IBM z Systems

z/VM Paging with SSD and Flash-Type Disk Devices

Version 2.6

Bill Bitner
IBM z/VM Development Client Focus & Care
bitnerb@us.ibm.com

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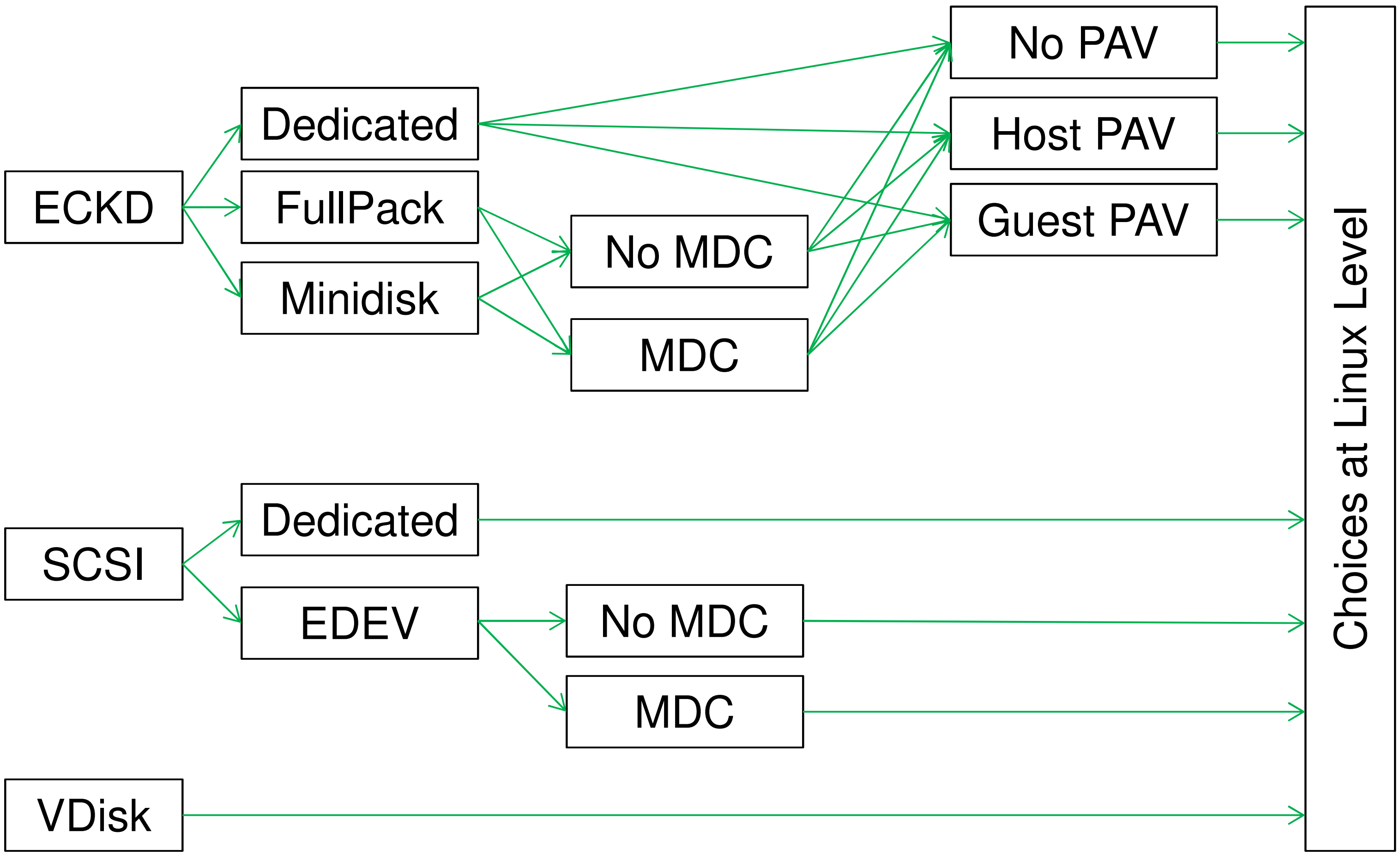
Agenda

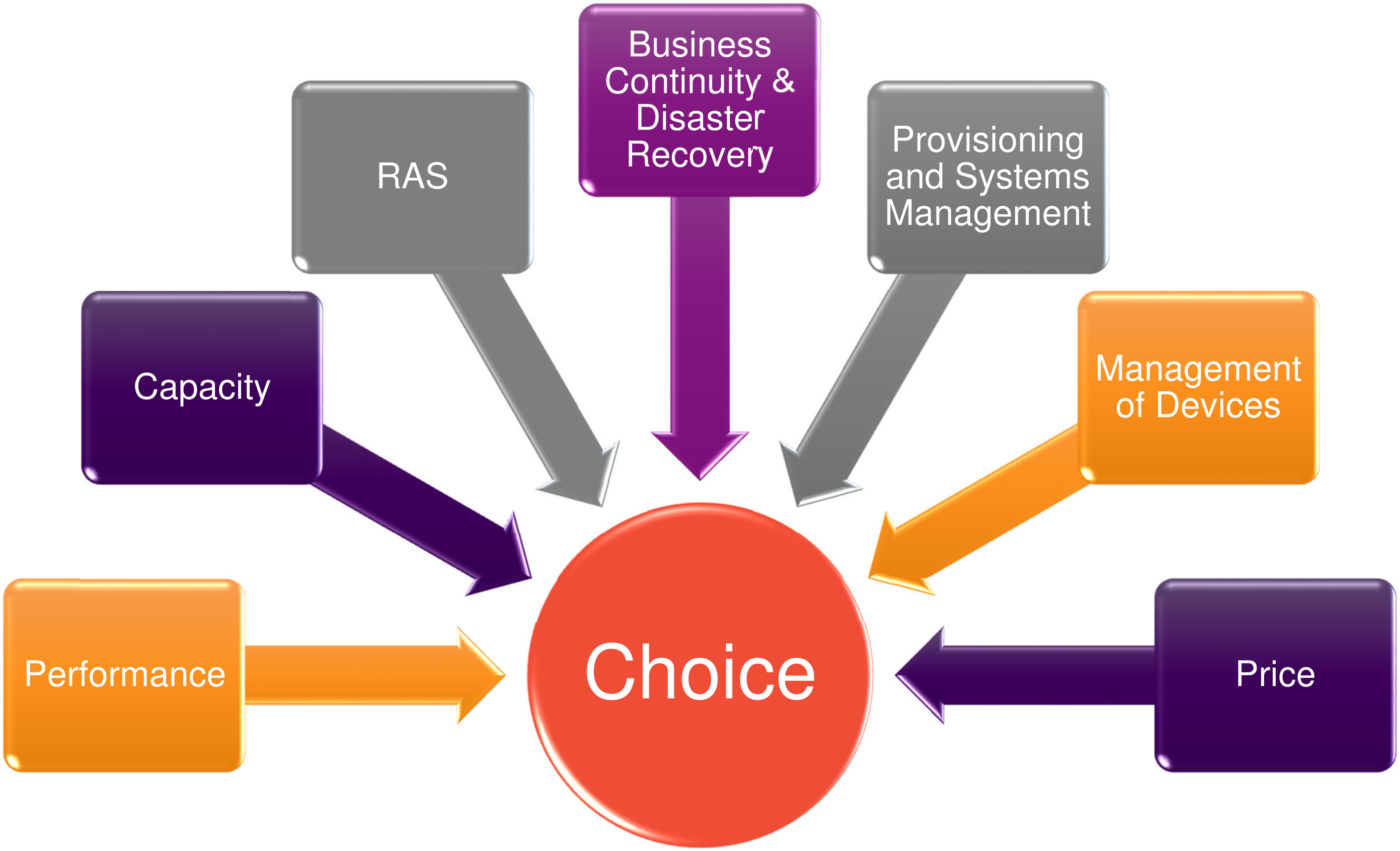
- Choosing the right disk storage
- High Performance Paging Options
- The Need for Faster Paging
- Case Study

Choosing the Right Disk Storage

So Many Choices



Look at All Attributes – Not Just One



A "loose" z/VM ECKD to SCSI Comparison

ECKD

- 1TB disk supported
  – Full volume only beyond 65520 cyl
- Flashcopy & PPRC supported from host
- Exploits HyperPAV concurrent I/O on behalf of guests, or if guest exploits
- Supported by GDPS
- Less host CPU utilization per start
- Host backup to FICON Tape
- No midrange storage option available
- Supports solid state DASD options
- Fully supported by SSI
- No concurrent code load issues
- Eliminates WWPN Management, but consumes space for Count/Keys

SCSI

- 1 TB – 4K CP LUN supported
  – Guest LUN up to hardware max
- Flashcopy & PPRC supported only from hardware interfaces
- Exploits concurrent I/O for CP paging (except XIV), or if guest exploits
- No GDPS
- High host CPU utilization per start for CP managed volumes, very low utilization for guest passthru
- No host backup to SCSI tape, but guest can backup to SCSI tape
- Supports V7000 or other midrange storage through an SVC
- Supports solid state DASD options & IBM Flash Systems (z/VM 6.4)
- SSI PDR & Install not supported
- WWPN Management Issues

A Few More Things to Think About

- Prior to z/VM 6.4, there was no HyperPAV support for z/VM system volumes (paging). So migrate to 6.4 or beyond for this support.

