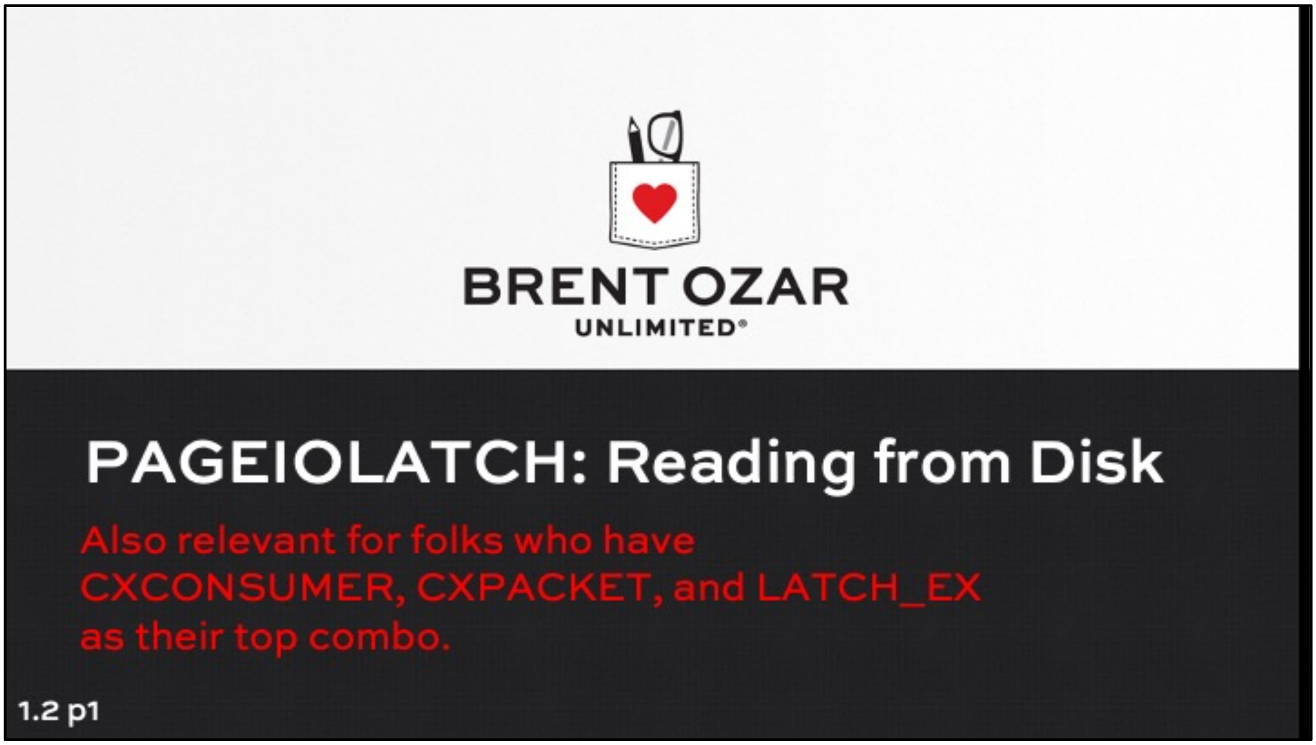
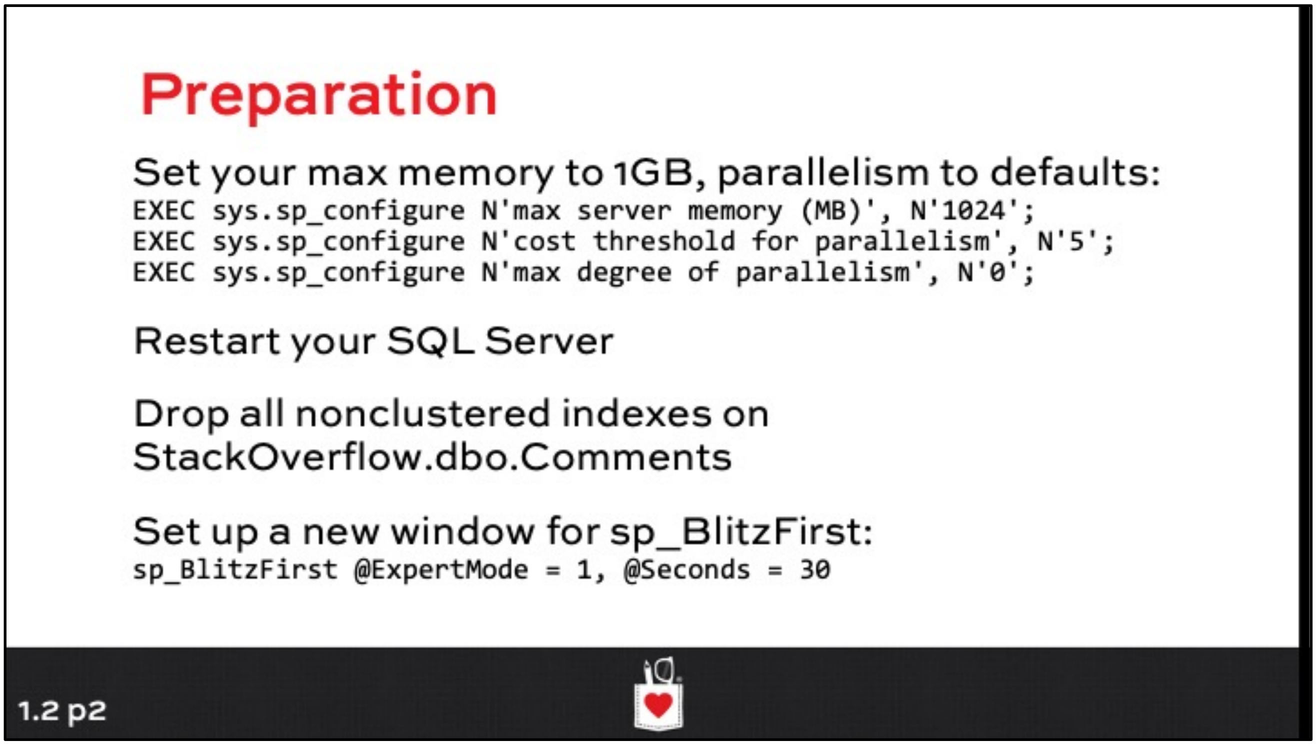


BRENT OZAR
UNLIMITED®

PAGEIOLATCH: Reading from Disk

Also relevant for folks who have
CXCONSUMER, CXPACKET, and LATCH_EX
as their top combo.

1.2 p1



Preparation

Set your max memory to 1GB, parallelism to defaults:

```
EXEC sys.sp_configure N'max server memory (MB)', N'1024';
EXEC sys.sp_configure N'cost threshold for parallelism', N'5';
EXEC sys.sp_configure N'max degree of parallelism', N'0';
```

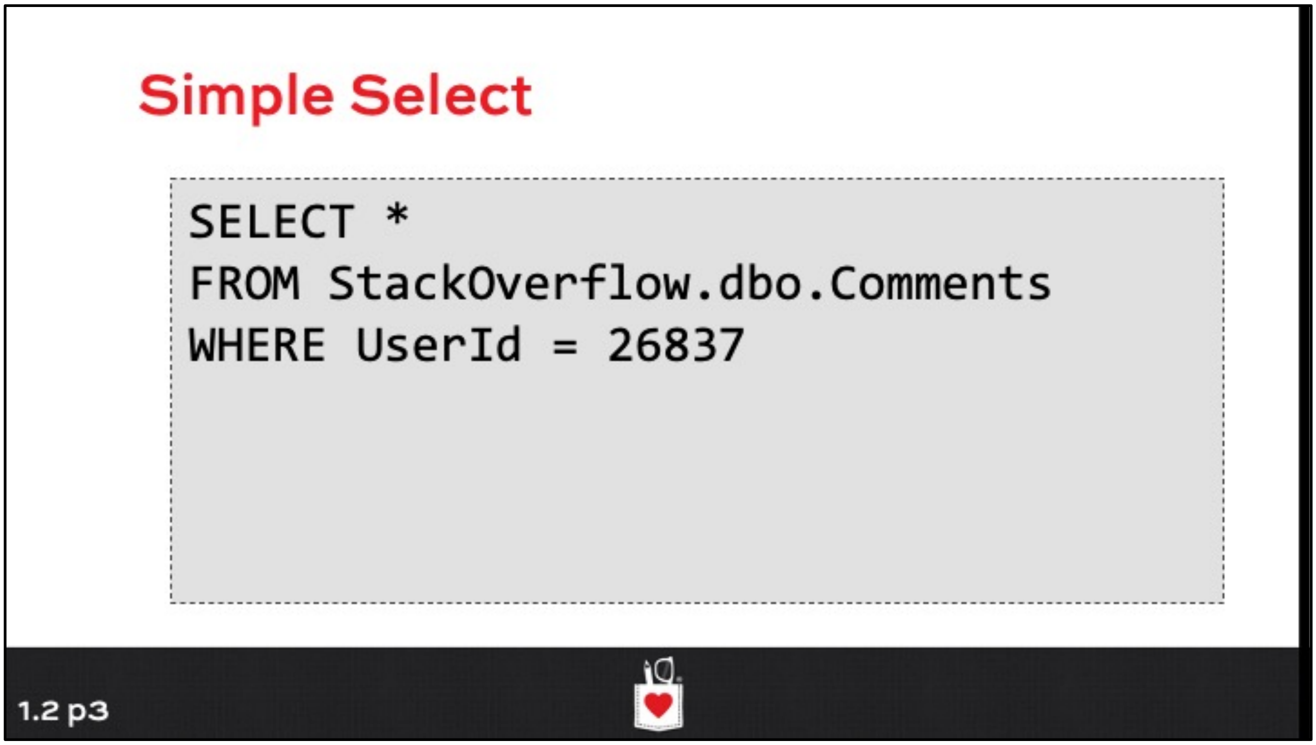
Restart your SQL Server

Drop all nonclustered indexes on StackOverflow.dbo.Comments

Set up a new window for sp_BlitzFirst:

```
sp_BlitzFirst @ExpertMode = 1, @Seconds = 30
```

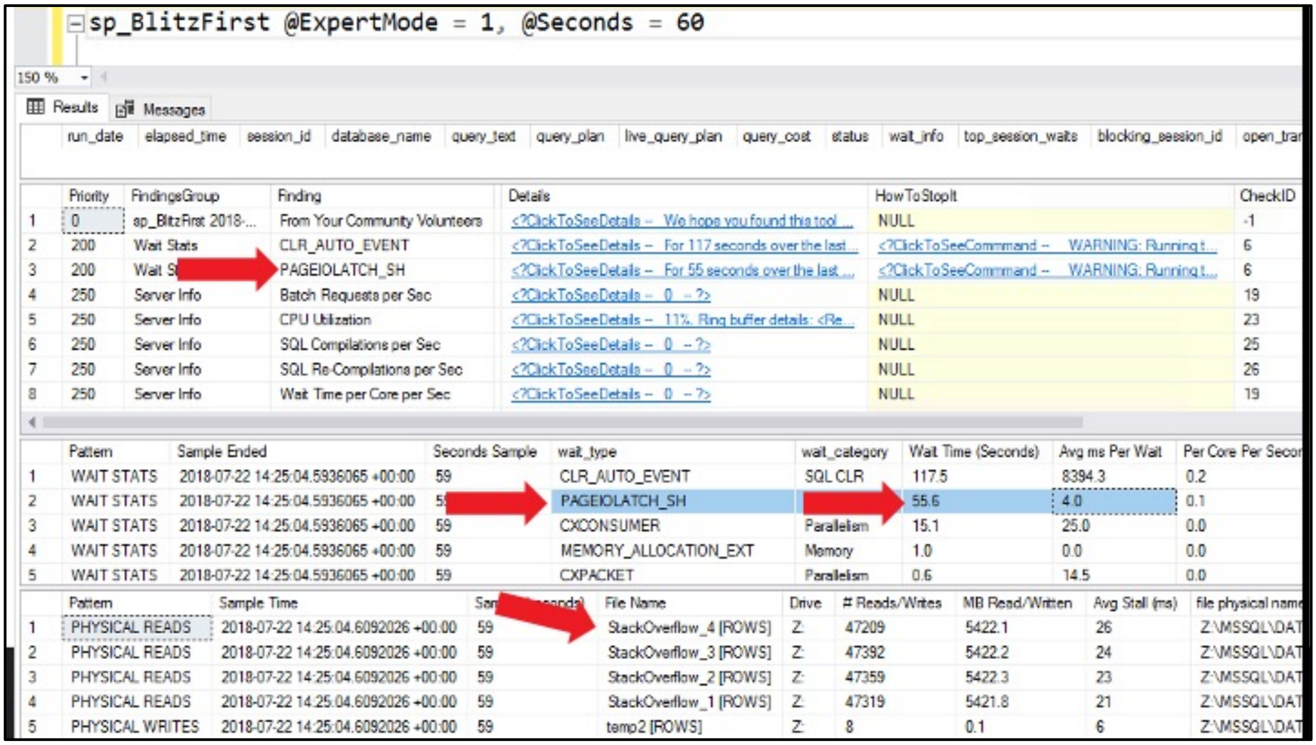
1.2 p2



Simple Select

```
SELECT *
FROM StackOverflow.dbo.Comments
WHERE UserId = 26837
```

1.2 p3



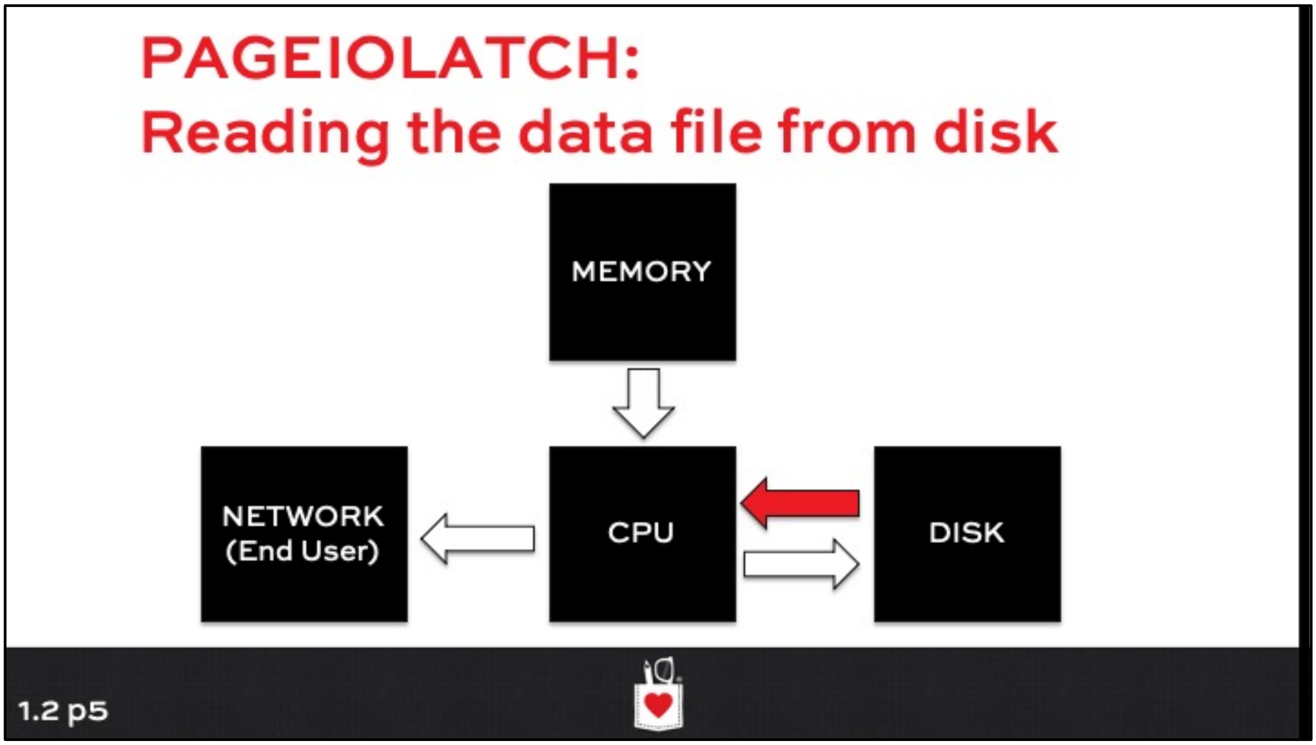
```
sp_BlitzFirst @ExpertMode = 1, @Seconds = 60
```

	run_date	elapsed_time	session_id	database_name	query_text	query_plan	live_query_plan	query_cost	status	wait_info	top_session_waits	blocking_session_id	open_tran

	Priority	FindingsGroup	Finding	Details	HowToStopIt	CheckID
1	0	sp_BlitzFirst 2018-...	From Your Community Volunteers	<?ClickToSeeDetails -- We hope you found this tool ...	NULL	-1
2	200	Wait Stats	CLR_AUTO_EVENT	<?ClickToSeeDetails -- For 117 seconds over the last ...	<?ClickToSeeCommmand -- WARNING: Running t...	6
3	200	Wait S	PAGEIOLATCH_SH	<?ClickToSeeDetails -- For 55 seconds over the last ...	<?ClickToSeeCommmand -- WARNING: Running t...	6
4	250	Server Info	Batch Requests per Sec	<?ClickToSeeDetails -- 0 -- ?>	NULL	19
5	250	Server Info	CPU Utilization	<?ClickToSeeDetails -- 11%. Ring buffer details: <Re...	NULL	23
6	250	Server Info	SQL Compilations per Sec	<?ClickToSeeDetails -- 0 -- ?>	NULL	25
7	250	Server Info	SQL Re-Compilations per Sec	<?ClickToSeeDetails -- 0 -- ?>	NULL	26
8	250	Server Info	Wait Time per Core per Sec	<?ClickToSeeDetails -- 0 -- ?>	NULL	19

	Pattern	Sample Ended	Seconds Sample	wait_type	wait_category	Wait Time (Seconds)	Avg ms Per Wait	Per Core Per Secon
1	WAIT STATS	2018-07-22 14:25:04.5936065 +00:00	59	CLR_AUTO_EVENT	SQL CLR	117.5	8394.3	0.2
2	WAIT STATS	2018-07-22 14:25:04.5936065 +00:00	5	PAGEIOLATCH_SH		55.6	4.0	0.1
3	WAIT STATS	2018-07-22 14:25:04.5936065 +00:00	59	CXCONSUMER	Parallelism	15.1	25.0	0.0
4	WAIT STATS	2018-07-22 14:25:04.5936065 +00:00	59	MEMORY_ALLOCATION_EXT	Memory	1.0	0.0	0.0
5	WAIT STATS	2018-07-22 14:25:04.5936065 +00:00	59	CXPACKET	Parallelism	0.6	14.5	0.0

	Pattern	Sample Time	Sam	File Name	Drive	# Reads/Writes	MB Read/Written	Avg Stall (ms)	file physical name
1	PHYSICAL READS	2018-07-22 14:25:04.6092026 +00:00	59	StackOverflow_4 [ROWS]	Z:	47209	5422.1	26	Z:\MSSQL\DAT
2	PHYSICAL READS	2018-07-22 14:25:04.6092026 +00:00	59	StackOverflow_3 [ROWS]	Z:	47392	5422.2	24	Z:\MSSQL\DAT
3	PHYSICAL READS	2018-07-22 14:25:04.6092026 +00:00	59	StackOverflow_2 [ROWS]	Z:	47359	5422.3	23	Z:\MSSQL\DAT
4	PHYSICAL READS	2018-07-22 14:25:04.6092026 +00:00	59	StackOverflow_1 [ROWS]	Z:	47319	5421.8	21	Z:\MSSQL\DAT
5	PHYSICAL WRITES	2018-07-22 14:25:04.6092026 +00:00	59	temp2 [ROWS]	Z:	8	0.1	6	Z:\MSSQL\DAT



