# Yes Virginia, There is an HPSS in Your Future

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– National Energy Research Scientific Computing Center - IBM

**HPSS Web Site URL:** www.hpss-collaboration.org

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# Yes Virginia, There is an HPSS in Your Future

- **The HPSS Collaboration has a roadmap to meet Petascale environment HSM/Archive requirements with relatively few changes.**

- **To quote Tom Ruwart (I/O Performance, Inc.)**
  - "HPSS is a mature, scalable, and reliable *architecture* that can be easily adapted to meet petascale computing requirements
  - It is easily adapted to support object-based systems and devices. Object concepts are inherent in the HPSS architecture
  - It's use of an enterprise-class relational database will allow HPSS to gracefully and robustly scale beyond a trillion files and a very large global name space
  - Why start something new when HPSS has a 15 year head start?"

- **Talk outline**
  - Review why HSM/archives are economically required in HPC environments.
  - Review the HPSS architecture, capabilities and scalability experience.
  - Outline the HPSS roadmap to meet Petascale environment requirements.

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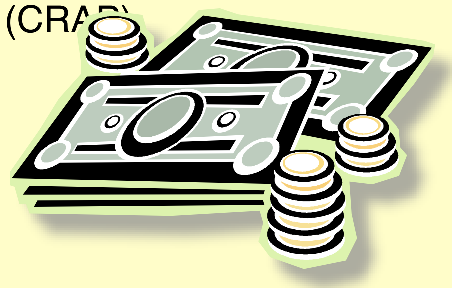
# Review: Why HSM/archives are economically required in HPC environments

# Need to look at the total cost

**One hears new "common wisdom":** *Disk is cheap, tape is dead*

***Total Cost of Ownership/Performance not*** **unit Price/Performance is the key**

- **Need to take into account all cost factors**
  - Purchase price (balanced reliability, capacity and I/O)
    Big interest as one wag notes in consumer reliability and price (CRAP)
  - Recurring maintenance
  - Power
  - Cooling
  - Administration/management
  - I/O Infrastructure to balance capacity and I/O requirements
  - Footprint
  - Site/specific and political…



- **Do your own study/analysis for your installation (I'd like to know what you find)**

# Example: tape is much less expensive than disk* - it really adds up for Petabytes -

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- **In the *LLNL, LANL* environments** tape is:**
  - *6.7X, 54X* cheaper to purchase (including drives, robotics, movers and media).
  - *56.7X, 14X [currently under warranty]* cheaper than disk for yearly maintenance
  - *72X, 105.5X* cheaper net yearly upkeep
  - *342X, 722X* cheaper than disk for electrical power to keep them spinning
  - *342X, 722X* cheaper for cooling (~1/3 total cost of power above)

Estimated total disk power cost is in the range $500K-700K/PB/yr

**Data obtained in 2005*
*** Differences primarily reflect different equipment*

# Storage device futures: no significant surprises expected, most technologies on their evolutionary tracks

- **Magnetic disk recording density progress slowdown**
  - Rate of advancement of magnetic disk operating point demos slows to 27% CAGR (products 29%)
  - 14 sq in on 3.5 in disk, currently .1Tb/sq, @30% CAGR reach superparamagnetic limit 8 yrs. approaching top of S-curve
  - More disk drive product differentiation and specialization – in lieu of traditional density progress
  - MAID looking for application space in HPC. Relatively expensive, data lifetime questions.
  - Removable disk in tape cartridges. Data lifetime questions.
- **Tape is not dead and can maintain its cost/GB advantage over disk (e.g. NSIC tape roadmap shows linear growth to 2015 (16TB/cartridge and 833MB/s))**
  - 14,000 sq in on tape cartridge, currently .00044 Tb sq ", 41%/yr CAGR capacity growth, no limit in 8 yrs. On mid steep slope of S-curve
- **Consumer products are fueling significant solid state memory price erosion (<$30/GB) with miniature magnetic disk "threatened"**
- **Optical disk consolidating on blue laser, DVD derived technologies – "blu-ray" devices available – roadmaps to 200 GB/disk, relatively low data rates ~10MB/s**
- **No holographic based storage systems available this year but more progress made – prototypes demonstrated, "HVD" holographic versatile disk standard introduced (as a wag says "it's the future, always has been, always will be")**
  - Vendors could package in cartridges for use in existing robotic libraries
- **MRAM low capacities, lithographic limits.**
- **MEMS, molecular storage, other new storage technologies in early research, many years away, if ever**