- Even if ECKD volumes could be infinitely large and infinitely fast, we would probably still want as many as there are logical processors for z/VM.

- FCP SCSI for z/VM Paging provides a level of parallelism but at a cost in processor time
  - Greater Bandwidth
  - Higher CPU costs

High Performance Paging Options

Flash vs. SSD and Terminology

- Purists will say “Flash” is not the equivalent of “SSD”
  - Solid State Disk – most often used to describe a device where the access is through an existing disk interface
  - Flash – access to it via direct interface to the memory

- Common Attributes:
  - Storage capacity
  - Write speed
  - Read speed
  - Active power
  - Standby power
  - Write endurance or wear-out
  - Type: NAND, NOR

Flash Express

- Flash Express Feature of zEC12 and zBC12 processors
- PCIe I/O Adapter with NAND Flash SSDs
- Accessed using Extended Asynchronous Data Mover Facility (EADMF)
- RAID 10 mirrored Pairs
- Protected with 128-bit AES encryption
- Maximum of 4 Cards provides 5.6 TB of usable storage

- Not supported by z/VM at this time. ☹

IBM FlashSystem

- IBM FlashSystem V840 - Based off technology from acquired Texas Memory System
  - Uses eMLC Flash

- FCP SCSI Only

- Prior to z/VM 6.4, to use as z/VM Paging volumes, must be behind an SAN Volume Controller (SVC)
  - Some models of FlashSystem include SVC
  - Restriction lifted with z/VM 6.4 GA November 11, 2016

- Various Features:
  - Easy Tier support
  - Compression
  - Data replication

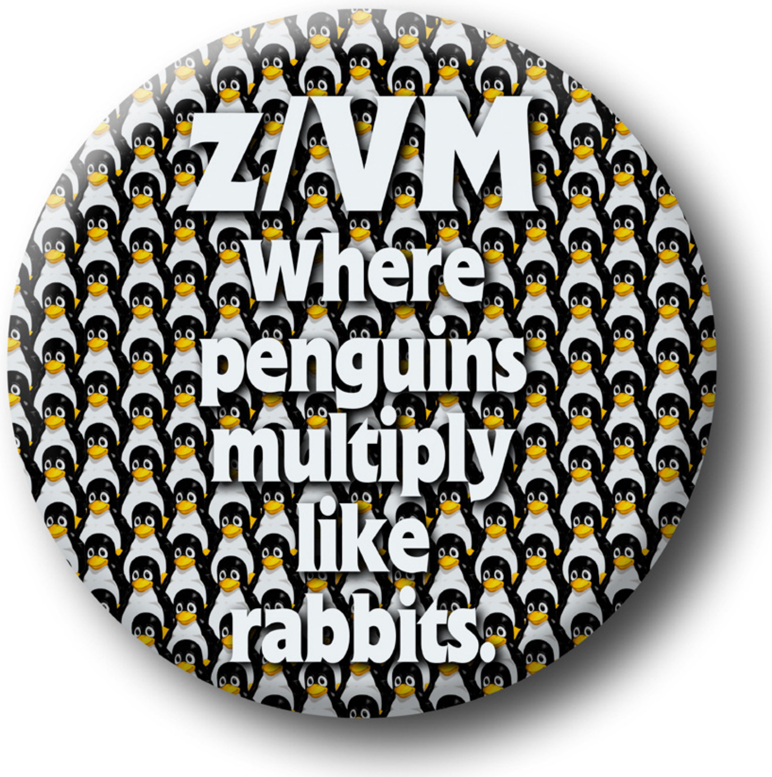
DS8870

- Part of the IBM DS8000® Series
- Can be equipped with SSD drives
- HPFE (High Performance Flash Enclosure) – Newest Option
- ECKD or FCP SCSI
- Lots of features/capabilities
  – RAID 5,6,10
  – Easy Tier
  – GDPS
  – Encryption
  – Etc.
- Maximum configuration 3072 TB

Flash also Available for Other Options

- Storwize V7000
  - Internal flash drives available
  - External IBM FlashSystem Storage
- XIV
  - Flash optimized options

The Need



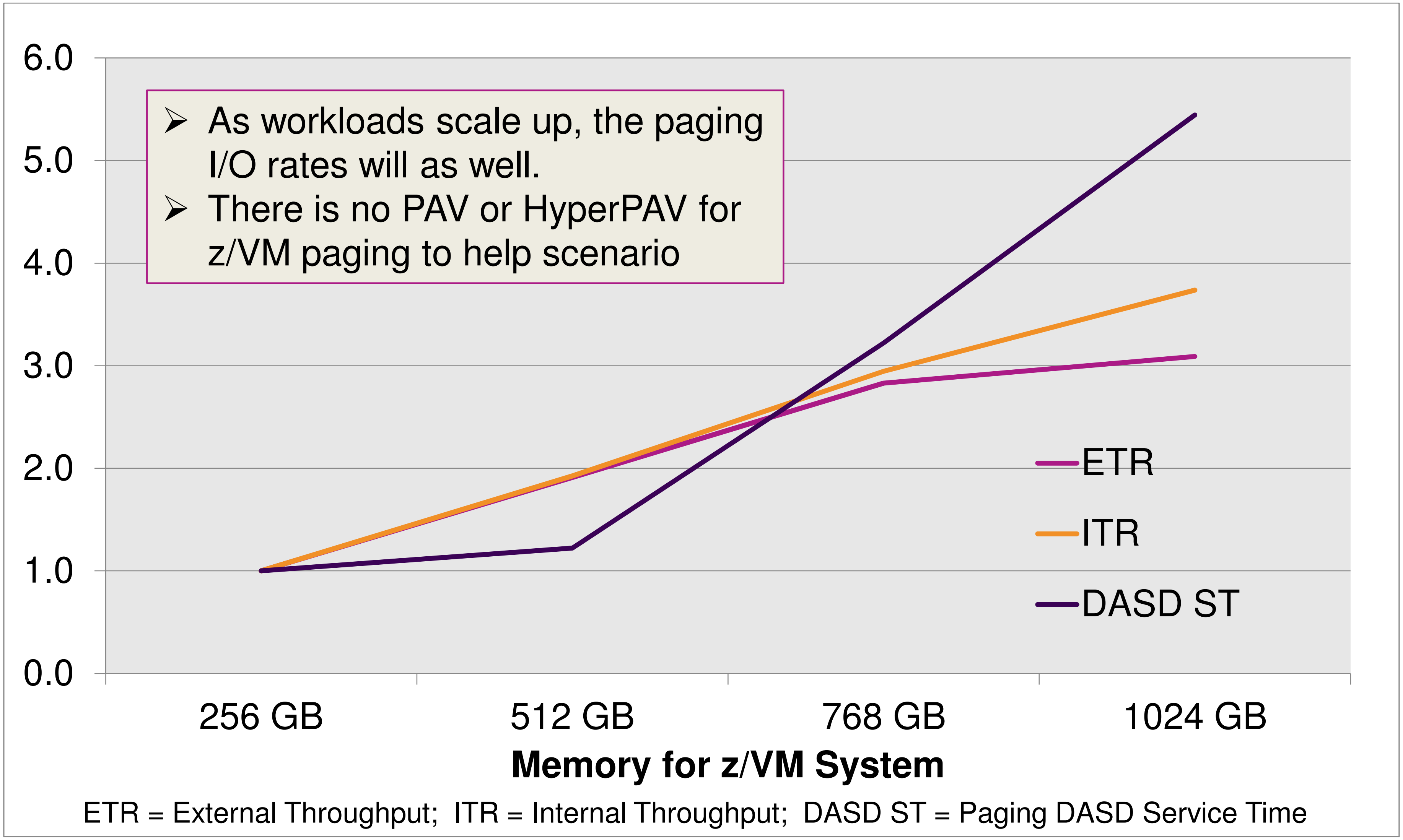
I/O Rates and Latency

- Two aspects of paging I/O
  - Overall capacity: IOPS or MB/Second
  - Performance or Latency: delay per page read

- Historically, top-end storage servers could not be saturated by z/VM Paging

- Changing History:
  - Larger amount of memory supported and page rates increasing
    - If z/VM 6.3 allows 4 times number of virtual machines, then 4 times the page rate when you add those virtual machines.
  - Elimination of scaling problems in z/VM that allow greater paging rates
  - Better determination of the actual disk paging bandwidth
    - z/VM 6.3 algorithms changed to better estimate and utilize disk paging bandwidth

Apache Workload in Scaling Overcommitted



Virtual to Real Memory Overcommitment

- One of the factors often forgotten is the performance (capacity and bandwidth) of the paging configuration.

- A 100 GB real memory system with 125 GB of active virtual memory basically means being able to constantly turn over 25 GB
  - Potentially more based on the amount of memory that is changing and resulting in page writes in addition to page reads.

