Mass Storage Upgrades at the NASA Center for Computational Sciences

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Earth and Space Data Computing Division

Earth Sciences Directorate

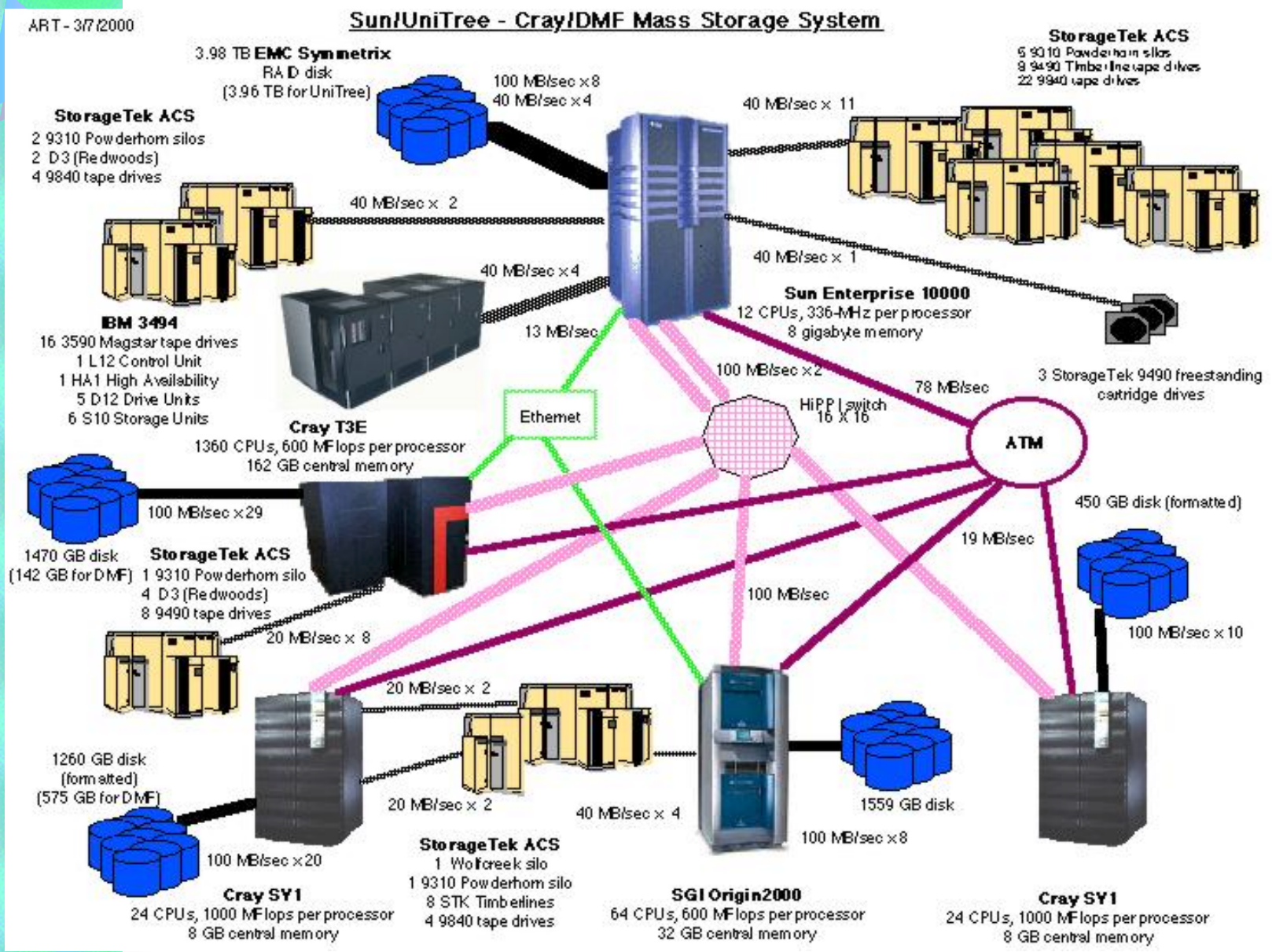
NASA Goddard Space Flight Center

Who We Are

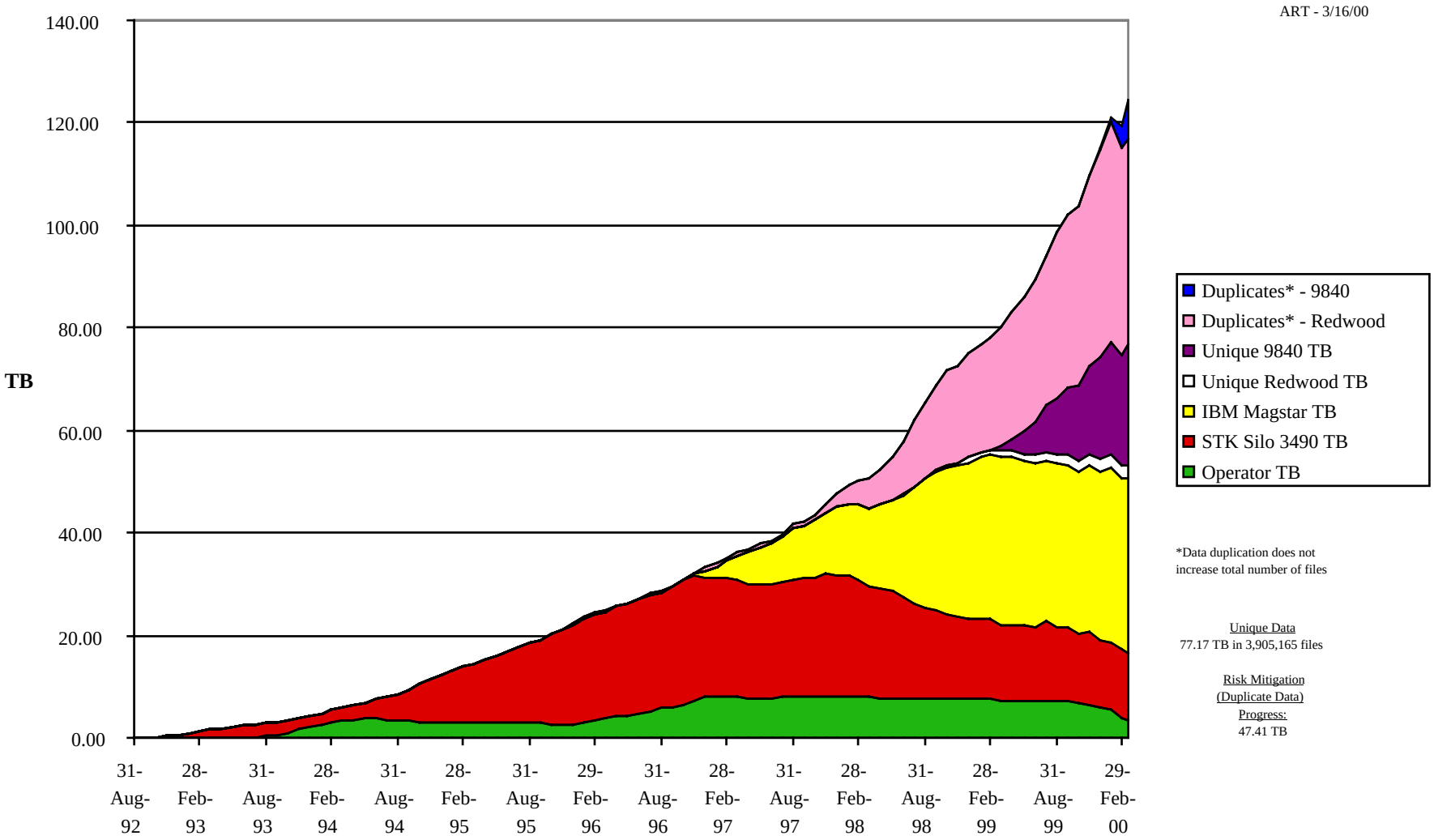
- **Central computing facility providing high-end computing and mass storage services for NASA-funded Earth and Space science researchers**
- **Part of Earth and Space Data Computing Division**
- **Cray SV1s, Origin 2000, Cray T3E compute servers (plus user desktop workstations) feed data into Sun-based UniTree mass storage system**

We've Come a Long Way with UniTree

- **We've run some form of UniTree since July '92**
- **Started out on a Convex C3240**
  - **Two STK silos with eight18-track tape drives**
  - **Eight freestanding 18-track tape drives**
  - **110 GB disk cache**
- **Currently on a Sun E10000**
  - **Seven STK silos**
    - **Eight 36-track Timberlines**
    - **26 9840 tape drives**
    - **Two Redwood SD-3 tape drives**
  - **One IBM 3494 library with sixteen Magstar E1A tape drives**
  - **Four freestanding Timberlines**
  - **Close to 4 TB disk cache**

