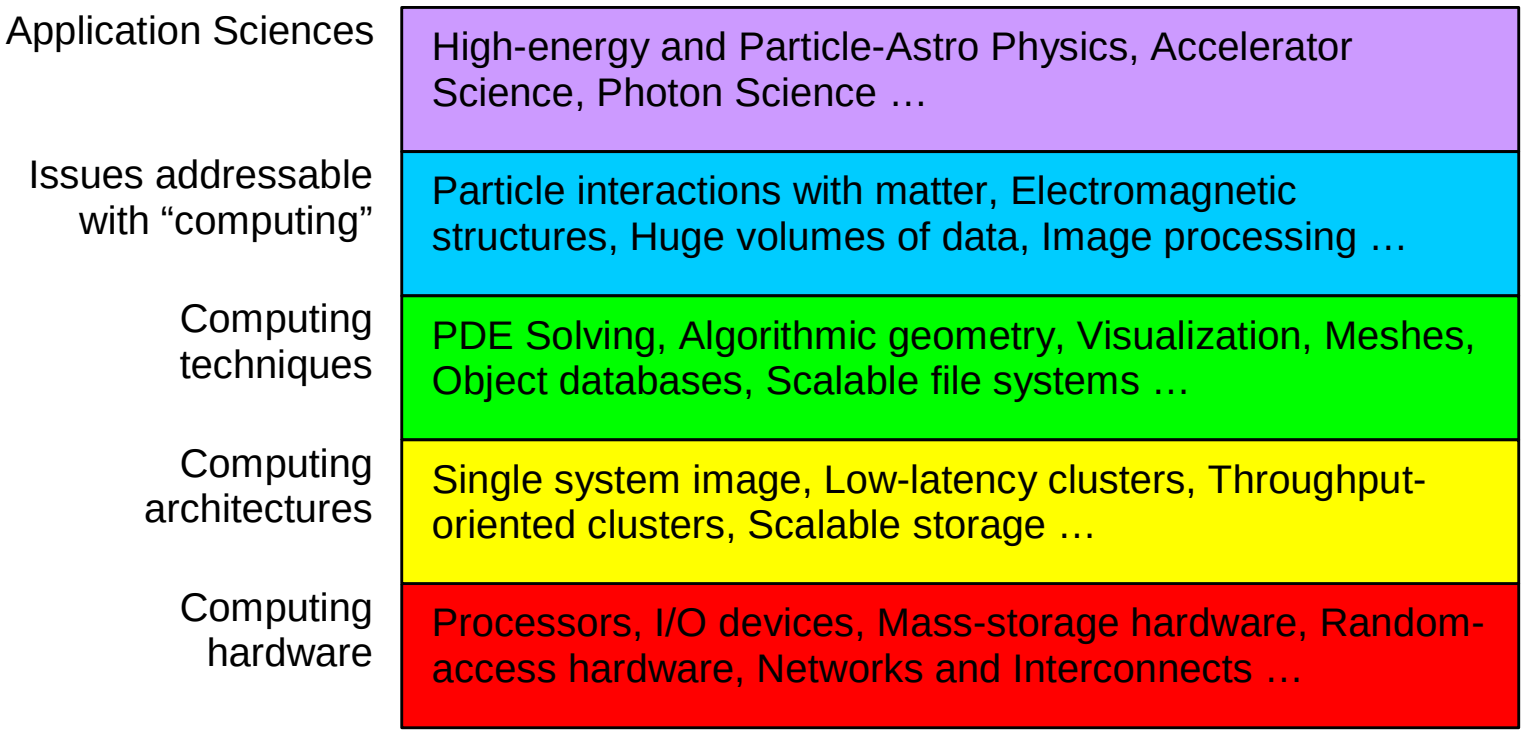
Director: Scientific Computing and Computing Services