PAGEIOLATCH:
Reading the data file from disk

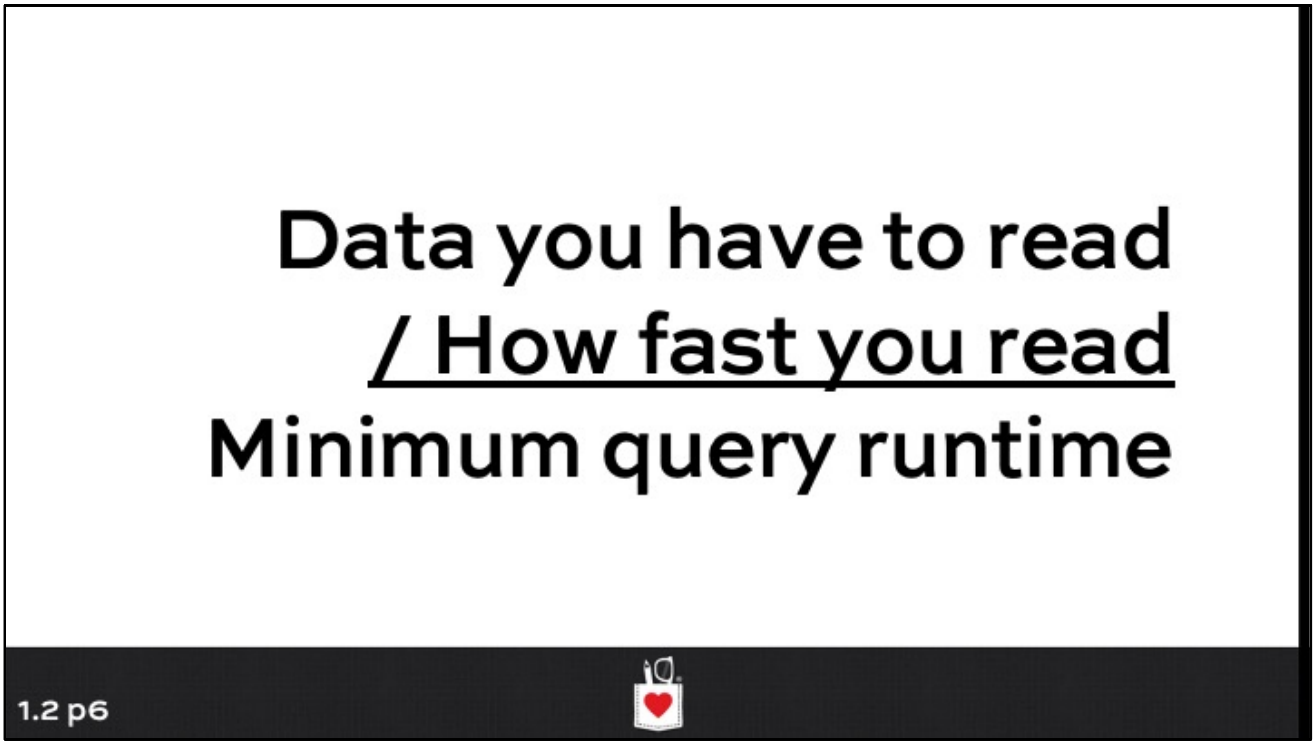
MEMORY

NETWORK
(End User)

CPU

DISK

1.2 p5



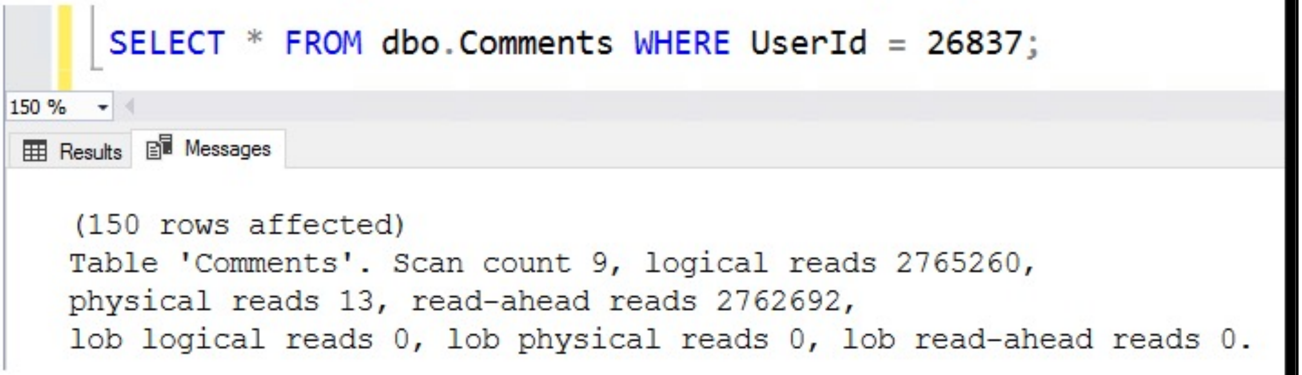
Data you have to read

/ How fast you read

Minimum query runtime

1.2 p6

Reading millions of 8KB pages

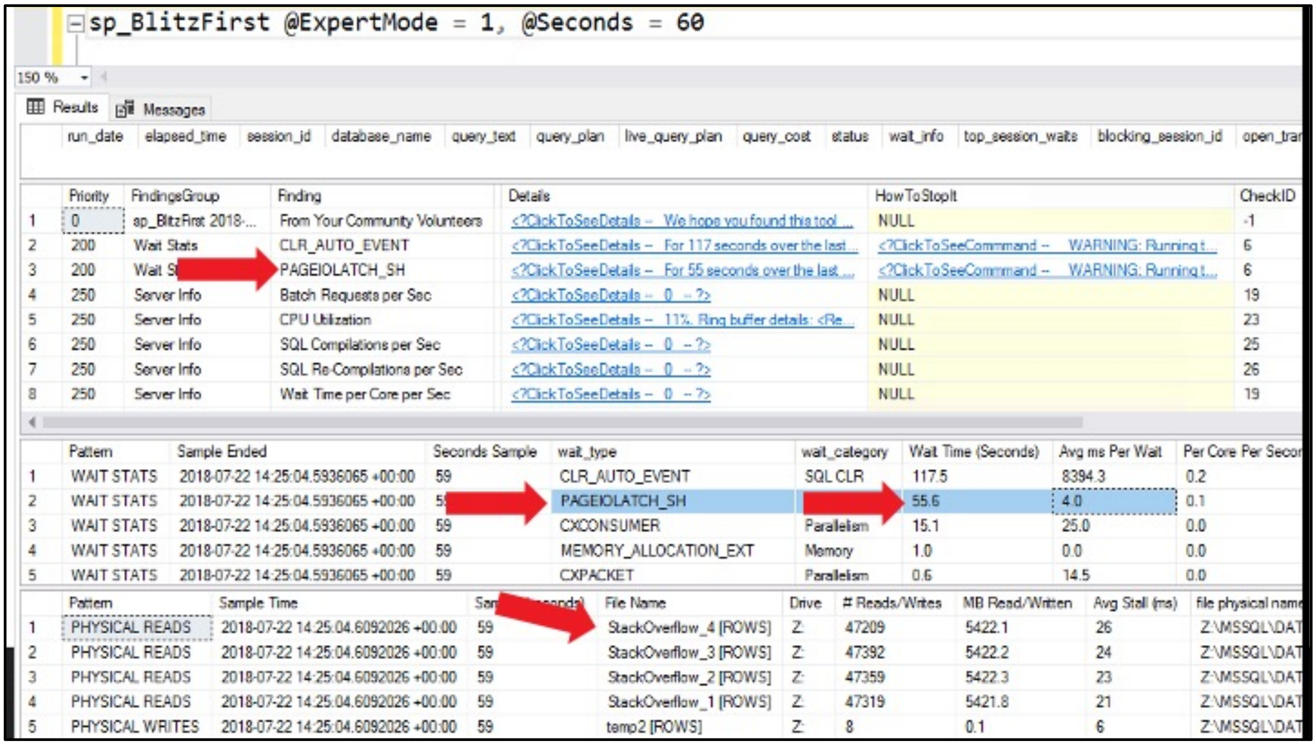


```
SELECT * FROM dbo.Comments WHERE UserId = 26837;
```

```
(150 rows affected)
Table 'Comments'. Scan count 9, logical reads 2765260,
physical reads 13, read-ahead reads 2762692,
lob logical reads 0, lob physical reads 0, lob read-ahead reads 0.
```

2,765,260 pages * 8KB each / 1,024 = 21.6GB

1.2 p7



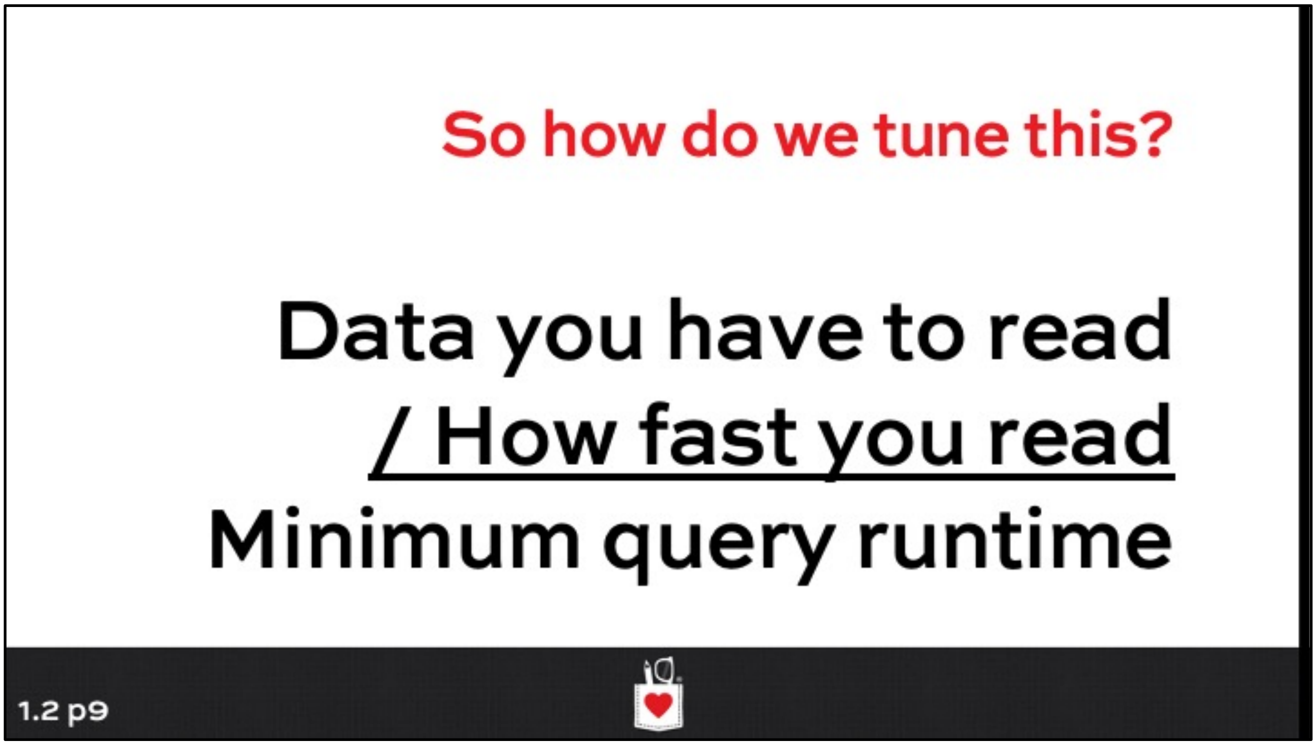
```
sp_BlitzFirst @ExpertMode = 1, @Seconds = 60
```

run_date	elapsed_time	session_id	database_name	query_text	query_plan	live_query_plan	query_cost	status	wait_info	top_session_waits	blocking_session_id	open_tra

	Priority	FindingsGroup	Finding	Details	HowToStopIt	CheckID
1	0	sp_BlitzFirst 2018-...	From Your Community Volunteers	<?ClickToSeeDetails -- We hope you found this tool ...	NULL	-1
2	200	Wait Stats	CLR_AUTO_EVENT	<?ClickToSeeDetails -- For 117 seconds over the last ...	<?ClickToSeeCommmand -- WARNING: Running t...	6
3	200	Wait S	PAGEIOLATCH_SH	<?ClickToSeeDetails -- For 55 seconds over the last ...	<?ClickToSeeCommmand -- WARNING: Running t...	6
4	250	Server Info	Batch Requests per Sec	<?ClickToSeeDetails -- 0 -- ?>	NULL	19
5	250	Server Info	CPU Utilization	<?ClickToSeeDetails -- 11%. Ring buffer details: <Re...	NULL	23
6	250	Server Info	SQL Compilations per Sec	<?ClickToSeeDetails -- 0 -- ?>	NULL	25
7	250	Server Info	SQL Re-Compilations per Sec	<?ClickToSeeDetails -- 0 -- ?>	NULL	26
8	250	Server Info	Wait Time per Core per Sec	<?ClickToSeeDetails -- 0 -- ?>	NULL	19

	Pattern	Sample Ended	Seconds Sample	wait_type	wait_category	Wait Time (Seconds)	Avg ms Per Wait	Per Core Per Secon
1	WAIT STATS	2018-07-22 14:25:04.5936065 +00:00	59	CLR_AUTO_EVENT	SQL CLR	117.5	8394.3	0.2
2	WAIT STATS	2018-07-22 14:25:04.5936065 +00:00	5	PAGEIOLATCH_SH		55.6	4.0	0.1
3	WAIT STATS	2018-07-22 14:25:04.5936065 +00:00	59	CXCONSUMER	Parallelism	15.1	25.0	0.0
4	WAIT STATS	2018-07-22 14:25:04.5936065 +00:00	59	MEMORY_ALLOCATION_EXT	Memory	1.0	0.0	0.0
5	WAIT STATS	2018-07-22 14:25:04.5936065 +00:00	59	CXPACKET	Parallelism	0.6	14.5	0.0

	Pattern	Sample Time	Sa onds)	File Name	Drive	# Reads/Writes	MB Read/Written	Avg Stall (ms)	file physical name
1	PHYSICAL READS	2018-07-22 14:25:04.6092026 +00:00	59	StackOverflow_4 [ROWS]	Z:	47209	5422.1	26	Z:\MSSQL\DAT
2	PHYSICAL READS	2018-07-22 14:25:04.6092026 +00:00	59	StackOverflow_3 [ROWS]	Z:	47392	5422.2	24	Z:\MSSQL\DAT
3	PHYSICAL READS	2018-07-22 14:25:04.6092026 +00:00	59	StackOverflow_2 [ROWS]	Z:	47359	5422.3	23	Z:\MSSQL\DAT
4	PHYSICAL READS	2018-07-22 14:25:04.6092026 +00:00	59	StackOverflow_1 [ROWS]	Z:	47319	5421.8	21	Z:\MSSQL\DAT
5	PHYSICAL WRITES	2018-07-22 14:25:04.6092026 +00:00	59	temp2 [ROWS]	Z:	8	0.1	6	Z:\MSSQL\DAT



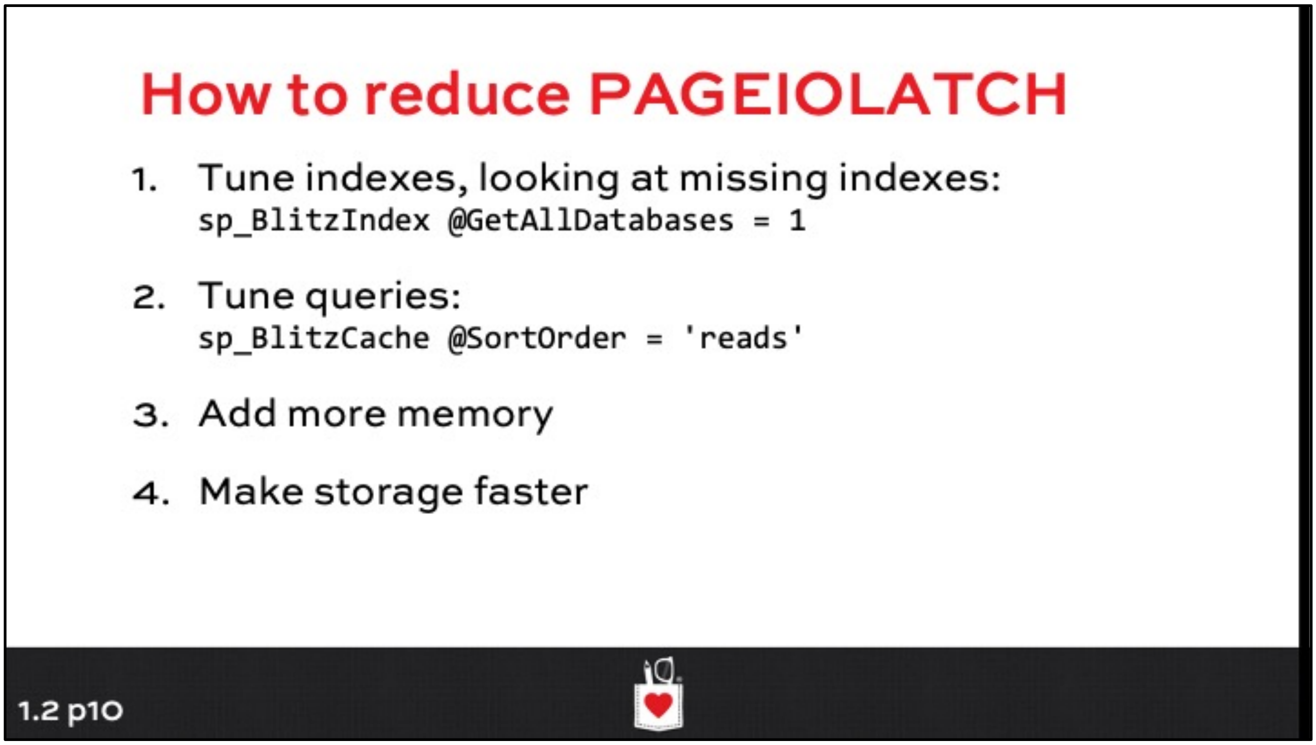
So how do we tune this?