*Thanks to Robert Raymond,Sun/STK: Gordon Hughes, UCSD: Dave Anderson, Seagate*

# Economics drives technology choices

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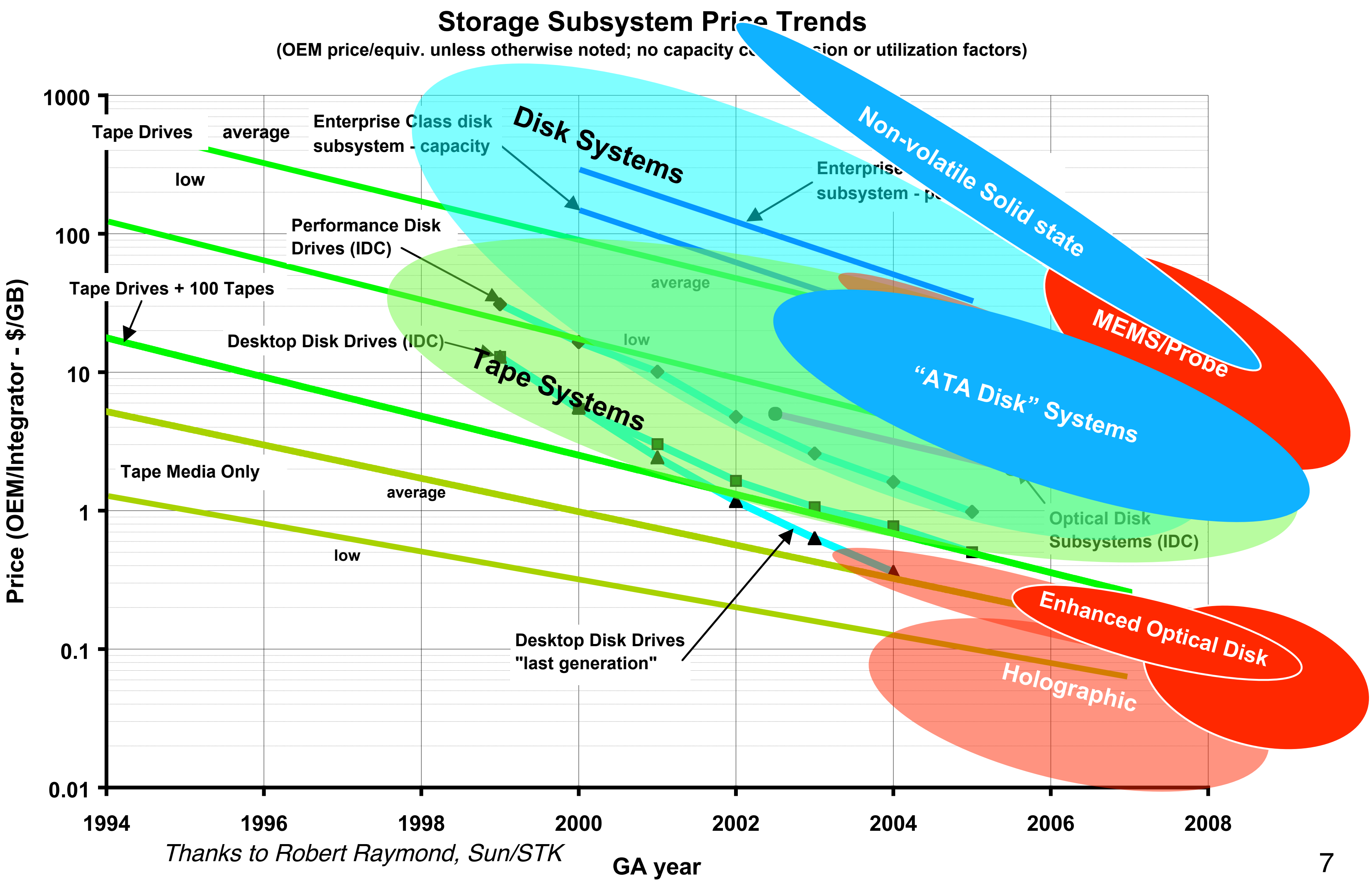


*Thanks to Robert Raymond, Sun/STK*

# Summary: Why need HSM/Archives

- ***Uses the most cost effective storage***
  - **Today tape is most affordable/sustainable media for large archives**
- **Machine/OS/file system agnostic storage solution**
- **Provides cost effective long-term data stewardship (ILM)**
  - Protection of billions of dollars of data investment
  - ***Outlive vendors, machines, operating systems, file systems***
  - Protection from platform disasters (software or hardware)
  - Repack and data rescue tools for information lifetime management
  - Multiple copies
- **Risk-averse solutions not tied to "latest" changes (e.g. OS releases, maintenance) on compute platforms**
- **Scales larger than most file systems - #files, directories, file sizes**
- **Intelligent resource usage/data placement**
  - Classes-Of-Service,
  - Stage/migrate/purge
- **Robotic/atomic mounts of sequential media**
- **Access to devices that have long inherent delays**
- **Any storage product (e.g. Object Storage Devices) can be used in HSM/archives where it makes economic sense.**

# Review: HPSS architecture, capabilities and scalability experience

More details in: Watson, R.W. 'High Performance Storage System Scalability: Architecture, Implementation and Experience," 22nd IEEE - 13th NASA Goddard (MSST2005) Conference on Mass Storage Systems and Technologies April 11-14, 2005, Monterey, California.

