The DiskSpd Storage Performance Tool

DiskSpd is a highly customizable I/O load generator tool that can be used to run storage performance tests against files, partitions, or physical disks. DiskSpd can generate a wide variety of disk request patterns for use in analyzing and diagnosing storage performance issues, without running a full end-to-end workload. You can simulate SQL Server I/O activity or more complex, changing access patterns, returning detailed XML output for use in automated results analysis.

This document corresponds to version 2.0.17 of DiskSpd.

Contents

1 Vision for the DiskSpd tool

The DiskSpd tool provides the functionality needed to generate a wide variety of disk request patterns, helpful in diagnosis and analysis of storage-based performance issues. For example, it can be used to simulate SQL Server I/O activity and more complex patterns of access which change over time. It enables the user to analyze storage performance without running a full end-to-end workload.

DiskSpd presents results in both a text summary and also a detailed XML form suitable for automated result analysis.

1.1 Acknowledgments

Previous versions of DiskSpd were developed under Jim Gray by Peter Kukol from Microsoft Research, results from which can be found here: http://research.microsoft.com/barc/Sequential_IO/.

A binary release of DiskSpd can be obtained here: http://aka.ms/diskspd

DiskSpd is open source (MIT License) and can be found here: https://github.com/microsoft/diskspd

2 The DiskSpd command and parameters

DiskSpd is a command-line utility that is invoked in the following way:

```
diskspd [options] target1 [ target2 [ target3 ...] ]
```

All available options and parameters are enumerated in the tables below, and more completely described in Section 3. Test targets can be regular files (C:\testfile.dat), partitions (C:), or physical drives (#1). Parameters can be specified as command line options or in an XML file.

2.1 DiskSpd basic parameters

Table 1 describes basic parameters that configure the DiskSpd tests. For example, the following command runs a test for 15 seconds using a single thread to drive 100% random 4KiB reads at a depth of 10 overlapped (outstanding) I/Os to a regular file:

```
diskspd –d15 –F1 –w0 –r –b4k –o10 c:\testfile.dat
```

Table 1. DiskSpd parameters

Parameter	Description
-?	Displays usage information for DiskSpd.
-ag	Group affinity - affinitize threads in a round-robin manner across Processor Groups, starting at group 0. This is default. Use **-n** to disable affinity.
-ag#,#[,#,...]	Advanced CPU affinity - affinitize threads round-robin to the CPUs provided. The g# notation specifies Processor Groups for the following CPU core #s. Multiple Processor Groups may

Parameter	Description
	be specified, and groups/cores may be repeated. If no group is specified, 0 is assumed.
	Additional groups/processors may be added, comma separated, or on separate parameters.
	Examples:
	-a0,1,2 and -ag0,0,1,2 are equivalent.
	-ag0,0,1,2,g1,0,1,2 specifies the first three cores in groups 0 and 1. -ag0,0,1,2 -ag1,0,1,2 is an equivalent way of specifying the same pattern with two -ag# arguments.
`-b<size>[K|M|G]`	Block size in bytes or KiB, MiB, or GiB (default = 64K)
`-B<offset>[K|M|G|b]`	Base target offset in bytes or KiB, MiB, GiB, or blocks from the beginning of the target (default offset = zero)
`-c<size>[K|M|G|b]`	Create files of the specified size. Size can be stated in bytes or KiBs, MiBs, GiBs, or blocks.
`-C<seconds>`	Cool down time in seconds - continued duration of the test load after measurements are complete (default = zero seconds).
`-D<milliseconds>`	Capture IOPs higher-order statistics in intervals of <milliseconds>. These are per-thread per-target: text output provides IOPs standard deviation, XML provides the full IOPs time series in addition (default = 1000ms or 1 second).
`-d<seconds>`	Duration of measurement period in seconds, not including cool-down or warm-up time (default = 10 seconds).
`-f<size>[K|M|G|b]`	Target size - use only the first <size> bytes or KiB, MiB, GiB or blocks of the specified targets, for example to test only the first sectors of a disk.
`-f<rst>`	Open file with one or more additional access hints specified to the operating system: r : the FILE_FLAG_RANDOM_ACCESS hint s : the FILE_FLAG_SEQUENTIAL_SCAN hint t : the FILE_ATTRIBUTE_TEMPORARY hint Note that these hints are generally only applicable to cached IO.
`-F<count>`	Total number of threads. Conflicts with -t, the option to set the number of threads per file.

Parameter	Description
-g*<bytes per ms>*	Throughput per-thread per-target is throttled to the given number of bytes per millisecond. This option is incompatible with completion routines (**-x**).
-h	Deprecated but still honored; see **-Sh**.
-i*<count>*	Number of IOs (burst size) to issue before pausing. Must be specified in combination with **-j**.
-j*<milliseconds>*	Pause in milliseconds before issuing a burst of IOs. Must be specified in combination with **-i**.
-I*<priority>*	Set IO priority to <priority>. Available values are: 1-very low, 2-low, 3-normal (default).
-l	Use large pages for IO buffers.
-L	Measure latency statistics. Full per-thread per-target distributions are available with XML result output.
-n	Disable default affinity (**-a**).
-o*<count>*	Number of outstanding I/O requests per target per thread. (1 = synchronous I/O, unless more than 1 thread is specified with by using -**F**) (default = 2).
-p	Start asynchronous (overlapped) I/O operations with the same offset. Only applicable with 2 or more outstanding I/O requests per thread (-**o**2 or greater)
-P*<count>*	Enable printing a progress dot after the specified each *<count>* [default = 65536] completed of I/O operations, counted separately by each thread.
-r*<alignment>*[K|M|G|b]	Random I/O aligned to the specified number of <align> bytes or KiB, MiB, GiB, or blocks. Overrides **-s**.
-R[*text|xml*]	Display test results in either text or XML format (default: text).
-s[i]*<size>*[K|M|G|b]	Sequential stride size, offset between subsequent I/O operations in bytes or KiB, MiB, GiB, or blocks. Ignored if **-r** specified (default access = sequential, default stride = block size).
	By default each thread tracks its own sequential offset. If the optional interlocked (i) qualifier is used, a single interlocked offset is shared between all threads operating on a given

Parameter	Description
	target so that the threads cooperatively issue a single sequential pattern of access to the target.
-S[h|r]	
-S	Disable software caching. This is equivalent to opening a file with the FILE_FLAG_NO_BUFFERING flag specified. This option is included in **-Sh** (default: caching is enabled).
-Sh	Disable both software caching and hardware write caching. This is equivalent to opening a file with the FILE_FLAG_NO_BUFFERING and FILE_FLAG_WRITE_THROUGH flags (default: caching is enabled). **Note**: SATA devices will generally not honor write through intent. Devices with persistent write caches - certain enterprise flash drives, and most storage arrays - tend to interpret write through as being satisfied when the write is stable in cache, so that **-S** and **-Sh** will see equivalent behavior.
-Sr	Disable local caching for remote filesystems. This leaves the remote system's cache enabled.
-t<count>	Number of threads per target. Conflicts with **-F**, which specifies the total number of threads.
-T<offset>[K|M|G|b]	Stride size between I/O operations performed on the same target by different threads in bytes or KiB, MiB, GiB, or blocks (default stride size = 0; starting offset = base file offset + (<thread number> * <offset>). Makes sense only when number of threads per target > 1.
-v	Verbose mode
-w<percentage>	Percentage of write requests to issue (default = 0, 100% read). The following are equivalent and result in a 100% read-only workload: omitting **-w**, specifying **-w** with no percentage, and **-w0**. **IMPORTANT**: a write test will destroy existing data without a warning.
-W<seconds>	Warmup time - duration of the test before measurements start (default = 5 seconds).