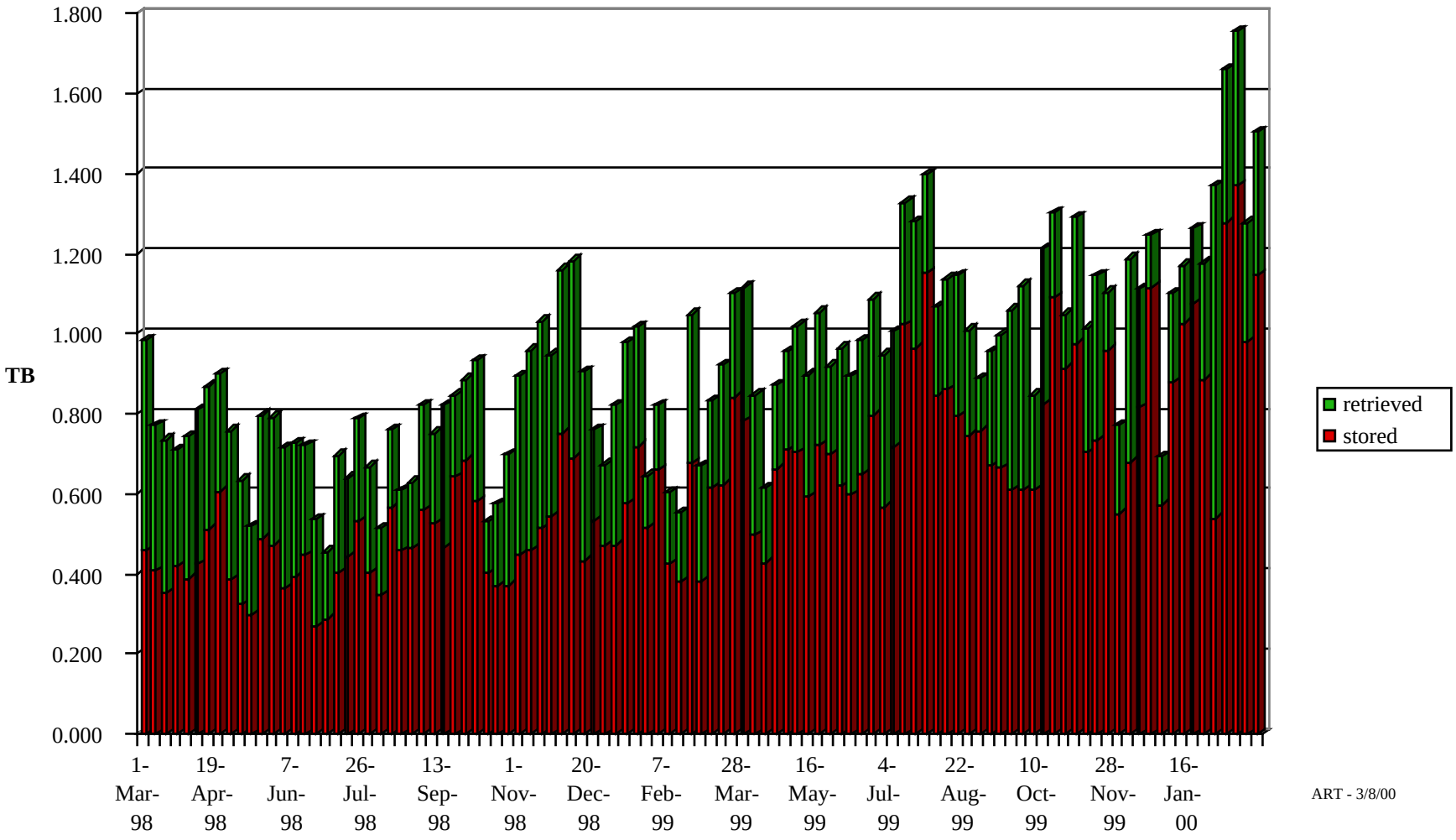

ART - 3/7/2000
Sun/UniTree - Cray/DMF Mass Storage System
3.98 TB EMC Symmetrix
RAID disk
(3.96 TB for UniTree)
100 MB/sec x8
40 MB/sec x4
StorageTek ACS
2 9310 Powderhorn silos
2 D3 (Redwoods)
4 9840 tape drives
40 MB/sec x 2
40 MB/sec x 11
StorageTek ACS
6 9310 Powderhorn silos
9 9490 Timberline tape drives
22 9940 tape drives
40 MB/sec x 1
40 MB/sec x4
13 MB/sec
IBM 3494
16 3590 Magstar tape drives
1 L12 Control Unit
1 HA1 High Availability
5 D12 Drive Units
6 S10 Storage Units
Sun Enterprise 10000
12 CPUs, 336-MHz per processor
8 gigabyte memory
100 MB/sec x2
78 MB/sec
3 StorageTek 9490 freestanding
cartridge drives
HiPPI switch
16 X 16
Ethernet
Cray T3E
1360 CPUs, 600 MFlops per processor
162 GB central memory
ATM
100 MB/sec x29
1470 GB disk
(142 GB for DMF)
StorageTek ACS
1 9310 Powderhorn silo
4 D3 (Redwoods)
8 9490 tape drives
450 GB disk (formatted)
19 MB/sec
100 MB/sec
20 MB/sec x 8
100 MB/sec x 10
20 MB/sec x 2
20 MB/sec x 2
1260 GB disk
(formatted)
(575 GB for DMF)
40 MB/sec x 4
1559 GB disk
100 MB/sec x8
100 MB/sec x20
Cray SY1
24 CPUs, 1000 MFlops per processor
8 GB central memory
StorageTek ACS
1 Wolfcreek silo
1 9310 Powderhorn silo
8 STK Timberlines
4 9840 tape drives
SGI Origin2000
64 CPUs, 600 MFlops per processor
32 GB central memory
Cray SY1
24 CPUs, 1000 MFlops per processor
8 GB central memory

NCCS Total UniTree Terabytes - 3/16/00



NCCS UniTree Weekly Traffic - 3/1/98 - 3/4/00

avg stored = 168.25 GB/day avg retrieved = 56.37 GB/day (averaged over last 30 days)



ART - 3/8/00

Spring of '98

- We upgraded our HP UniTree+ software from Rel. 2.0 to 3.0
  - Final upgrade occurred after 3 test upgrades
  - Gave us the ability to duplicate existing files
- HP informed us that the C3830 that hosted our UniTree+ system was not Y2K-compliant
- Very short lead time
  - No time to adequately evaluate alternative HSM software
  - Needed to find a system that could read the TB written already in UniTree+ format
  - Wanted the shortest learning curve possible
- We decided that UniTree Software Inc.'s UniTree Central File Manager would be our choice, at least for the interim
  - Still needed to decide on platform and disk

On What Machine?