**http://storageconference.org/2005/presentations/watson.pdf**

# Scalability is crucial: yesterday, today and tomorrow

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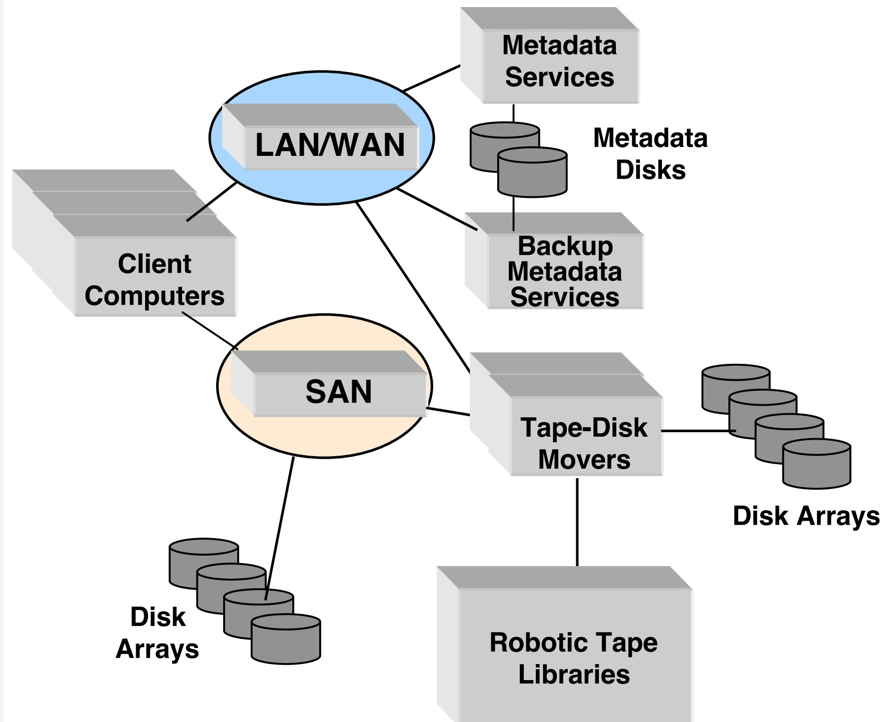
| Parameter | Yesterday (1992) | Today (2006) | Tomorrow (2015) |
|---|---|---|---|
| Computing Power as Driver | 10’s Gigaops | 10’s - 100’s Teraops | 10’s Petaops…. |
| Storage Capacity | 10’s Terabytes | Petabytes | 100’s Petabytes - Exabytes |
| Instantaneous Throughput | Megabytes/s | Gigabytes/s | 100’s Gigabytes/s - Terabytes/s |
| Daily throughput | Gigabytes/day | 10’s Terabytes/day | Petabytes/day…. |

# HPSS meets key scalability and other requirements

| | |
|---|---|
| **Reliability/recoverability/availability**<br>• Metadata-mirrored,backup,recovery<br>• Atomic transaction<br>• Multiple file copies | ✓ |
| **Performance (separation of control and data)**<br>• I/O rate to single file GBs/s and beyond<br>• Direct client to HPSS parallel I/O<br>• Simultaneous throughput GBs/s and beyond<br>• Transaction rate | ✓<br>✓ *(Today metadata performance scalability is by static subtrees)* |
| **Capacity**<br>• Global name space and data sharing (LAN/SAN/WAN access)<br>• 10s Petabytes and beyond (flexible expansion granularity)<br>• # files billions (unlimited file size)<br>• # directories billions and beyond (unlimited directory size)<br>• Automatic migration/staging<br>• Multiple, multilevel hierarchies, Classes of Service, file families | ✓ |
| **Transparency, user interfaces, file system integration**<br>• Access methods (e.g. Posix, PFTP, NFS, PSI, HSI, HTAR, VFS)<br>• File System integration (VFS, DMAPI, Lustre, Panasas, GPFS, other) | ✓ |
| **Security**<br>• Authentication, Posix permissions, ACLS<br>• Secure network transfers | ✓ |
| **Others (e.g. extendibility by labs, manageability, # of clients)** | ✓ |