Data you have to read

/ How fast you read

Minimum query runtime

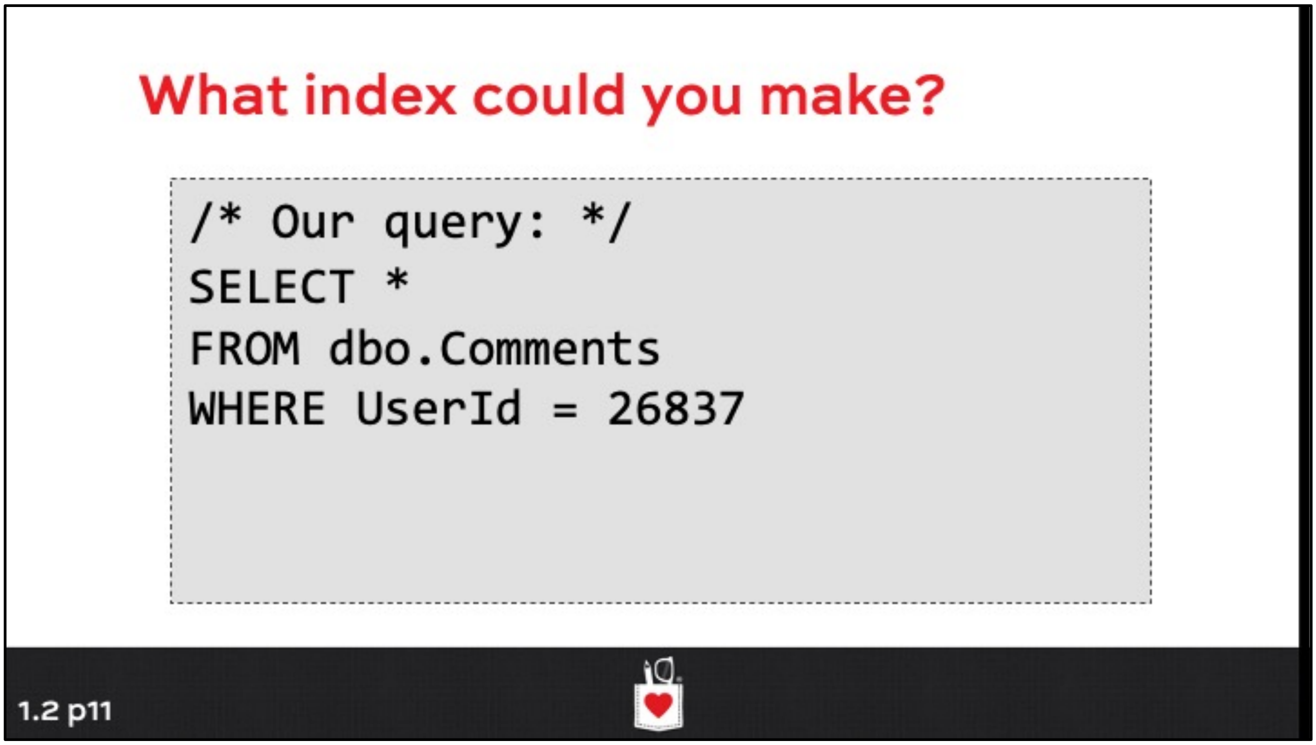
1.2 p9



How to reduce PAGEIOLATCH

1. Tune indexes, looking at missing indexes:
   `sp_BlitzIndex @GetAllDatabases = 1`
2. Tune queries:
   `sp_BlitzCache @SortOrder = 'reads'`
3. Add more memory
4. Make storage faster

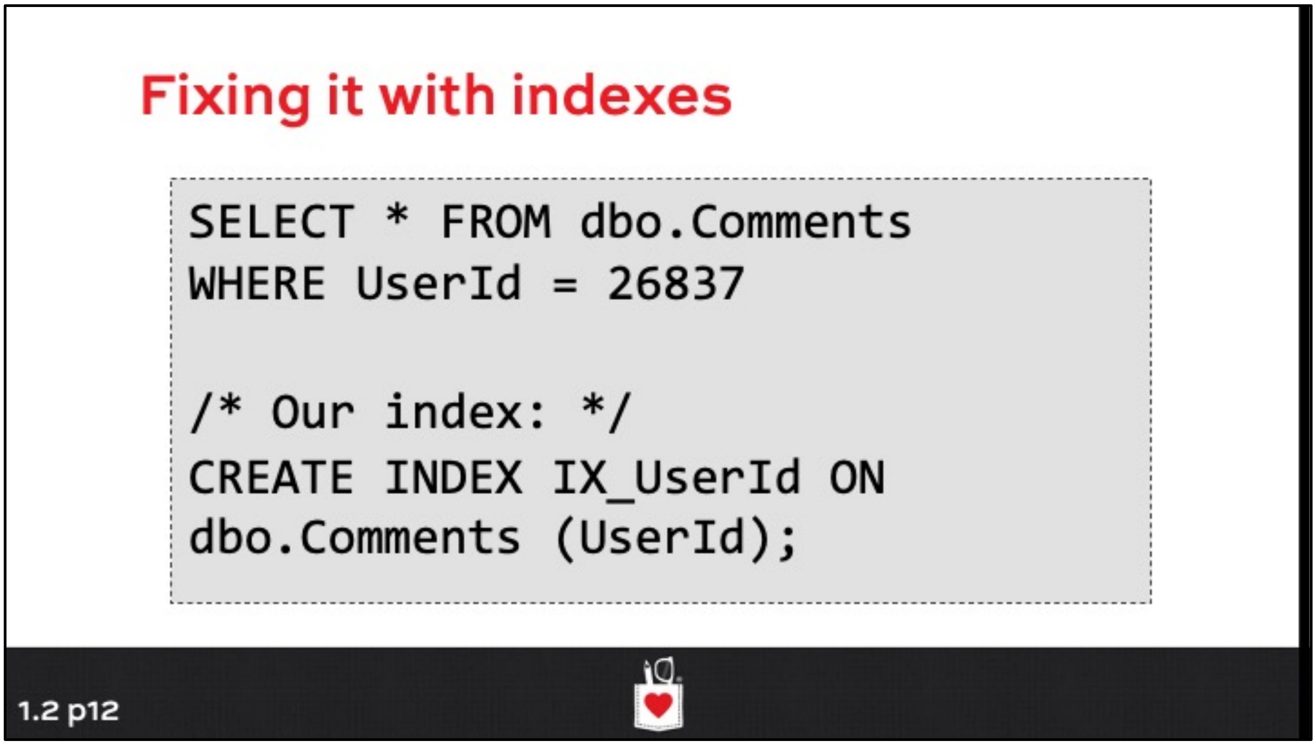
1.2 p10



What index could you make?

```
/* Our query: */
SELECT *
FROM dbo.Comments
WHERE UserId = 26837
```

1.2 p11



Fixing it with indexes

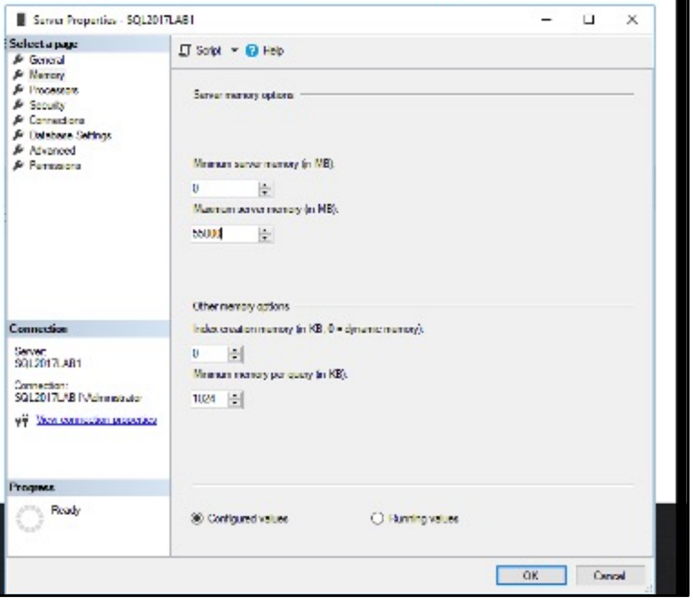
```
SELECT * FROM dbo.Comments
WHERE UserId = 26837

/* Our index: */
CREATE INDEX IX_UserId ON
dbo.Comments (UserId);
```

1.2 p12

Before you do that, add memory.

Otherwise, trust me, the index build takes forever.

My default: leave 4GB or 10% free for the OS, whichever is greater.



Server memory options

Minimum server memory (in MB): 0

Maximum server memory (in MB): 56000

Other memory options

Index creation memory (in KB, 0 = dynamic memory): 0

Minimum memory per query (in KB): 1024

Server: SQL2017LAB1

Connection: SQL2017LAB1\Administrator

● Configured values ○ Running values

1.2 p13

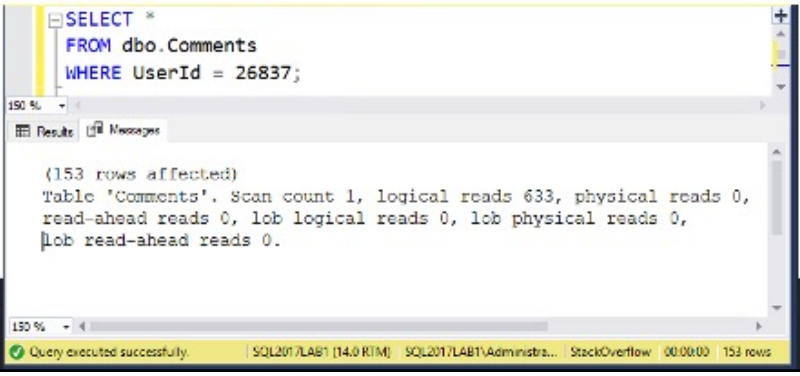
With the index, we read less pages

Under 1K pages down from millions, and finishes in a second

Frees up our memory for other queries

Reduces the workload on our slow storage

We don't have to cover the whole query – just one column helps



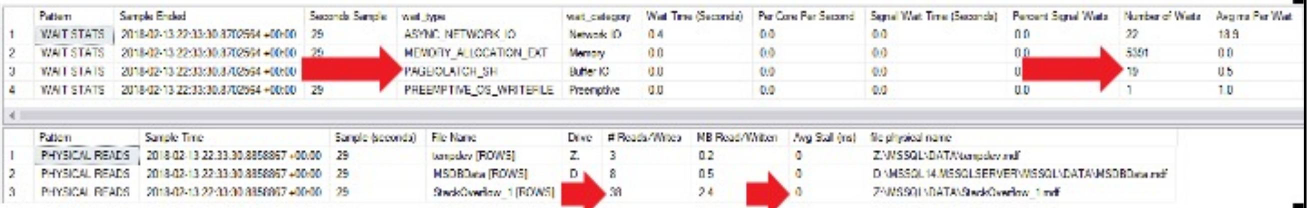
```
SELECT *
FROM dbo.Comments
WHERE UserId = 26837;
```

```
(153 rows affected)
Table 'Comments'. Scan count 1, logical reads 633, physical reads 0,
read-ahead reads 0, lob logical reads 0, lob physical reads 0,
lob read-ahead reads 0.
```

Query executed successfully. | SQL2017LAB1 (14.0 RTM) | SQL2017LAB1\Administra... | StackOverflow | 00:00:00 | 153 rows

1.2 p14

With the index, we read less pages



	Pattern	Sample Ended	Seconds Sample	wait_type	wait_category	Wait Time (Seconds)	Per Core Per Second	Signal Wait Time (Seconds)	Percent Signal Waits	Number of Waits	Avg ms Per Wait
1	WAIT STATS	2018-02-13 22:33:30.8702964 +00:00	29	ASYNC_NETWORK_IO	Network IO	0.4	0.0	0.0	0.0	22	18.9
2	WAIT STATS	2018-02-13 22:33:30.8702964 +00:00	29	MEMORY_ALLOCATION_EXT	Memory	0.0	0.0	0.0	0.0	5391	0.0
3	WAIT STATS	2018-02-13 22:33:30.8702964 +00:00	[illegible]	PAGEIOLATCH_SH	Buffer IO	0.0	0.0	0.0	0	19	0.5
4	WAIT STATS	2018-02-13 22:33:30.8702964 +00:00	29	PREEMPTIVE_OS_WRITEFILE	Preemptive	0.0	0.0	0.0	0.0	1	1.0

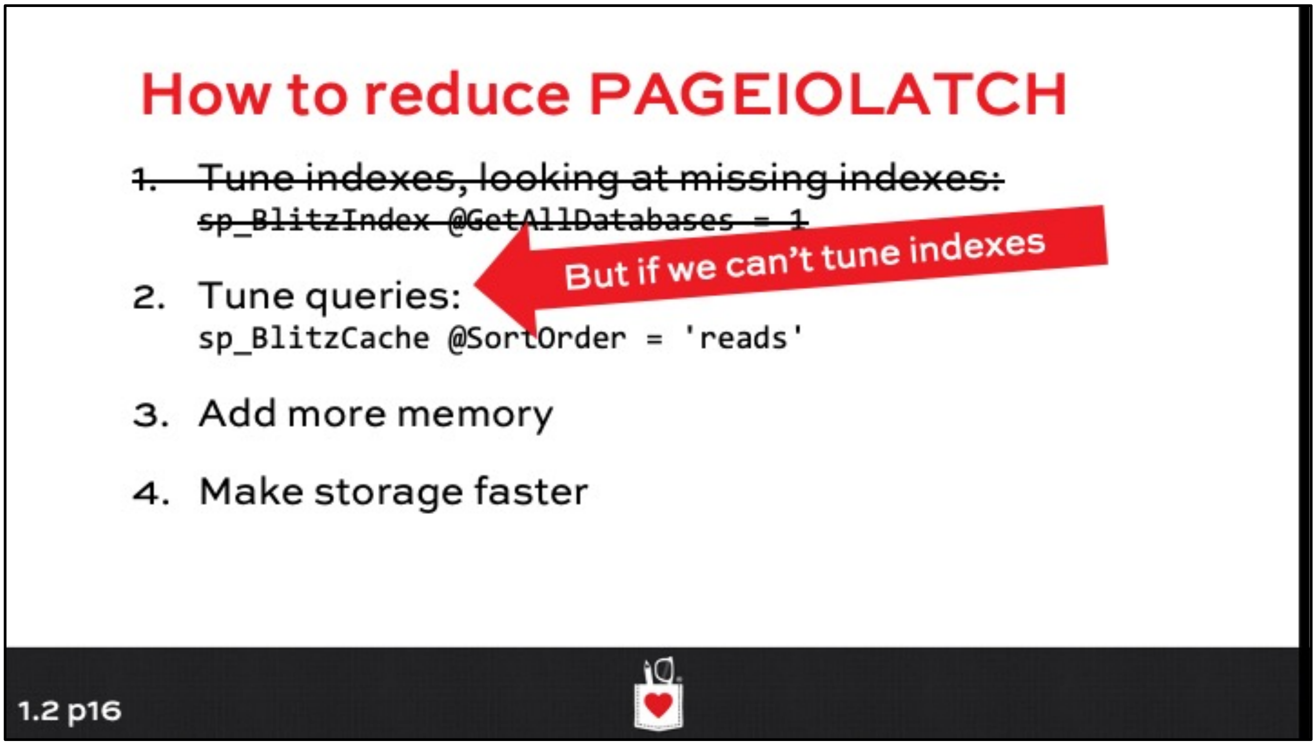
	Pattern	Sample Time	Sample (seconds)	File Name	Drive	# Reads/Writes	MB Read/Written	Avg Stall (ms)	file physical name
1	PHYSICAL READS	2018-02-13 22:33:30.8858867 +00:00	29	tempdev [ROWS]	Z:	3	0.2	0	Z:\MSSQL\DATA\tempdev.mdf
2	PHYSICAL READS	2018-02-13 22:33:30.8858867 +00:00	29	MSDBData [ROWS]	D:	8	0.5	0	D:\MSSQL14.MSSQLSERVER\MSSQL\DATA\MSDBData.mdf
3	PHYSICAL READS	2018-02-13 22:33:30.8858867 +00:00	29	StackOverflow_1 [ROWS]		38	2.4	0	Z:\MSSQL\DATA\StackOverflow_1.mdf

Waits down under 1 second.

The quality of the storage simply no longer matters.

Storage stalls disappear because less work means faster average response time per task.

1.2 p15

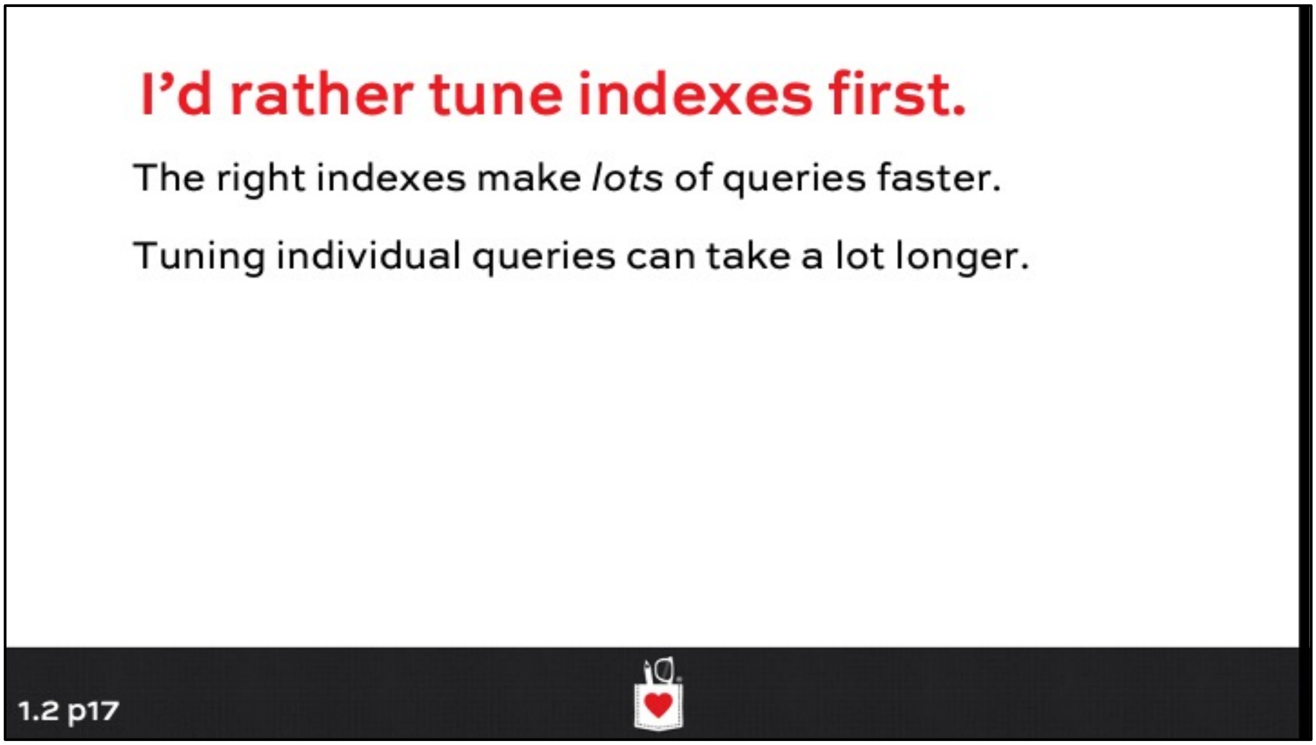


How to reduce PAGEIOLATCH

1. ~~Tune indexes, looking at missing indexes:~~
   ~~`sp_BlitzIndex @GetAllDatabases = 1`~~
2. Tune queries:
   `sp_BlitzCache @SortOrder = 'reads'`
3. Add more memory
4. Make storage faster

But if we can't tune indexes

1.2 p16

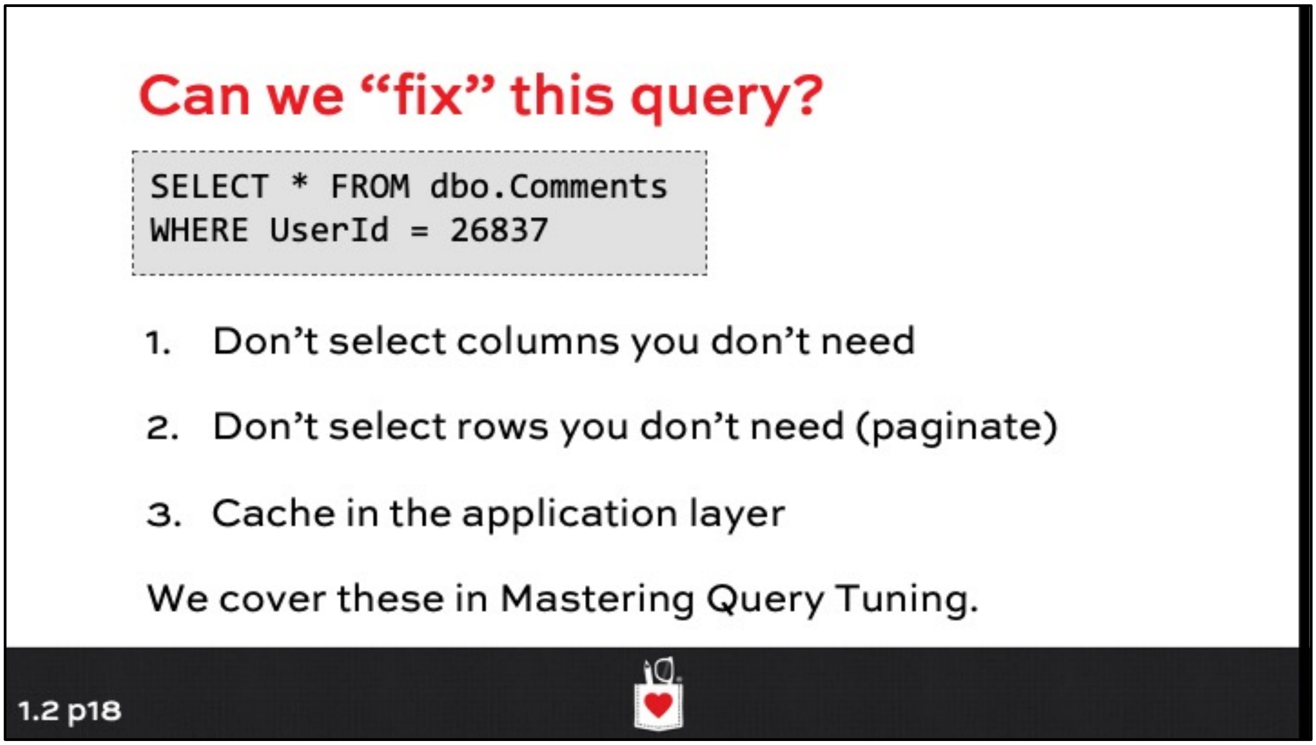


I’d rather tune indexes first.