Parameter	Description
-x	Use I/O completion routines instead of I/O completion ports for cases specifying more than one IO per thread[1] (see **-o**). Unless there is a specific reason to explore differences in the completion model, this should generally be left at default.
-X<filepath>	Use an XML file for configuring the workload. Cannot be used with other parameters. XML output <Profile> block is a template. See the diskspd.xsd file for details.
-z[seed]	Set random seed to specified integer value. With no -z, seed=0. With plain -z, seed is based on system run time.
-Z	Zero the per-thread I/O buffers. Relevant for write tests. By default, the buffers are filled with a repeating pattern (0, 1, 2, …, 255, 0, 1, …)
-Z<size>[K|M|G|b]	Separate read and write buffers, and initialize a per-target write source buffer sized to the specified number of bytes or KiB, MiB, GiB, or blocks. This write source buffer is initialized with random data, and per-IO write data is selected from it at 4-byte granularity.
-Z<size>[K|M|G|b],<file>	Same, but using a file as the source of data to fill the write source buffers.

2.2   DiskSpd event parameters

The parameters in Table 2 specify events that can be used to start, end, cancel, or send notifications for a DiskSpd.exe test run.

Table 2. DiskSpd Event Parameters

Parameter	Description
-ys<eventname>	Signals event <*eventname*> before starting the actual run (no warmup). Creates a notification event if <*eventname*> does not exist.
-yf<eventname>	Signals event <*eventname*> after the test run completes (no cooldown). Creates a notification event if <*eventname*> does not exist.

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[1] See the Synchronous and Asynchronous I/O topic here for more details:
http://msdn.microsoft.com/en-us/library/windows/desktop/aa365683(v=vs.85).aspx

Parameter	Description
`-yr<eventname>`	Waits on event *<eventname>* before starting the test run (including warmup). Creates a notification event if *<eventname>* does not exist.
`-yp<eventname>`	Stops the run when event *<eventname>* is set. CTRL+C is bound to this event. Creates a notification event if *<eventname>* does not exist.
`-ye<eventname>`	Sets event *<eventname>* and quits.

2.3 ETW parameters for use with DiskSpd.exe

Using the parameters in Table 3, you can have DiskSpd obtain data concerning events from an NT Kernel Logger trace session. Because event tracing (ETW) carries additional overhead, this is turned off by default.

Table 3. DiskSpd ETW parameters

Parameter	Description
`-e<q|c|s>`	Use query perf timer (qpc), cycle count, or system timer respectively (default = q, query perf timer (qpc))
`-ep`	Use paged memory for the NT Kernel Logger (default = non-paged memory).
`-ePROCESS`	Capture process start and end events.
`-eTHREAD`	Capture thread start and end events.
`-eIMAGE_LOAD`	Capture image load events.
`-eDISK_IO`	Capture physical disk I/O events.
`-eMEMORY_PAGE_FAULTS`	Capture all page fault events.
`-eMEMORY_HARD_FAULTS`	Capture hard fault events.
`-eNETWORK`	Capture TCP/IP, UDP/IP send and receive events.
`-eREGISTRY`	Capture registry call events.

2.4 Size conventions for DiskSpd parameters

Several DiskSpd options take sizes and offsets specified as bytes or as a multiple of kilobytes, megabytes, gigabytes, or blocks: **[K|M|G|b]**.

The conventions used for referring to multiples of bytes are a common source of confusion. In networking and communication, these multiples are universally in powers of ten: a 'GB' is 10^9 (1 billion) bytes. By comparison, a 'GB' of RAM is universally understood to be 2^{30} (1,073,741,824) bytes. Storage

has historically been in a gray area where file sizes are spoken of in powers of two, but storage system manufacturers refer to total capacity in powers of ten. Since storage is always accessed over at least one (SAS, SATA) or more (PCI, Ethernet, Infiniband) communication links, this adds complexity into the already challenging exercise of understanding end-to-end flows.

The **iB** notation is an international convention which unambiguously refers to power of two-based sizing for numbers of bytes, as distinct from powers of ten which continue to use KB/MB/GB notation.

- 1KiB = 2^{10} = 1,024 bytes
- 1MiB = 1024 KiB = 2^{20} = 1,048576 bytes
- 1GiB = 1024 MiB = 2^{30} = 1,073,741,824 bytes

This notation will be used in this document. DiskSpd itself reports power of two-based quantities *without* the **iB** notation, though this may evolve over time.

To specify sizes to DiskSpd:

- bytes: use a plain number (65536)
- KiB: suffix a number with 'K' or 'k' (64k)
- MiB: suffix a number with 'M' or 'm' (1m)
- GiB: suffix a number with 'G' or 'g' (10g)
- multiples of blocks: suffix a number with 'b' (5b) - multiplying the block size specified with -b

Fractional sizes with decimal points such as 10.5 are not allowed.

3 Customizing DiskSpd tests

The following sections explain how you can use the DiskSpd parameters to customize tests so that they more closely emulate the performance factors that your environment requires.

3.1 Display usage information

To display a short description of all available options, use the **-?** parameter.

3.2 Set a test duration

The default measured test duration is 10 seconds. This can be changed with the **-d** parameter, for example **-d50** will result in a ~50s long test. Actual measured test duration may be slightly longer than the requested time because of additional thread synchronization and precision of operating system's sleep methods. The actual duration of the test is reported as part of the results.

A warmup time may also be specified, during which the specified I/O requests are being issued but no measurements are performed. The default warmup duration is 5 seconds, and can be changed using the **-W** parameter (for example, **-W10** sets a 10-second warmup).

A cool-down period can be specified using the -**C** parameter; for example, **-C5** adds a 5-second cool-down period. The default cool-down time is 0 seconds. A use case for cool-down is to ensure that, especially in multi-system tests, all instances of DiskSpd are active during each instance's measurement

period. Specify a cool-down which is at least as long as the time taken to launch the DiskSpd instances on the systems providing the test.

3.3   Control caching

To disable software (operating system) caching, use the -**S** parameter. Disabling the software cache introduces additional constraints:

- File access must begin at byte offsets within the file that are integer multiples of the volume's sector size.
- File access must be for numbers of bytes that are integer multiples of the volume's sector size. For example, if the sector size is 512 bytes, an application can request reads and writes of 512, 1024, or 2048 bytes, but not of 335, 981, or 7171 bytes.

This parameter is equivalent to using FILE_FLAG_NO_BUFFERING on the Win32 CreateFile API.

The -**Sh** parameter disables both software caching and hardware write caching, and has the same constraints that apply to disabling software caching. It is equivalent to using both FILE_FLAG_NO_BUFFERING and FILE_FLAG_WRITE_THROUGH on the Win32 CreateFile API.