# HPSS environment in a nutshell

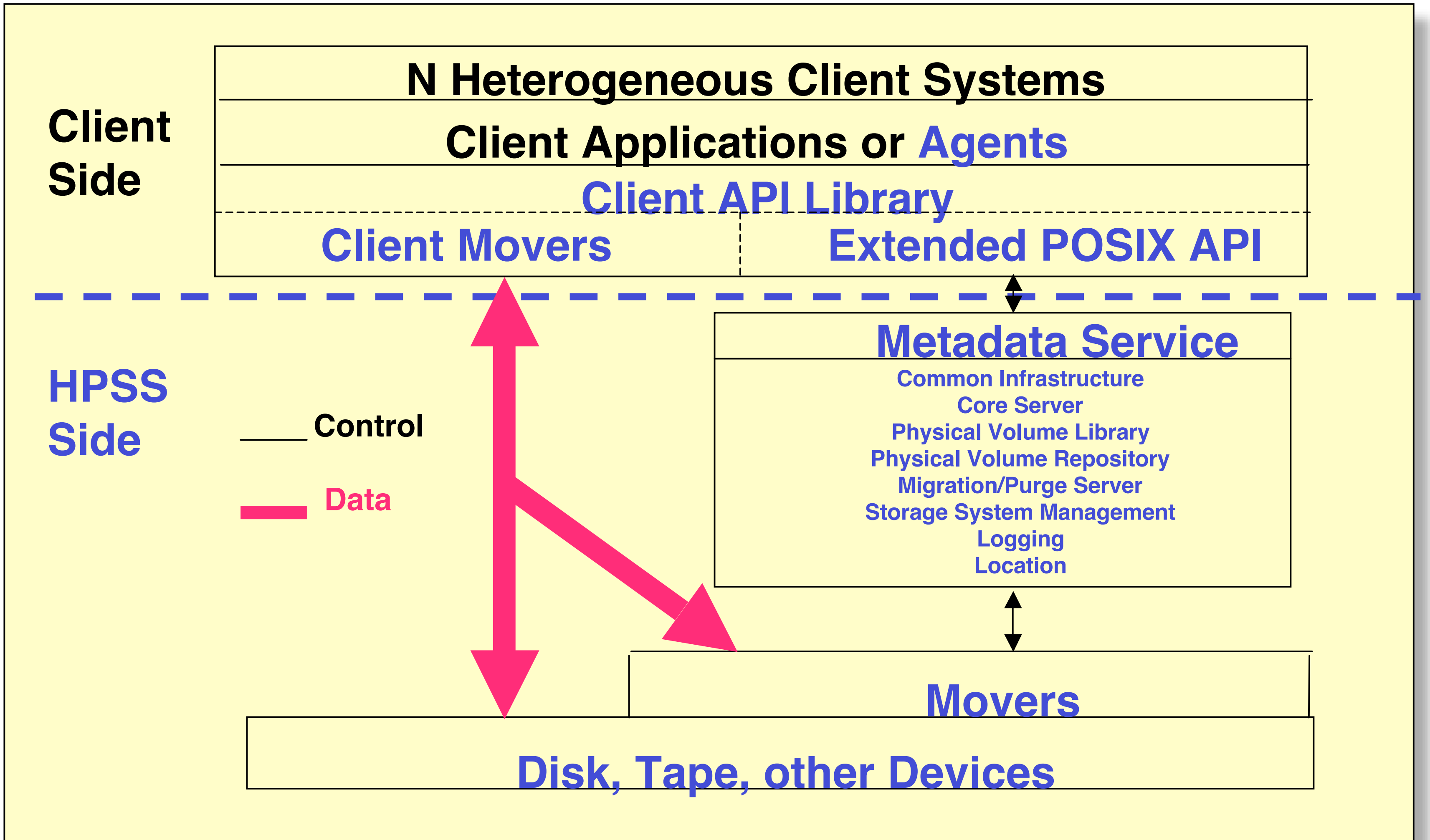
- **HPSS is a true cluster hierarchical storage system**
- **DB2 metadata engine assures reliability and quick recovery**
- **Cluster architecture and metadata architecture support horizontal scaling to:**
  - 10s of petabytes
  - 100s of millions of files
  - gigabytes per second data rates
  - All in a single system
- **Supports technology insertion**
  - Add new components, no need to replace
  - Mix and match vendors and models