DOE Review

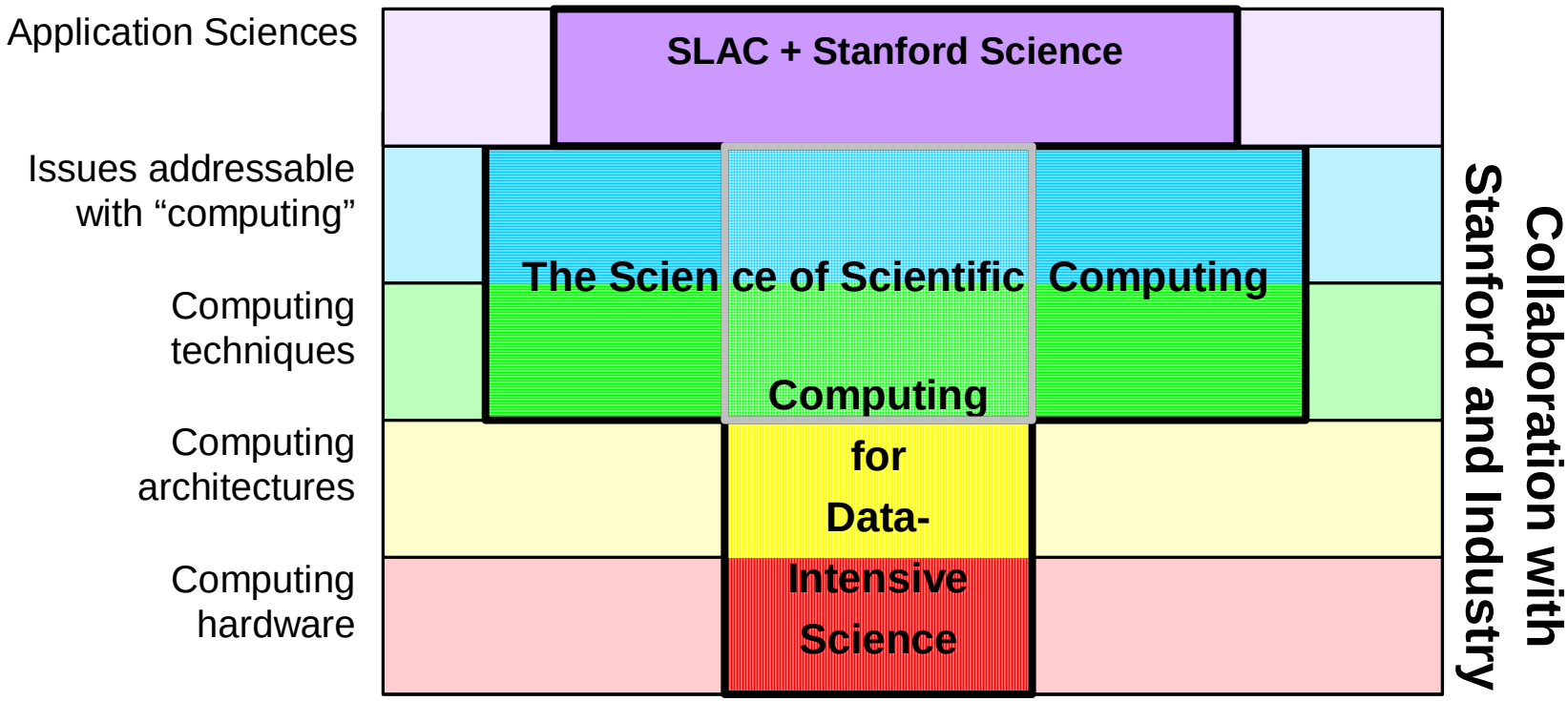
June 15, 2005

Scientific Computing

The relationship between Science and the components of Scientific Computing

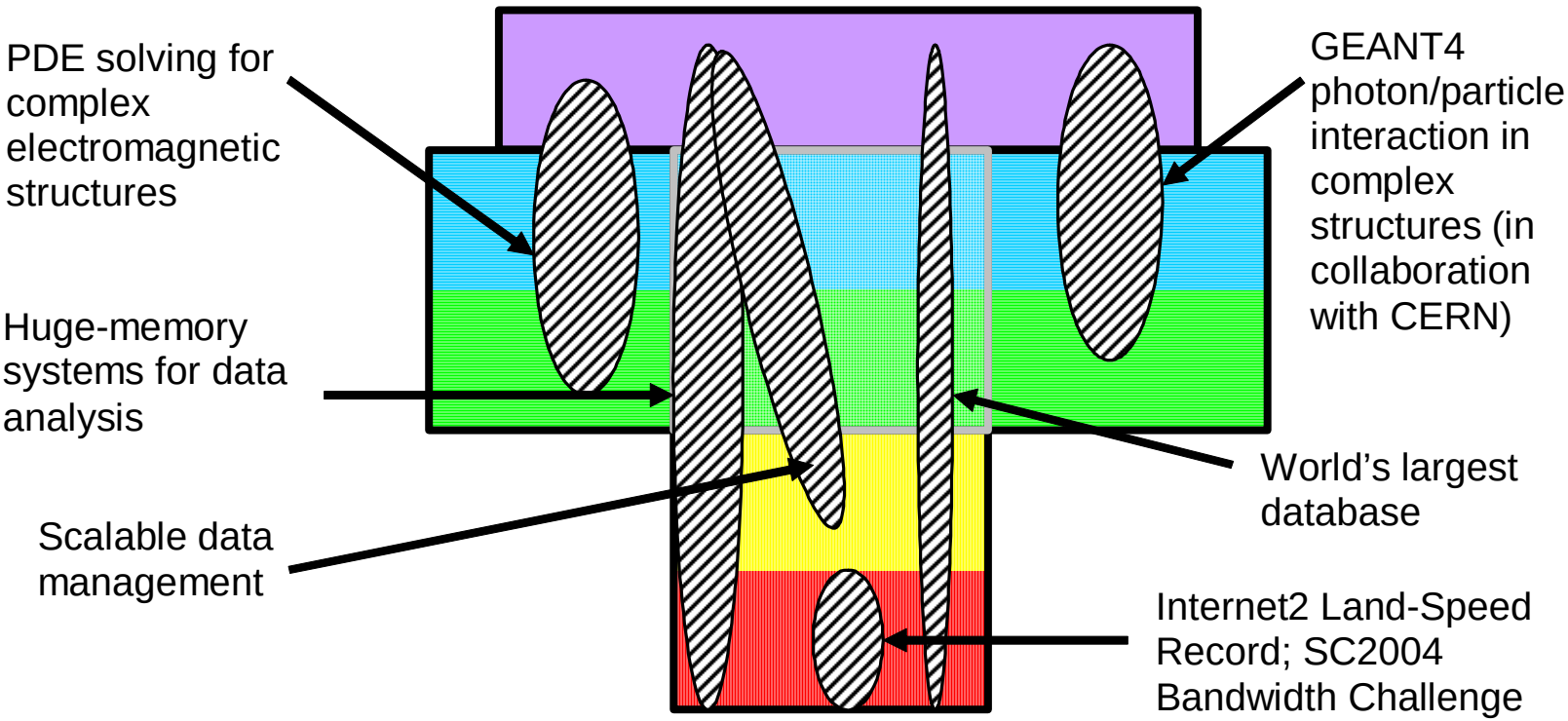


Scientific Computing:
SLAC's goals for leadership in Scientific Computing



Scientific Computing:

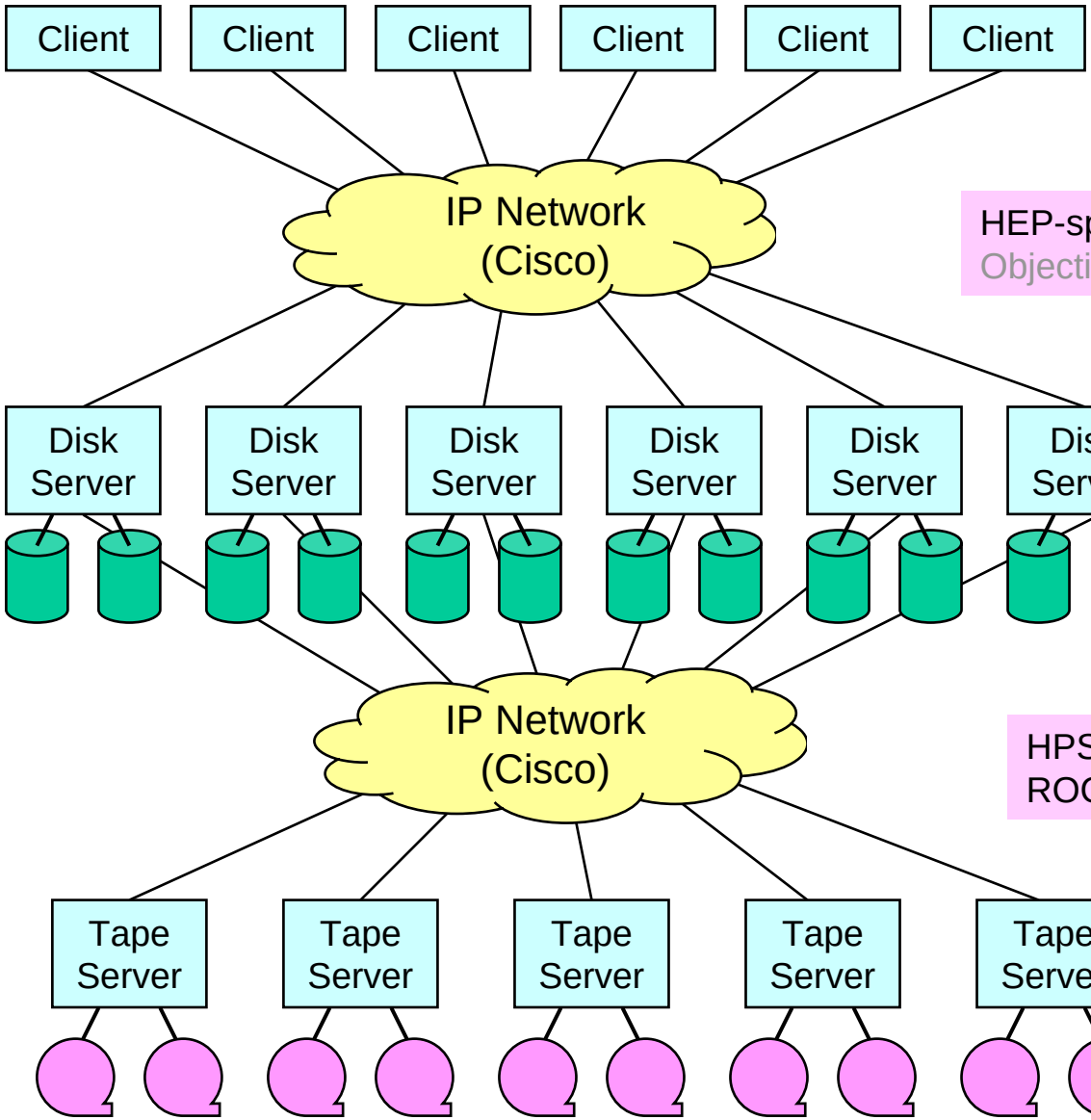
Current SLAC leadership and recent achievements in Scientific Computing



SLAC Scientific Computing Drivers

- BaBar (data-taking ends December 2008)
  - The world's most data-driven experiment
  - Data analysis challenges until the end of the decade
- KIPAC
  - From cosmological modeling to petabyte data analysis
- Photon Science at SSRL and LCLS
  - Ultrafast Science, modeling and data analysis
- Accelerator Science
  - Modeling electromagnetic structures (PDE solvers in a demanding application)
- The Broader US HEP Program (aka LHC)
  - Contributes to the orientation of SLAC Scientific Computing R&D