SATA devices will generally not honor the write through intent that -**Sh** specifies. Devices with persistent write caches - certain enterprise flash drives, and most storage arrays - tend to interpret write through as being satisfied when the write is stable in cache, so that -**S** and -**Sh** will see equivalent behavior.

The -**Sr** parameter is specific to running tests over remote filesystems such as SMB, and disables the local cache while leaving the remote system's cache enabled. This can be useful when investigating the remote filesystem's wire transport performance and behavior, allowing the test to occur without needing extremely fast storage subsystems. Note that if a write test is performed, the temporary file attribute must be used to delay background cache writes on the remote system during the test (see Section 3.4).

3.4   Set random or sequential access hints

The –**f<rst>** parameters results in, respectively, the random-access, sequential-only and/or temporary file hints being indicated to the operating system when opening the targets.

These hints are generally applicable only to files, and only if software caching is enabled for the test. They are equivalent to using the following flags on the Win32 CreateFile API:

- **r** : FILE_FLAG_RANDOM_ACCESS
- **s** : FILE_FLAG_SEQUENTIAL_SCAN
- **t** : FILE_ATTRIBUTE_TEMPORARY

Please see the operating system documentation for CreateFile[2] for the behavioral definitions of these options. Note that the random access and sequential-only hints indicate access patterns which are exclusive of the other, and combining them may result in unusual behavior.

The temporary file attribute only takes effect if the file is newly created (e.g., Section 3.19), and has the effect of delaying background cache writes until memory pressure requires progress or the file is closed. In conventional use, this allows a spill file to be created on the assumption that it will be quickly deleted, avoiding all writes. This may be useful in focused performance tests for similar reasons.

3.5   Block Size

The block size used for IO operations is set with the -**b** parameter. The default value is 64KiB.

3.6   Test random I/O

The **-r** parameter turns on random I/O access. The file offset at which the I/O operation will be performed is chosen randomly before each I/O operation. All offsets are aligned to the size specified with the **-r** parameter.

If you use the **-r** parameter without specifying the size, offsets are block-aligned. The block size is set with the **-b** parameter.

This parameter can't be used with the -**s** parameter, because **-s** defines the offset for the next I/O operation, and in case of random I/O the offset of the next operation is not a constant value. If both -**r** and -**s** are specified, -**r** overrides -**s**.

3.7   Test sequential I/O

The -**s** sequential I/O parameter specifies the stride from the prior I/O to the next operation. For example, if a 64KiB stride is chosen for a 4KiB block size, the first IO will be at zero, the second at 64KiB, and so forth.

After the whole file is read, I/O resumes at the base offset (**-B**) or zero, as appropriate.

If multiple threads operate on a single target, the threads will operate independently and the target will see multiple sequential streams. This is most useful with sequential stride (**-T**, see Section 3.12).

If the optional interlocked (**i**) qualifier is used, **-si**, a single interlocked offset is shared between all threads operating on a given target. This mode is most useful when a single sequential pattern is desired and a single thread is unable to fully drive very fast storage.

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[2] https://msdn.microsoft.com/en-us/library/windows/desktop/aa363858(v=vs.85).aspx

3.8 Perform a write test

Use the **-w** parameter to specify the mix of IO operations, as a percentage of write requests to issue in increments of 1%. The default is 0% write, or 100% read.

The following are equivalent and result in a 100% read-only workload: omitting -w, specifying -w with no percentage, and -**w0**.

As example of a mixed load **-w10** will result in a 10% write workload, with the remaining 90% being reads. This is implemented as a random choice at the dispatch of each operation. DiskSpd does not track the resulting mix, and instead relies on the long term behavior of the random number generator to deliver the expected ratio.

CAUTION: a write test will destroy existing data without a warning.

3.9 Set a base target offset

To omit the beginning of a target during testing, use the -**B** parameter to specify a base target offset. The default offset is zero. No I/O operations will be performed between the start of the target and the base offset.

- random operations (**-r**) are issued at base + <random offset>
- sequential operations (**-s**) wrap back to the base offset when they pass the end of the target

For example, the following command runs a 10-second test on physical drive 1 with a block size of 8KiB, and skips the first 10 blocks (80KiB):

```
diskspd –b8K –B10b #1
```

3.10 Set the maximum target offset

The maximum offset in the target to be tested can be specified with the **-f** parameter. If specified, DiskSpd will not access beyond that point in the file, partition, or disk. This option is especially useful for testing first sectors of physical drives. In combination with **-B** (Section 3.9) the total range of the target to be tested can be controlled.

3.11 Limit the total number of threads

One thread can run a test against more than one target (file, physical drive, partition). The total number of threads can be set with the **-F** (fixed threads) parameter. For example, the following command uses 2 threads, each accessing 5 files:

```
diskspd –F2 –o2 file1 file2 file3 file4 file5
```

In this example, -**F2** causes only two threads to be created. Each thread will access all of the files, with two outstanding operations per target (-**o2**). As a result, there are 5 x 2 = 10 outstanding operations per thread and 2 x 10 = 20 total operations.

By contrast, the **-t** (per-target threads) parameter creates sets of threads which only access a specific target.

```
diskspd -t2 -o2 file1 file2 file3 file4 file5
```

In this example, the -**t2** parameter causes two threads per target to be started, for 5 x 2 = 10 total threads with 2 outstanding operations each. Again, this would produce 2 x 10 = 20 total operations.

The -**F** parameter is especially useful for balancing the workload on multiprocessor (or multi-core) systems. You can set -**F** to the number of processors in the system. By default, the threads are affinitized in a Round Robin manner, which distributes processing evenly across the CPUs, enabling you to test a more devices simultaneously before you hit a CPU bottleneck.

The -**F** and -**t** parameters are mutually exclusive. Figure 1 and Figure 2 illustrate the differences between -**t** and -**F**.
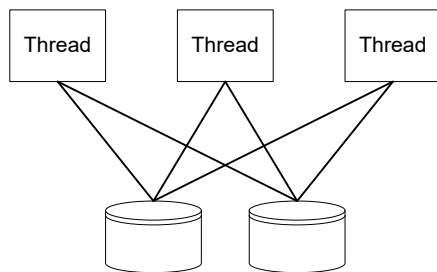

Figure 1. Threads specified with the -F (-F3) fixed threads parameter
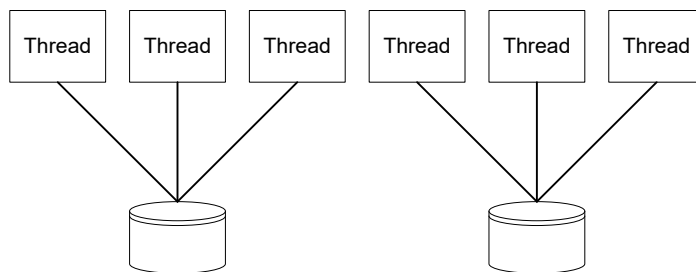
Figure 2. Threads specified with the -t (-t3) per-target threads parameter

3.12 Access from multiple threads & thread stride

By default, a target is accessed by only one thread, although that thread can contain more than one overlapped I/O operation.

With the -**t** or -**F** parameters discussed in the previous section multiple threads will access the same file. By default, threads performing sequential operations will all start from offset 0 (zero) of the target. Use the -**T** parameter to specify the offset between threads (thread stride) if necessary.