# Three factors supporting scalability HPSS

- **Hardware**
  - Computational power
  - Networking
  - Storage capacity and I/O rate of media and controllers
- **Software**
  - Architecture
  - Implementation
- **Deployment**
  - Full attention end-to-end process
    - **Balanced configuration**
    - **Tuning**
    - **Planning**
    - **Support**

# HPSS high-level architecture:
## (network-centric, robust metadata service)



# HPSS second level architecture and implementation

- **HPSS Infrastructure**
  - Metadata Services (Enterprise class RDBMS (DB2))
    - Scalable data structures and algorithms
  - Concurrency
  - Security Services
- **Communication Services**
- **Device Striping**
- **Storage Hierarchies, Classes-of-service, File Families**
- **Subsystems**
- **Client Interfaces**
- **No Kernel Modifications**

# Scalable Robustness

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- **Architecture**
  - Logically centralized metadata service
  - Separation of metadata storage and user data storage
- **Implementation**
  - Enterprise class RDBMS metadata engine
  - Atomic transactions
  - Log restore time independent of amount of user data
- **Deployment**
  - Mirrored RAID disks backed up at least daily
  - Redundant metadata machine(s) with manual or automatic failover
- **Issues needing work**
  - None identified

# Scalable modular capacity

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- **Architecture**
  - Hierarchical storage architecture
  - Multiple hierarchies, COS and file families
  - Separation of migration/purge policies and mechanism
- **Implementation**
  - Metadata engine choice and scalable metadata design and organization
  - Scalable data structures
- **Deployment**
  - Periodic review of storage requirements and technologies
  - Scalable units
- **Issues needing improvement**
  - None identified

# Scalable data throughput

- **Architecture**
  - Separation of data and control and use of Movers
  - Storage service and its virtual volume service (e.g. striping)
- **Implementation**
  - Concurrent requests and I/Os
  - Modular set of communication services including intelligent client agents
  - Device striping
- **Deployment**
  - Scalable-units
  - Use of commodity multiprocessor clusters
  - Periodic I/O planning
- **Issues needing work**
  - Improved disk allocation algorithms
  - Improved tape aggregation
  - Improve small file performance (e.g. # of creates/s and read-writes/s)

# Capacity and I/O scaling examples HPSS

- **2.4 PB** Lawrence Livermore National Lab (LLNL) Secure Computing Facility (SCF) (**~34 million files**) **scaled from13 TB** in 1992.
  - **2.7 PB** LLNL Open Computing Facility (OCF) **(~31 million files).**
  - **~1 million directories in the OCF and 1.2 million in the SCF (10K - 90K entries).**
- **5 PB**: Los Alamos National Laboratory (LANL) SCF, **(~ 52M files).**
- **LLNL** - Aggregate data transfer rates to the archive, before HPSS, were well under **10MB/s** and now exceed **2.5GB/s** to caching disk. Single file rates, using a four-way stripe to a RAID array, generally run at around **300 MB/s**. Daily throughput to the archive has exceeded **50 TB/day**.
- **LANL** - A 2005 user archive operation stored **122,000 files occupying 10TB in six hours** with the transfer rate limited by network throughput. In a recent performance demonstration, a data transfer rate of **550 MB/s was achieved using 16-way mirrored tape stripes** storing files over 100 GB in size on StorageTek 9940Bs.
- **IBM** - At the SC04 supercomputing conference in November 2004, IBM demonstrated HPSS (an early version of HPSS 6.2) performance using three computers, one each for HPSS, reading and writing. A large 128 GB file was written and read in 512 MB blocks using **16-way striped SAN-attached disk files**, using 8 host bus adapters on each client computer. As one computer wrote each block, it was immediately read by a second computer, thus demonstrating **"read behind write"** performance. The **file transfers were measured at 1016 MB/s on the write side and 1008 MB/s** on the read side, for an aggregate data rate of just over two GB per second.

# HPSS Roadmap to 2011 to Support Petascale Environments

# What do Petascale environments imply for HPSS?

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- **Relatively few improvements needed.**
  - Need improved small file performance in general and to tape in particular.
  - An improvement in device allocation to minimize I/O and networking conflicts.
  - Improved file system integration.