- As virtual machines are delayed for paging, pages that are resident tend to be needed longer, creating more demand and potential spiral-effect.

Paging Best Practices

- All paging volumes should have the same attributes: Size, Performance, etc.
- Do not mix page space with other data types
- Do not mix FCP SCSI and ECKD paging volumes
- Be aware of any shared hardware in the path (channels, control units) and who/what is sharing them
- Follow planning guidelines for amount of space

Case Study

Customer Proof of Concept

- Customer moved paging volumes from multiple z/VM LPARs and CECs to a DS8870

- For this study, everything was placed in one Logical Control Unit (LCU)
  - This is not recommended but for part of the experiment
  - Limiting to one LCU restricted full use of DS8870 cache and processing power

- The area that came under question what happens when you IPL multiple z/VM systems and need to restart 100s and 100s of virtual machines?

Key Observations

- Performance of DS8870 is a significant improvement over spinning disk.

- No single number can really portray that performance

- Factors that will be examined:
  - Peaks across different LPARs
  - Data per I/O
  - Read / Write Ratio

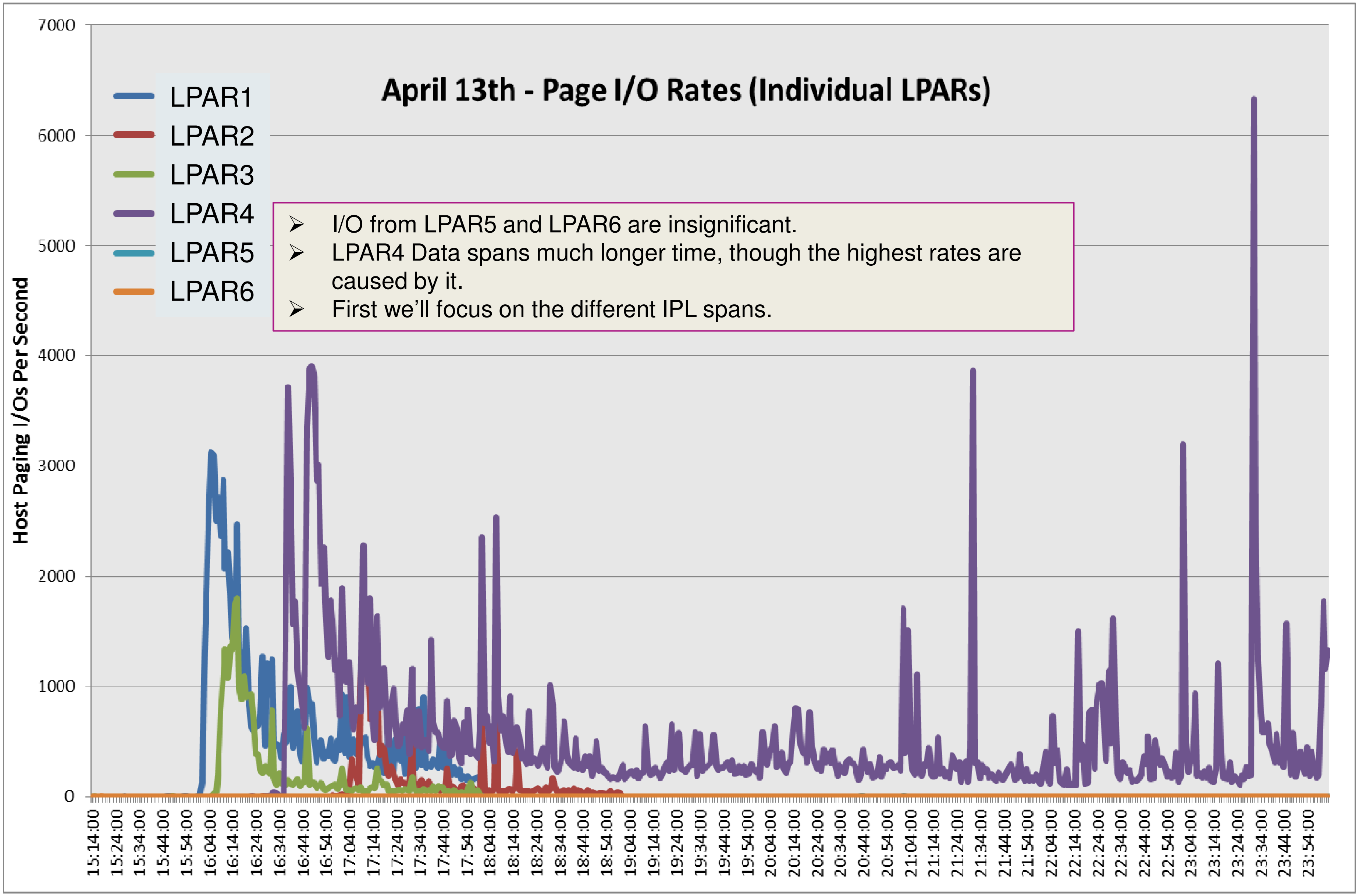
- Study will explore the data in the different dimensions above

- Brief comparison to the non SSD storage servers

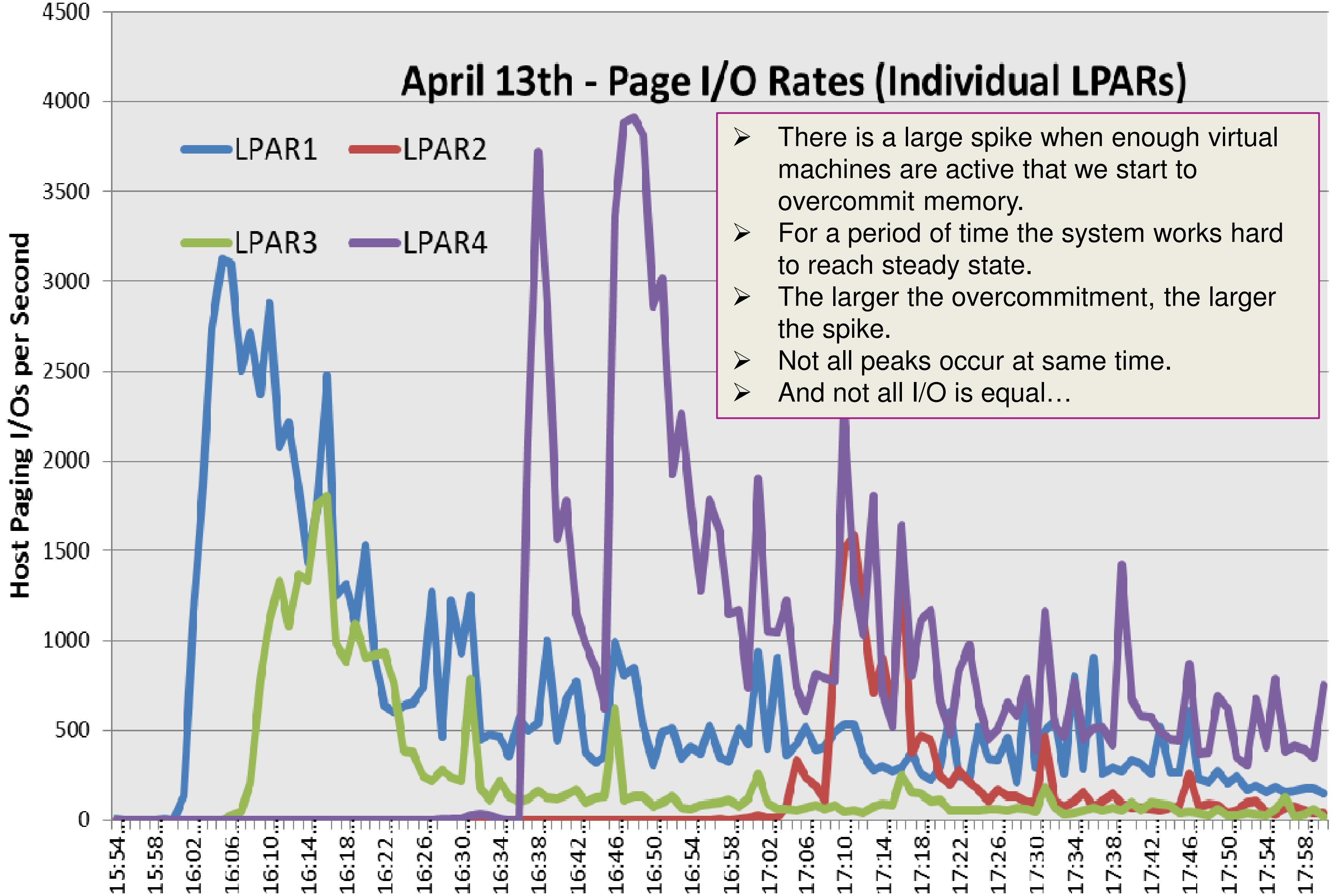
Summary of Systems from April 13th Data

LPAR	z/VM	Page Vols	Memory Virt:Real	IPL Time	Peak Page Rate	Peak Page Time
LPAR1	6.3.0	43	2.36	15:11:14	73690	16:04:00
LPAR2	6.3.0	41	2.34	15:51:33	39865	17:10:00
LPAR3	6.3.0	29	1.76	15:11:30	39800	16:16:00
LPAR4	6.3.0	49	2.48	15:41:23	93229	16:38:00
LPAR5	6.3.0	27	2.36	15:11:34	170	21:01:00
LPAR6	6.3.0	10	0.87	15:11:10	30	15:26:00