Figure 3 shows an example of access with stride creating a interleaved pattern between multiple threads. Thread 1 accesses blocks 1, 4, and 7 of the file. Thread 2 accesses blocks 2, 5, and 8, and thread 3 accesses blocks 3, 6, and 9.

To get such a pattern, thread stride (-**T**) must be equal to block size (-**b**) and sequential stride size (-**s**) must equal number of threads (in this case 3) times the block size. This is a case where specifying strides in units of blocks can be more concise. Either of the following commands will produce that pattern:

```
diskspd -t3 -T4k -b4k -s12k C:\testfile
```

-or-

```
diskspd -t3 -T1b -b4K -s3b c:\testfile
```
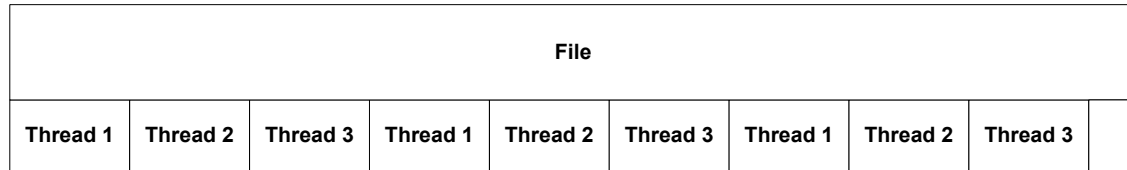
File								
Thread 1	Thread 2	Thread 3	Thread 1	Thread 2	Thread 3	Thread 1	Thread 2	Thread 3

Figure 3. Accessing the file from multiple threads

All the used parameters are also explained in Figure 4.
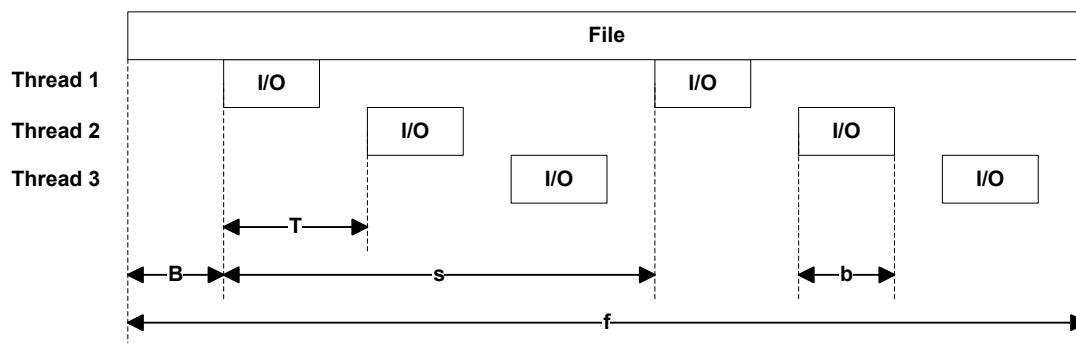
Figure 4. Parameters: base file offset (B), block size (b), stride size (s) and offset between threads (T)

In the previous example, while the pattern is suggestive, there is no interlock between the threads to maintain a strictly sequential pattern of access to the storage (see further discussion in Section 3.7). It is possible due to thread scheduling that the pattern could separate over time, with one or more threads falling behind or racing ahead of their peers.

A second use case for thread stride is to create multiple spatially separated sequential streams on a target:

```
diskspd -c3G -t3 -T1G -b4K -s c:\testfile
```

This pattern will create a 3GiB file and three threads, with each thread starting I/O at succeeding 1GiB intervals.

- Thread 1: 0, 4KiB, 8KiB, …
- Thread 2: 1GiB, 1GiB+4KiB, 1GiB+8KiB, …
- Thread 3: 2GiB, 2GiB+4KiB, 2GiB+8KiB, …

Thread stride need not be a multiple of sequential stride (or vice versa). When the end of file is encountered, access wraps back to the beginning at an offset such that each thread will reproduce the same IO offsets on its next sweep through the target. In the earlier examples each thread will loop back to 0 (zero). Consider the following counter-example:

```
diskspd -c3G -t3 -T13k -b4K -s c:\testfile
```

In this case, the second thread will loop back to offset 1K and then produce 5K, 9K, before returning to 13K and continuing through the file again.

3.13 Number of outstanding I/O requests

The default number of outstanding I/O requests per thread per target is 2. This value can be changed with the **-o** parameter; for example, **-o32** specifies 32 I/O requests per thread per target. If -**o1** is used and threads are accessing only one target (**-F** is not used or there is only one target specified), I/O is issued synchronously.

At the time the test starts, each thread issues its initial batch of I/O up to the limit created by -**o**. Then, by default, as completion for one I/O operation is received another is issued to replace it in the queue.

For sequential I/O, by default the new operation will be issued with respect to the most recent I/O operation started within the same thread. Figure 5 shows an example of this behavior with 3 outstanding I/Os per thread (-o3) and a sequential stride equal to the block size (**-s**). The next I/O operation will start at the offset immediately after I/O #3, which is marked with a dashed line.
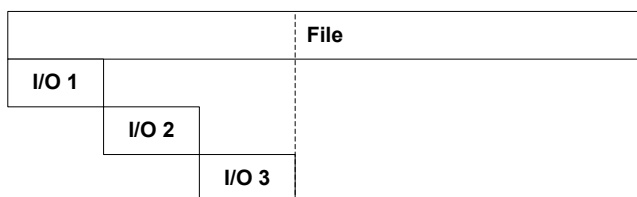
Figure 5. Overlapped I/O (-o3)

The sequential I/O process can be explained with the following pseudo-code. Each thread has its own **lastFileOffset** variable.

```
UINT64 GetNextOffset()
{
    lastFileOffset += stride;
    return lastFileOffset;
}
```

This behavior changes with the **-p** parameter, for parallel overlapping I/Os. When used, the offset of the next I/O operation is calculated by using the offset of the I/O operation that has just finished instead of the most recent I/O operation that started. Figure 6 shows how the -**p** parameter changes the behavior with 3 I/Os per thread (**-o3**) and a sequential stride equal to the block size (**-s**).
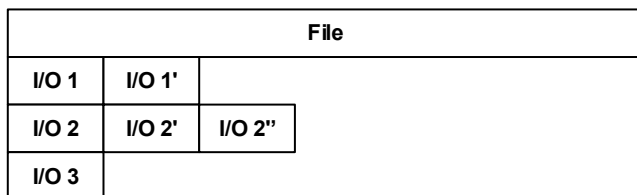
Figure 6. I/O dispatch pattern of the -p parameter (at -o3)

In the figure, the primed (') I/Os indicate the sequence of completion and dispatch, for example that I/O 2'' was issued on the completion of I/O 2'. At the time the diagram stops the three outstanding I/Os are 1', 2'' and 3.

With **-p**, the next sequential offset is calculated in the manner shown in the following pseudo-code, assuming there is enough data left in the file:

```
UINT64 GetNextOffset(struct IO *completedIO)
{
    return completedIO->startOffset + stride;
}
```

The -**p** option creates a very specific pattern perhaps most suitable for cache stress, and its effect should be carefully considered before use in a test.