# 2011 HPSS Performance Requirements

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| Parameter | 2011 |
|---|---|
| Computing Power as Driver | 10 Petaops |
| Storage Capacity | ~ 25-100 Petabytes (economics main limit) |
| Instantaneous Throughput | ~ 50+ Gigabytes/s (economics main limit) |
| Daily throughput | ~ 250 - 500 Terabytes/day (economics main limit) |
| Small file create-writes/s | Low 1000s (assumes small file aggregation) |

# Determining small file performance requirement difficult: University of Chicago 1 Week BG/L Run

- **The numbers below are only for a 180TF peak partition.**
- **During the week they ran on 32K nodes (32K processors).**
- **They generated 74M files and about 150TB of data.**
- **They generated 32K file filesets organized into a directory for each fileset.**
  - 3.2 10^4 * (200 + 1400 + 700) = 7.4 10^7 files stored in Lustre
- **Here's the number of filesets (each with 32K files) stored in HPSS as single HTAR bundles:**
  - Checkpoint: 200 (Each fileset 640GB), only 15 stored in HPSS
  - Particle Plotfile: 1400 (Each fileset 20GB), all stored in HPSS
  - Grid Plotfile: 700 (Each fileset 0.5GB), all stored in HPSS
- **HTAR reduced the number of objects to be managed by HPSS by factor of 10,000.**
  - Even with such aggregation we assume could need small file transactions/s in the range of low 1000s/s for a petascale environment.

# HPSS Roadmap to 2011- Focus: Scaling Small File Performance

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**Deploy 6.2**

**Q1 2006**
**6.2**
**Complete**
**Core Server**
**Infrastructure**
**Upgrade**

**Deploy 7.1**

**Q3 2007**
**7.1**
**Performance Tuning**
**Logically Single**
**Core Server on Cluster**
**Goal - 5X performance improvement**

**Deploy 8.1**

**Q1 2009**
**8.1**
**Ver. 1 Dynamic Multiple Core Server Clusters**
**Ver. 1 (OSD support?*)**
**Ongoing Tuning**
**Goal >10X improvement**

**Deploy 8.2**

**Q4 2010**
**8.2**
**Ver. 2 Dynamic Multiple Core Server Clusters**
**Ver. 2 (OSD support?*)**
**Ongoing Tuning**
**Goal >5X improvement**

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***Need to establish requirement and economics but straightforward to support**

# HPSS near term requirements
## (Release 7.1, Q3 2007)

- **Improve performance (goal 5X)**
  - Improve small file performance (e.g. improve tape file management, improve metadata performance overall)
  - Facilitate greater throughput (e.g. Storage Server device allocation algorithm, above)
- **Improve site integration**
  - File system integration (e.g. Lustre, Panasas, GPFS, VFS)
    - GPFS <-> HPSS demonstrated at SC 05
  - Mover device affinity (multiple Movers can share a device, clients)
  - 64 bit PFTP
- **Improve transparency and administration**
  - Dynamic segment size allocation
  - Multiple streams of COS changes
- **Provide a common Trilab user interface (in planning phase during this timeframe)**

# Beyond 7.1 - Key requirement is continued improvement in metadata performance

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- **To further improve metadata performance requires more metadata handling parallelism.**
- **There are three main areas being studied:**
  - Multiple Core Servers with dynamic load balancing
  - More intelligent devices (e.g. OSDs)
  - More processing, aggregation and caching in clients.

# Multiple dynamic Core Servers

- **Ultimately achieving more parallelism beyond multithreading is required for more scalable metadata performance.**
- **Currently have multiple subsystems (Core Servers) based on static name space assignment distribution.**
  - Multiple subsystems load balance by static name space subtree allocation.
- **HPSS project currently studying how to most effectively utilize DB2 partitioning and other capabilities to support multiple dynamic Core Servers (Metadata Servers).**

# Object Storage Device support straightforward

- **OSDs offer another way to improve parallelism at a lower level.**

- **Basic integration is straightforward**
  - HPSS architecture has separation of data and control logic and appropriate object abstraction layering supporting a segment abstract object.
  - OSD support would integrate simply into segment layering of the Storage Server.
  - Need to modify authentication so OSD can authenticate capabilities for each I/O.
  - Client library and Mover logic needs adaptation as Client will do direct I/O on cached metadata from Open.