- At the time, UniTree Software, Inc.'s (UTSI) UniTree Central File Manager (UCFM) was supported on Sun, HP, DEC, and SGI
- Sun offered us an E6000 through SEWP as a test machine; HP, SGI, and DEC also provided machines for testing
- Eventually, we found ourselves with the following test platforms:
  - Sun E6000 with A3000 and A5000 RAID disk arrays
  - SGI Origin2000 with Clariion RAID fibre disk array
  - HP V2250 with EMC RAID fibre disk array
  - DEC Alpha 4000 with DEC StorageWorks RAID USCSI disk array
- Each machine was allocated a silo Timberline and a silo Magstar drive

Testing Begins, Summer of '98

- dd-testing to all disks except for EMC showed poor performance for simultaneous reads and writes
  - reads would be stuck waiting until writes completed
- HiPPI gave us big headaches, but was required to get adequate transfer performance with Cray J90s
  - Sun, SGI, and DEC machines had serial (fiber) HiPPI interfaces, while our production Netstar switch was all parallel (copper)
  - We managed to get hold of both an ODS HiPPI modem for the Netstar switch and a fiber blade for our Gigalabs switch that was still in test mode
  - HiPPI modem induced hangs for retrieves over a certain size

Out of Time

- **By August '98, time had run out, and we were forced to decide--a Sun E6500 was selected**
- **Many factors were considered, including**
  - **Reasonable cost**
  - **Performance**
  - **Other UniTree sites with a greater load than ours were running successfully on a Sun**
  - **Solaris was the initial port for UTSI releases**
- **We chose RAID disk arrays that were attachable to other machines, in case long-term follow-on system was not a Sun**
  - **1.3 TB EMC disk**
  - **900 GB Clariion fibre disk (purchased from STK)**

Tape Drives

- **At the same time, we also purchased Storage Tek 9840 tape drives**
  - **Until they were ready, we received Timberlines in their place**
- **We had 16 IBM Magstars in our silos**
  - **Were working well for us, until...**
  - **STK's next version of LMU microcode disallowed "J"s on cartridges, which we needed Magstar cleaning carts to have if we wanted automatic cleaning**
  - **We remained on back-level microcode so we could continue to run**
  - **9840s, though, required newest microcode**

Tape Drives (cont'd)

- IBM 3494 robotic library already had 8 Magstar drives
- We purchased 4 more D12 cabinets to hold the 16 drives that were in the silos, so that 9840s could be installed
- IBM afterwards told us that with SCSI drives in our library we couldn't install any more than the 8 drives we already had
- More research indicated that with new feature code we could install 8 more, leaving us with 8 silo drives in limbo

Tape Drives (cont'd)

- **After negotiating with both IBM and STK, we decided to give the 8 extra Magstars back to IBM**
- **In return IBM agreed to**
  - **apply whatever feature codes were necessary to the 3494 so it could run with 16 SCSI-attached drives**
  - **move the 8 drives down into the 3494 (silos were upstairs)**
  - **give us certain upgrades to the drives that were soon to be available**
- **This tape drive move-and-return wound up not happening until after conversion to UTSI UniTree (more on this later)**

UniTree Tapes, Fall of '98

- **Test conversion of a UniTree+ 3.0 test system to UTSI UniTree went fine**
- **No problems storing and migrating new data**
  - **Sun driver for Magstars wouldn't let us append to current write tapes, but IBM driver worked well**
- **Trouble encountered retrieving some UniTree+ written files, but not others**
- **UTSI discovered that many of our tapes that we thought had the identical media type actually differed in block size**

UniTree Tapes (cont'd)

- **It was determined, based on the tapes with the strange new media types, that UT+ 3.0 formatted its tapes differently than UT+ 2.0**
- **UT+ 2.0 easily read UT+ 3.0-written tapes, and vice versa**
  - we knew that because we had converted and reverted to and from 3.0 3 times until we stayed on 3.0 for good

UniTree Tapes (cont'd)

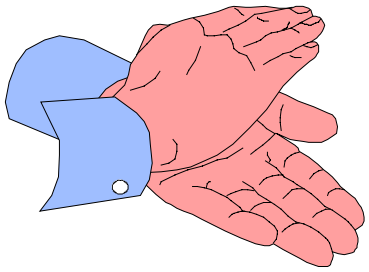
- **Each conversion and reversion to and from UT+ 3.0 had created tapes half-written in 2.0 format, half-written in 3.0 format**
- **Mark Saake of UniTree Software Inc. analyzed our UniTree+ logs and determined the tapes that were totally 3.0-written and the tapes that were mixed-format**
- **3.0-written tapes needed a separate media type for UTSI UniTree**
- **Mixed-format tapes needed to be repacked under UniTree+**
  - **considerable manual intervention would be needed for mixed-format tapes to be readable under UTSI UniTree, resulting in delays for users**

More UniTree Testing

- **Test system had very many mixed-format tapes, making it difficult to work with**
- **A read-only copy of the production UniTree+ system could provide a large-scale, realistic test**
- **Once production UniTree+ copy 0 mixed-format tapes were repacked, UTSI converted a snapshot of production UniTree+ databases for the new test system**
- **Pilot users selected and given access**
- **Some minor bugs were found and quickly fixed**

Actual Conversion, Jan. '99

- User traffic was halted on UniTree+ while migration completed
- Databases ftped to Sun and converted
- Critical files moved
- Sun acquired IP address of the C3830
- All tape devices uncabled from C3830 and cabled to Sun
- Success!