3.14 Balance queues

I/O requests started by each thread are placed in a separate queue. DiskSpd assures that the queues will be balanced, which means that an I/O operation is restarted as soon as it completes. By default queue refilling is implemented using I/O Completion Ports. As discussed previously (see 3.11), by default DiskSpd creates one thread for each target (file, physical drive, or partition).

Each thread opens a separate I/O Completion Port and uses it to wait until one of the overlapped (outstanding) I/O operations finishes. The operation that finished is restarted (at a new offset). The thread behavior is shown in the following pseudo-code:

```
SetThreadIdealProcessor
AffinitizeThread
CreateIOCompletionPort
WaitForASignalToStart
for(int x=0; x<overlappedIONumber; ++x)
{
    io = ReadFile
}

while(bRun)
{
    GetQueuedCompletionStatus //wait on IO Completion Port
    CalculateNextOffset
    RestartIOOperation
}
```

I/O Completion Ports have small overhead and therefore are convenient to use in I/O performance measurements.

In case of synchronous access (**-o1**), DiskSpd uses a different approach. Because only one I/O operation is running at any time, the use of I/O Completion Ports is not needed. Instead, I/O operations are executed in a loop, as demonstrated by the following pseudo-code:

```
SetThreadIdealProcessor
AffinitizeThread
CreateIOCompletionPort
WaitForASignalToStart

while(bRun)
{

    ReadFile
    CalculateNextOffset
    SetFilePointer

}
```

In both cases, the **bRun** global variable is used by the main thread to inform the worker threads how long they should work. The main thread of the I/O request generator works in the following manner:

```
OpenFiles
CreateThreads
StartTimer
SendStartSignal
Sleep(duration)
bRun = false
StopTimer
WaitForThreadsToCleanUp
SendResultsToResultParser
```

3.15 Alternatively, specify "think" time and I/O Bursts

An exception to purely balanced queue operation is a specification of I/O dispatch scheduling in terms of per-thread per-target "think" time and I/O burst size. This can be specified with the combination of **-i** and **-j** parameters.

- **-i<count>** : number of I/Os to issue per burst
- **-j<milliseconds>** : number of milliseconds to pause between bursts

Ensure that there is sufficient outstanding I/O allowed (**-o**) to achieve the intended bursts. Storage latency may prevent the system from achieving the rates theoretically specified with these parameters.

3.16 Rate limits

A more advanced exception to balanced queue operation can be specified with the **-g** parameter, which specifies a target number of bytes to operate on per-millisecond per-thread per-target.

The following example targets 80 bytes/millisecond * 1000 milliseconds/second = 80,000 bytes/second, or equivalently 80,000 bytes/second / 8KiB/IO = ~9.8 IOPs.

```
diskspd -t1 -o1 -s8k -b8k -Sh -w100 -g80 c:\test1
```

By adding a second file, the following example doubles the total I/O target to 160,000 bytes/second, or ~19.5 IOPs.

```
diskspd -t1 -o1 -s8k -b8k -Sh -w100 -g80 c:\test1 c:\test2
```

Adding a second thread doubles the total I/O target again to 320,000 bytes/second, or ~39.1 IOPs.

```
diskspd -t2 -o1 -s8k -b8k -Sh -w100 -g80 c:\test1 c:\test2
```

The precision of rate limits can be affected by thread scheduling, total CPU consumption, instantaneous storage latency and other factors. Longer total test times will generally converge on the requested rate limits. If rate limits aren't reached, consider providing additional outstanding I/Os (**-o**) to threads, dividing work across adding additional threads (**-t** or **-F**) or, as appropriate to test goals, adding targets.

In general effective use of rate limits may require some experimentation.

3.17 Use completion routines instead of I/O completion ports

As stated earlier, DiskSpd by default uses I/O completion ports to refill outstanding operation queues. However, Completion Routines can also be used. The **-x** parameter instructs DiskSpd to use I/O completion routines instead of I/O completion ports.

When using completion routines the next I/O dispatched from the completion routine as opposed to returning to a single master loop, as with I/O completion ports.

3.18 Set CPU affinity

Thread migration can produce inconsistent results during performance testing. For that reason, DiskSpd by default affinitizes all of its threads to CPU cores in a Round Robin manner starting at logical CPU 0 in Processor Group 0, assigning one thread per CPU in that group, and so forth for each subsequent Processor Group in the system. If there are more threads than logical CPUs, assignment returns to CPU 0 in Processor Group 0 and the process repeats until all threads are assigned.

This current default behavior is the same as -**ag** in prior versions of DiskSpd, and can still be explicitly specified as **-ag**. The prior version's default affinity only looped the logical CPUs in the Processor Group which DiskSpd started in. This could have led to inconsistent results in multiple Processor Group systems as successive runs of DiskSpd could have been in different Processor Groups, leading to uncontrolled NUMA effects.

This default affinity can be turned off by the **-n** parameter.

Advanced CPU affinity can be turned on by the **-ag#,#[,#,…]** parameter, which specifies a Processor Group number followed by the CPU numbers separated by commas (for example, **-ag1,2,0,3,1**). Threads will be affinitized to the specified CPUs in a Round Robin manner until all threads are assigned.

- multiple -ag# specifications can be made on the same command line; they accumulate in the order specified
- multiple g#,#[,#,…] specifications can be made within the same switch; the following are equivalent
  - -ag0,0,1,2,g1,0,1,2
  - -ag0,0,1,2 -ag1,0,1,2
- the number of CPUs can differ from the number of threads.
- a CPU can be stated more than once.

Threads cannot be assigned to inactive processors. They will be skipped under -**ag**, and if one is assigned via **-ag#**, an error will be returned.

The processor group topology of the system and active/inactive processor mask is provided in the <System/> element of the XML results.

3.19 Create test files automatically

Use the -**c** parameter to indicate that the target files to be used in testing should be (re)created with the specified size. There is no default size.

For example, the following command creates two 100 MiB files, c:\test1 and d:\test2, and runs a 20-second read test on both files:

```
diskspd –c100M –d20 c:\test1 d:\test2
```

When creating files, DiskSpd ensures that the valid data length as tracked by the filesystem is the same as the size of the file prior to starting test operations. If possible an optimized fast path is taken using the Win32 SetFileValidData API; however, if the test is run in a security context which does not have access to the SeManageVolumePrivilege that API requires, the file must be written through once prior to test operations, which may take significant time for large files. See the Win32 SetFileValidData API reference[3] for more information. Administrative contexts generally have access to this privilege.

DiskSpd will display a warning if the slow path is taken.

> *WARNING: Could not set privileges for setting valid file size; will use a slower method of preparing the file*

IMPORTANT: the optimized fast path for extending valid data length may expose previously written but logically deleted content from the storage subsystem. Ensure that if this path is used, either:

- test files are not accessible by unauthorized users
- the storage subsystem provides protection for previously deleted data

3.20 Separate buffers for Read and Write operations

Each thread allocates a separate buffer for read I/O operations. The reason for having one buffer per thread instead of having one buffer for all of the threads is to speed up processing in Non-Uniform Memory Access (NUMA) systems. Threads should use memory from the node on which they are running because that is faster than accessing memory from a different node. Separate buffers should also increase the chances of cache locality.