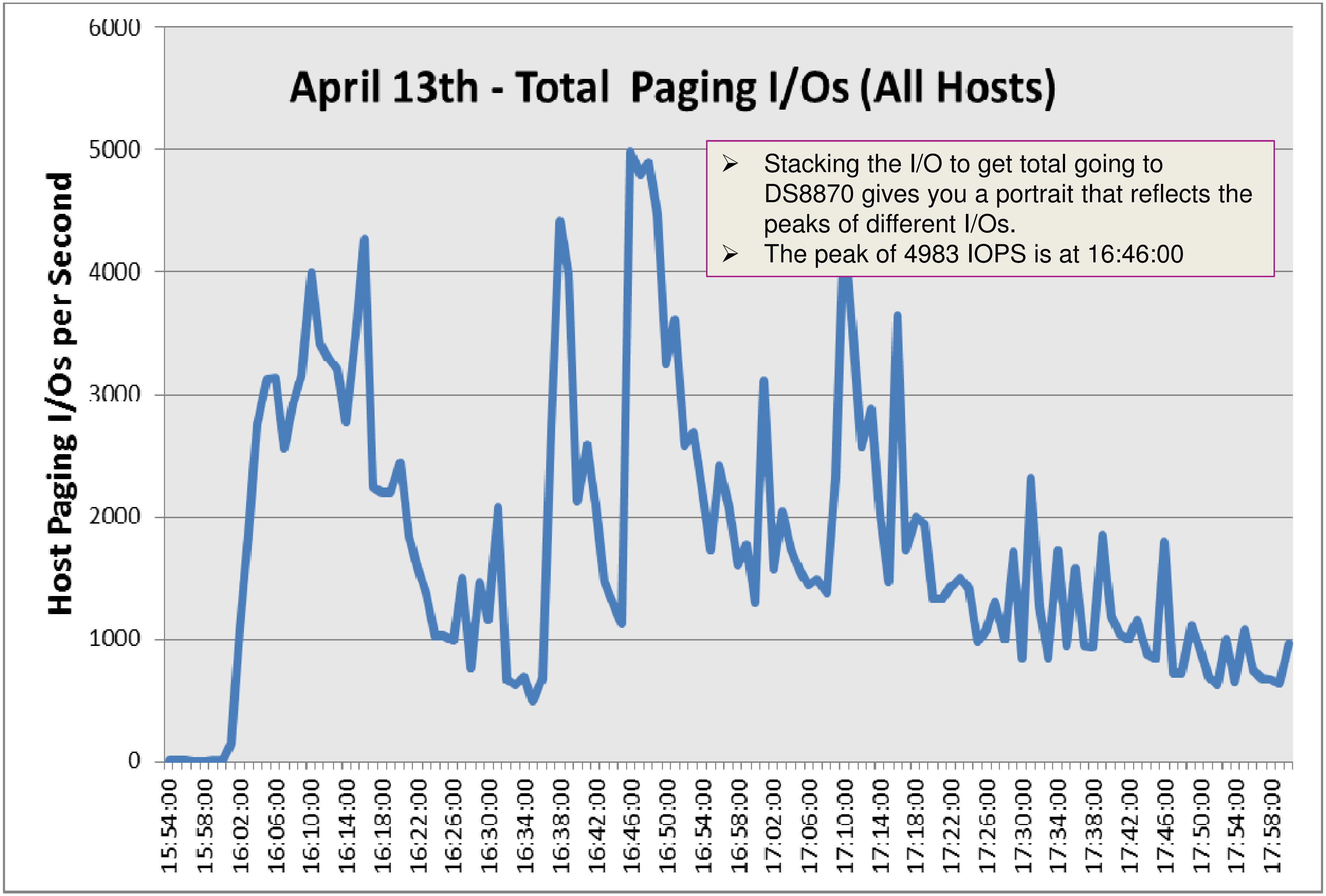
- Peak Page Rate: 4KB Pages/Second, includes read and write
- IPL Time: Time at which z/VM system was IPLed, not necessarily when all virtual machines were brought online.
- LPAR5 and LPAR6 are boring, from a performance perspective.