Next Hurdle

- **IBM had greatly delayed the move of the silo Magstars into the 3494**
  - **We could not upgrade the necessary silo components to install 9840s until this happened**
- **Finally, after conversion to UTSI, this move occurred**
- **Dual-active-accessor also installed**
  - **allowed both robots (one used to be just a hot backup) to actually work at the same time**
- **With Magstar tapes and drives no longer in silos, STK C.E. upgraded our Library Management Unit, LMU microcode, and the robot hands (also required for 9840 support)**
- **We then upgraded the silo control software (ACSLS), and finally installed the 9840 tape drives**

More Tape Drive Upgrades

- **IBM then announced their 256-track Magstar tape drive, the E1A**
- **Over the next several months, we gradually upgraded all 16 of our Magstars to 256-track**
- **Currently rewriting older data on 3490s to the 256-track Magstar tapes**

Platform Upgrade

- **With 16 Magstars, 26 9840s, 6 Redwoods, 4 freestanding tape drives, and 1.5 TB of disk, we were nearly out of I/O slots**
- **Users were already indicating increasing requirements within the next few years**
- **In June of ‘99 we upgraded the UniTree server from the E6500 to an E10000**
  - **5 times the I/O bandwidth**
  - **11 additional USCSI adapters**
  - **4 additional CPUs**
  - **Room for 4 additional system boards with I/O slots**

UniTree Upgrade, Aug. '99

- **UniTree 2.1 was now available**
  - **Some of its features, such as Y2K-compliance and support for 64 tape drives had been backported to 1.9.1 for us**
- **2 initial upgrade attempts made, then third attempt succeeded**
  - **As first site to upgrade with 56 tape drives, we brought to light some previously unknown bugs**

More Disk

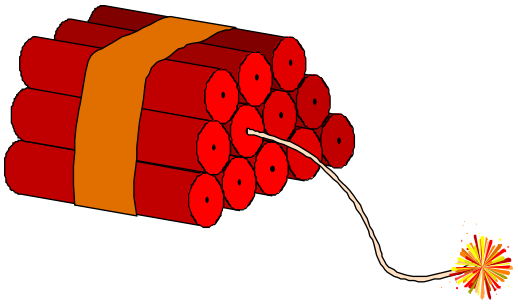
- **Under UniTree 1.9.1 we had 817.5 GB for UniTree disk cache**
- **Couldn’t add much more because 1.9.1 was limited to 110 partitions**
- **2.1 extended that limit to 256, so after upgrade to 2.1 we gradually added 775 GB of the Clariion disk we had purchased**
- **For several months we had a total of 1.56 TB of disk cache**

More Disk (cont'd)

- **Clariion's inability to failover or load-balance caused concern**
  - **ATF, the product provided for failover, interfered with the installation of totally unrelated patches, as well as with the EMC disk devices, so we could not run it**
  - **When one of the fibre interfaces failed, UniTree took a hard hit**
- **Eventually we purchased another 3.5 TB of EMC fibre-attached disk and decommissioned the Clariion**
  - **EMC's PowerPath had been working well for us for both load-balancing and failover**
  - **Currently have nearly 4 TB of UniTree disk cache, all EMC**

Redwoods

- **Since Nov. '97 we had been duplicating all new UniTree data to Redwood tape stored in a remote silo**
- **StorageTek recently announced the end of Redwood support as of 9/30/2002**
- **We moved one of our 6 local silos with its 4 9840 drives to the remote location, to take over the duplication task from the Redwoods**
- **We have more than 40 TB of duplicate UniTree data on Redwood media to rewrite by then**