---

[3] SetFileValidData: http://msdn.microsoft.com/en-us/library/windows/desktop/aa365544(v=vs.85).aspx

3.20.1 Specifying write entropy

By default, the same buffer is used as the source for write I/O operations and is initialized with a repeating byte pattern of 0x00, 0x01, 0x02, … 0xFF, 0x00, 0x01, 0x02 and so forth. The **-Z** parameter instead causes these buffers to be zeroed at the start of the test.

In many modern storage systems, data is compressed and/or de-duplicated in-line or near-line to the I/O path. The extent to which data can be compressed or de-duplicated can have strong effects on storage performance. Therefore, some control on the entropy (randomness) of data is useful to both test whether a storage system is performing such actions, in comparing performance with highly compressible and incompressible data, or in choosing a data pattern which may be appropriate for a given workload simulation, such as a some sample database content.

The **-Z<size>[K|M|G|b]** form instead causes dedicated per-target write source buffers of the specified size to be allocated. Write content is selected from these buffers at random on a 4 byte alignment. This allows for many distinct block-sized patterns to be chosen from a small source buffer. For instance, an 8KiB write source buffer used for a 4KiB block test provides (8KiB - 4KiB)/4 = 1024 potentially unique blocks.

By default, write source buffers will be filled with random data. With the **-Z<size>[K|M|G|b],<file>** form, a sample file can be provided whose initial contents (from byte zero) is used initialize the write source buffers. If the file is smaller than the desired buffer size, its content is repeated into the buffer until they are filled. Each write source buffer filled with random data will be distinct, but each filled from a sample file will have the same content.

3.20.2 Support for large pages

In certain cases, it may be useful to use large-page support for I/O buffers. This is specified using the **-l** parameter, which requires the user to have access to the SeLockMemoryPrivilege.

By default, DiskSpd allocates buffers as follows:

```
VirtualAlloc( …, MEM_COMMIT, PAGE_READWRITE)
```

The **-l** parameter instead does this:

```
VirtualAlloc( …, MEM_COMMIT | MEM_RESERVE | MEM_LARGE_PAGES,
PAGE_EXECUTE_READWRITE)
```

3.21 Include performance counters

DiskSpd can obtain data concerning events from an NT Kernel Logger trace session. Because event tracing (ETW) carries additional overhead, it's turned off by default. You can use the following parameters to turn on event tracing for one or more groups of kernel events:

- **-eDISK_IO:** Trace physical disk I/O events.
- **-ePROCESS:** Trace process start and end events.
- **-eTHREAD:** Trace thread start and thread end events.
- **-eIMAGE_LOAD:** Trace image loads.
- **-eMEMORY_PAGE_FAULTS:** Trace all memory page faults.

- **-eMEMORY_HARD_FAULTS:** Trace only hard page faults.
- **-eNETWORK:** Trace TCP/IP and UDP/IP send and receive events.
- **-eREGISTRY:** Trace registry calls.

By default, DiskSpd instructs NT Kernel Logger to use non-paged memory for event tracing. If you want NT Kernel Logger to use paged memory, include the **-ep** parameter.

By default, ETW data will be timestamped using the high resolution Query performance counter[4]. This can be adjusted as follows:

- **-eq** : Query performance counter [default]
- **-ec** : CPU cycle counter
- **-es** : System time

The following command instructs DiskSpd to save trace data for physical disk I/O events and registry events:

```
diskspd -eDISK_IO -eREGISTRY testfile.dat
```

The test will return data similar to the following:

```
ETW:
----

        Disk I/O
                Read: 128
                Write: 28
        Registry
                NtCreateKey: 1
                NtDeleteKey: 0
                NtDeleteValueKey: 0
                NtEnumerateKey: 0
                NtEnumerateValueKey: 0
                NtFlushKey: 0
                KcbDump/create: 0
                NtOpenKey: 222
                NtQueryKey: 118
                NtQueryMultipleValueKey: 0
                NtQueryValueKey: 229
                NtSetInformationKey: 0
                NtSetValueKey: 0


        ETW Buffer Settings & Statistics
-------------------------------------------------------------
(KB)                              Buffers    (Secs)    (Mins)
```

---

[4] Please see the discussion of the WNODE_HEADER ClientContext member at the following location for more information on timestamp tradeoffs:
http://msdn.microsoft.com/en-us/library/windows/desktop/aa364160(v=vs.85).aspx

```
Size  | Min |  Max  |  Free  | Written  | Flush    Age
138       4     26     7        225         0       15


Allocated Buffers: 7
LOST EVENTS:               0
LOST LOG BUFFERS:          0
LOST REAL TIME BUFFERS: 203
```

3.22 Display a progress indicator

A progress indicator can be helpful, especially for long-running tests and debugging purposes. By default, no progress indicator is displayed as it can affect performance. If you want to see one, use the -**P** parameter to specify the number of completed I/O operations after which DiskSpd will print a dot in the progress indicator. For example, **-P10000** adds a dot after every 10,000 completed I/O operations. The number of completed I/O operations is calculated independently by each thread.

3.23 Control the initial state of the random number generator

Use the -**z[seed]** parameter to control the initial state of DISKSPD's random number generator. By default, a seed value of zero is used. If the parameter is specified without an explicit seed the value of the Win32 GetTickCount API is used, which is a high resolution counter based on the current system uptime.

Note that the total behavior of a multi-threaded test also depends on thread scheduling effects, so the random number generator is not a complete control on test behavior.

3.24 Run DiskSpd in verbose mode

Use the -**v** parameter to run DiskSpd in verbose mode. In verbose mode, DiskSpd returns the following information about its actions:

- When a worker thread is created
- When start and end signals are sent to worker threads
- The offset of the next I/O operation (along with the worker thread number and I/O number)
- Start and stop time for each NT Kernel Logger session

3.25 Use named events to synchronize testing

DiskSpd can synchronize on named events that the user provides. If any event that is specified using these parameters (**-ys**, **-yf**, **-yr**, or **-yp**) does not exist, DiskSpd creates a notification event.

- If the **-yr** parameter is specified (for example, **-yrMyStartEvent**), DiskSpd initializes itself but does not start the test (not even the warmup phase) until the specified event is set.

- Similarly, you can specify a custom stop event with the **-yp** parameter (for example, **-ypMyStopEvent**). By default, a test run ends when the specified test time elapses or the user presses Ctrl+C to cancel the test. With the **-yr** parameter, the test run ends, and results are displayed, when the stop event occurs. Moreover, if the stop event is provided, Ctrl+C becomes

associated with the stop event, enabling you to stop all DiskSpd instances waiting on the same object at the same time by pressing CTRL+C in one of them.

- The events can be set by any external tool or by running DiskSpd with the parameter **-ye** (for example, **-yeMyStartEvent**). You can specify multiple instances of the -**ye** parameter if needed.

- There are also two more events that, if provided by the user, send a notification when the actual test begins and ends. An event provided with **-ys** (for example, -**ysMyTestStartedEvent**) is signaled right before the measurements start; an event provided with **-yf** (for example, -**yfMyTestFinishedEvent**) sends a notification right after measurements are completed.

3.26 Use an XML file to provide DiskSpd parameters

Parameters controlling a test can be passed to DiskSpd as part of the command line or in an XML file.