SLAC-BaBar Computing Fabric



1700 dual CPU Linux
400 single CPU
Sun/Solaris

HEP-specific ROOT software (Xrootd) + Objectivity/DB object database

120 dual/quad CPU
Sun/Solaris
~400 TB Sun
FibreChannel RAID
arrays

HPSS + SLAC enhancements to ROOT and Objectivity server code

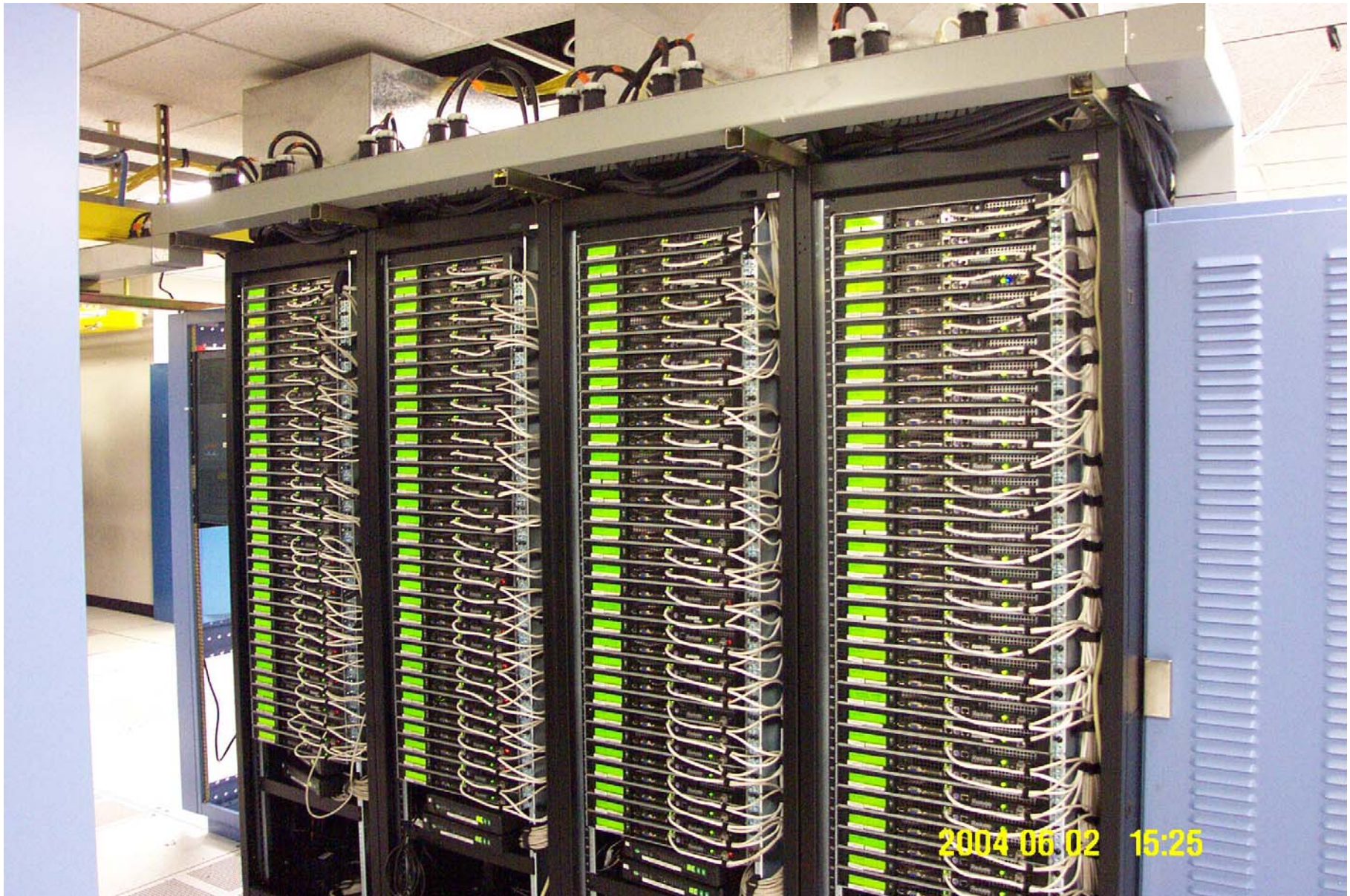
25 dual CPU
Sun/Solaris
40 STK 9940B
6 STK 9840A
6 STK Powderhorn
over 1 PB of data

BaBar Computing at SLAC

- Farm Processors (5 generations, 3700 CPUs)
- Servers (the majority of the complexity)
- Disk storage (2+ generations, 400+ TB)
- Tape storage (40 Drives)
- Network “backplane” (~26 large switches)
- External network

Rackable Intel P4 Farm (bought in 2003/4)

384 machines, 2 per rack unit, dual 2.6 GHz CPU



Disks and Servers

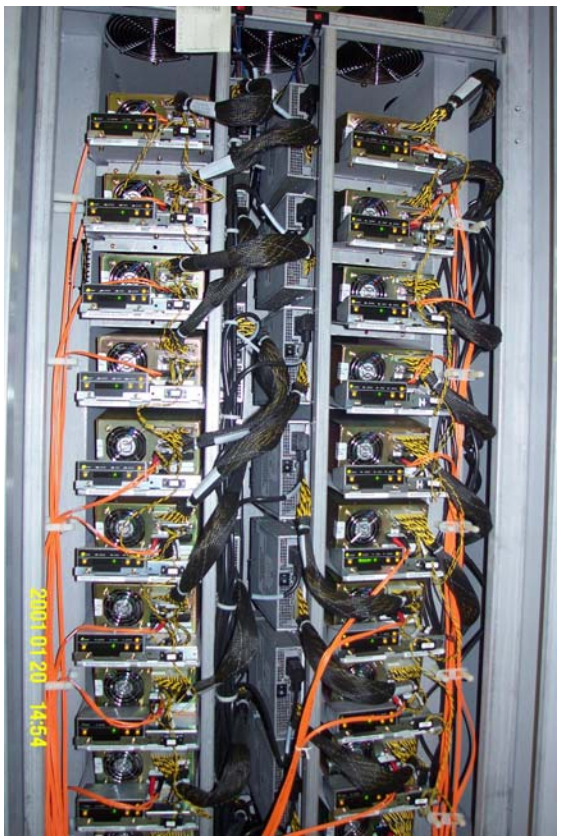
1.6 TB usable per tray, ~160 trays bought 2003/4

Tape Drives

40 STK 9940B (200 GB) Drives

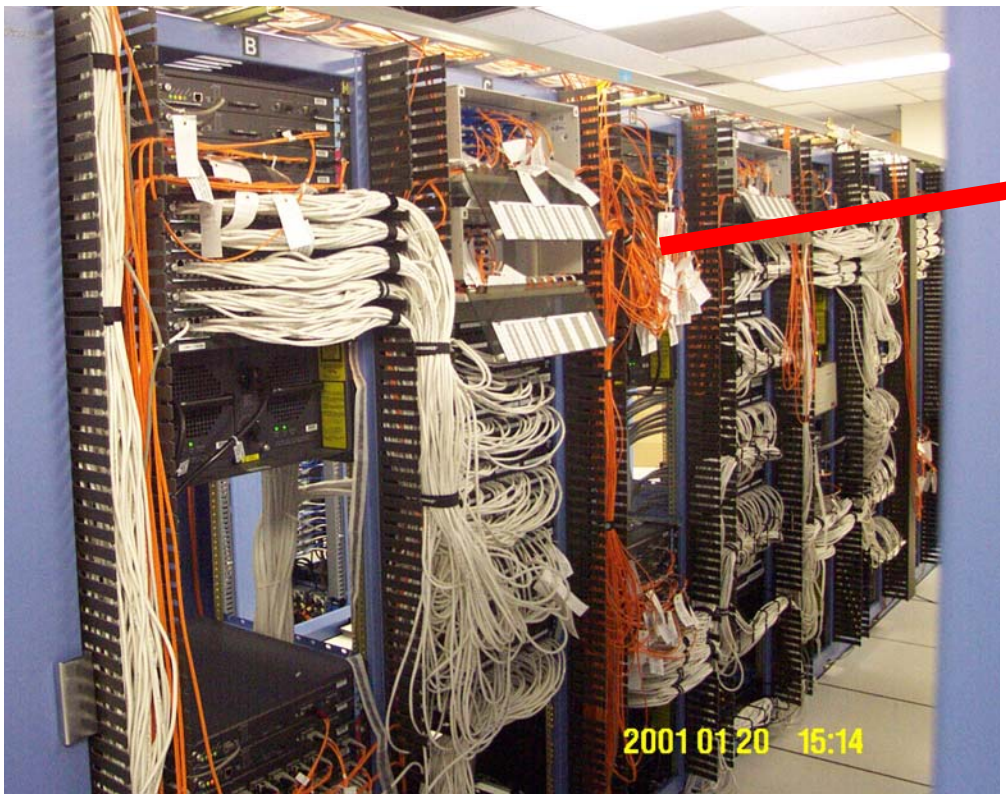
6 STK 9840 (20 GB) Drives

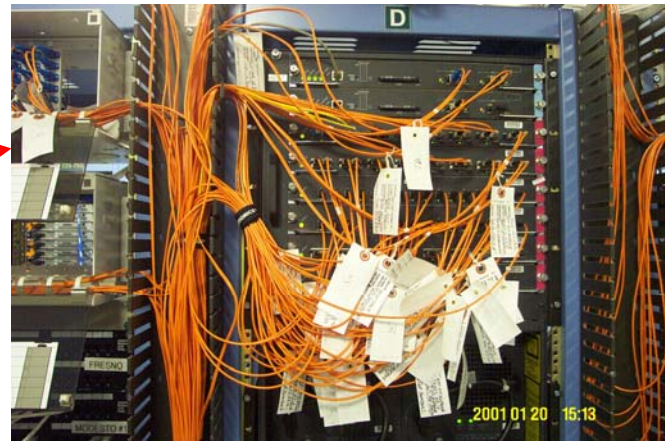
6 STK Silos (capacity 30,000 tapes)