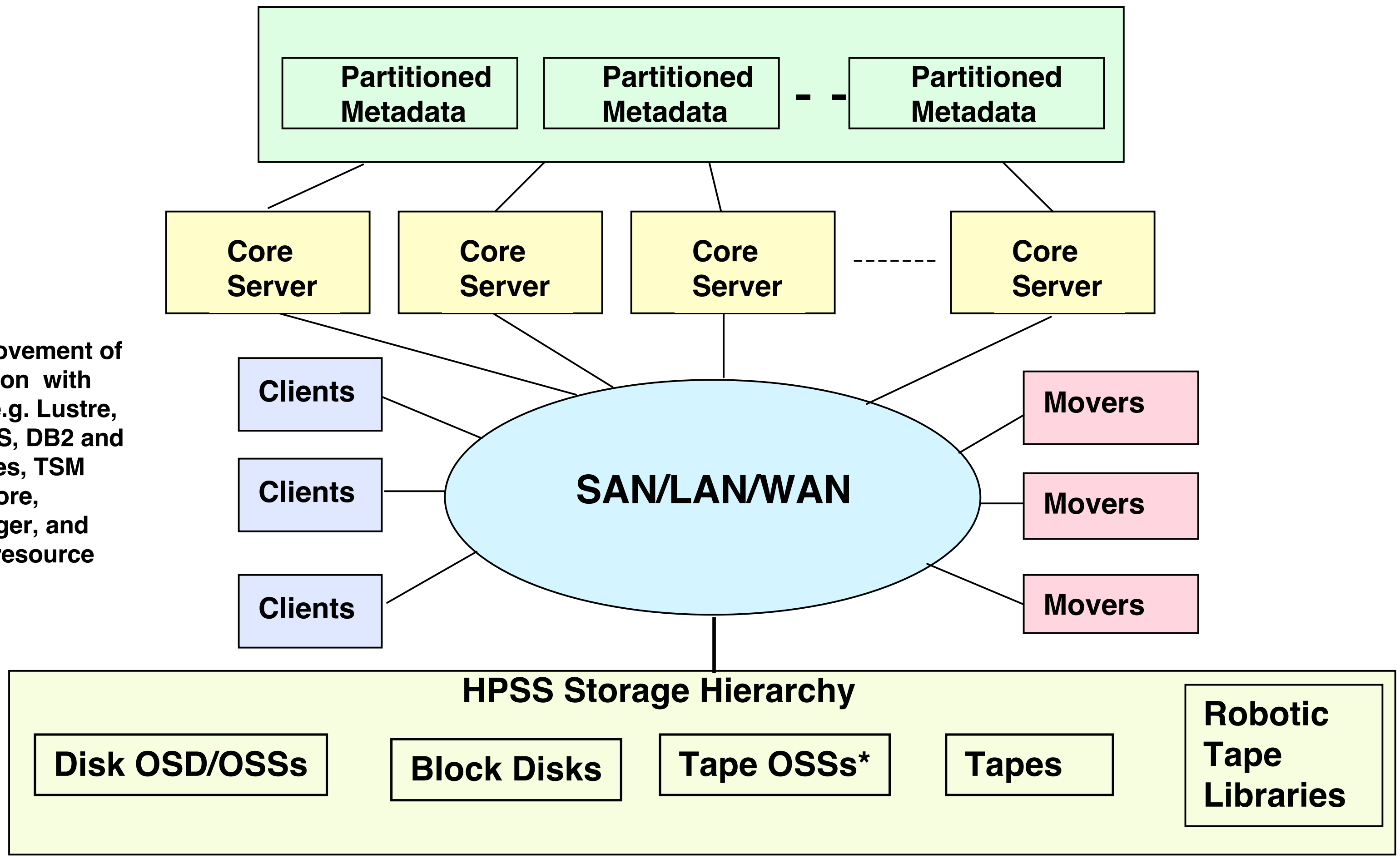
- **Questions**
  - What percent of current operation time(e.g. create, read, write) would be in this level of metadata processing and thus how much would system performance benefit?
  - What Mover latency would be saved, again how much would performance benefit?
  - How to assure metadata in OSD/OSSs is “safe”? (There are issues with current implementations and deployments)
  - Would developing tape OSSs make sense given all the latencies and other issues managing tape?

# What things might make sense for an HSM to do in the client?

- **Currently HPSS client utilities such as PFTP, PSI, HSI, HTAR do sophisticated client side operations to optimize performance.**
  - Examples include file bundling (aggregation); data transfer, striping, device, multithreading, staging optimization; restart and error recovery; directory listing caching;  and more.
- **Studying other client level functionality to increase parallelism and latency hiding.**
  - The standard system approaches are forms of buffering, aggregation and caching.
    - One example planned is transparent Client access to bundled file metadata.
  - Given the requirement for very high robustness, which options make sense for an HSM/archive?