Using command line parameters (e.g. **-w, -b8k**, etc.) is easy for simple, homogenous tests. The limitation, though, is that parameters passed on the command line apply to all targets and threads; for instance, using a different block size for different targets is not possible when the command line parameters are used. Specifying the configuration of a test in an XML file does not have this limitation. Each target is treated separately and thus can be accessed using different block sizes, offsets, strides, flags, and so forth.

XML run profiles are provided by the -**X<path>** option, where <path> is a path to an XML file compliant with the diskspd.xsd schema. The -**X** parameter is not compatible with any other parameter and thus has to be used alone (e.g. diskspd -Xprofile.xml). The diskspd.xsd file is distributed with the diskspd.exe file.

3.26.1 Creating an XML profile file

The XML result output (see **-Rxml**, Section 5) contains a subsection describing the test, which can be used to repeat a given test or as a base for more complex test descriptions. This is the "<Profile>…</Profile>" section. Copy this section to a file, modify as needed and provide to the **-X<path>** parameter.

3.26.2 Specify multiple time spans in the XML profile

On top of the per-target set of parameters, using an XML-based test configuration allows for specifying multiple time spans. Each time span, "<Timespan>..</Timespan>" is treated as a separate test with its own duration, set of targets, and so forth. This can be useful when a workload that changes over time is needed.

4 Canceling a test run (CTRL+C)

You can cancel a DiskSpd run at time by pressing CTRL+C. DiskSpd exits gracefully and displays all of the data it collected before the cancellation, as long as the warm-up period has completed.

5   Analyzing DiskSpd test results

On completion, DiskSpd will provide a description of the test and a set of results. By default this will be human-readable text summary, which can also be explicitly specified as -**Rtext**. An XML summary can be requested with -**Rxml**. The XML summary also contains a summary of system configuration (processor topology, run start time, DiskSpd version), and the full configuration of the test in an XML format, which can be used to convert command line parameters to their XML equivalents and subsequently passed to the -**X** parameter.

DiskSpd provides per-thread per-target statistics on data read and written by each thread in terms of total bytes, bandwidth and IOPs, in addition to any requested NT Kernel Logger events.

DiskSpd also provides a per-processor CPU utilization summary. It is currently limited to only providing CPU usage with respect to the Processor Group its main thread is created on. In order to collect CPU utilization on multiple Processor Group systems, please use alternate mechanisms. This may be addressed via a future update.

Powershell code for processing batches of XML results into tabular form is provided in the Examples (Section 6).

There are two more advanced sets of statistics which DiskSpd can optionally collect:

- latency, specified with the -**L** parameter
- IOPs statistics, specified with the -**D** parameter

5.1   Latency

Latency is gathered in per-thread per-target histograms at high precision. In text output, this results in per-thread per-target per-operation-type average latency along with a summary table of per percentile latencies as in the following text output example:

```
  %-ile | Read (ms) | Write (ms) | Total (ms)
----------------------------------------------
    min |     0.086 |      0.199 |      0.086
   25th |     0.351 |      0.371 |      0.362
   50th |     5.214 |      0.978 |      1.128
   75th |     7.454 |      1.434 |      7.014
   90th |     8.412 |      7.671 |      8.092
   95th |     8.513 |      8.393 |      8.455
   99th |    17.406 |      9.024 |     16.098
3-nines |    34.938 |     25.804 |     34.360
4-nines |    38.058 |     35.514 |     38.058
5-nines |    38.058 |     35.514 |     38.058
6-nines |    38.058 |     35.514 |     38.058
7-nines |    38.058 |     35.514 |     38.058
8-nines |    38.058 |     35.514 |     38.058
    max |    38.058 |     35.514 |     38.058
```

NOTE: The 'nines' refer to the number of nines: 3-nines is the 99.9[th] percentile, and so forth.

When designing tests to characterize the high percentiles it is important to consider the number of operations which each represent. The data which produced this sample consisted of 6049 I/Os of which a nearly equal number were reads (2994) and writes (3055). In the case of the 99.9th percentile for writes, only 3055 * (1 - 0.999) = ~3 write operations are between its 25.804ms and the maximum 35.514ms. As a result, the 99.99th (4-nines) percentile and onward are the same as the maximum since there is not enough data to differentiate them.

As a result, storage performance and test length need to be considered together in order to acquire enough data to accurately state the higher-nines percentiles.

Latency is gathered internally at a per-thread per-target, and this full resolution is available in the XML output form (**-Rxml**).

Given the per-thread per-target resolution, the memory overhead of these histograms can become significant with higher thread and target counts. The interplay of **-t** and **-F** is important to consider. In the following examples, both describe 16 threads:

- **-t1** <target1> … <target16>
- **-F16** <target1> … <target16>

However, the second results in 16 times as many histograms being tracked. This memory overhead can in extreme circumstances affect results.

5.2   IOPs statistics

The higher-order IOPs statistics are based on capturing I/O counts per interval, by default 1 second. A different interval can be specified in units of milliseconds: **-D*milliseconds***

Similar to the way in which latency statistics are gathered, DiskSpd captures this data per-thread per-target. These carry relatively low cost and should not add substantial overhead except in cases of very long runtimes. In those cases, a proportionally longer sampling interval may be appropriate.

In text output, this adds the standard deviation of the IOPs per-thread per-target per-operation-type over the entire measured test. This provides some insight into how significant performance variation was interval-to-interval during the test. However, this statistic should be used with care since it cannot describe the outliers or their frequency.

In XML output (**-Rxml**), the full per-thread per-target per-operation-type vectors are included in the results. In addition to allowing the standard deviation to be put in context, in many cases these may eliminate the need for external measurements of IO rates in generating visualizations.

6   XML results processing
Processing XML with Windows PowerShell is relatively straightforward.

An XML document can be imported in one line:

```
$x = [xml](Get-Content filename.xml)
```

The resulting System.Xml.XmlDocument object exposes the element structure of the XML as a set of nested properties and values. Normal Powershell capabilities such as implicit nested enumeration work as expected, making extraction of results across threads and targets concise.

Please explore the XML document alongside the parsed XML in Powershell, and automation should follow quickly.

The following code is an example of processing a collection of XML results into a tabular form suitable for direct import into a spreadsheet for analysis. The column schema can be summarized as:

- Computer which produced the result
- WriteRatio (**-w**)
- Threads (as a result **-t** or **-F**)
- Outstanding (as a result of **-o**)
- Block (as a result of **-b**)
- Read IOPs
- Read Bandwidth
- Write IOPs
- Write Bandwidth
- 25th, 50th, 75th, 90th, 99th, 99.9^{th} and maximum read & write IO latency (assuming **-L**)

In addition, it produces a second file per result with the full latency distribution in tabular form, with percentile, read latency, and write latency columns.