The right indexes make *lots* of queries faster.

Tuning individual queries can take a lot longer.

1.2 p17



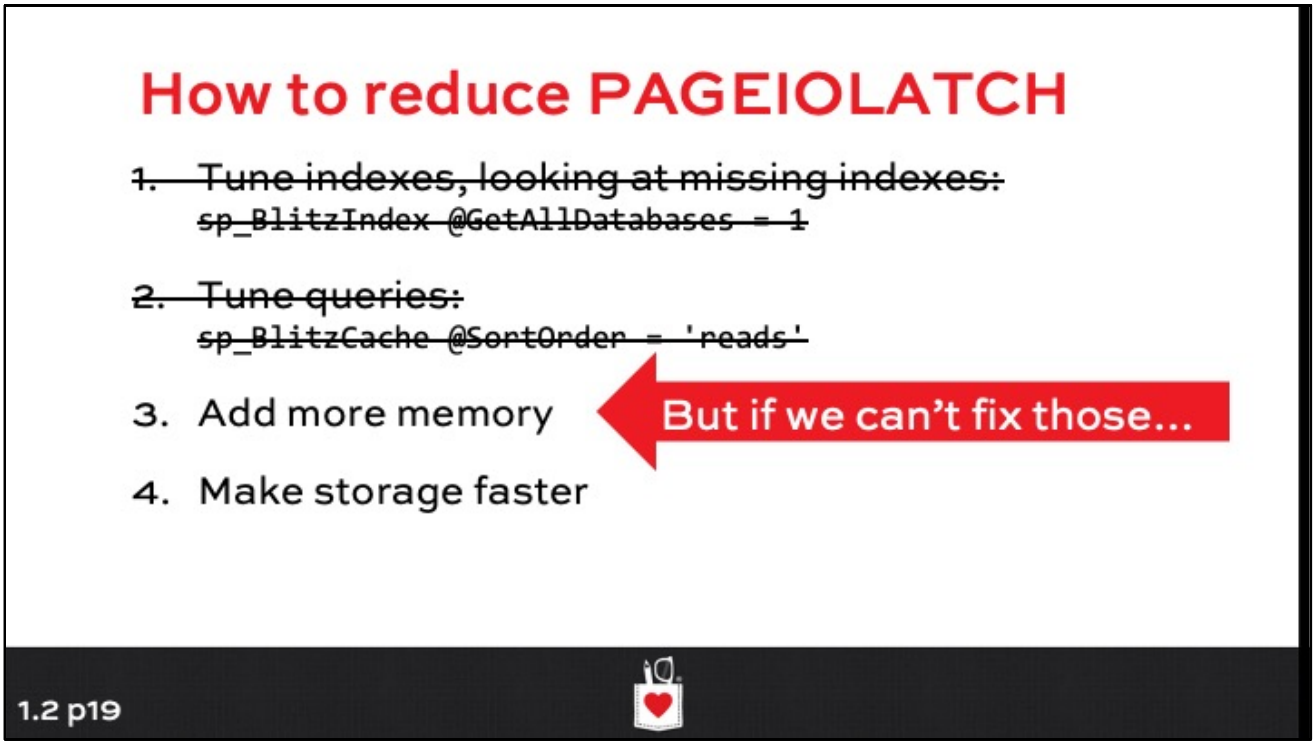
Can we “fix” this query?

```
SELECT * FROM dbo.Comments
WHERE UserId = 26837
```

1. Don’t select columns you don’t need
2. Don’t select rows you don’t need (paginate)
3. Cache in the application layer

We cover these in Mastering Query Tuning.

1.2 p18



How to reduce PAGEIOLATCH

1. ~~Tune indexes, looking at missing indexes:~~
   ~~sp_BlitzIndex @GetAllDatabases = 1~~

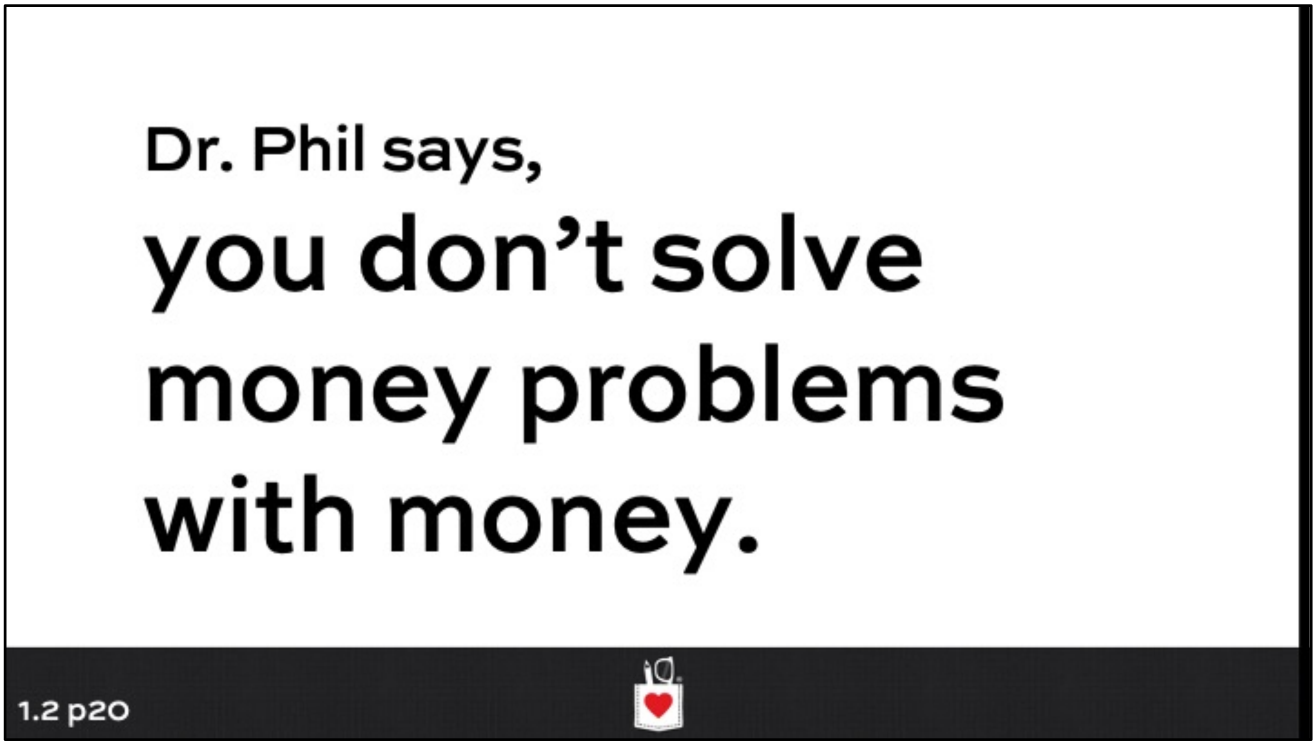
2. ~~Tune queries:~~
   ~~sp_BlitzCache @SortOrder = 'reads'~~

3. Add more memory

4. Make storage faster

But if we can't fix those...

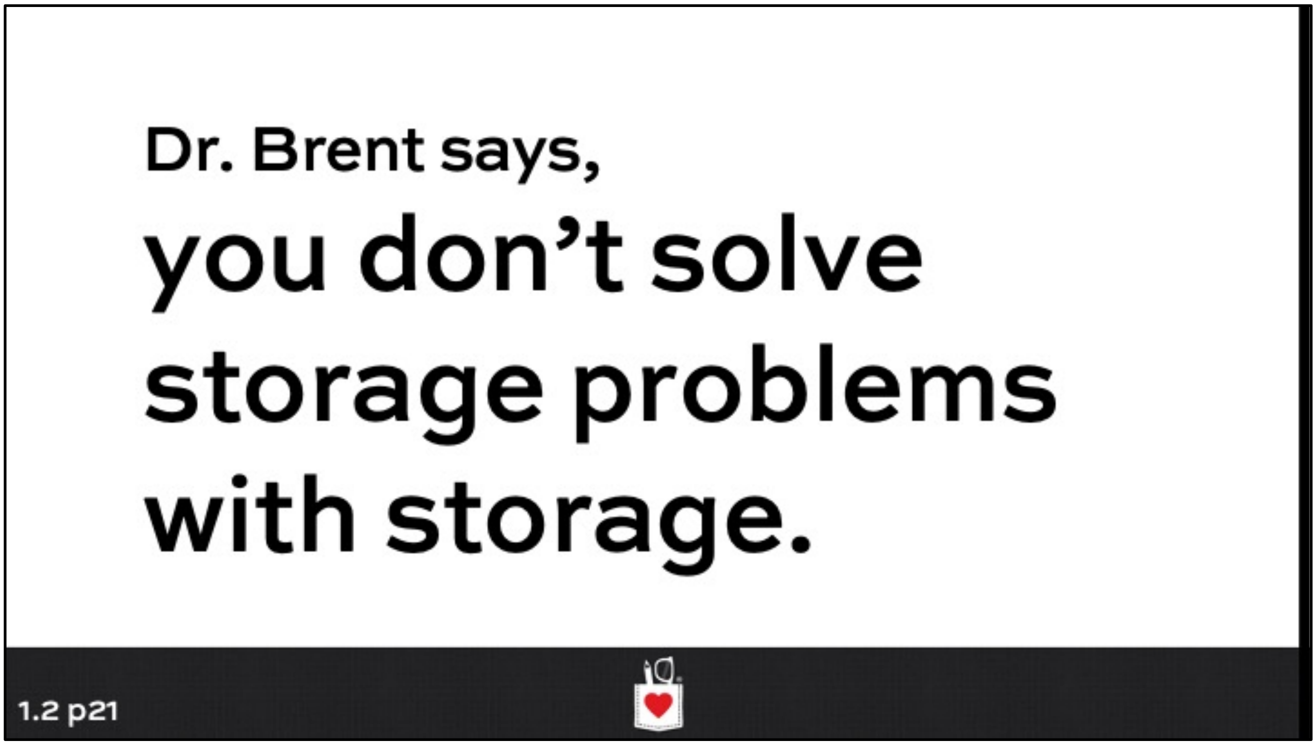
1.2 p19



Dr. Phil says,

you don’t solve money problems with money.

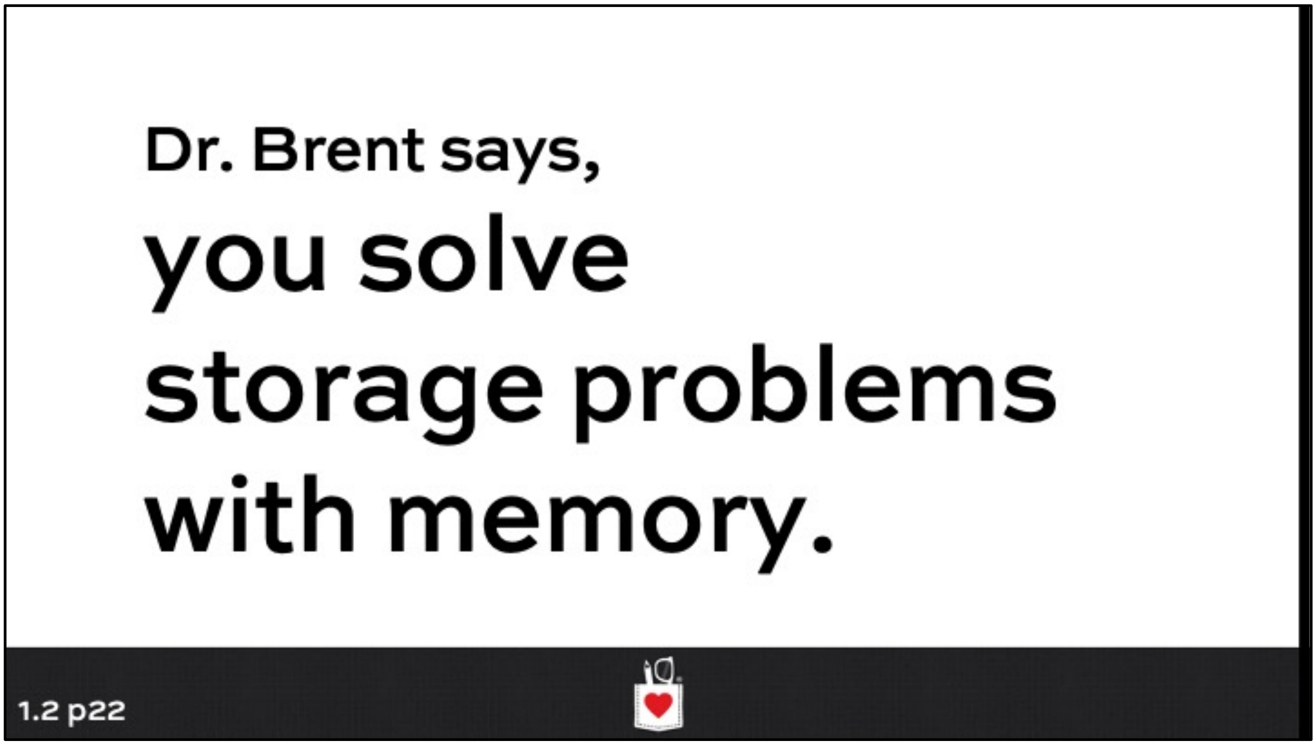
1.2 p20



Dr. Brent says,

you don’t solve storage problems with storage.

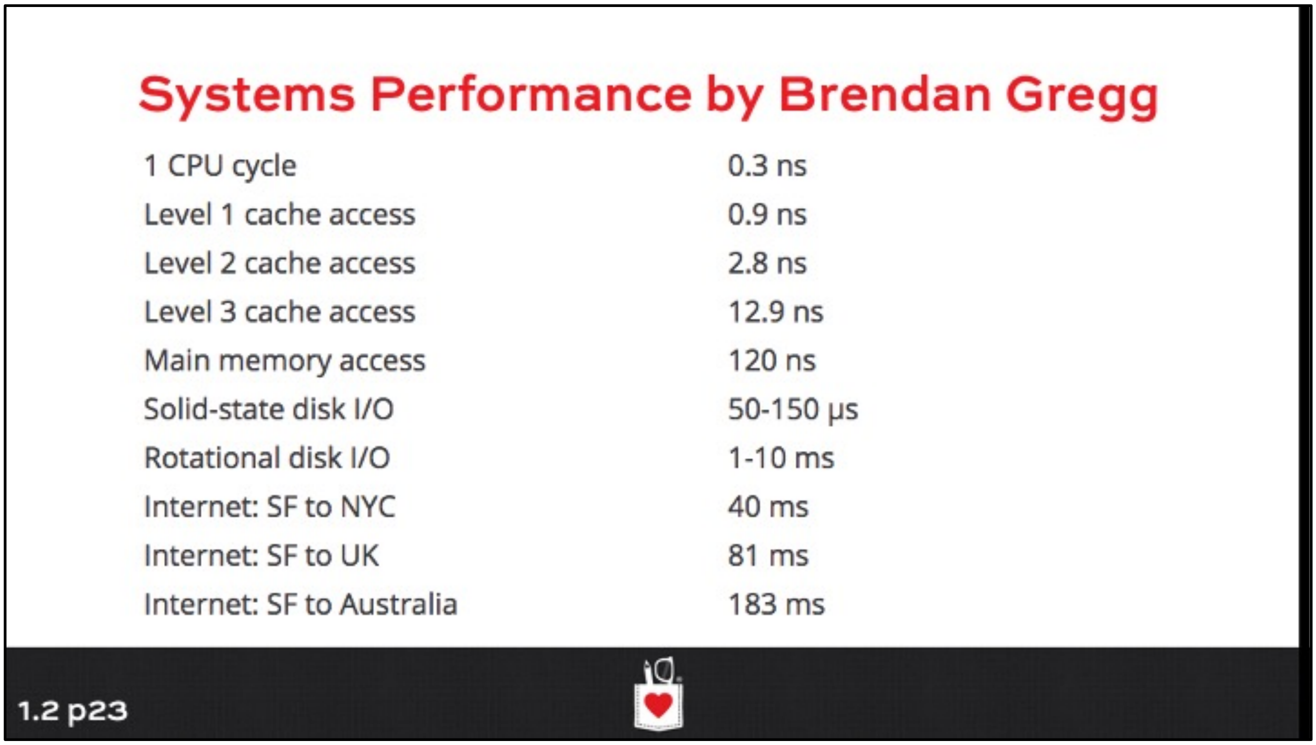
1.2 p21



Dr. Brent says,

you solve storage problems with memory.

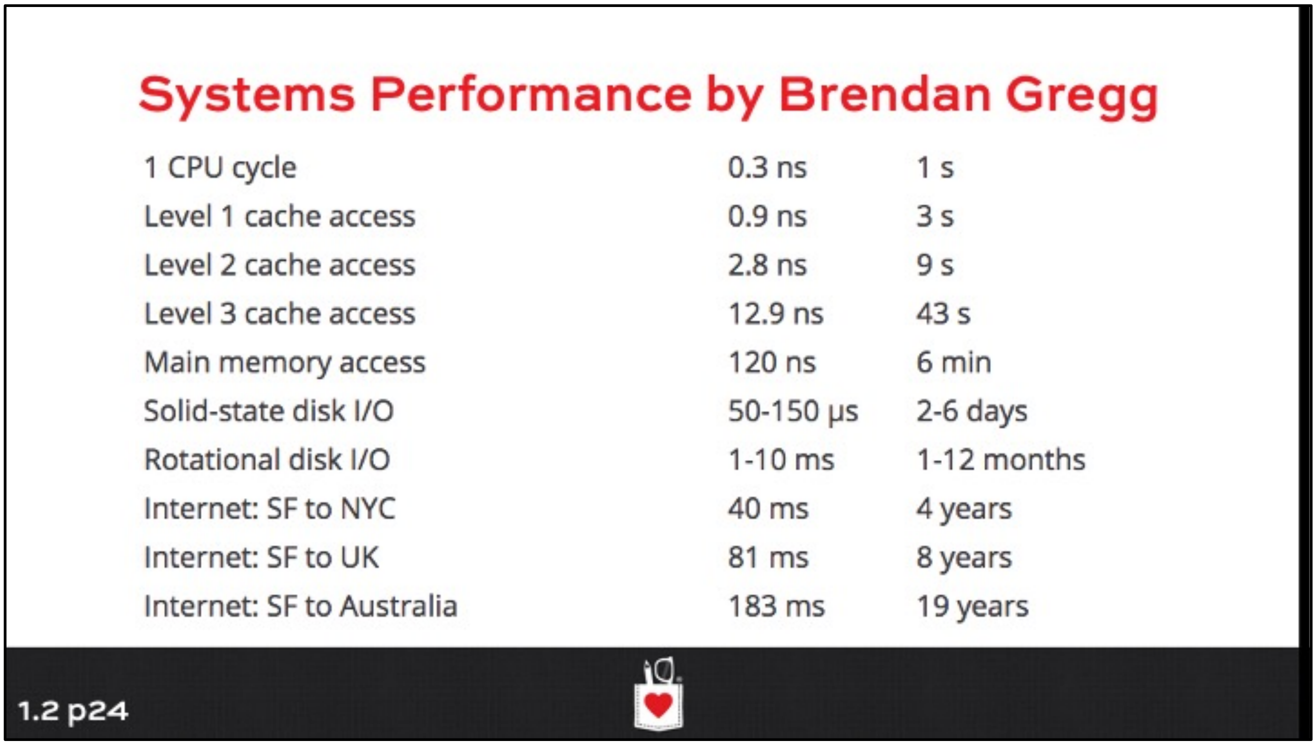
1.2 p22



Systems Performance by Brendan Gregg

1 CPU cycle	0.3 ns
Level 1 cache access	0.9 ns
Level 2 cache access	2.8 ns
Level 3 cache access	12.9 ns
Main memory access	120 ns
Solid-state disk I/O	50-150 μs
Rotational disk I/O	1-10 ms
Internet: SF to NYC	40 ms
Internet: SF to UK	81 ms
Internet: SF to Australia	183 ms