BaBar Farm-Server Network

~26 Cisco 65xx Switches





Farm/Server Network

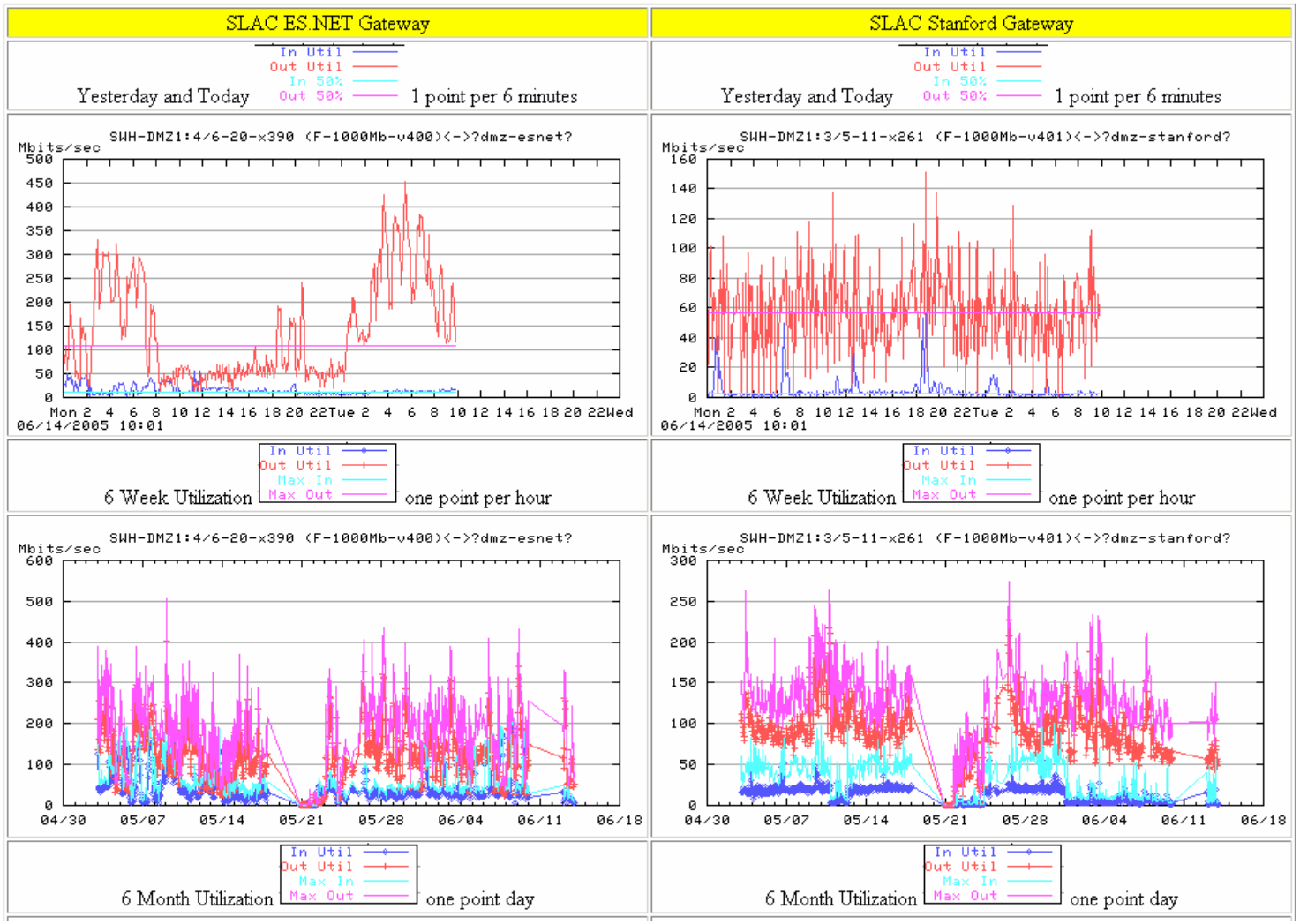
SLAC External Network (June 14, 2005)

622 Mbits/ to ESNet

1000 Mbits/s to Internet 2

~300 Mbits/s average traffic

Two 10 Gbits/s wavelengths to ESNET, UltraScience Net/NLR coming in July



Research Areas (1)

(Funded by DOE-HEP and DOE SciDAC and DOE-MICS)

- Huge-memory systems for data analysis
  (SCCS Systems group and BaBar)
  - Expected major growth area (more later)

- Scalable Data-Intensive Systems:
  (SCCS Systems and Physics Experiment Support groups)
  - "The world's largest database" (OK not really a database any more)
  - How to maintain performance with data volumes growing like "Moore's Law"?
  - How to improve performance by factors of 10, 100, 1000, … ?
    (intelligence plus brute force)
  - Robustness, load balancing, troubleshootability in 1000 – 10000-box systems
  - Astronomical data analysis on a petabyte scale (in collaboration with KIPAC)

Research Areas (2)

(Funded by DOE-HEP and DOE SciDAC and DOE MICS)

- Grids and Security:
  (SCCS Physics Experiment Support. Systems and Security groups)
  - **PPDG**: Building the US HEP Grid – OSG;
  - Security in an open scientific environment;
  - Accounting, monitoring, troubleshooting and robustness.

- Network Research and Stunts:
  (SCCS Network group – Les Cottrell et al.)
  - Land-speed record and other trophies

- Internet Monitoring and Prediction:
  (SCCS Network group)
  - **IEPM:** Internet End-to-End Performance Monitoring (~5 years)
    SLAC is the/a top user of ESNet and the/a top user of Internet2. (Fermilab doesn't do so badly either)
  - **INCITE**: Edge-based Traffic Processing and Service Inference for High-Performance Networks

Research Areas (3)

(Funded by DOE-HEP and DOE SciDAC and DOE MICS)

- GEANT4: Simulation of particle interactions in million to billion-element geometries:
  (SCCS Physics Experiment Support Group – M. Asai, D. Wright, T. Koi, J. Perl …)
  - BaBar, GLAST, LCD …
  - LHC program
  - Space
  - Medical

- PDE Solving
  for complex electromagnetic structures:
  (Kwok 's advanced Computing Department + SCCS clusters)

Growing Competences

- Parallel Computing (MPI …)
  - Driven by KIPAC (Tom Abel) and ACD (Kwok Ko)
  - SCCS competence in parallel computing (= Alf Wachsmann currently)
  - MPI clusters and SGI SSI system
- Visualization
  - Driven by KIPAC and ACD
  - SCCS competence is currently experimental-HEP focused (WIRED, HEPREP …)
  - (A polite way of saying that growth is needed)