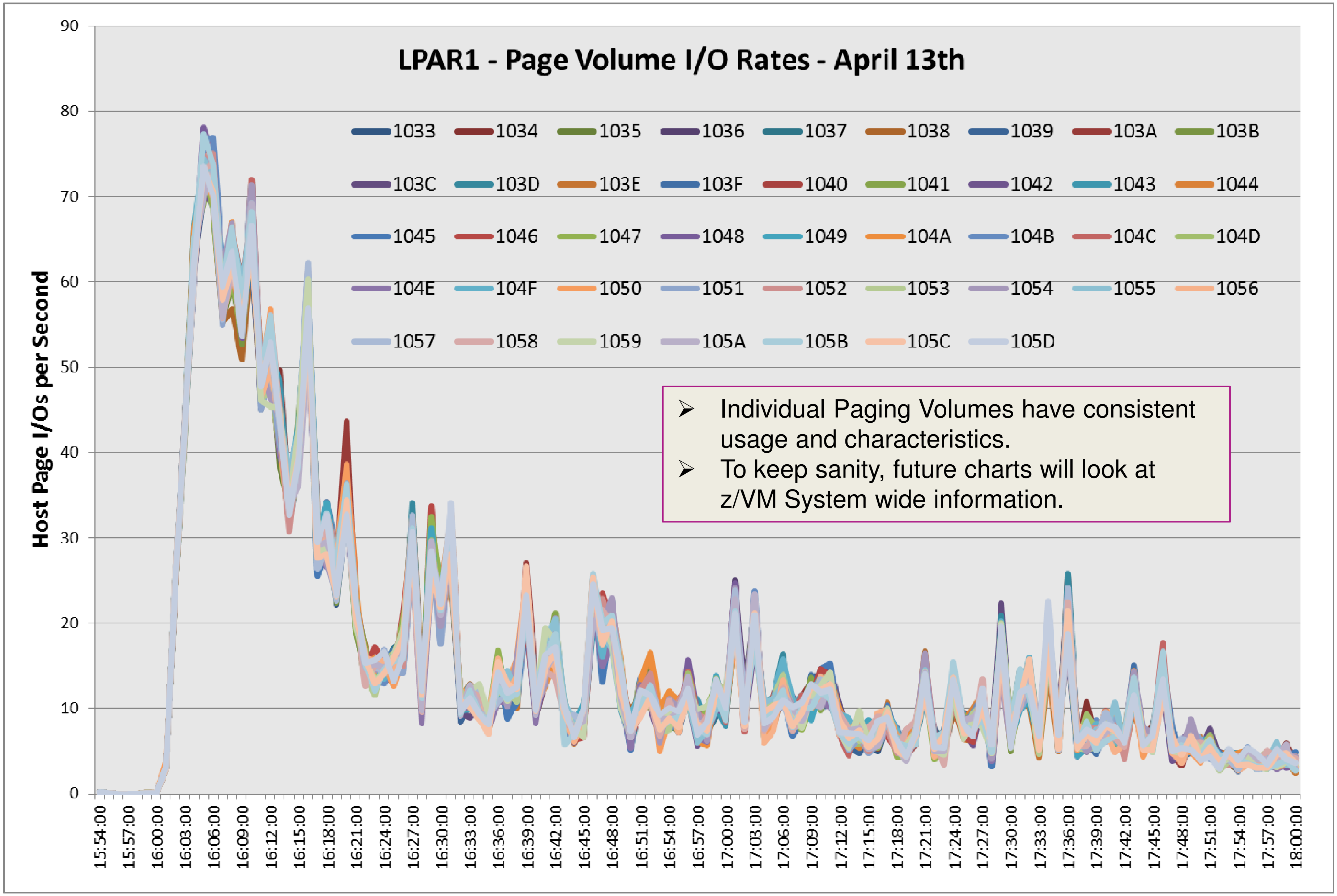


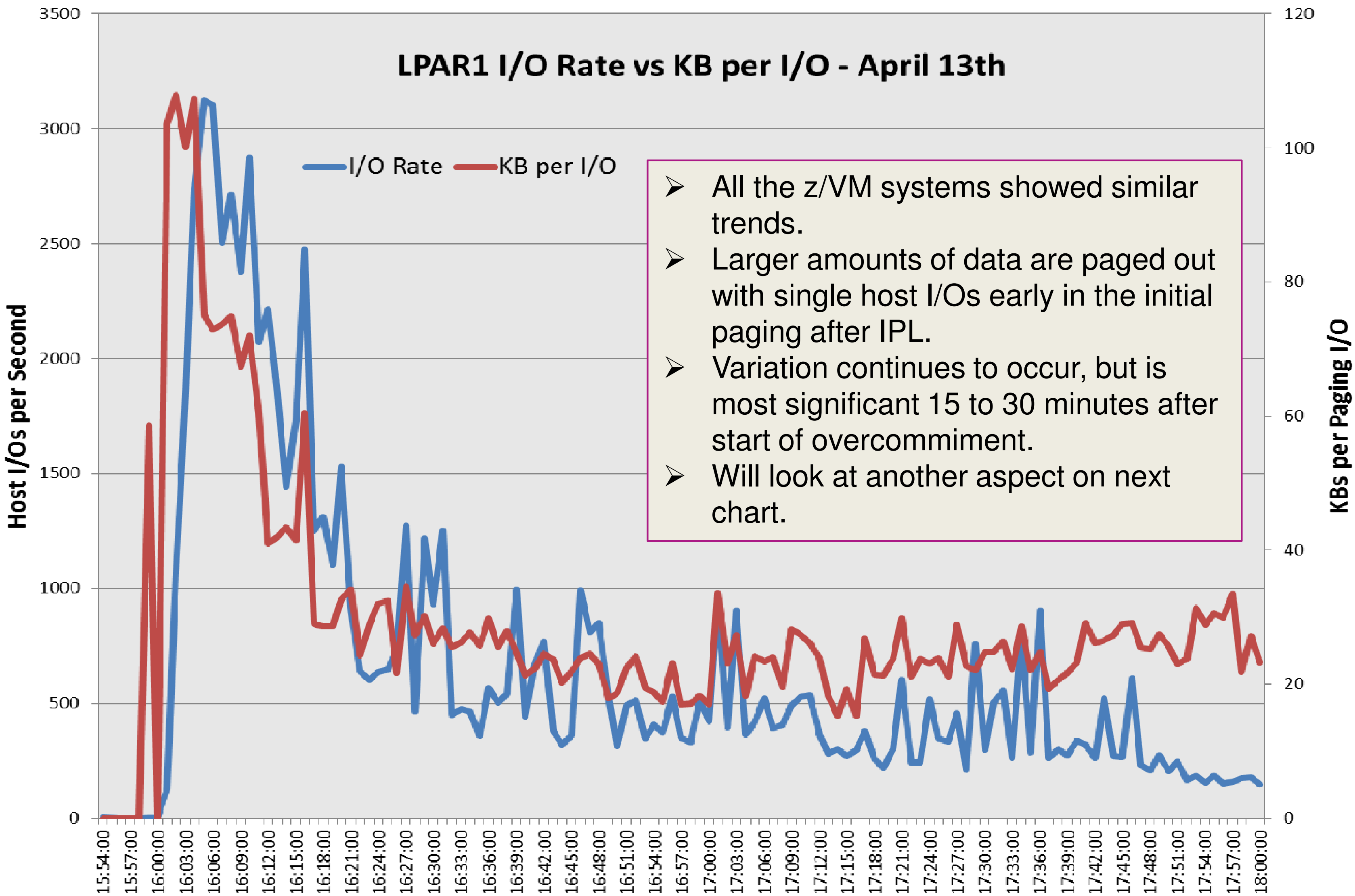
- I/O from LPAR5 and LPAR6 are insignificant.
- LPAR4 Data spans much longer time, though the highest rates are caused by it.
- First we'll focus on the different IPL spans.



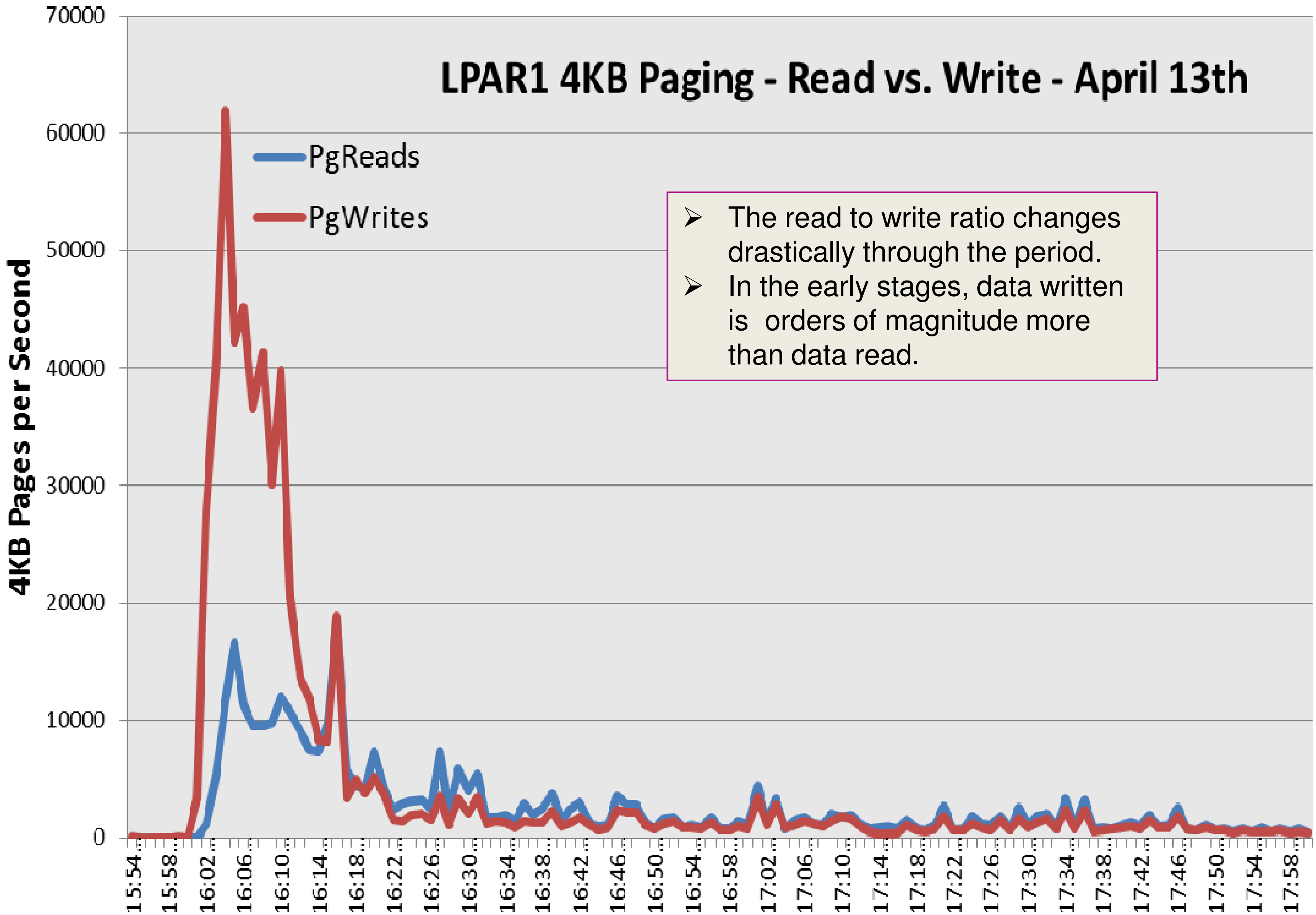
- There is a large spike when enough virtual machines are active that we start to overcommit memory.
- For a period of time the system works hard to reach steady state.
- The larger the overcommitment, the larger the spike.
- Not all peaks occur at same time.
- And not all I/O is equal…


April 13th - Total Paging I/Os (All Hosts)
Host Paging I/Os per Second
6000
5000
4000
3000
2000
1000
0
Stacking the I/O to get total going to DS8870 gives you a portrait that reflects the peaks of different I/Os.
The peak of 4983 IOPS is at 16:46:00
15:54:00
15:58:00
16:02:00
16:06:00
16:10:00
16:14:00
16:18:00
16:22:00
16:26:00
16:30:00
16:34:00
16:38:00
16:42:00
16:46:00
16:50:00
16:54:00
16:58:00
17:02:00
17:06:00
17:10:00
17:14:00
17:18:00
17:22:00
17:26:00
17:30:00
17:34:00
17:38:00
17:42:00
17:46:00
17:50:00
17:54:00
17:58:00