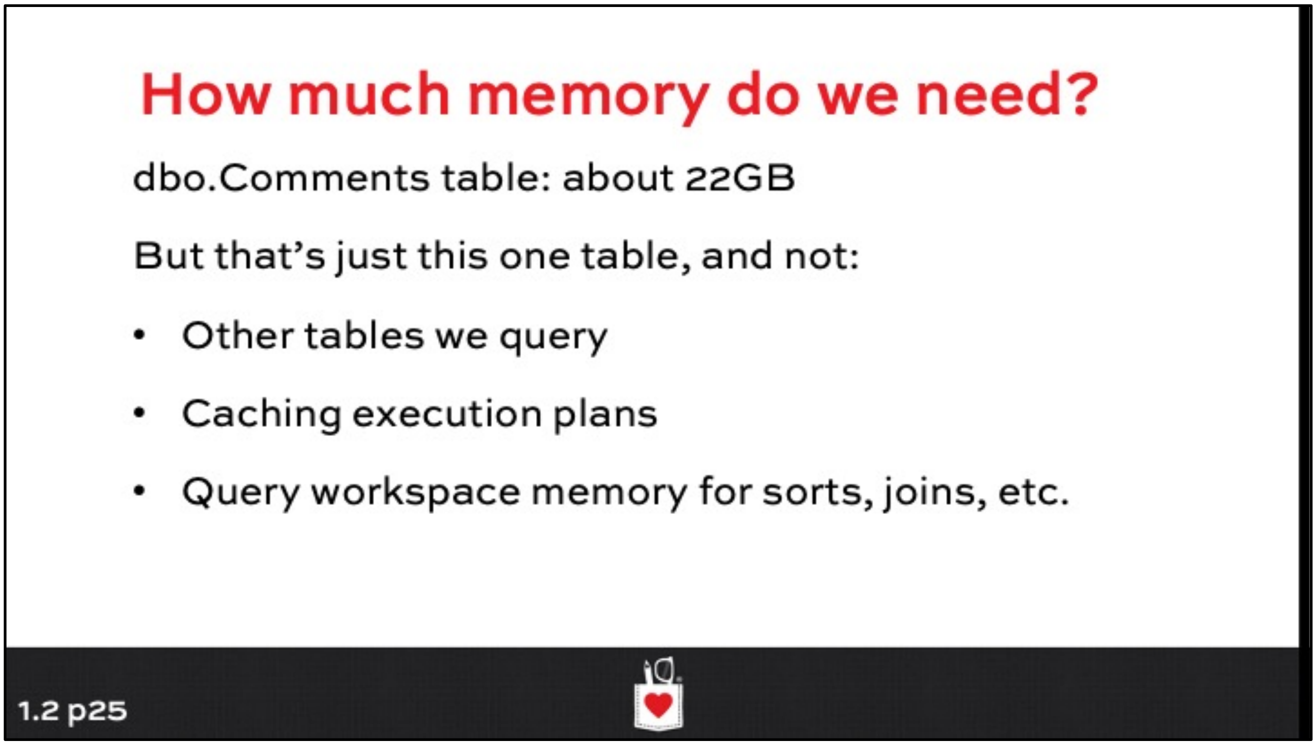
1.2 p23



Systems Performance by Brendan Gregg

1 CPU cycle	0.3 ns	1 s
Level 1 cache access	0.9 ns	3 s
Level 2 cache access	2.8 ns	9 s
Level 3 cache access	12.9 ns	43 s
Main memory access	120 ns	6 min
Solid-state disk I/O	50-150 μs	2-6 days
Rotational disk I/O	1-10 ms	1-12 months
Internet: SF to NYC	40 ms	4 years
Internet: SF to UK	81 ms	8 years
Internet: SF to Australia	183 ms	19 years

1.2 p24



How much memory do we need?

dbo.Comments table: about 22GB

But that’s just this one table, and not:

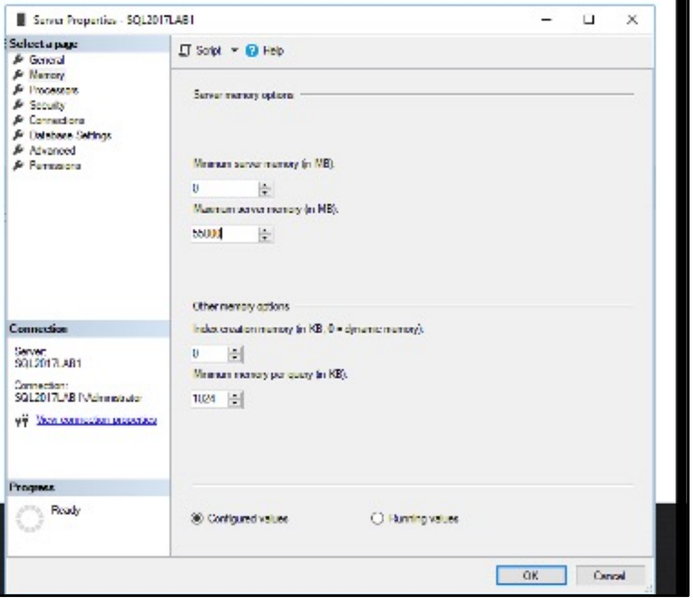
- Other tables we query
- Caching execution plans
- Query workspace memory for sorts, joins, etc.

1.2 p25

Take off the handcuffs

If you temporarily restricted memory, crank it back up to high.

In our lab, this lets us cache the entire table in memory.



Server: SQL2017LAB1

Connection: SQL2017LAB1\Administrator

Server memory options

Minimum server memory (in MB): 0

Maximum server memory (in MB): 56000

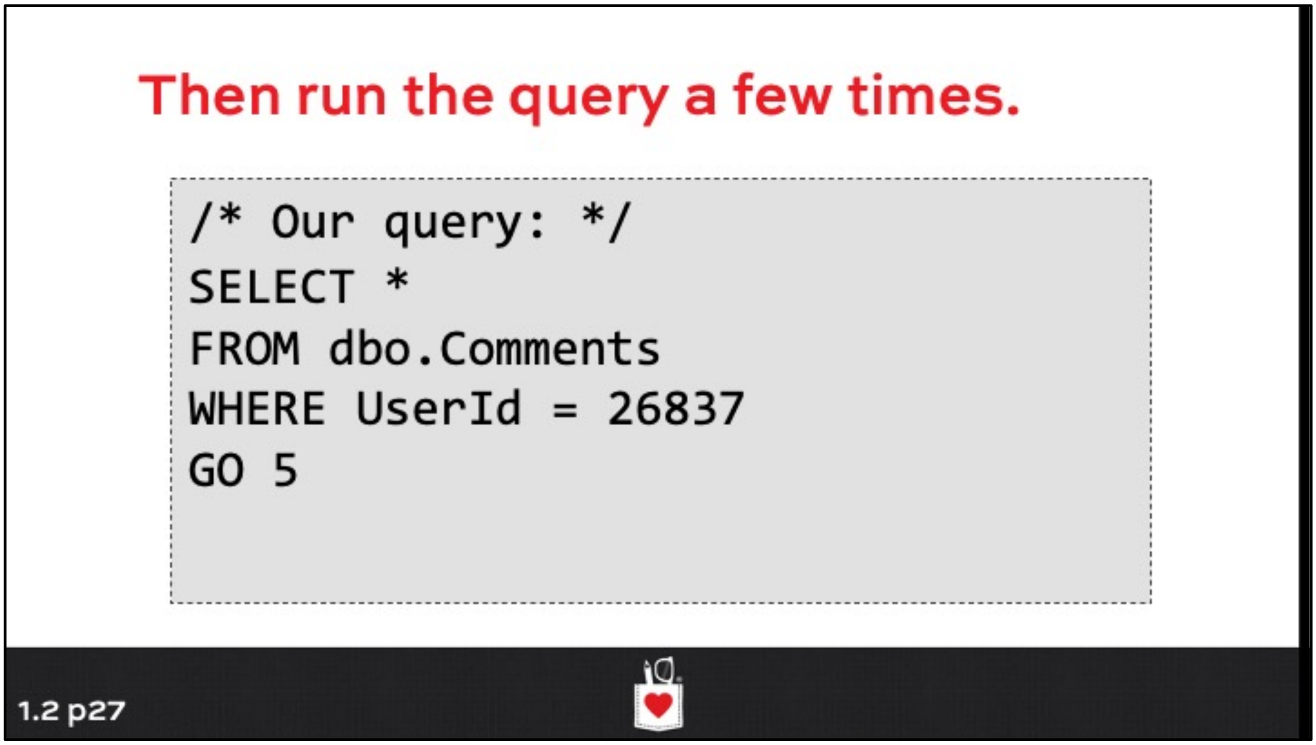
Other memory options

Index creation memory (in KB, 0 = dynamic memory): 0

Minimum memory per query (in KB): 1024

● Configured values ○ Running values

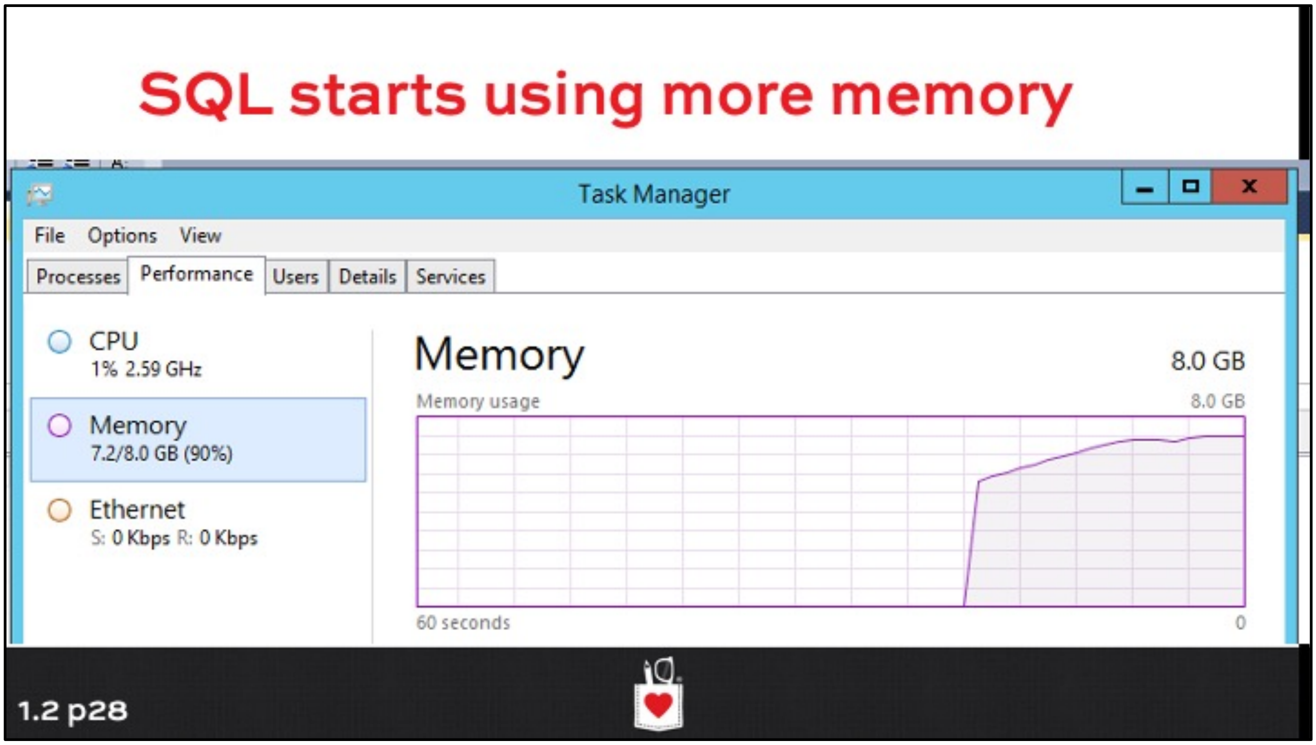
1.2 p26



Then run the query a few times.

```
/* Our query: */
SELECT *
FROM dbo.Comments
WHERE UserId = 26837
GO 5
```

1.2 p27



SQL starts using more memory

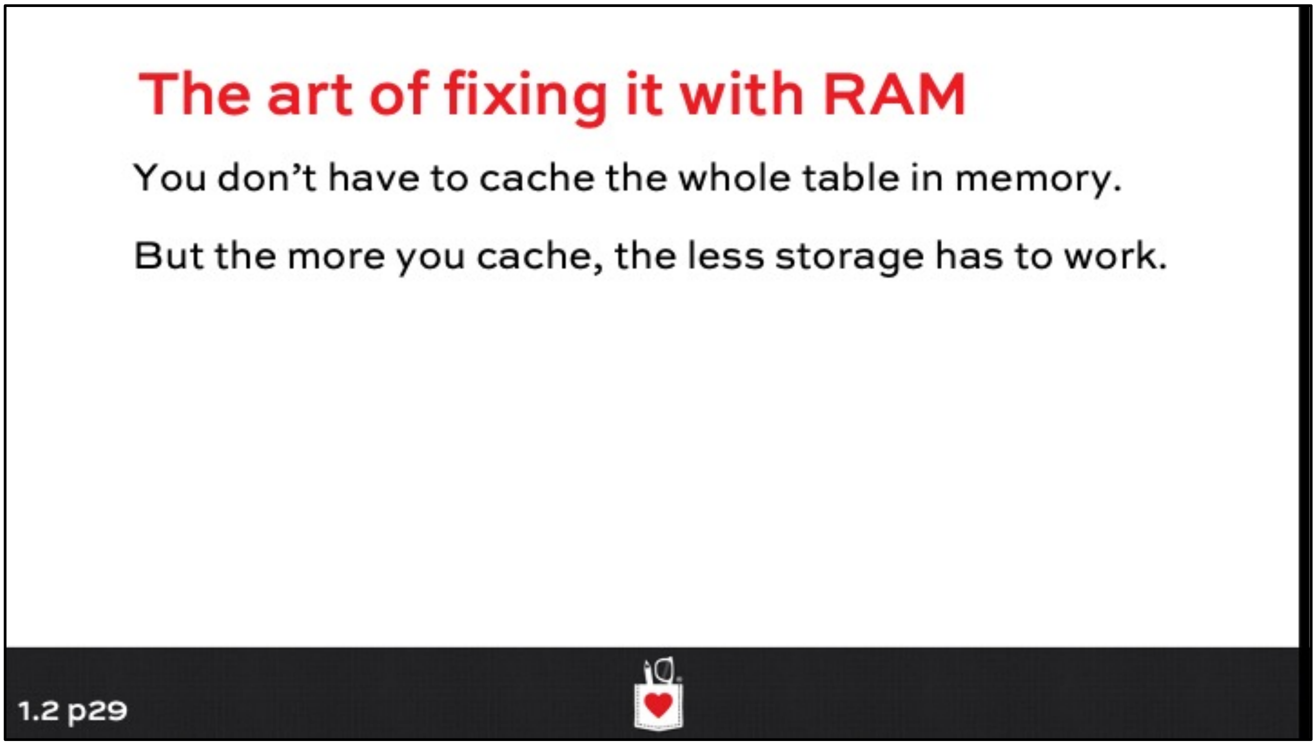
CPU
1% 2.59 GHz

Memory
7.2/8.0 GB (90%)

Ethernet
S: 0 Kbps R: 0 Kbps

Memory 8.0 GB

1.2 p28

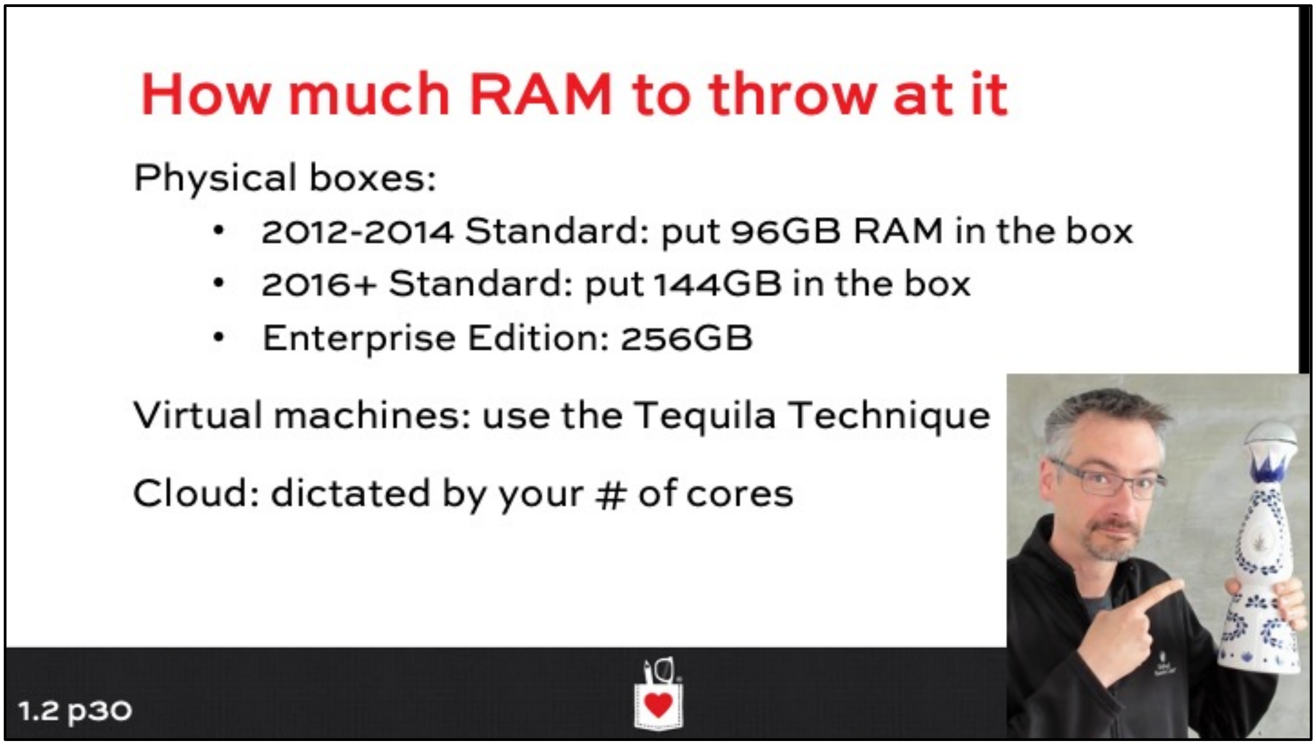


The art of fixing it with RAM

You don’t have to cache the whole table in memory.

But the more you cache, the less storage has to work.