A Leadership-Class Facility for Data-Intensive Science

The PetaCache Project

Richard P. Mount

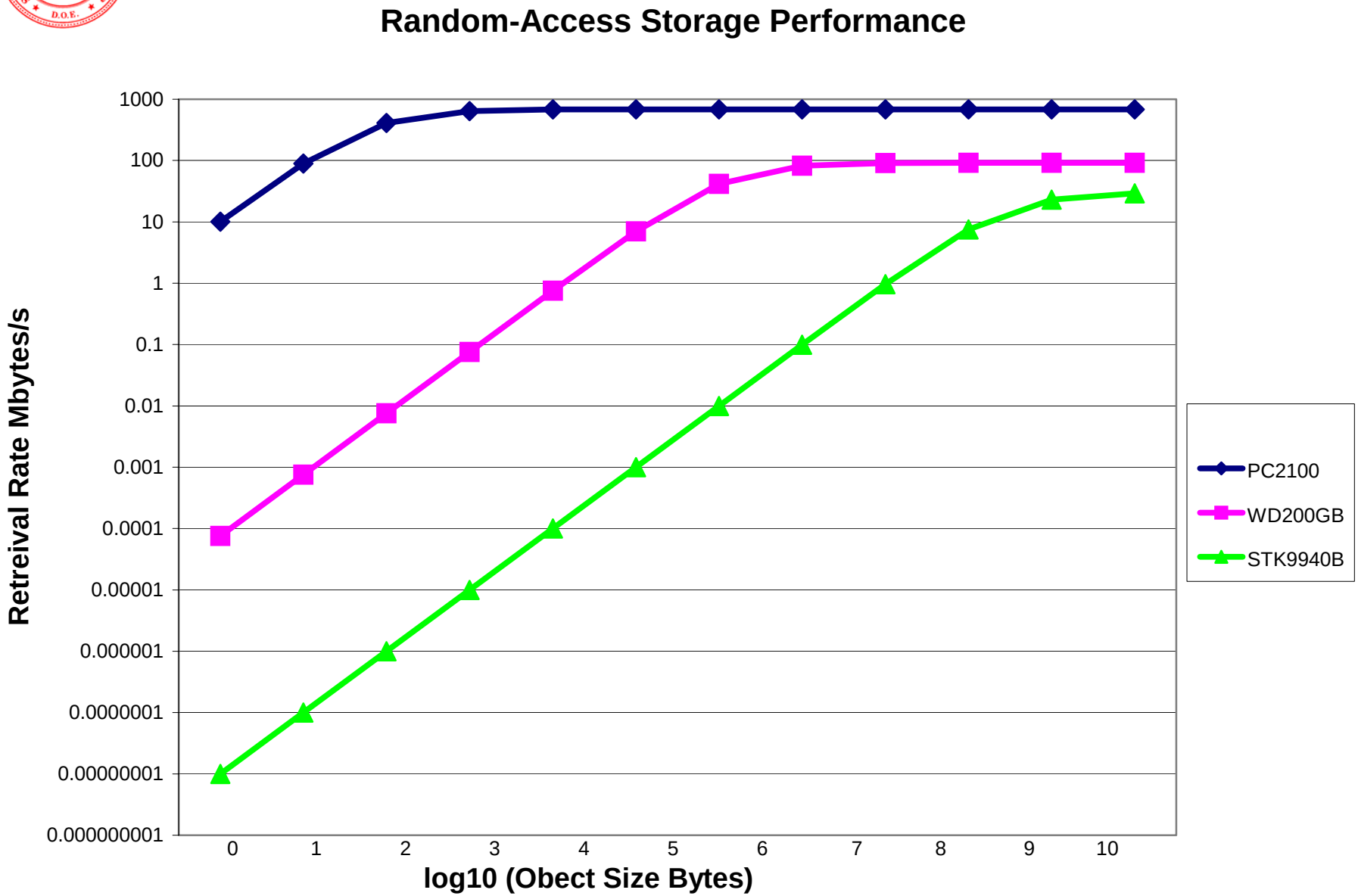
Director, SLAC Computing Services
Assistant Director, SLAC Research Division

Washington DC, April 13, 2004

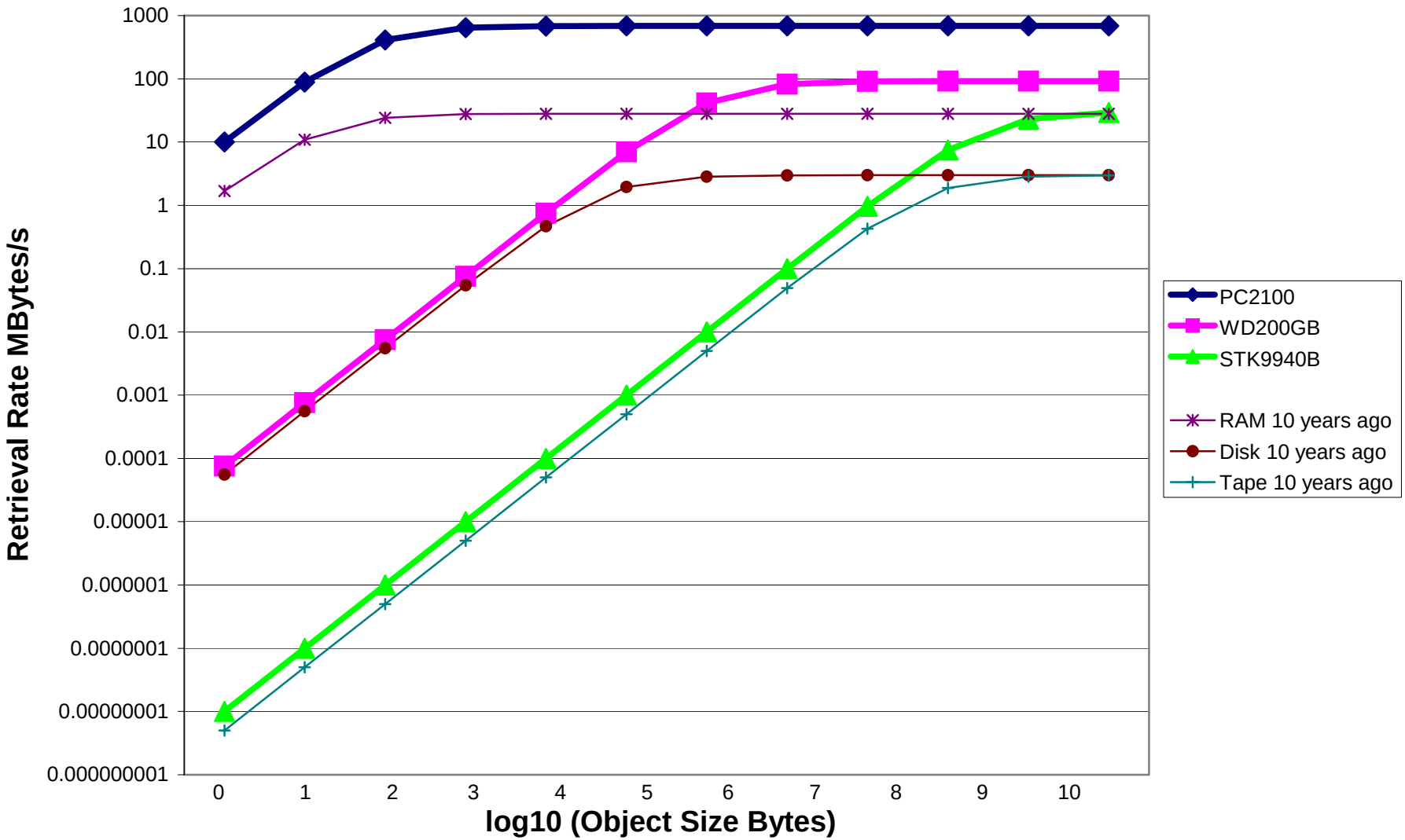
Technology Issues in Data Access

- Latency
- Speed/Bandwidth
- (Cost)
- (Reliabilty)

Latency and Speed – Random Access



Latency and Speed – Random Access



The Strategy

- There is significant commercial interest in an architecture including data-cache memory
- **But**: from interest to delivery will take 3-4 years
- **And**: applications will take time to adapt not just codes, but their whole approach to computing, to exploit the new architecture
- **Hence**: two phases
  1. Development phase (years 1,2,3)
     - Commodity hardware taken to its limits
     - BaBar as principal user, adapting existing data-access software to exploit the configuration
     - BaBar/SLAC contribution to hardware and manpower
     - Publicize results
     - Encourage other users
     - Begin collaboration with industry
  2. Production-Class Facility (year 3 onwards)
     - Optimized architecture
     - Strong industrial collaboration
     - Wide applicability

PetaCache
The Team

- David Leith, Richard Mount, PIs
- Randy Melen, Project Leader
- Bill Weeks, performance testing
- Andy Hanushevsky, xrootd
- Systems group members
- Network group members
- BaBar (Stephen Gowdy)