A more advanced version of XML post-processing, based on this example, is maintained at GitHub: process-diskspd.ps1. See Section 1.1 (page 3) for links to the DiskSpd GitHub repo.

```powershell
function get-latency( $x ) {

    $x.Results.TimeSpan.Latency.Bucket |% {
        $_.Percentile,$_.ReadMilliseconds,$_.WriteMilliseconds -join "`t"
    }
}

$l = @(); foreach ($i in 25,50,75,90,95,99,99.9,100) { $l += ,[string]$i }

dir *.xml |% {

    $x = [xml](Get-Content $_)

    $lf = $_.fullname -replace '.xml','.lat.tsv'

    if (-not [io.file]::Exists($lf)) {
        get-latency $x > $lf
    }

    $system = $x.Results.System.ComputerName
    $t = $x.Results.TimeSpan.TestTimeSeconds

    # extract the subset of latency percentiles as specified above in $l
    $h = @{}; $x.Results.TimeSpan.Latency.Bucket |% { $h[$_.Percentile] = $_ }

    $ls = $l |% {
        $b = $h[$_];
        if ($b.ReadMilliseconds) { $b.ReadMilliseconds } else { "" }
        if ($b.WriteMilliseconds) { $b.WriteMilliseconds } else { "" }
    }

    # sum read and write iops across all threads and targets
```

```powershell
$ri = ($x.Results.TimeSpan.Thread.Target |
        measure -sum -Property ReadCount).Sum
$wi = ($x.Results.TimeSpan.Thread.Target |
        measure -sum -Property WriteCount).Sum
$rb = ($x.Results.TimeSpan.Thread.Target |
        measure -sum -Property ReadBytes).Sum
$wb = ($x.Results.TimeSpan.Thread.Target |
        measure -sum -Property WriteBytes).Sum

# output tab-separated fields. note that with runs specified on the command
# line, only a single write ratio, outstanding request count and blocksize
# can be specified, so sampling the one used for the first thread is
# sufficient.
(($system,
  ($x.Results.Profile.TimeSpans.TimeSpan.Targets.Target.WriteRatio |
    select -first 1),
 $x.Results.TimeSpan.ThreadCount,
 ($x.Results.Profile.TimeSpans.TimeSpan.Targets.Target.RequestCount |
    select -first 1),
 ($x.Results.Profile.TimeSpans.TimeSpan.Targets.Target.BlockSize |
    select -first 1),
    # calculate iops
    ($ri / $t),
    ($rb / $t),
    ($wi / $t),
    ($wb / $t)) -join "`t"),
($ls -join "`t") -join "`t"

} | out-file result.tsv -Encoding ascii -Width 9999
```

7 Sample command lines

Note that there also some additional examples in Section 3 when describing more complex options.

Test description	Sample command
Large area random concurrent reads of 4KB blocks	`diskspd –c2G –b4K –F8 –r –o32 –W60 –d60 –Sh testfile.dat`
Large area random concurrent writes of 4KB blocks	`diskspd –c2G –w –b4K –F8 –r –o32 –W60 –d60 – Sh testfile.dat`
Large area random concurrent reads of 64KB blocks	`diskspd –c2G –b64K –F8 –r –o32 –W60 –d60 –Sh testfile.dat`
Large area random concurrent writes of 64KB blocks	`diskspd –c2G –w –b64K –F8 –r –o32 –W60 –d60 – Sh testfile.dat`
Large area random serial reads of 4KB blocks.	`diskspd –c2G –b4K –r –o1 –W60 –d60 –Sh testfile.dat`
Large area random serial writes of 4KB blocks	`diskspd –c2G –w –b4K –r –o1 –W60 –d60 –Sh testfile.dat`
Large area random serial reads of 64KB blocks	`diskspd –c2G –b64K –r –o1 –W60 –d60 –Sh testfile.dat`
Large area random serial writes of 64KB blocks	`diskspd –c2G –w –b64K –r –o1 –W60 –d60 –Sh testfile.dat`

Test description	Sample command
Large area sequential concurrent reads of 4KB blocks	`diskspd –c2G –b4K –F8 –T1b –s8b –o32 –W60 –d60 –Sh testfile.dat`
Large area sequential concurrent writes of 4KB blocks	`diskspd –c2G –w –b4K –F8 –T1b –s8b –o32 –W60 –d60 –Sh testfile.dat`
Large area sequential concurrent reads of 64KB blocks	`diskspd –c2G –b64K –F8 –T1b –s8b –o32 –W60 –d60 –Sh testfile.dat`
Large area sequential concurrent writes of 64KB blocks	`diskspd –c2G –w –b64K –F8 –T1b –s8b –o32 –W60 –d60 –Sh testfile.dat`
Large area sequential serial reads of 4KB blocks	`diskspd –c2G –b4K –o1 –W60 –d60 –Sh testfile.dat`
Large area sequential serial writes of 4KB blocks	`diskspd –c2G –w –b4K –o1 –W60 –d60 –Sh testfile.dat`
Large area sequential serial reads of 64KB blocks	`diskspd –c2G –b64K –o1 –W60 –d60 –Sh testfile.dat`
Large area sequential serial writes of 64KB blocks	`diskspd –c2G –w –b64K –o1 –W60 –d60 –Sh testfile.dat`
Small area concurrent reads of 4KB blocks	`diskspd –c100b –b4K –o32 –F8 –T1b –s8b –W60 –d60 –Sh testfile.dat`
Small area concurrent writes of 4KB blocks	`diskspd –c100b –w –b4K –o32 –F8 –T1b –s8b –W60 –d60 –Sh testfile.dat`
Small area concurrent reads of 64KB blocks	`diskspd –c100b –b64K –o32 –F8 –T1b –s8b –W60 –d60 –Sh testfile.dat`
Small area concurrent writes of 64KB blocks	`diskspd –c100b –w –b64K –o32 –F8 –T1b –s8b –W60 –d60 –Sh testfile.dat`
Gather data about physical disk I/O events and memory events from NT Kernel Logger	`diskspd –eDISK_IO –eMEMORY_PAGE_FAULTS testfile.dat`
Instruct NT Kernel Logger to use paged memory instead of non-paged memory and gather data concerning physical disk I/O events	`diskspd –eDISK_IO –ep testfile.dat`
Run a DiskSpd and signal events when the actual test starts and finishes	`diskspd –ysMyTestStartedEvent –yfMyTestFinishedEvent testfile1.dat`

Test description	Sample command

Run a few separate instances of DiskSpd, but synchronize their start and stop times	`diskspd –o1 –t2 –a0,1 –yrMyStartEvent –ypMyStopEvent testfile1.dat`
	
	`diskspd –r –t2 –a2,3 –yrMyStartEvent –ypMyStopEvent testfile2.dat`
	
	`diskspd –Sh –t4 –a4,5,6,7 –yrMyStartEvent –ypMyStopEvent testfile3.dat`
	
	`diskspd –yeMyStartEvent`
	
	`rem After a few seconds`
	
	`diskspd –yeMyStopEvent`

8   Future Improvements

The following are recommendations for future improvements of the DiskSpd tool.

8.1   Verification of written data

DiskSpd is capable of performing read tests and write tests. However, written data is not verified. Adding data verification would allow running not only performance tests but also check if the equipment is working properly.

8.2   Dynamic warm-up

Many modern storage systems adapt to I/O patterns and may take varying periods of time to enter steady state operation once a load is started. Specifying a fixed warm-up interval can both add unnecessary time to a test and/or not warm up the storage system sufficiently. In the latter case, misleading results will be generated.

A mechanism which monitored warm-up performance and only entered the measurement phase once performance had stabilized within some acceptable band would be useful.