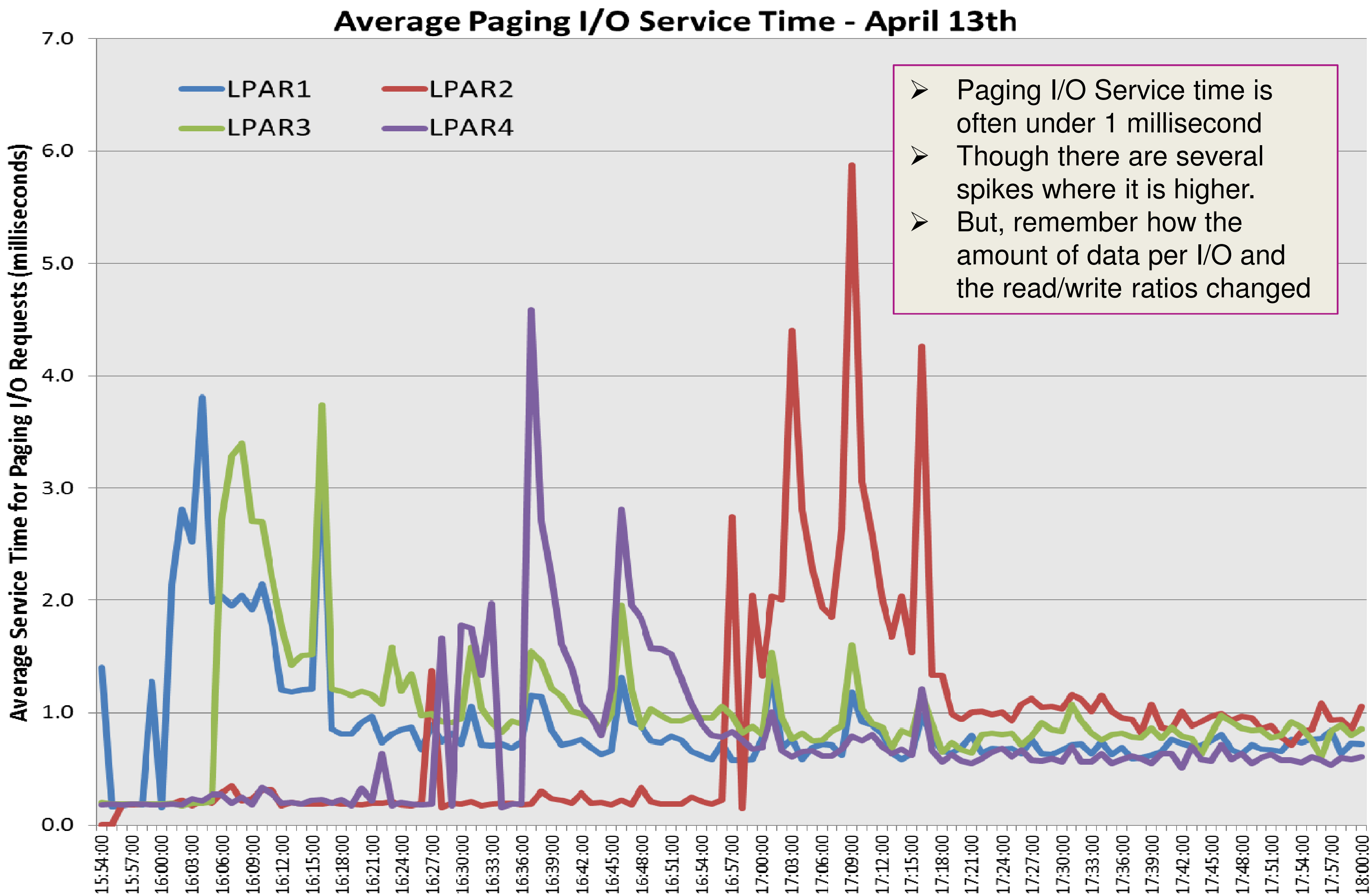

LPAR1 - Page Volume I/O Rates - April 13th
Host Page I/Os per Second
1033 1034 1035 1036 1037 1038 1039 103A 103B
103C 103D 103E 103F 1040 1041 1042 1043 1044
1045 1046 1047 1048 1049 104A 104B 104C 104D
104E 104F 1050 1051 1052 1053 1054 1055 1056
1057 1058 1059 105A 105B 105C 105D
0 10 20 30 40 50 60 70 80 90
15:54:00 15:57:00 16:00:00 16:03:00 16:06:00 16:09:00 16:12:00 16:15:00 16:18:00 16:21:00 16:24:00 16:27:00 16:30:00 16:33:00 16:36:00 16:39:00 16:42:00 16:45:00 16:48:00 16:51:00 16:54:00 16:57:00 17:00:00 17:03:00 17:06:00 17:09:00 17:12:00 17:15:00 17:18:00 17:21:00 17:24:00 17:27:00 17:30:00 17:33:00 17:36:00 17:39:00 17:42:00 17:45:00 17:48:00 17:51:00 17:54:00 17:57:00 18:00:00
Individual Paging Volumes have consistent usage and characteristics.
To keep sanity, future charts will look at z/VM System wide information.



- ➢ All the z/VM systems showed similar trends.
- ➢ Larger amounts of data are paged out with single host I/Os early in the initial paging after IPL.
- ➢ Variation continues to occur, but is most significant 15 to 30 minutes after start of overcommiment.
- ➢ Will look at another aspect on next chart.