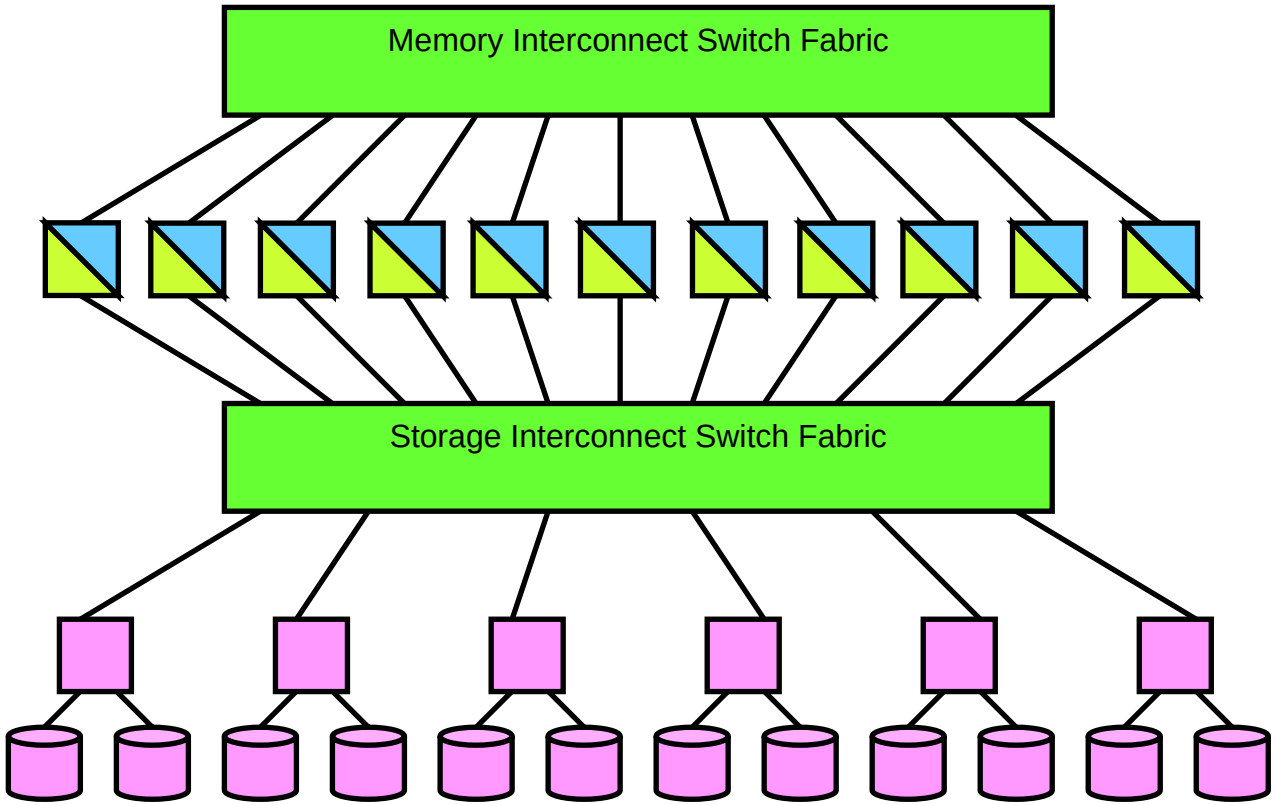
Development Machine Design Principles

- Attractive to scientists
  - Big enough data-cache capacity to promise revolutionary benefits
  - 1000 or more processors
- Processor to (any) data-cache memory latency < 100 μs
- Aggregate bandwidth to data-cache memory > 10 times that to a similar sized disk cache
- Data-cache memory should be 3% to 10% of the working set (approximately 10 to 30 terabytes for BaBar)
- Cost effective, but acceptably reliable
  - Constructed from carefully selected commodity components
- Cost no greater than (cost of commodity DRAM) + 50%

Development Machine Design Choices

- Intel/AMD server mainboards with 4 or more ECC dimm slots per processor
- 2 Gbyte dimms (4 Gbyte too expensive this year)
- 64-bit operating system and processor
  - Favors Solaris and AMD Opteron
- Large (500+ port) switch fabric
  - Large IP switches are most cost-effective
- Use of ($10M+) BaBar disk/tape infrastructure, augmented for any non-BaBar use