1.2 p29



How much RAM to throw at it

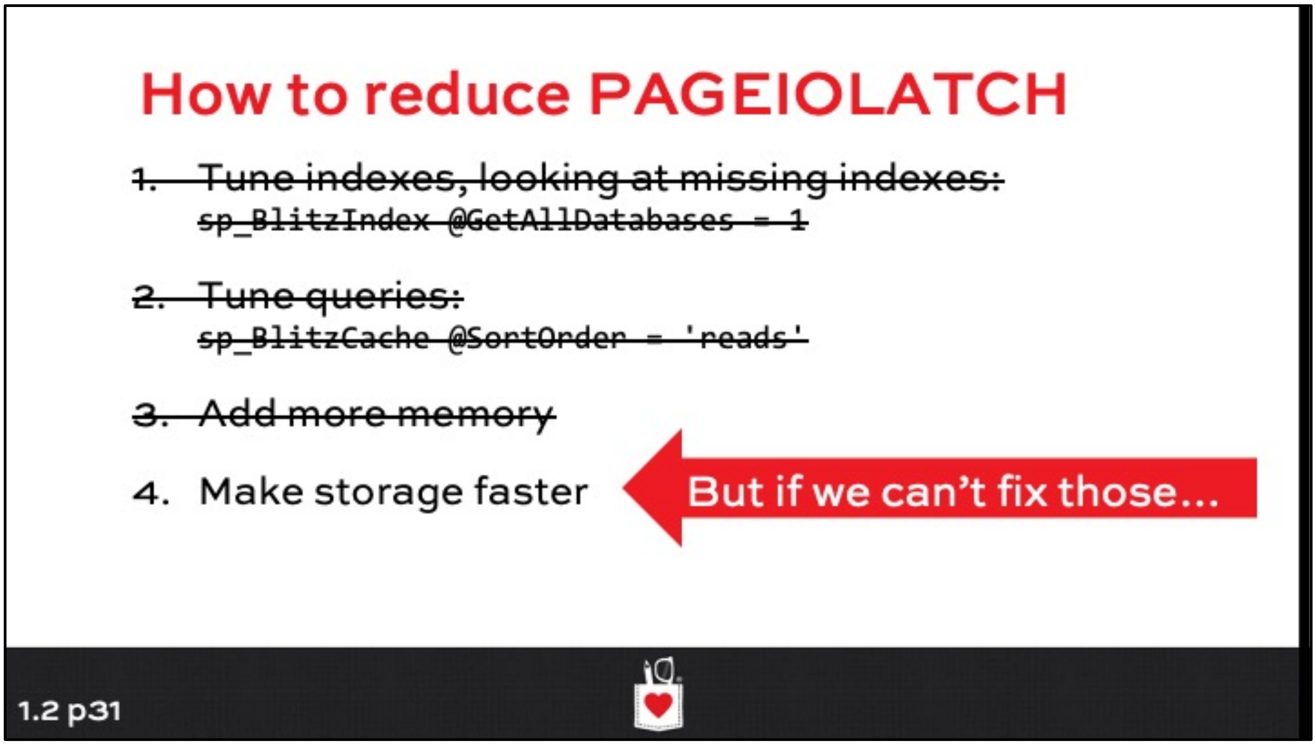
Physical boxes:

- 2012-2014 Standard: put 96GB RAM in the box
- 2016+ Standard: put 144GB in the box
- Enterprise Edition: 256GB

Virtual machines: use the Tequila Technique

Cloud: dictated by your # of cores

1.2 p30



How to reduce PAGEIOLATCH

1. ~~Tune indexes, looking at missing indexes:~~
   ~~`sp_BlitzIndex @GetAllDatabases = 1`~~

2. ~~Tune queries:~~
   ~~`sp_BlitzCache @SortOrder = 'reads'`~~

3. ~~Add more memory~~

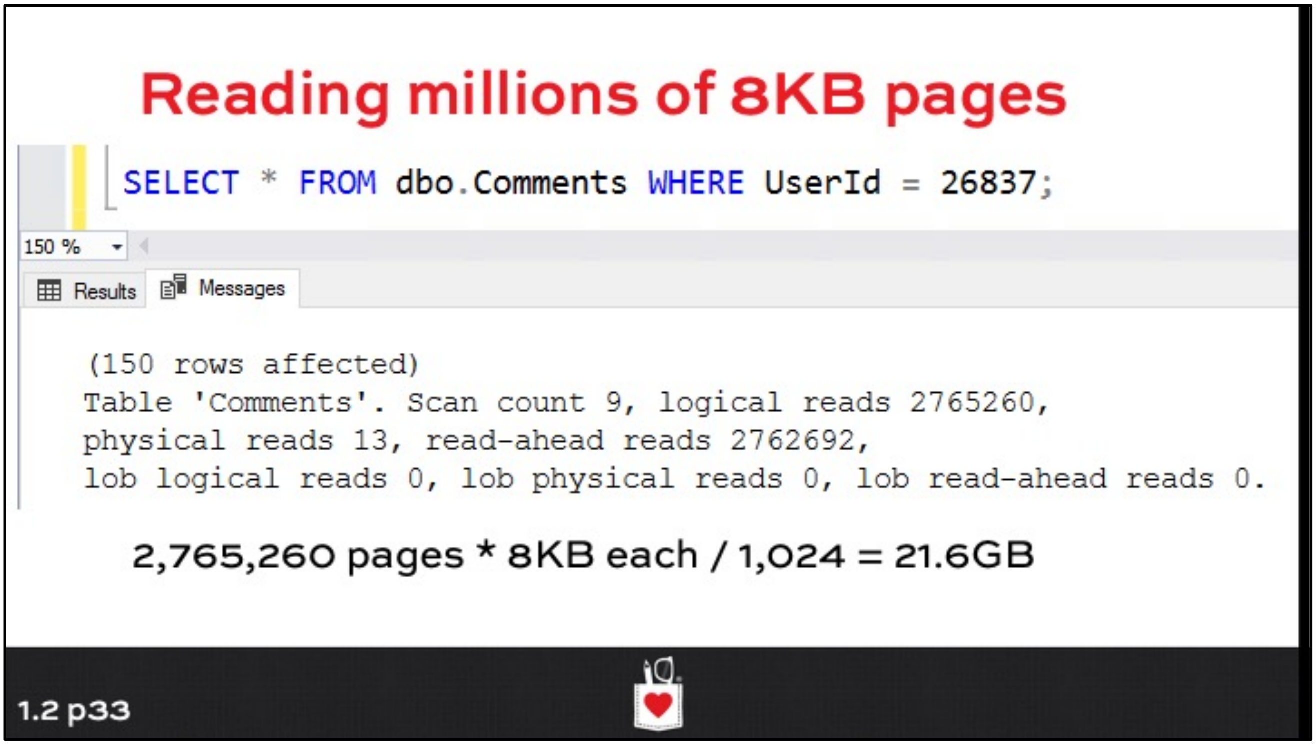
4. Make storage faster

But if we can’t fix those…

1.2 p31

Let’s do the math.

1.2 p32



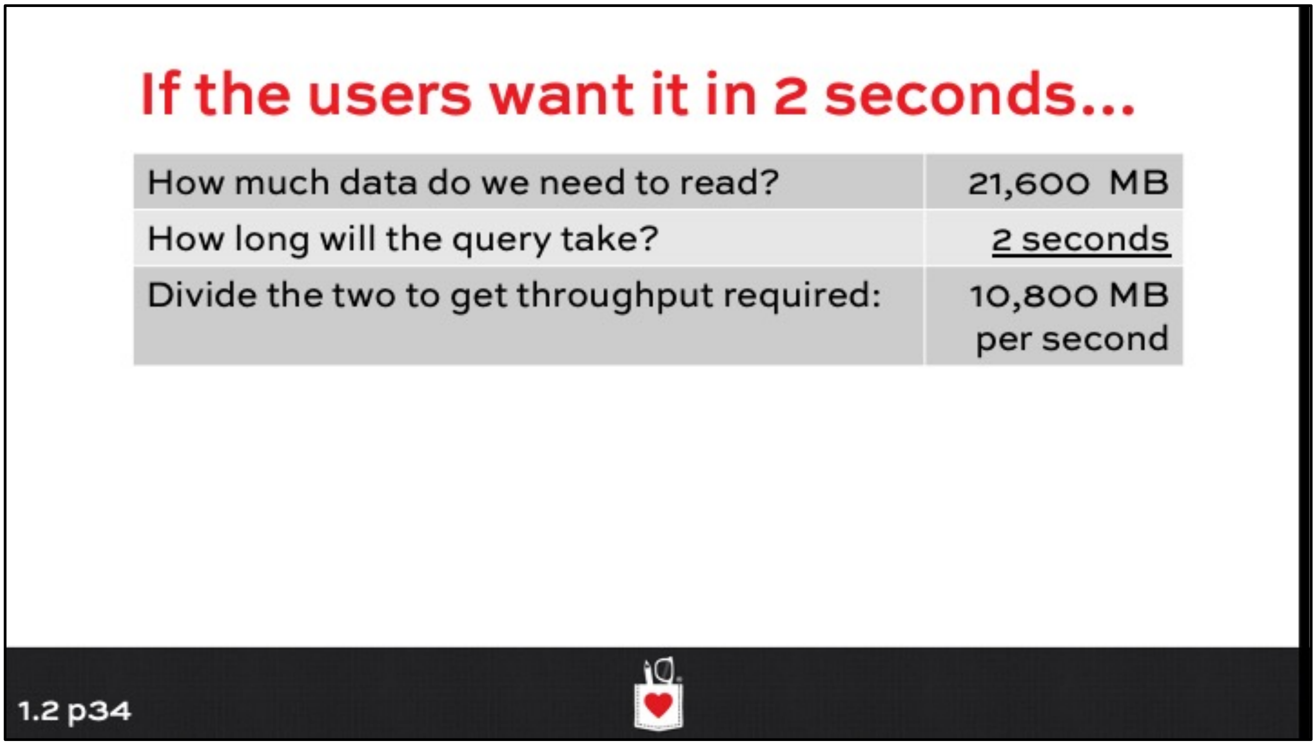
Reading millions of 8KB pages

```sql
SELECT * FROM dbo.Comments WHERE UserId = 26837;
```

```
(150 rows affected)
Table 'Comments'. Scan count 9, logical reads 2765260,
physical reads 13, read-ahead reads 2762692,
lob logical reads 0, lob physical reads 0, lob read-ahead reads 0.
```

2,765,260 pages * 8KB each / 1,024 = 21.6GB

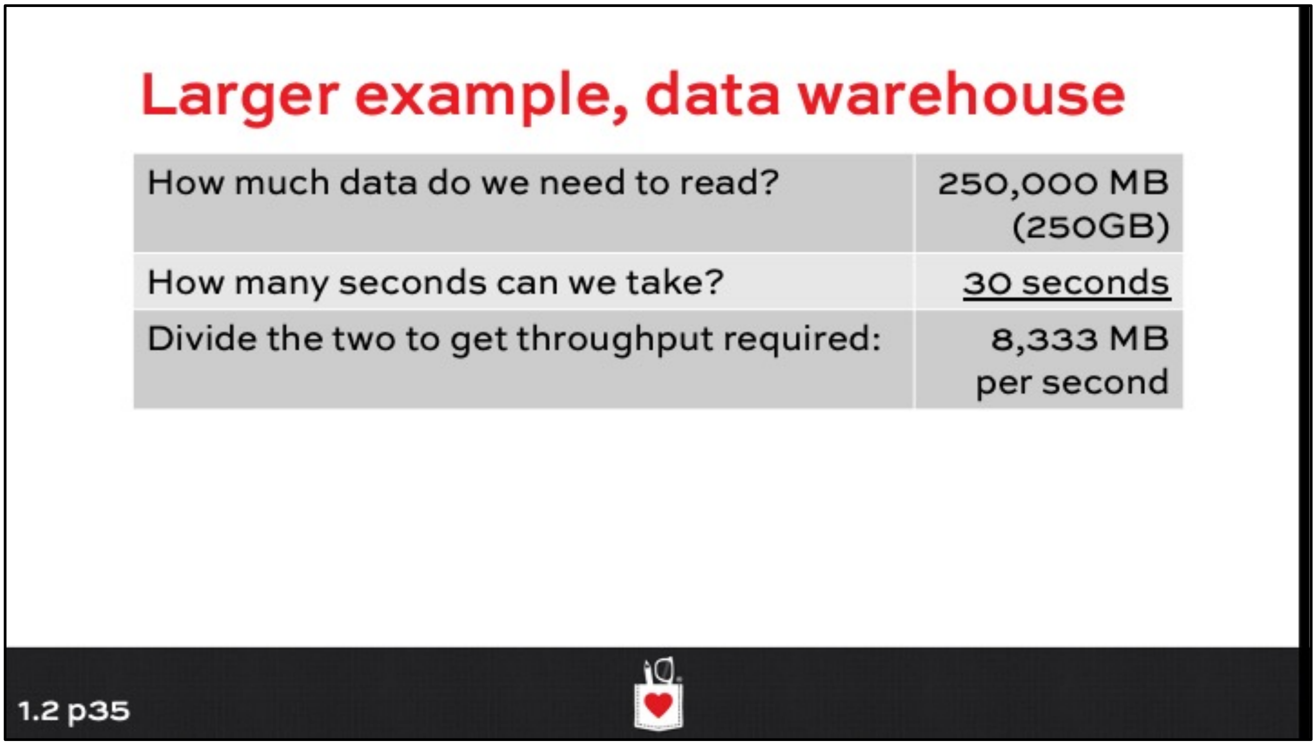
1.2 p33



If the users want it in 2 seconds...

How much data do we need to read?	21,600 MB
How long will the query take?	2 seconds
Divide the two to get throughput required:	10,800 MB per second

1.2 p34



Larger example, data warehouse

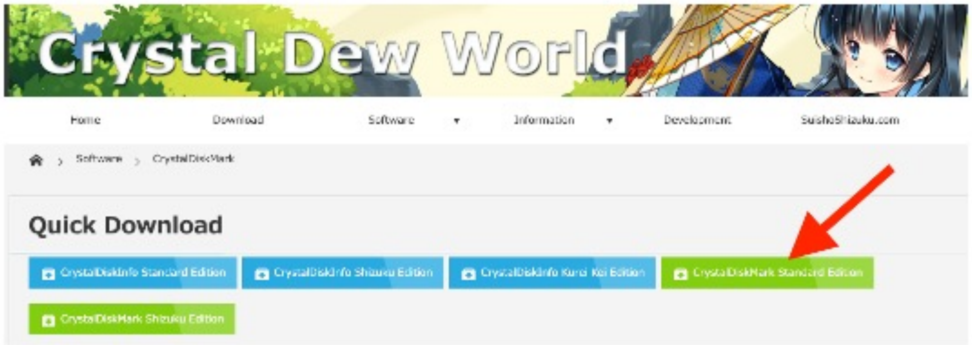
How much data do we need to read?	250,000 MB (250GB)
How many seconds can we take?	30 seconds
Divide the two to get throughput required:	8,333 MB per second

1.2 p35

Benchmark your current storage

CrystalDiskMark: BrentOzar.com/go/cdm

Get the zip edition without ads, save it to a share



Crystal Dew World
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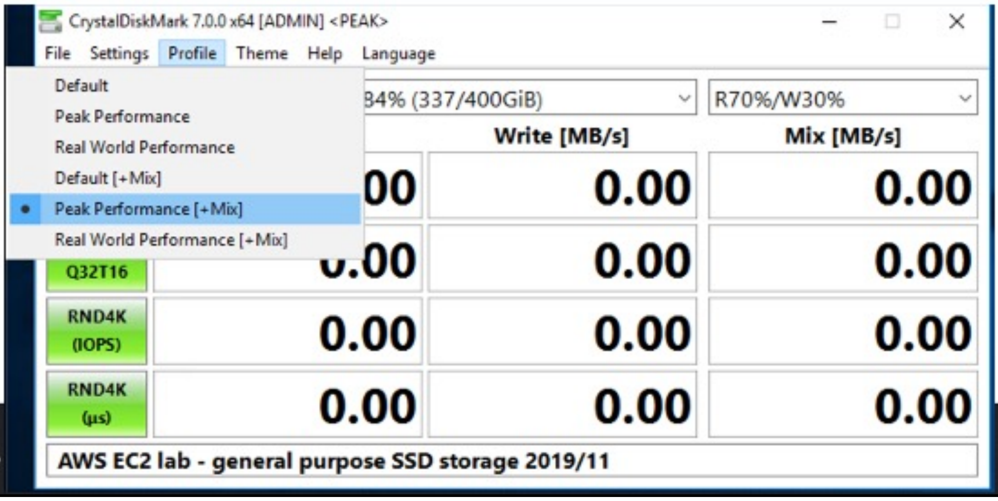
CrystalDiskMark Standard Edition
CrystalDiskMark Shizuku Edition

1.2 p36

Setting it up

Click Profile, Peak Performance + Mix



84% (337/400GiB)

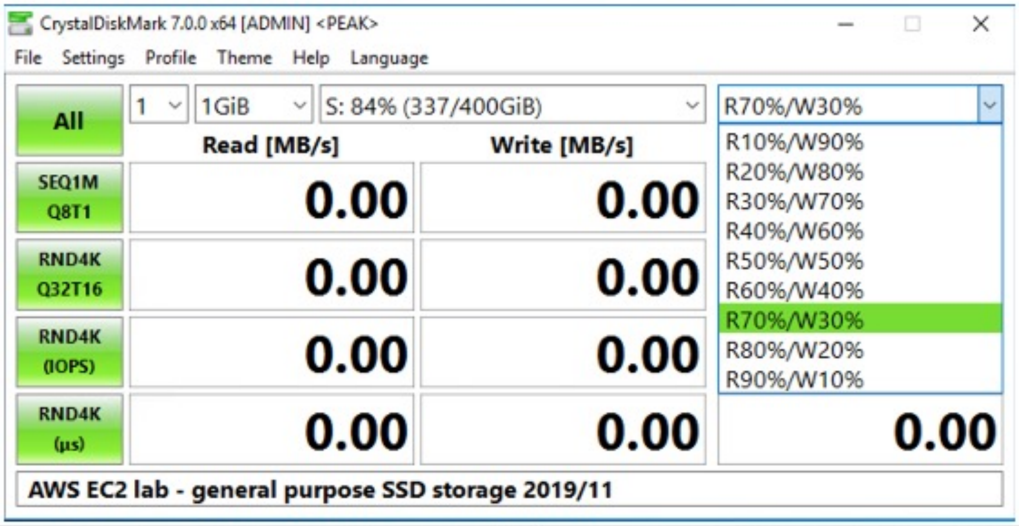
R70%/W30%

		Write [MB/s]	Mix [MB/s]
	00	0.00	0.00
Q32T16	0.00	0.00	0.00
RND4K (IOPS)	0.00	0.00	0.00
RND4K (μs)	0.00	0.00	0.00

AWS EC2 lab - general purpose SSD storage 2019/11

1.2 p37

Bonus points: choose your mix

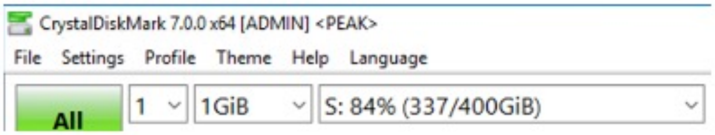


1 | 1GiB | S: 84% (337/400GiB) | R70%/W30%

	Read [MB/s]	Write [MB/s]	
SEQ1M Q8T1	0.00	0.00	
RND4K Q32T16	0.00	0.00	
RND4K (IOPS)	0.00	0.00	
RND4K (µs)	0.00	0.00	0.00

AWS EC2 lab - general purpose SSD storage 2019/11

Settings across the top

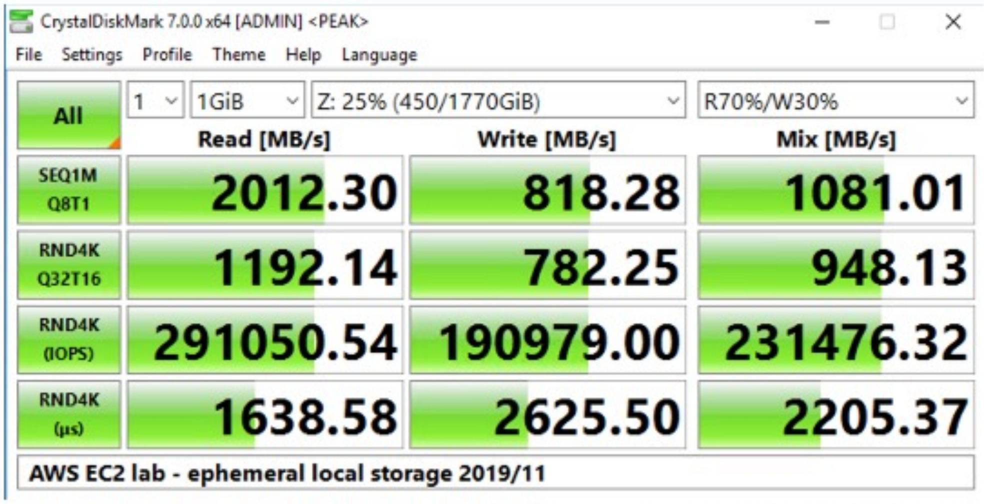

CrystalDiskMark 7.0.0 x64 [ADMIN] <PEAK>
File Settings Profile Theme Help Language
All
1
1GiB
S: 84% (337/400GiB)