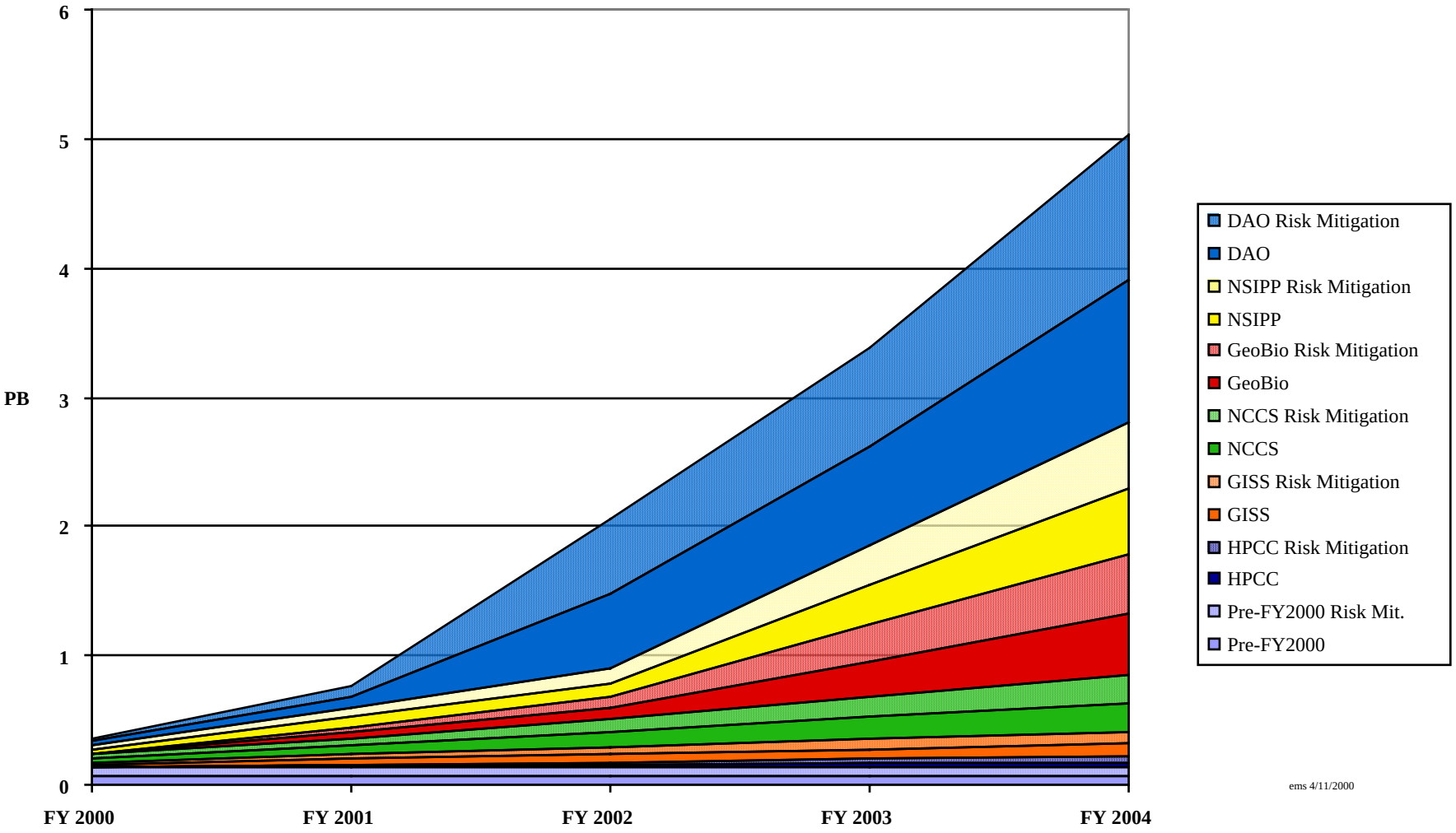


Near-term

- **Users have indicated massively increased requirements for the next several years**
- **Working on a mass acquisition to fill those requirements**

Earth Science Computing Center Mass Storage Requirements 2000-2004

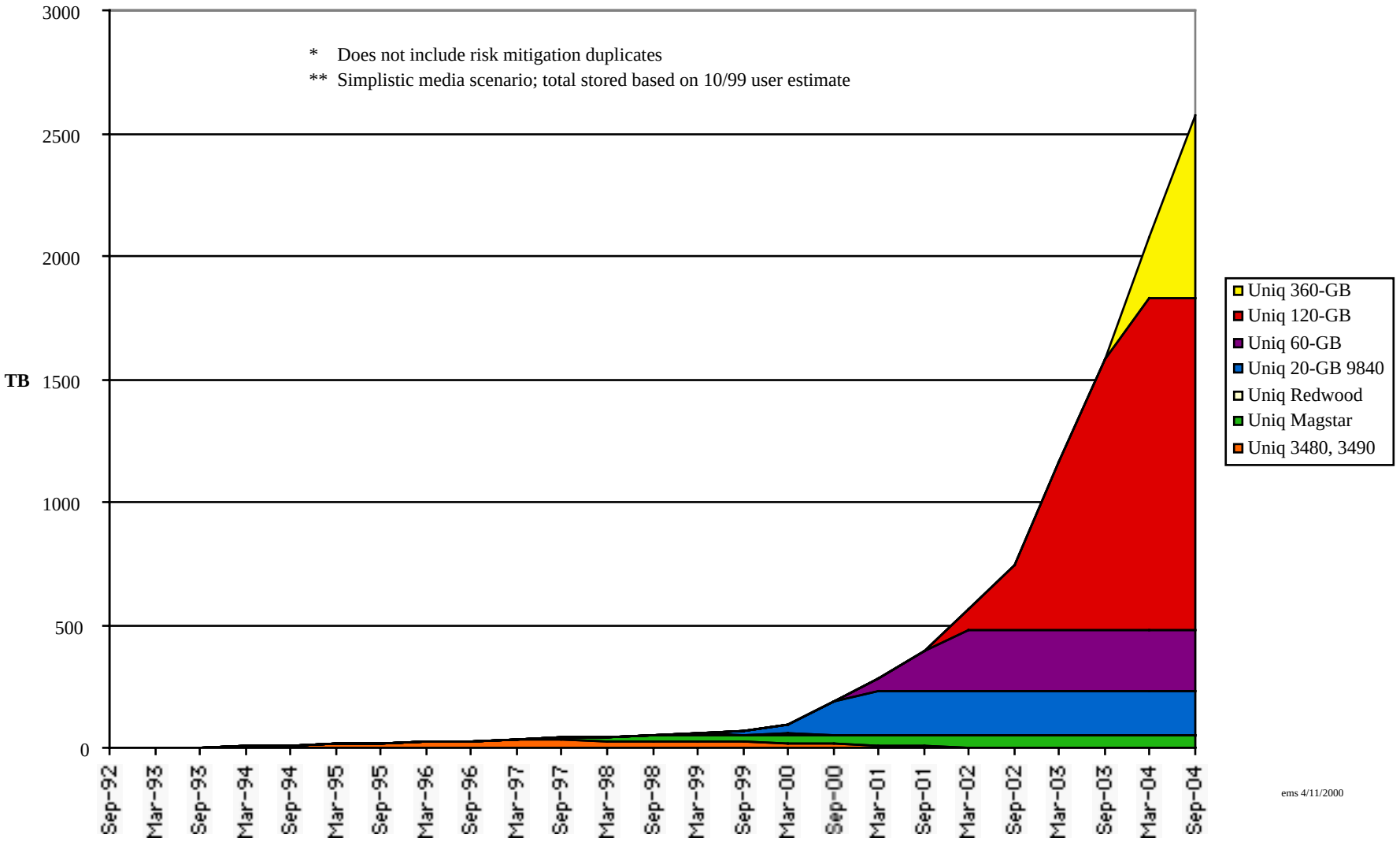
Earth Science Computing Center
Projected Total Data Stored Requirements