Development Machine Deployment – Proposed Year 1



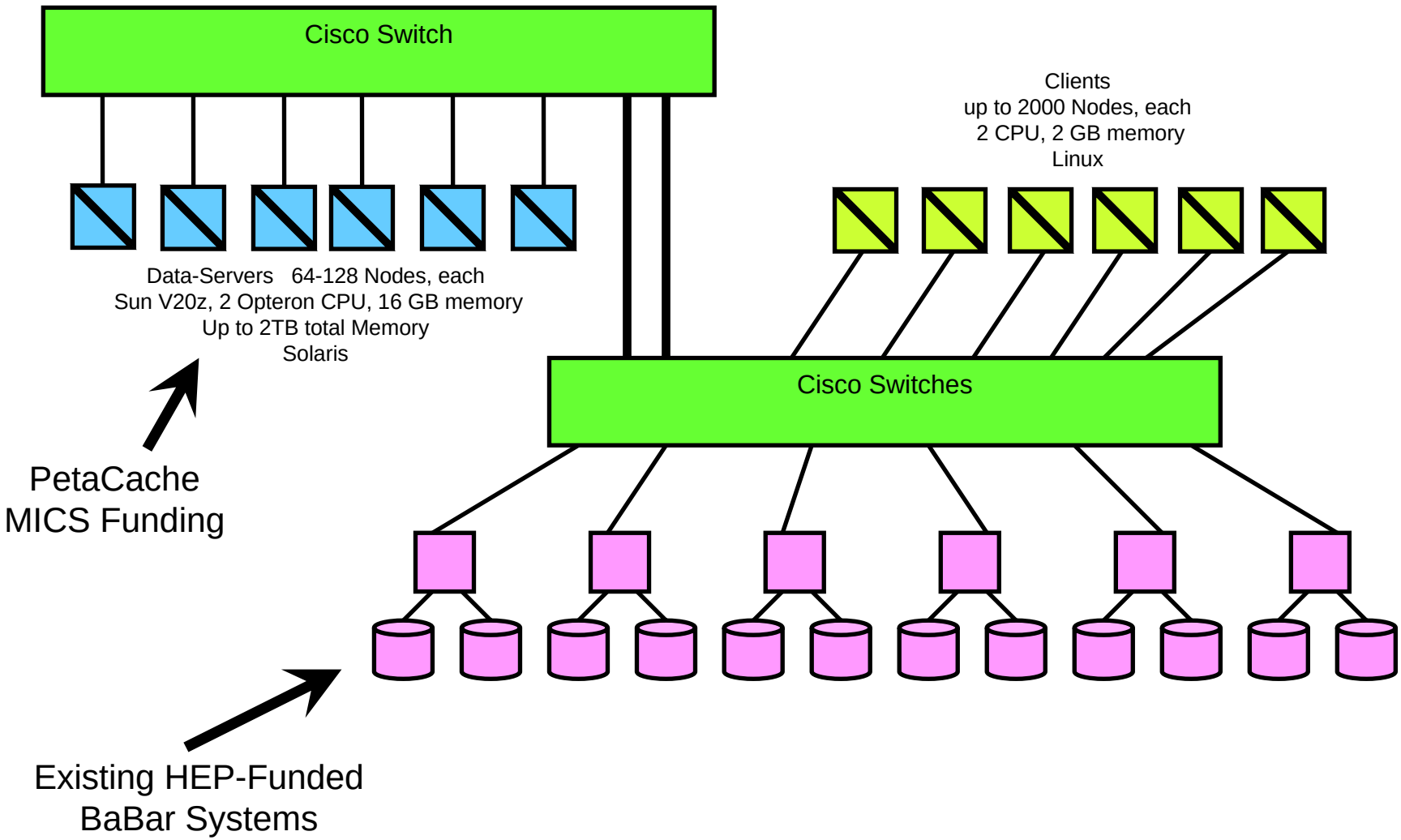
Cisco/Extreme/Foundry

650 Nodes, each
2 CPU, 16 GB memory

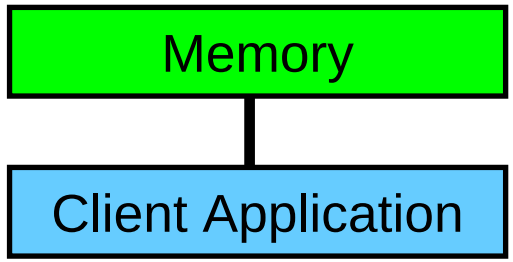
Cisco/Extreme/Foundry

> 100 Disk Servers
Provided by BaBar

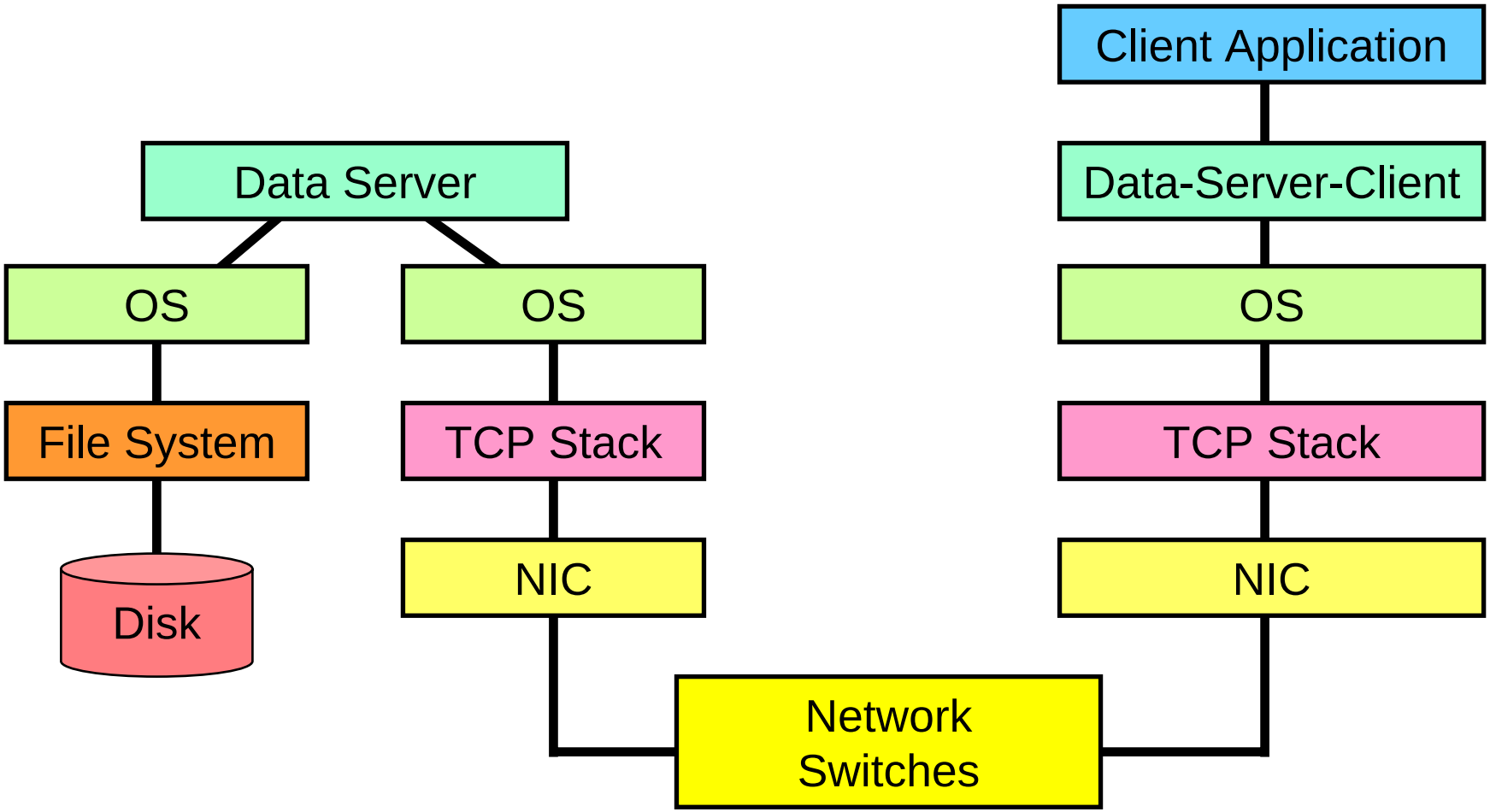
Development Machine Deployment – Currently Funded