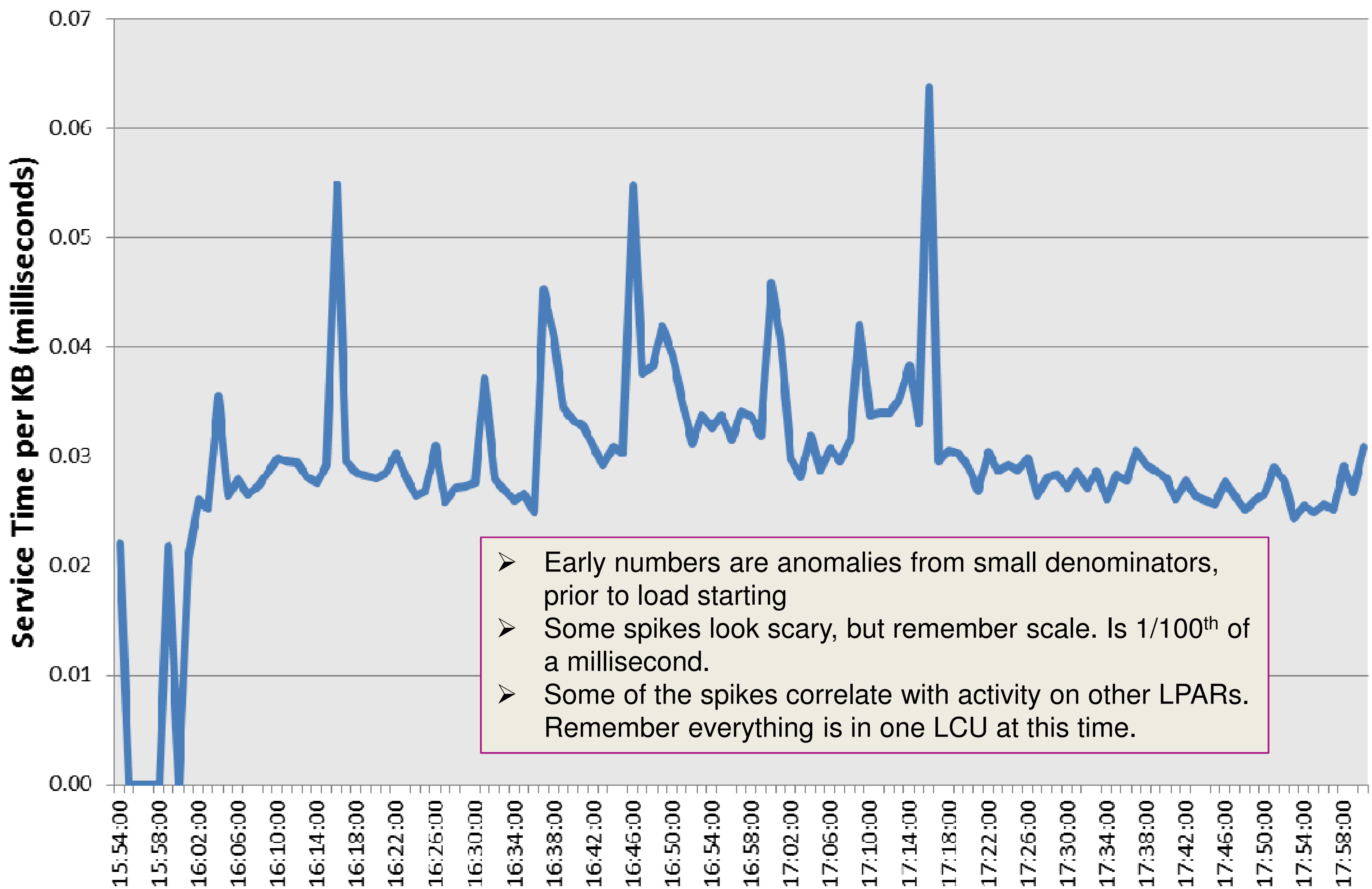


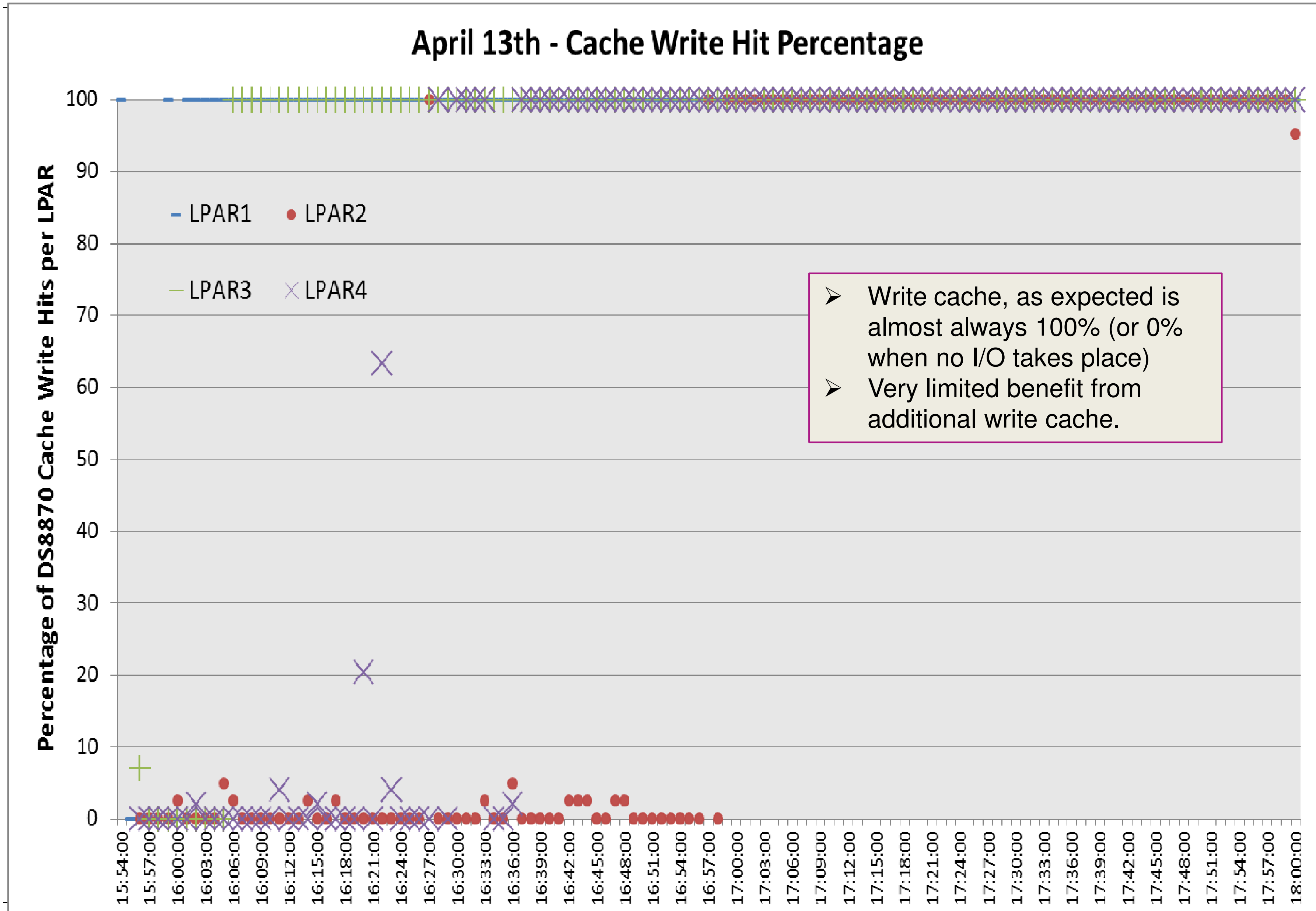
- The read to write ratio changes drastically through the period.
- In the early stages, data written is orders of magnitude more than data read.



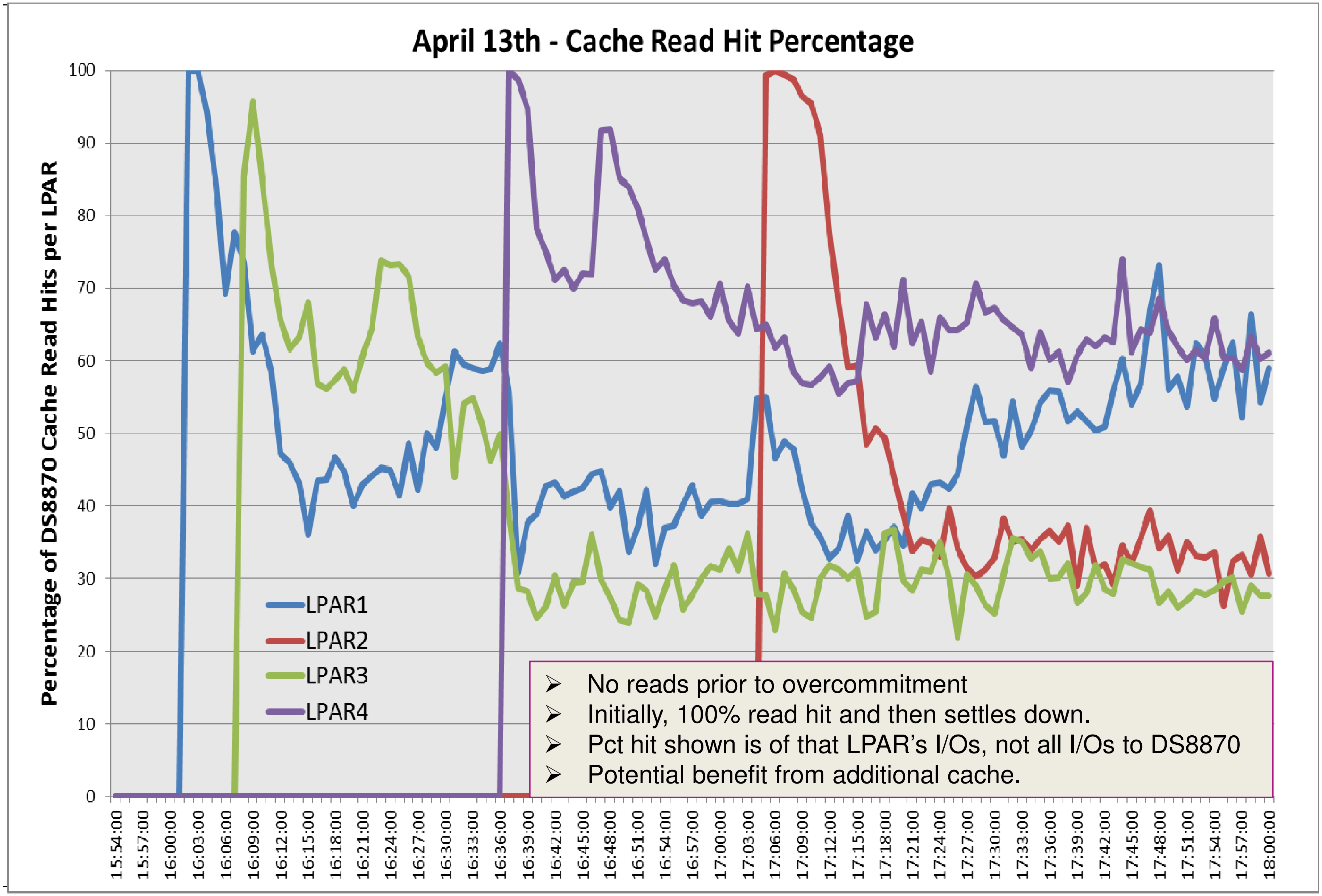
- Paging I/O Service time is often under 1 millisecond
- Though there are several spikes where it is higher.
- But, remember how the amount of data per I/O and the read/write ratios changed

LPAR1- Service Time per KB - April 13th





- Write cache, as expected is almost always 100% (or 0% when no I/O takes place)
- Very limited benefit from additional write cache.