ems 4/11/2000

Projections from "Refined Earth Science Computing Requirements" 10/21/1999

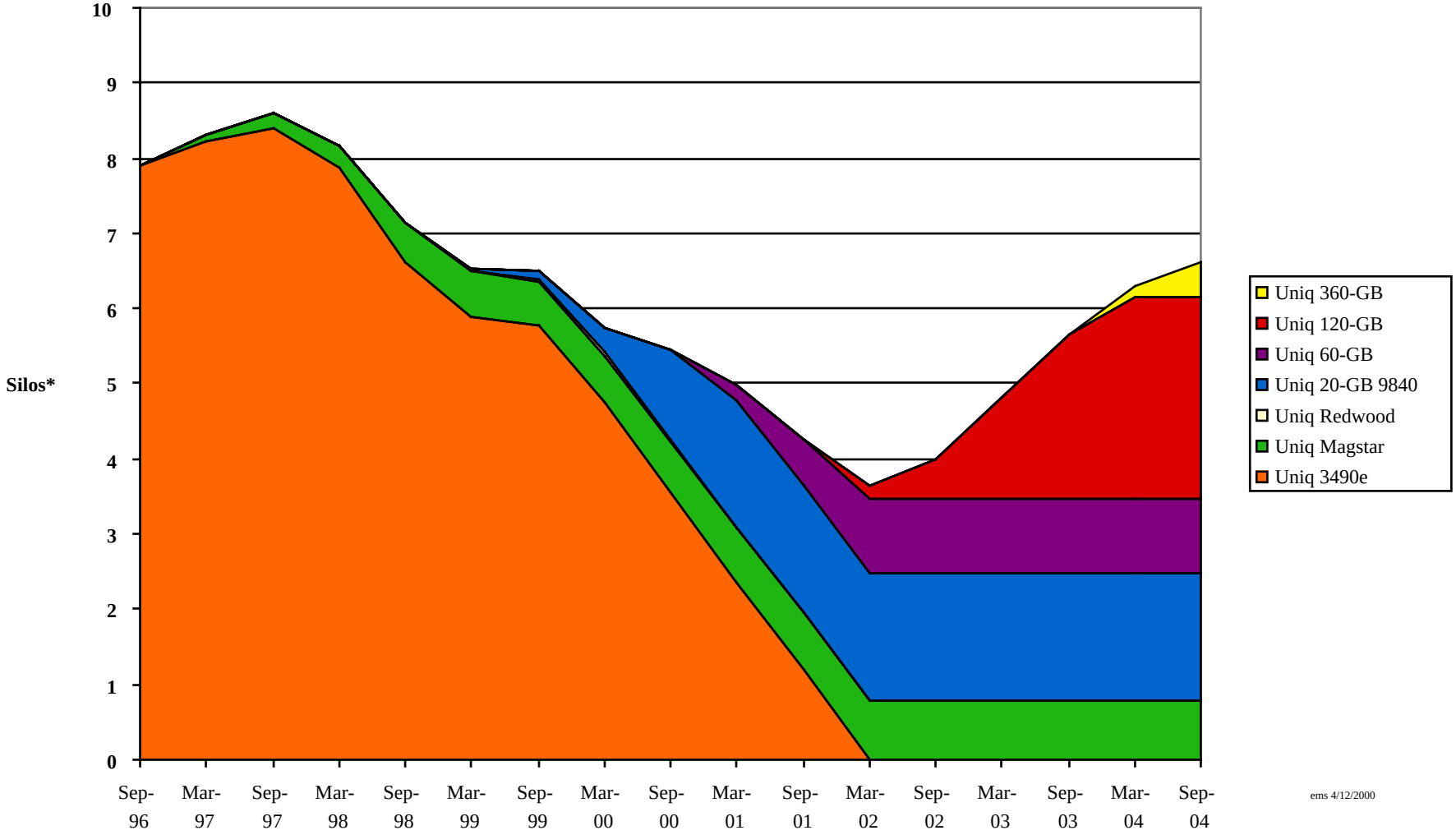
Earth Science Computing Center Unique* Data
Observed and Projected** Terabytes by Media Type



ems 4/11/2000

Earth Sciences Computing Center Unique Data**
Estimated-Observed and Projected- ***Optimistic*** **Media Usage**