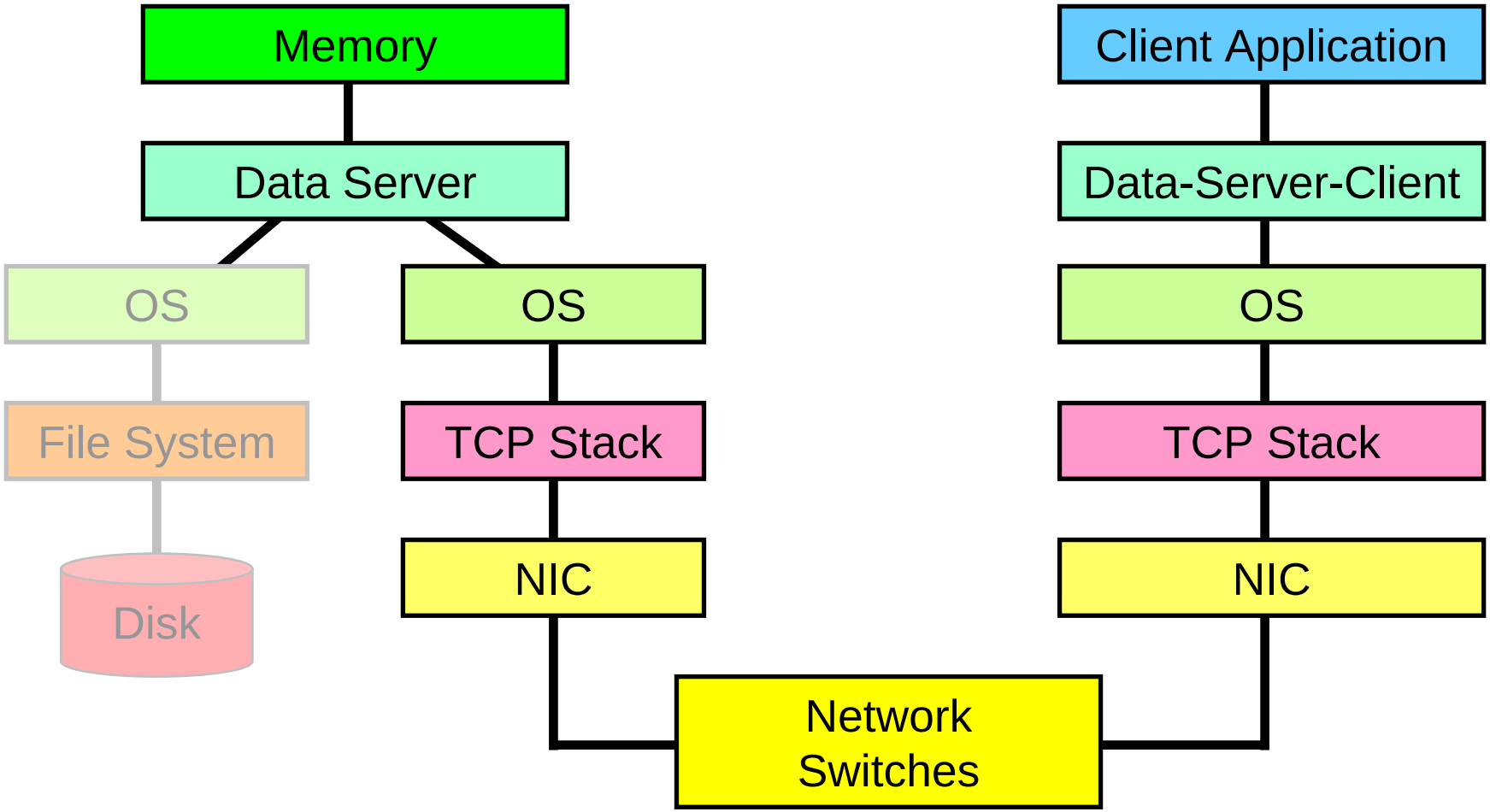
Latency (1)
Ideal



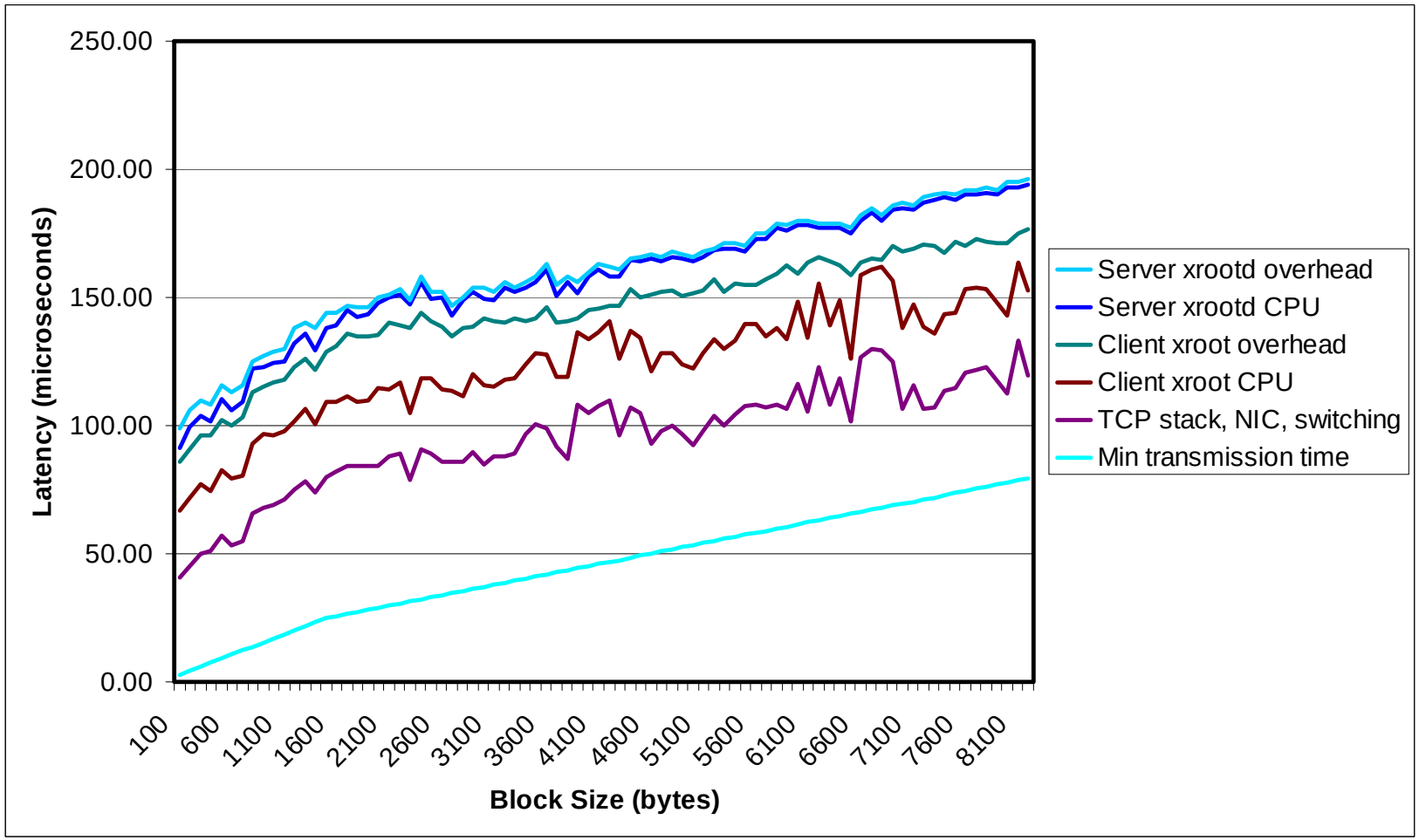
Latency (2)
Current reality



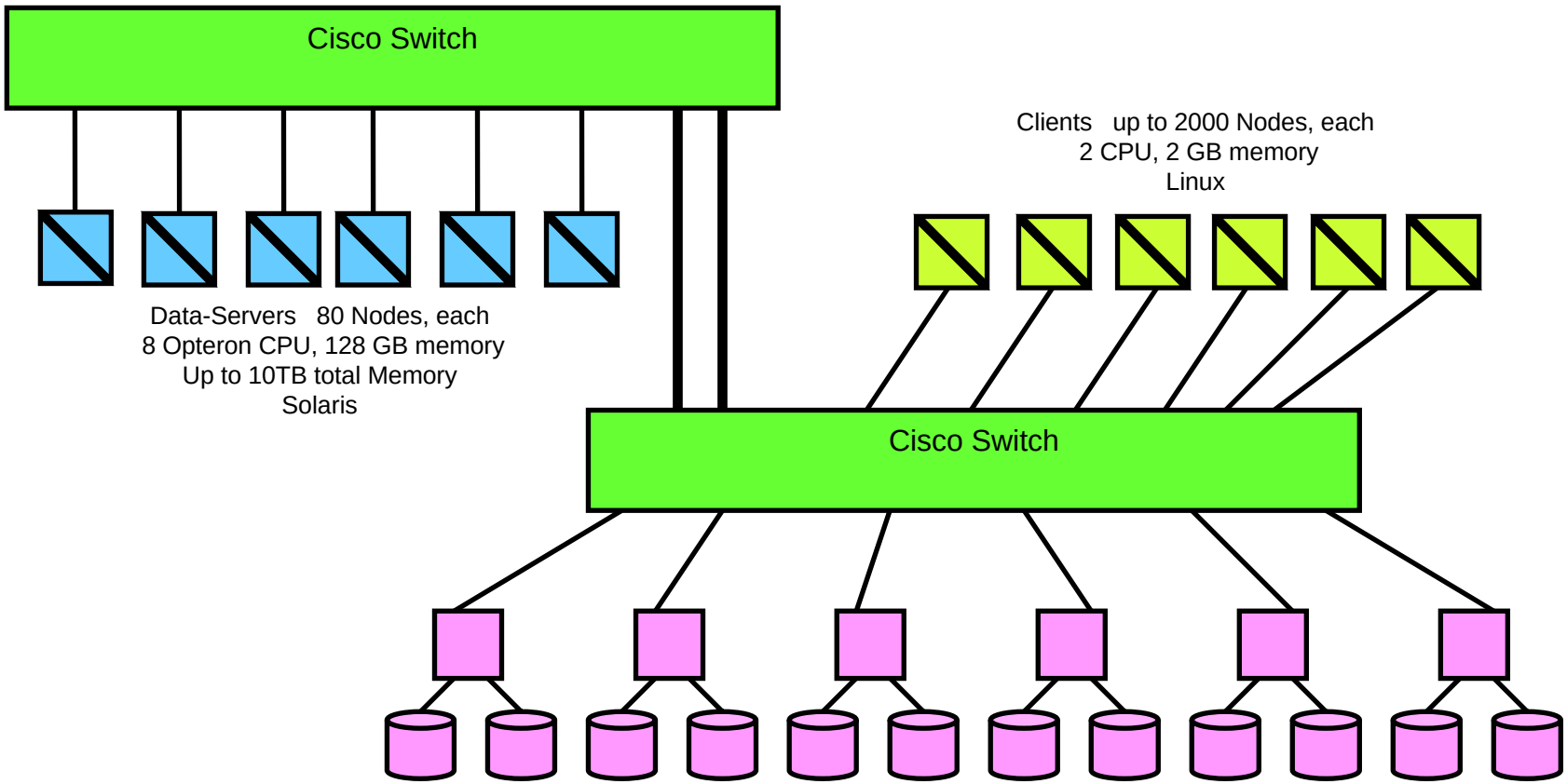
Latency (3)
Immediately Practical Goal



Latency Measurements
(Client and Server on the same switch)



Development Machine Deployment Likely "Low-Risk" Next Step



Development Machine Complementary "Higher Risk" Approach

- Add Flash-Memory based subsystems
  - Quarter to half the price of DRAM
  - Minimal power and heat
  - Persistent
  - 25 μs chip-level latency (but hundreds of μs latency in consumer devices)
  - Block-level access (~1kbyte)
  - Rated life of 10,000 writes for two-bit-per-cell devices (NB BaBar writes FibreChannel disks < 100 times in their entire service life)
- Exploring necessary hardware/firmware/software development with PantaSys Inc.

Object-Serving Software

- AMS and Xrootd (Andy Hanushevsky/SLAC)
  - Optimized for read-only access
  - Make 1000s of servers transparent to user code
  - Load balancing
  - Automatic staging from tape
  - Failure recovery
- Can allow BaBar to start getting benefit from a new data-access architecture within months without changes to user code
- Minimizes impact of hundreds of separate address spaces in the data-cache memory

Summary:
SLAC's goals for leadership in Scientific Computing