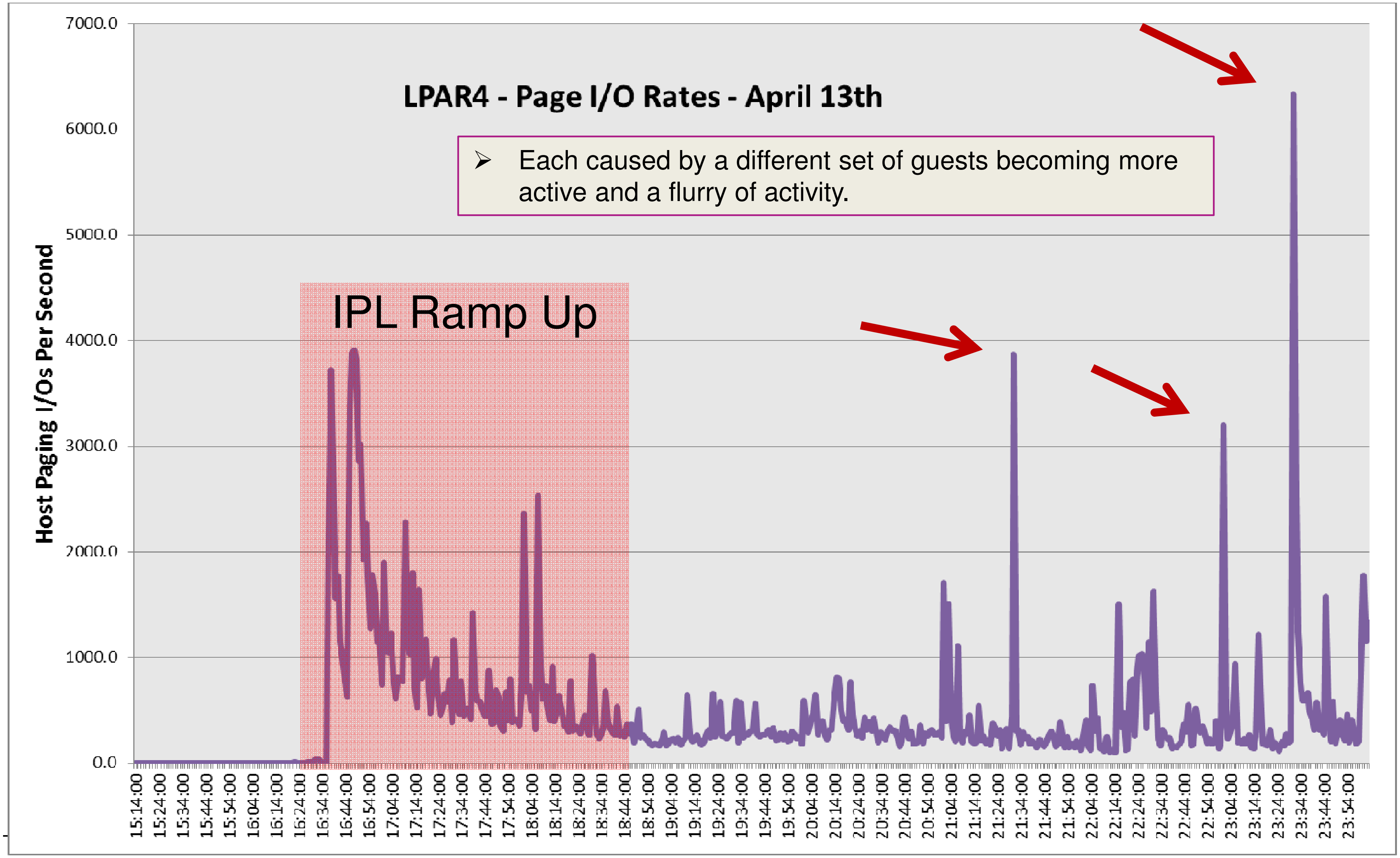

April 13th - Cache Read Hit Percentage
Percentage of DS8870 Cache Read Hits per LPAR
100
90
80
70
60
50
40
30
20
10
0
LPAR1
LPAR2
LPAR3
LPAR4
15:54:00 15:57:00 16:00:00 16:03:00 16:06:00 16:09:00 16:12:00 16:15:00 16:18:00 16:21:00 16:24:00 16:27:00 16:30:00 16:33:00 16:36:00 16:39:00 16:42:00 16:45:00 16:48:00 16:51:00 16:54:00 16:57:00 17:00:00 17:03:00 17:06:00 17:09:00 17:12:00 17:15:00 17:18:00 17:21:00 17:24:00 17:27:00 17:30:00 17:33:00 17:36:00 17:39:00 17:42:00 17:45:00 17:48:00 17:51:00 17:54:00 17:57:00 18:00:00
➢ No reads prior to overcommitment
➢ Initially, 100% read hit and then settles down.
➢ Pct hit shown is of that LPAR’s I/Os, not all I/Os to DS8870
➢ Potential benefit from additional cache.

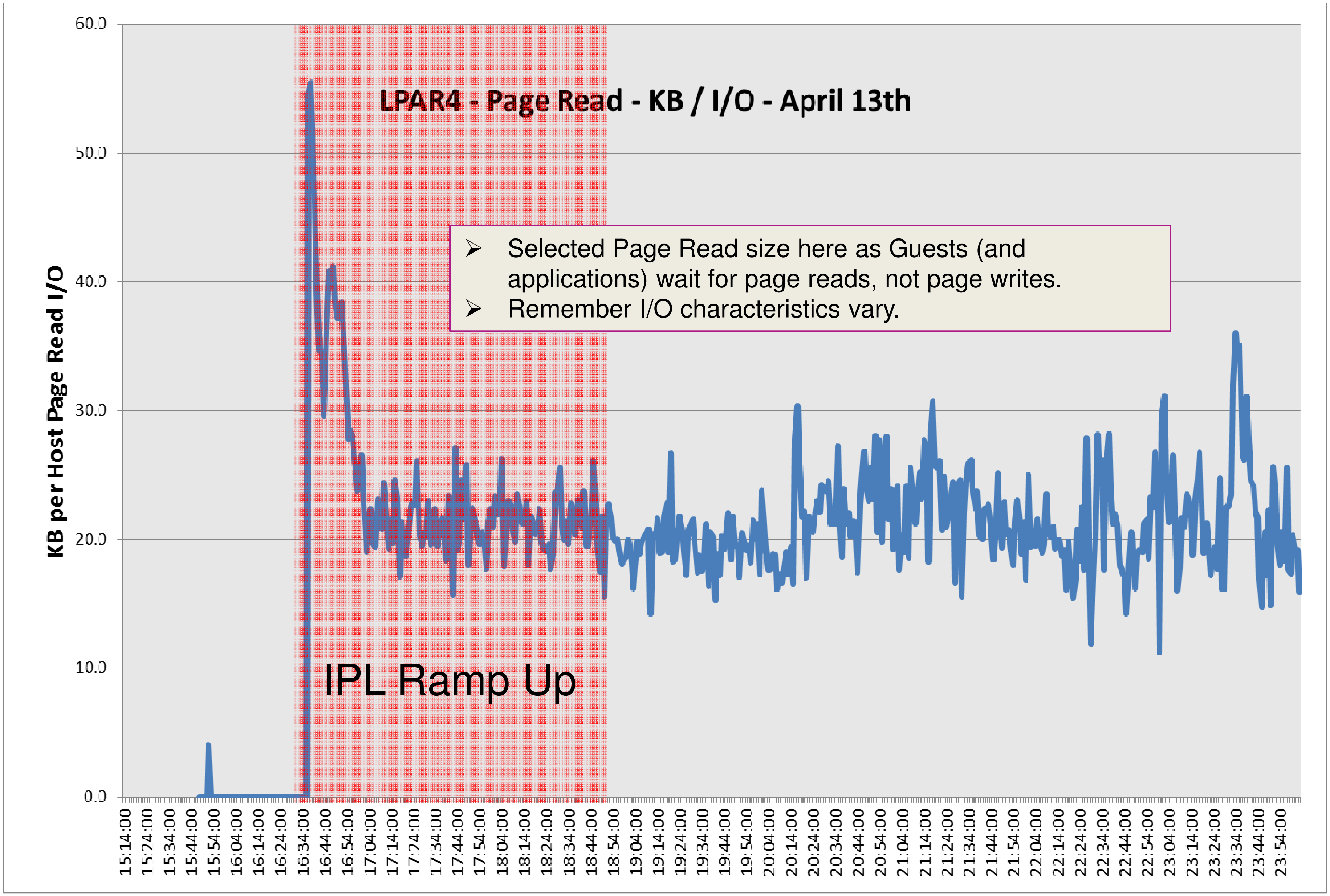
Does the new DS8870 Make a Difference?

- Yes!
- How much is always hard to quantify without perfectly controlled environment.
- A few items from LPAR1 (Remember not apples to apples)
  - Shutdown processing is as "interesting" as IPL processing

Metric	w/o DS8870	w/ DS8870	Difference
Mload (z/VM Measurement of Paging Subsystem Performance)	36.8	3.7	-90%
Average Queue Length of Paging Volumes	12.9	0.44	-97%
Average %PGW from State Sampling	6%	0%	-100%
Average Service Time on Paging Volumes (milliseconds)	17.4	0.21	-99%

Remember Other Spikes on LPAR4?




LPAR4 - Page Read - KB / I/O - April 13th
KB per Host Page Read I/O
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Selected Page Read size here as Guests (and applications) wait for page reads, not page writes.
Remember I/O characteristics vary.
IPL Ramp Up
15:14:00
15:24:00
15:34:00
15:44:00
15:54:00
16:04:00
16:14:00
16:24:00
16:34:00
16:44:00
16:54:00
17:04:00
17:14:00
17:24:00
17:34:00
17:44:00
17:54:00
18:04:00
18:14:00
18:24:00
18:34:00
18:44:00
18:54:00
19:04:00
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21:44:00
21:54:00
22:04:00
22:14:00
22:24:00
22:34:00
22:44:00
22:54:00
23:04:00
23:14:00
23:24:00
23:34:00
23:44:00
23:54:00

Perfect Storms

- The z/VM systems are started at different offsets, but spent some time looking at what would happen if they did align.

- It would be significantly more activity, still containable, but I would recommend holding to the staggered start.

Metric	Actual Peak	Perfect Storm
Host Page I/Os	4983/second	11,963/second
Paging MB/second	385 MB/Second	963 MB/Second

Summary

- DS8870 with SSD is providing much better I/O performance characteristics compared to spinning disk.
  - Bonus benefit in Processor resource savings
- The process of restarting 100s of Linux guests impacts paging performance significantly, though the characteristics can be different from high paging rates after the system has stabilized.
- Need to continue to track I/O operations and data rates, as well as the normal performance metrics:
  - Page wait
  - Asynchronous Page wait
  - Available List management
- The need for higher IOPS and bandwidth can be important to z/VM
  - Other limits eliminated
  - Higher consolidation workloads

QUESTIONS & DISCUSSION