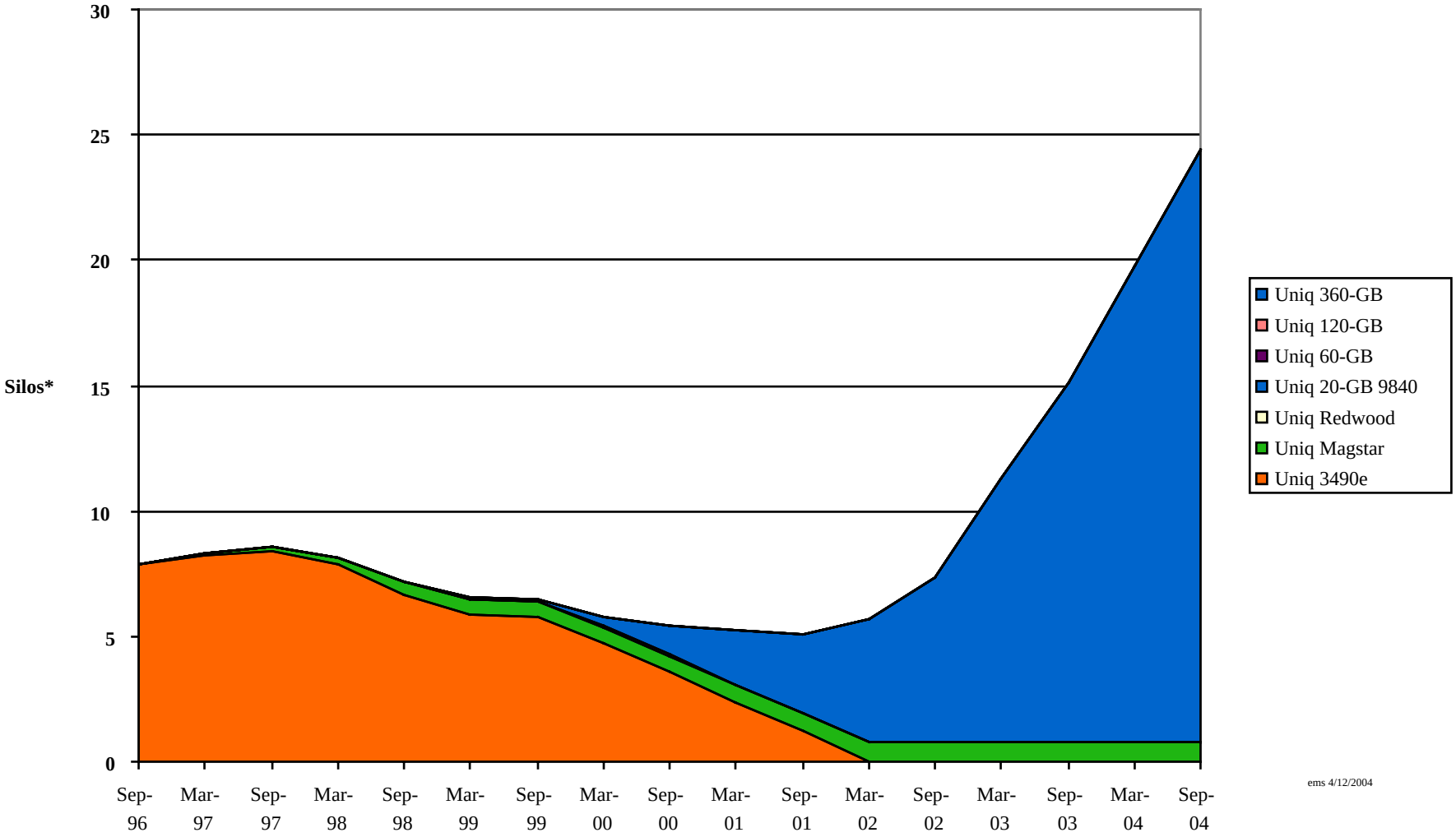
*1 "Silo" = 5743 Cartridges ** Does not include risk mitigation duplicates



ems 4/12/2000

Earth Science Computing Center Unique** Data
Estimated-0bserved and Projected- *Pessimistic* Media Usage

*1 "Silo" = 5743 Cartridges ** Does not include risk mitigation



ems 4/12/2004

FY 2004: 5 PB total, 2.7 TB/day new

- **Implications and questions:**
  - **5 PB at $4/GB = $21M for media alone**
    - **$7.9M if $1.50/GB**
  - **Media density: 7 silos per building or 27?**
  - **~130 million files (4 million files today), performance for metadata operations?**
  - **Avg. network 55 MB/s (437 Mbps) sustained (assumes retrieve traffic ~1.8 TB/day)**