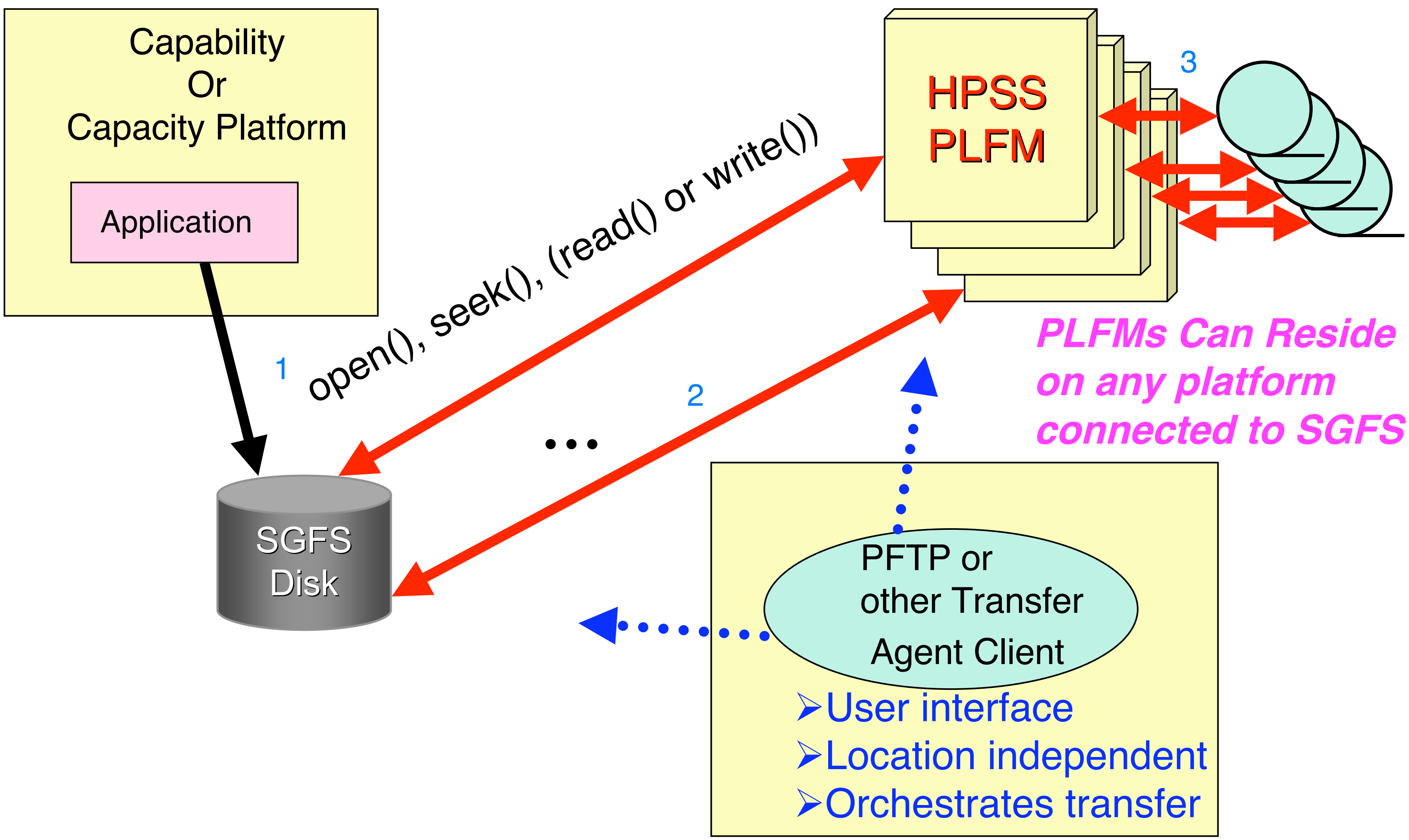
# HPSS (8.1, 8.2) in 2009 - 2011

Ongoing improvement of client integration with file systems (e.g. Lustre, Panasas, GPFS, DB2 and other databases, TSM backup & restore, Content Manager, and Grid storage resource brokers)




* No such devices currently exist or are planned nor is it clear that such devices make economic sense. I'm very interested in discussion here.

# Example: Integrating HPSS with a Scalable Global FS (SGFS) using Parallel Local File Movers (PLFM)



# Yes Virginia, There is an HPSS in Your Future

- **HSMs/Archives are required as far into the future of storage devices as we can see.**
- **HPSS has demonstrated significant scaling capabilities:**
  - **100** for capacity to petabytes,
  - **1000** for single file bandwidth to GB/s.
  - **1000** for instantaneous throughput to GB/s,
  - **1000** for daily throughput to 10s TB/day, and
- **The object-oriented, flexible, network-centric architecture of HPSS and modular industry standard product infrastructure are sound.**
  - Use of an enterprise class DB engine is crucial part of scalability strategy
  - Enterprise DB also key part of HPSS robustness strategy.
- **The HPSS architecture and implementation have lots of room for further scaling in I/O, capacity, metadata performance and other dimensions by further orders of magnitude in the future.**
  - Multiple Core Servers, OSDs, more client side functionality fit naturally.
- **HPSS has roadmap to meet future Petascale environment HSM/Archive requirements with relatively few changes.**

**Acknowledgement**

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