1 = number of tests (1 = quick test, 9 = many tests)

1GiB = test file size (1GiB = quick test, 64GiB = in-depth test that won’t just get cached)

S: = the drive letter or folder that you want to test

Interpreting the results


CrystalDiskMark 7.0.0 x64 [ADMIN] <PEAK>
File Settings Profile Theme Help Language
All

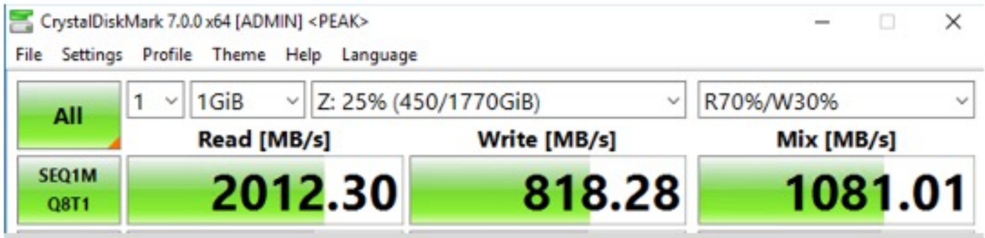
1 | 1GiB | Z: 25% (450/1770GiB) | R70%/W30%

	Read [MB/s]	Write [MB/s]	Mix [MB/s]
SEQ1M Q8T1	2012.30	818.28	1081.01
RND4K Q32T16	1192.14	782.25	948.13
RND4K (IOPS)	291050.54	190979.00	231476.32
RND4K (µs)	1638.58	2625.50	2205.37

AWS EC2 lab - ephemeral local storage 2019/11

1.2 p40

Interpreting the results



1 | 1GiB | Z: 25% (450/1770GiB) | R70%/W30%

	Read [MB/s]	Write [MB/s]	Mix [MB/s]
SEQ1M Q8T1	2012.30	818.28	1081.01

SEQ1M = sequential operations, 1MB in size
Q8T1 = 8 queued operations on 1 thread

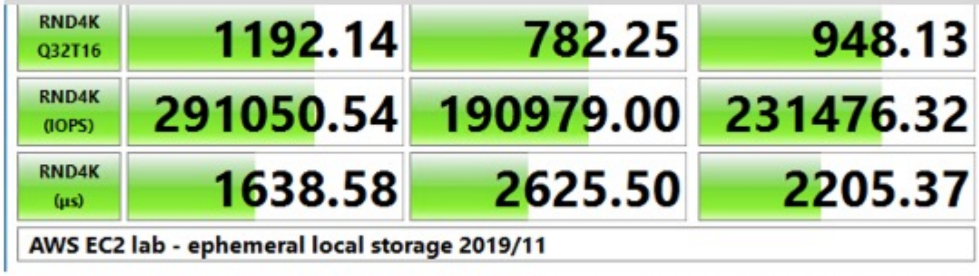
Long, sustained operations like
single-table scans or backups

1.2 p41

Interpreting the results

RND 4K= random operations, tiny 4KB size
Q32T16 = 32 queued operations on 16 threads: busy!

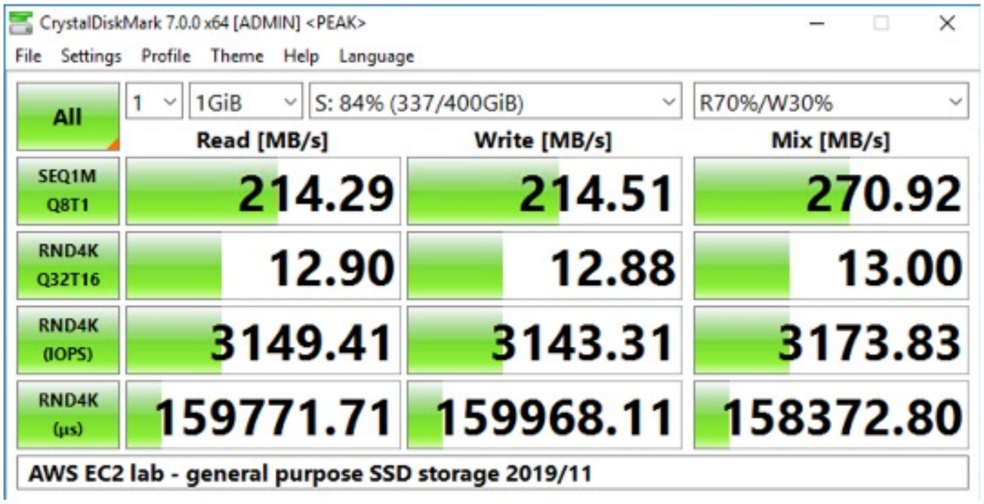
Kinda like an active, busy OLTP server or TempDB



RND4K Q32T16	1192.14	782.25	948.13
RND4K (IOPS)	291050.54	190979.00	231476.32
RND4K (μs)	1638.58	2625.50	2205.37

AWS EC2 lab - ephemeral local storage 2019/11

Slower storage



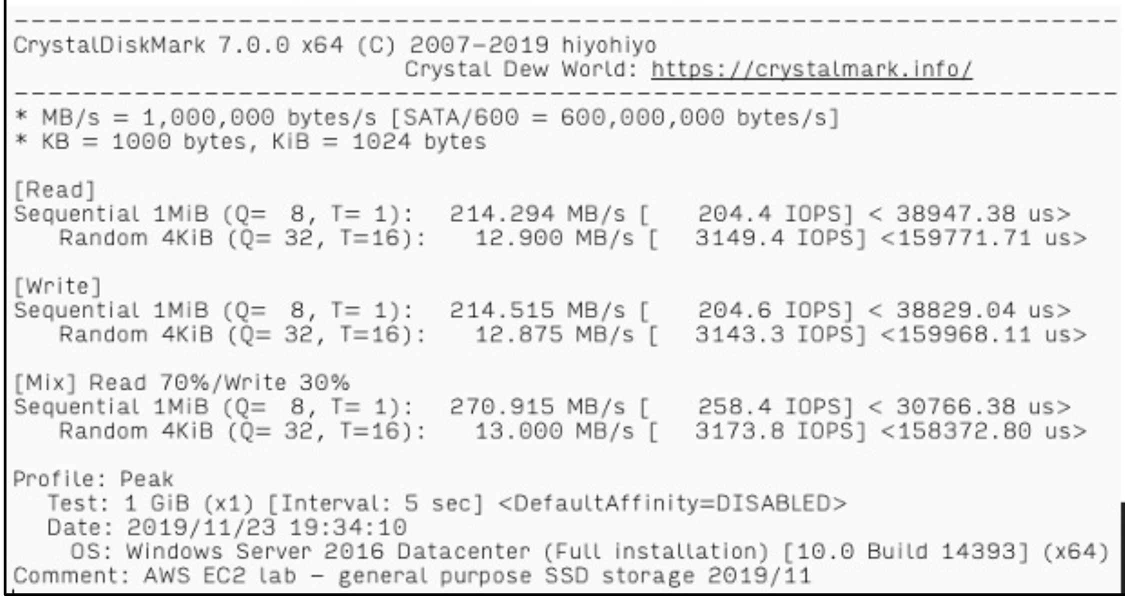
CrystalDiskMark 7.0.0 x64 [ADMIN] <PEAK>
File Settings Profile Theme Help Language

1 | 1GiB | S: 84% (337/400GiB) | R70%/W30%

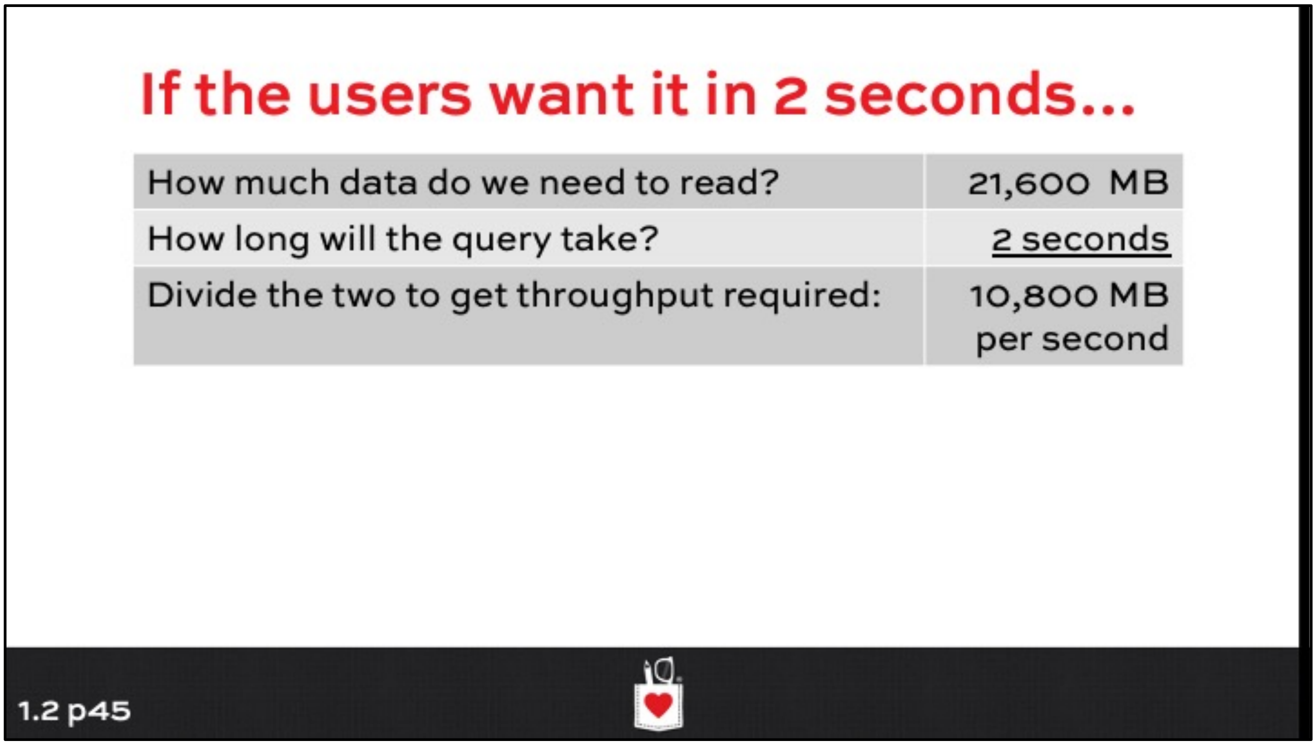
All	Read [MB/s]	Write [MB/s]	Mix [MB/s]
SEQ1M Q8T1	214.29	214.51	270.92
RND4K Q32T16	12.90	12.88	13.00
RND4K (IOPS)	3149.41	3143.31	3173.83
RND4K (μs)	159771.71	159968.11	158372.80

AWS EC2 lab - general purpose SSD storage 2019/11

Click File, Copy, and paste into Notepad



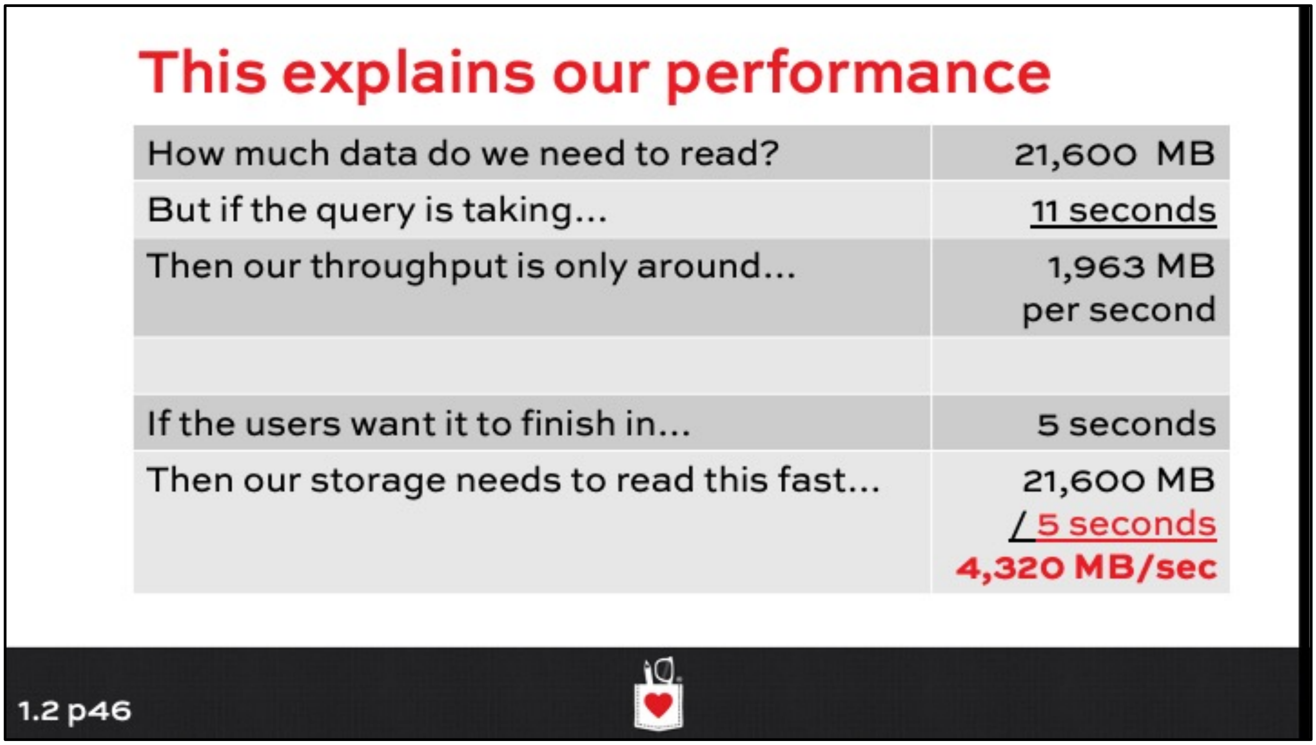
```
------------------------------------------------------------------------------
CrystalDiskMark 7.0.0 x64 (C) 2007-2019 hiyohiyo
                          Crystal Dew World: https://crystalmark.info/
------------------------------------------------------------------------------
* MB/s = 1,000,000 bytes/s [SATA/600 = 600,000,000 bytes/s]
* KB = 1000 bytes, KiB = 1024 bytes

[Read]
Sequential 1MiB (Q=  8, T= 1):   214.294 MB/s [    204.4 IOPS] < 38947.38 us>
   Random 4KiB (Q= 32, T=16):    12.900 MB/s [   3149.4 IOPS] <159771.71 us>

[Write]
Sequential 1MiB (Q=  8, T= 1):   214.515 MB/s [    204.6 IOPS] < 38829.04 us>
   Random 4KiB (Q= 32, T=16):    12.875 MB/s [   3143.3 IOPS] <159968.11 us>

[Mix] Read 70%/Write 30%
Sequential 1MiB (Q=  8, T= 1):   270.915 MB/s [    258.4 IOPS] < 30766.38 us>
   Random 4KiB (Q= 32, T=16):    13.000 MB/s [   3173.8 IOPS] <158372.80 us>

Profile: Peak
  Test: 1 GiB (x1) [Interval: 5 sec] <DefaultAffinity=DISABLED>
  Date: 2019/11/23 19:34:10
    OS: Windows Server 2016 Datacenter (Full installation) [10.0 Build 14393] (x64)
Comment: AWS EC2 lab - general purpose SSD storage 2019/11
```



If the users want it in 2 seconds...

How much data do we need to read?	21,600 MB
How long will the query take?	2 seconds
Divide the two to get throughput required:	10,800 MB per second

1.2 p45



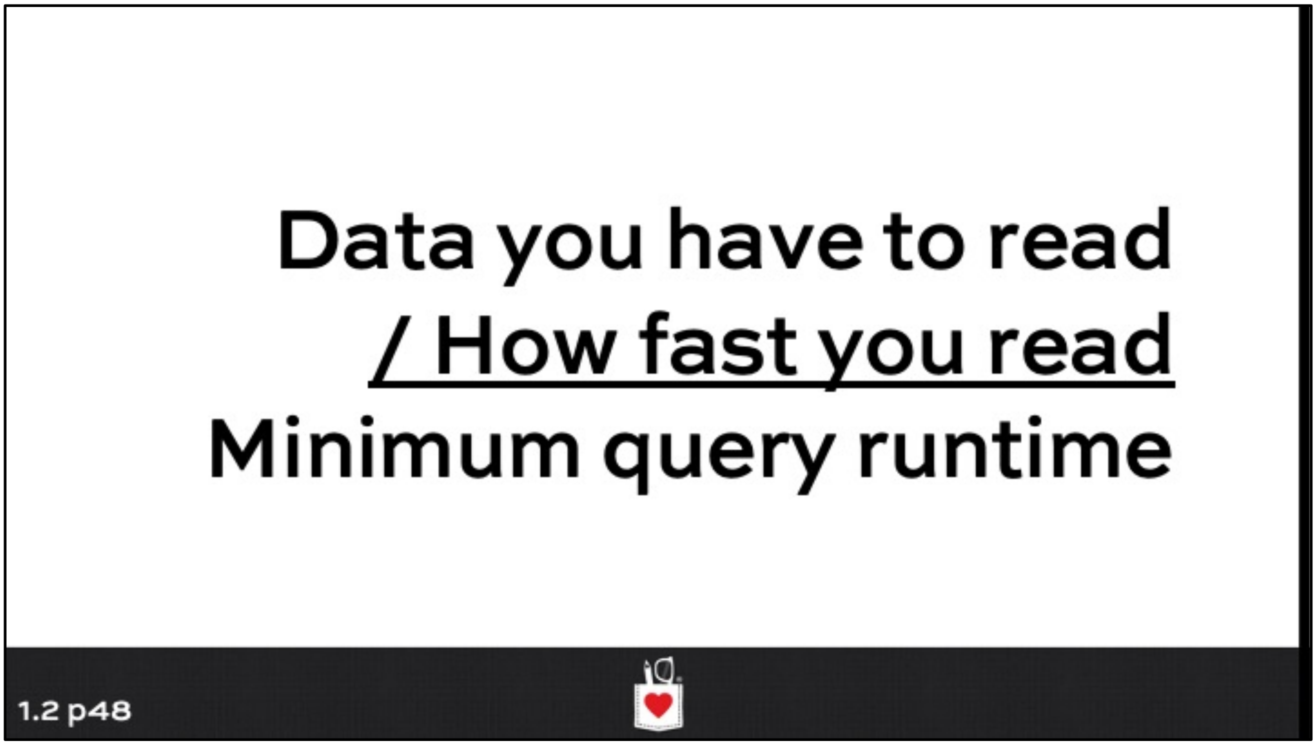
This explains our performance

How much data do we need to read?	21,600 MB
But if the query is taking…	11 seconds
Then our throughput is only around…	1,963 MB per second
If the users want it to finish in…	5 seconds
Then our storage needs to read this fast…	21,600 MB / 5 seconds **4,320 MB/sec**

1.2 p46

This simple formula drives everything.

1.2 p47

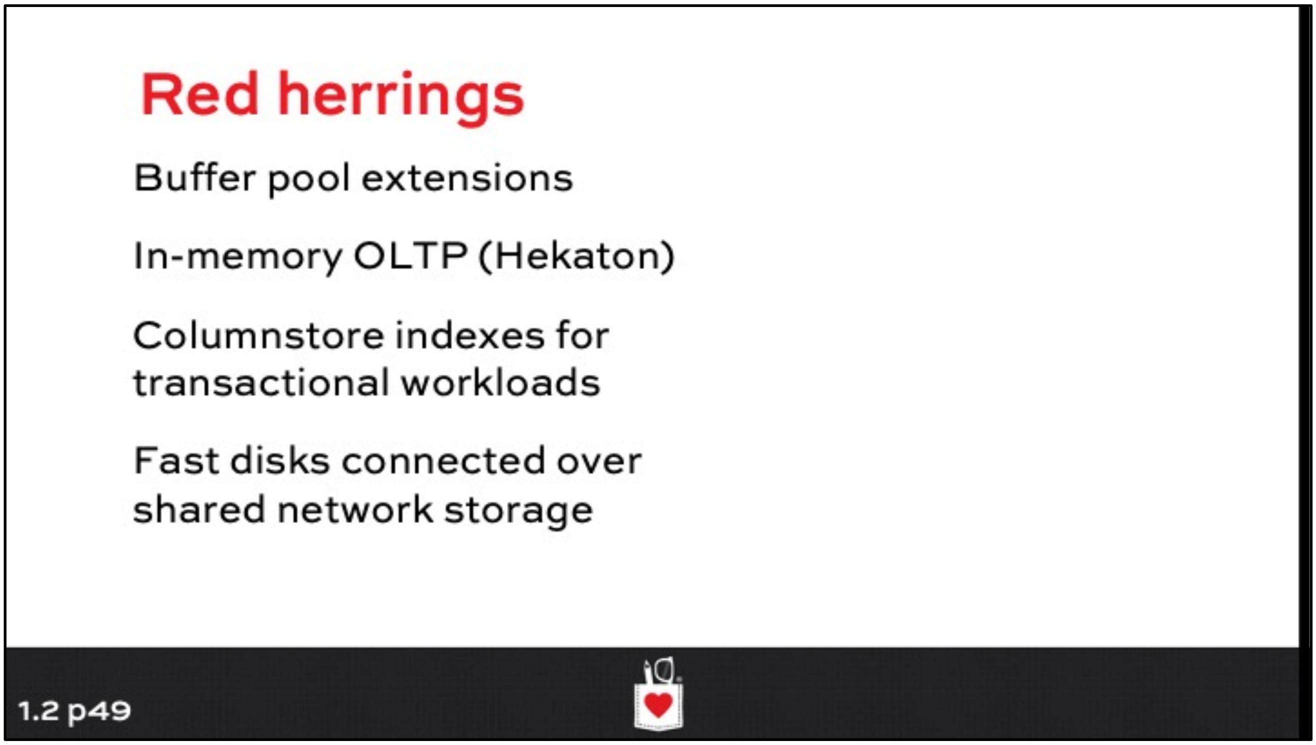


Data you have to read

/ How fast you read

Minimum query runtime

1.2 p48



Red herrings

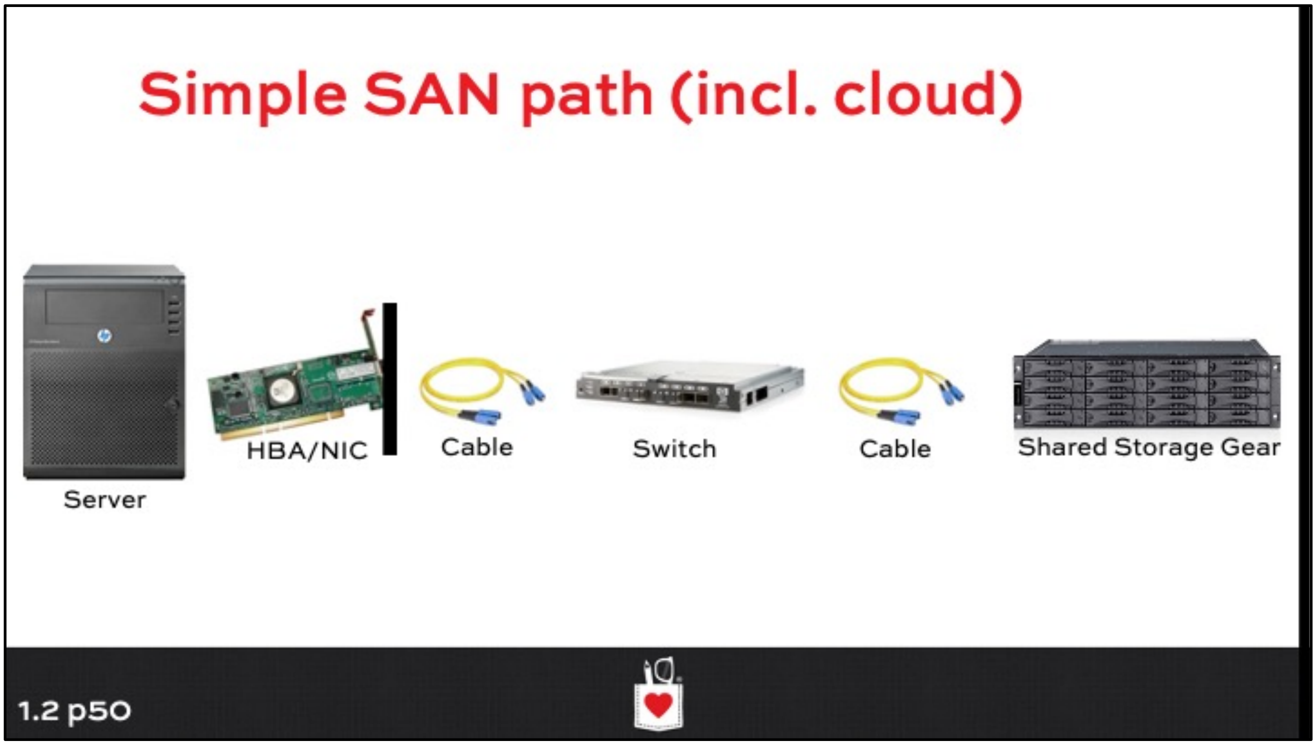
Buffer pool extensions

In-memory OLTP (Hekaton)

Columnstore indexes for transactional workloads

Fast disks connected over shared network storage

1.2 p49



Simple SAN path (incl. cloud)

Server

HBA/NIC

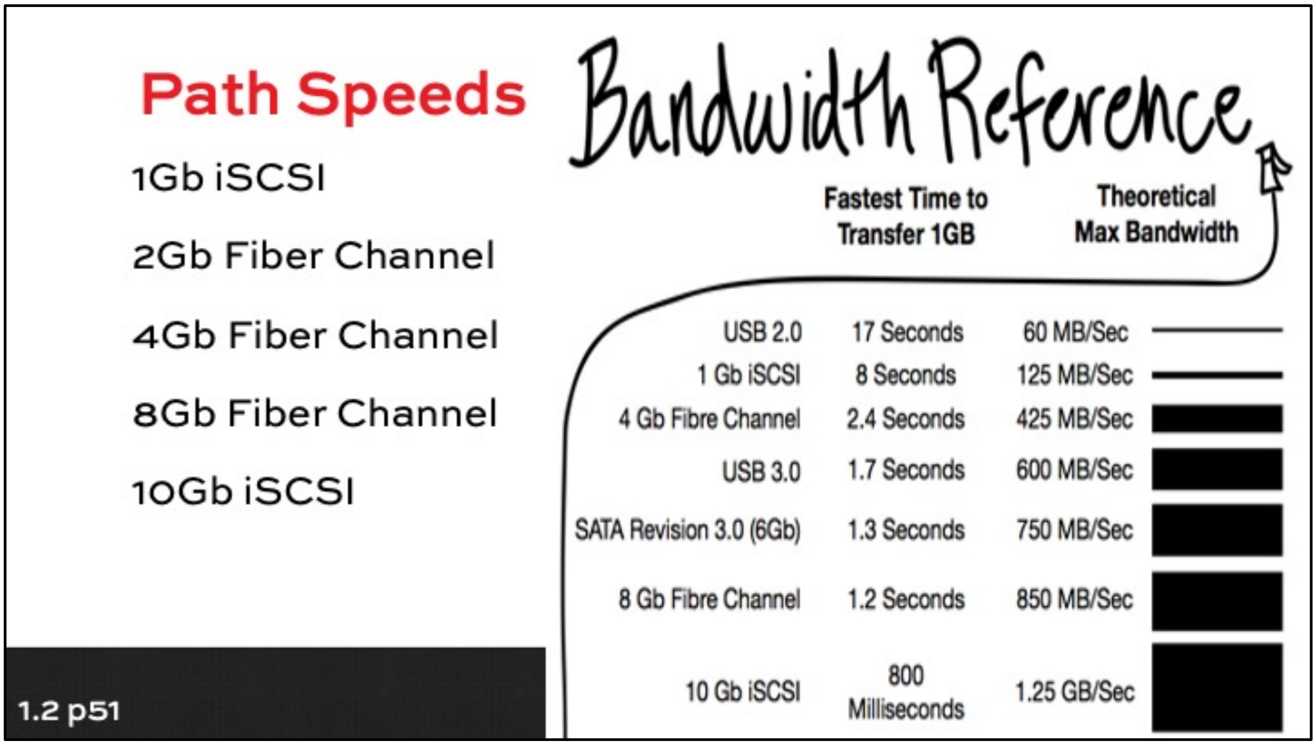
Cable

Switch

Cable

Shared Storage Gear

1.2 p50



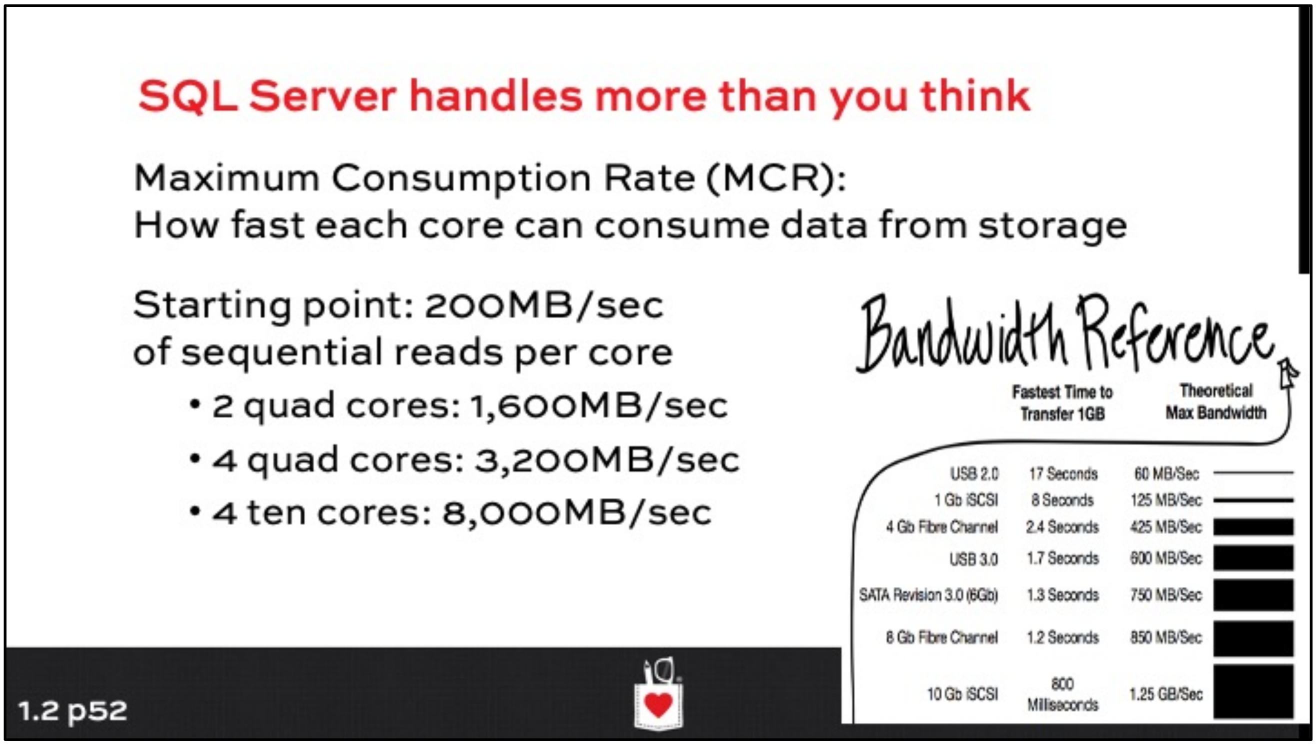
Path Speeds

- 1Gb iSCSI
- 2Gb Fiber Channel
- 4Gb Fiber Channel
- 8Gb Fiber Channel
- 10Gb iSCSI

1.2 p51

Bandwidth Reference

	Fastest Time to Transfer 1GB	Theoretical Max Bandwidth
USB 2.0	17 Seconds	60 MB/Sec
1 Gb iSCSI	8 Seconds	125 MB/Sec
4 Gb Fibre Channel	2.4 Seconds	425 MB/Sec
USB 3.0	1.7 Seconds	600 MB/Sec
SATA Revision 3.0 (6Gb)	1.3 Seconds	750 MB/Sec
8 Gb Fibre Channel	1.2 Seconds	850 MB/Sec
10 Gb iSCSI	800 Milliseconds	1.25 GB/Sec



SQL Server handles more than you think

Maximum Consumption Rate (MCR):
How fast each core can consume data from storage

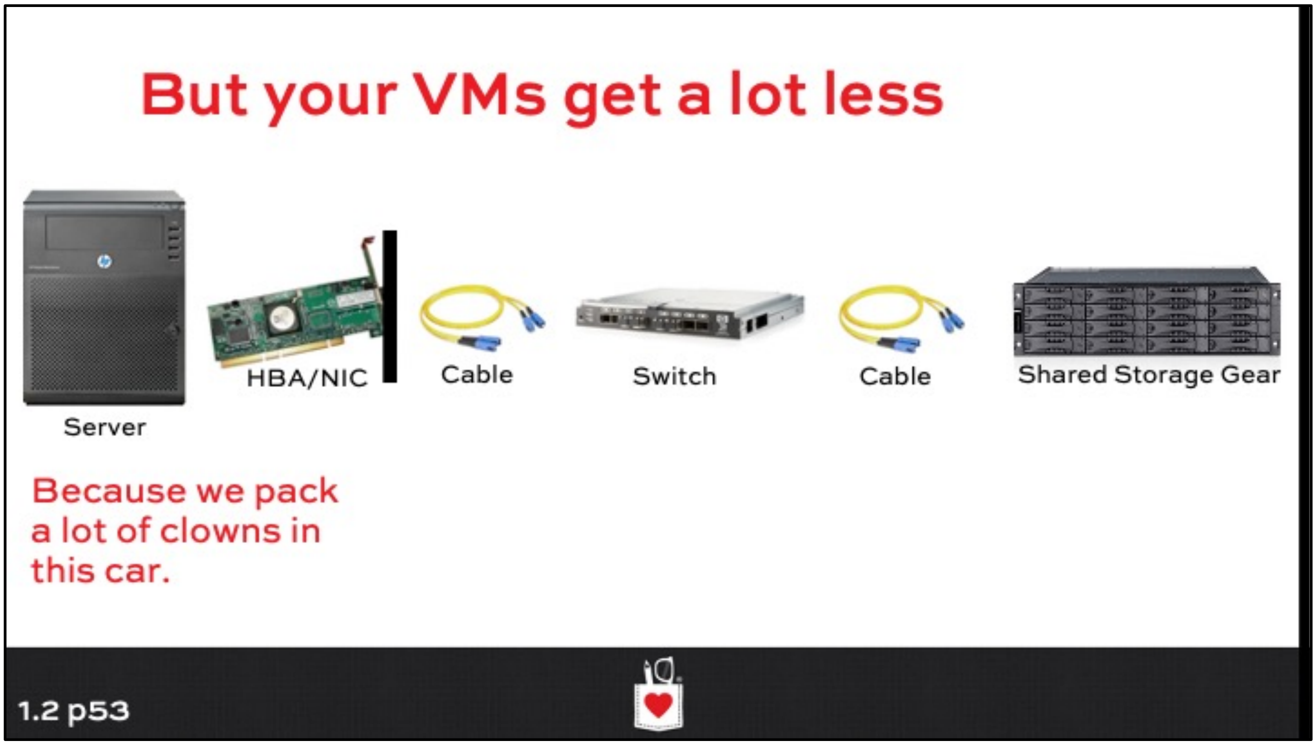
Starting point: 200MB/sec of sequential reads per core

- 2 quad cores: 1,600MB/sec
- 4 quad cores: 3,200MB/sec
- 4 ten cores: 8,000MB/sec

Bandwidth Reference

	Fastest Time to Transfer 1GB	Theoretical Max Bandwidth
USB 2.0	17 Seconds	60 MB/Sec
1 Gb iSCSI	8 Seconds	125 MB/Sec
4 Gb Fibre Channel	2.4 Seconds	425 MB/Sec
USB 3.0	1.7 Seconds	600 MB/Sec
SATA Revision 3.0 (6Gb)	1.3 Seconds	750 MB/Sec
8 Gb Fibre Channel	1.2 Seconds	850 MB/Sec
10 Gb iSCSI	800 Milliseconds	1.25 GB/Sec

1.2 p52



But your VMs get a lot less

Server

HBA/NIC

Cable

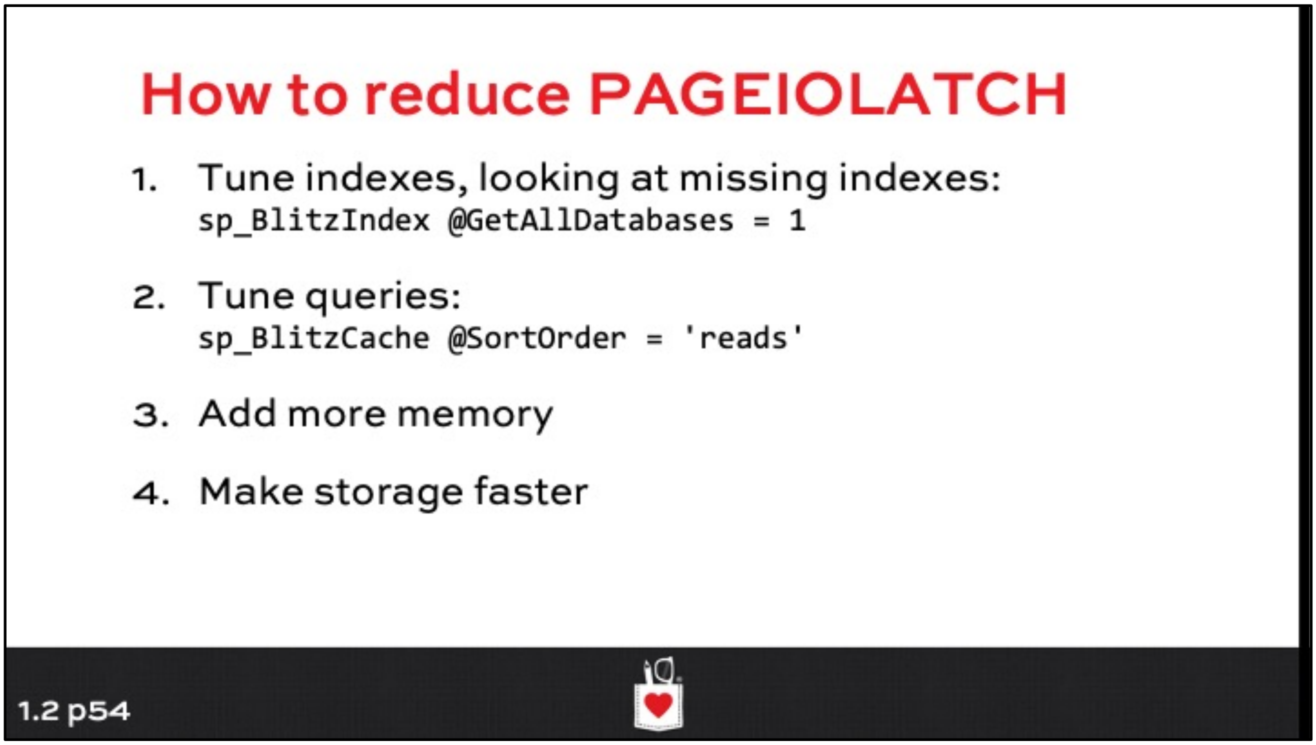
Switch

Cable

Shared Storage Gear

Because we pack a lot of clowns in this car.

1.2 p53



How to reduce PAGEIOLATCH

1. Tune indexes, looking at missing indexes:
   ```
   sp_BlitzIndex @GetAllDatabases = 1
   ```
2. Tune queries:
   ```
   sp_BlitzCache @SortOrder = 'reads'
   ```
3. Add more memory
4. Make storage faster

1.2 p54