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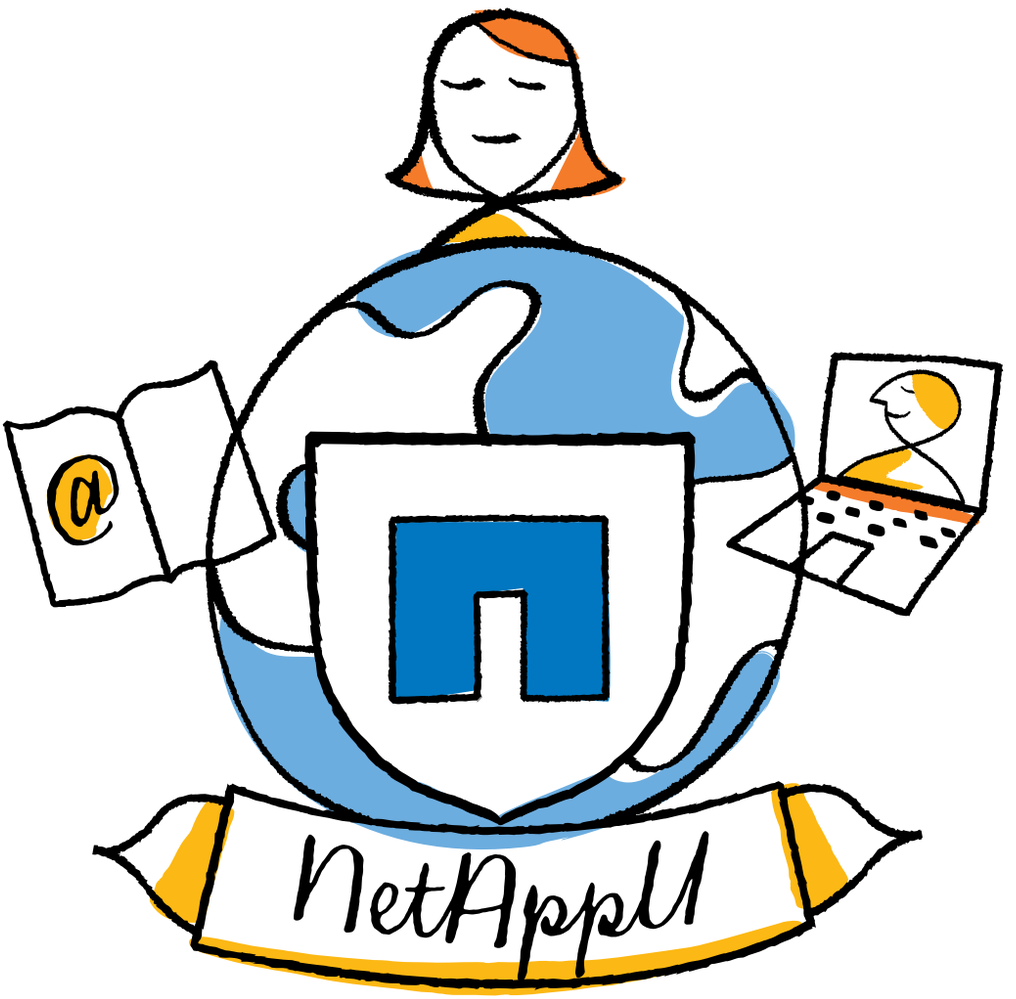
Performance Analysis on Clustered Data ONTAP

Student Guide



NETAPP UNIVERSITY

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Student Guide

Course ID: STRSW-ILT-PERFCDOT
Catalog Number: STRSW-ILT-PERFCDOT-SG
Content Version: 1.0

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Performance Analysis on Clustered Data ONTAP

Course ID:
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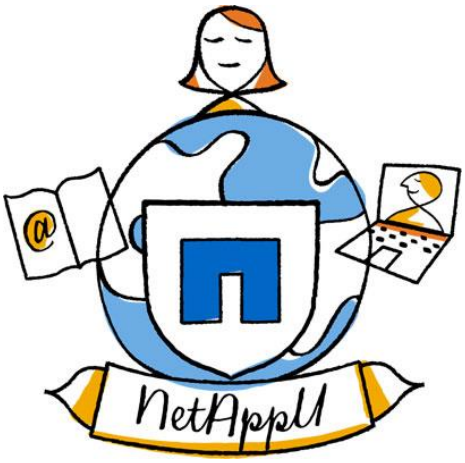
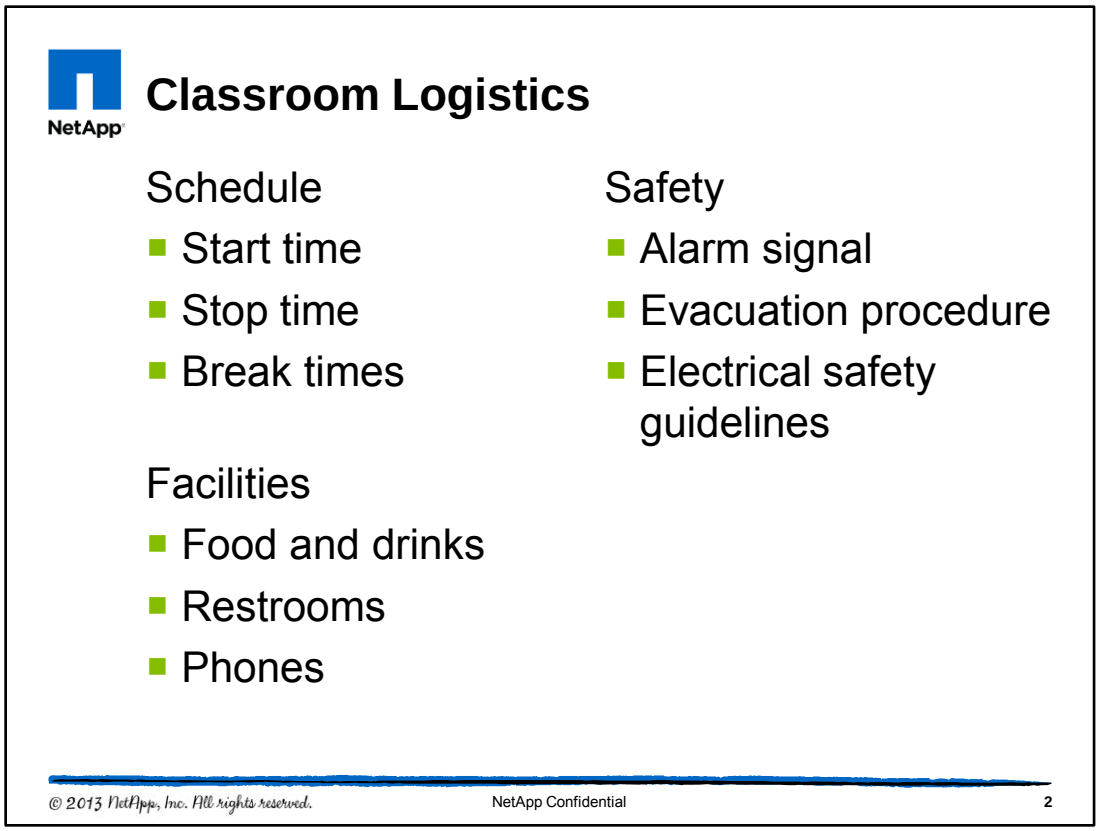
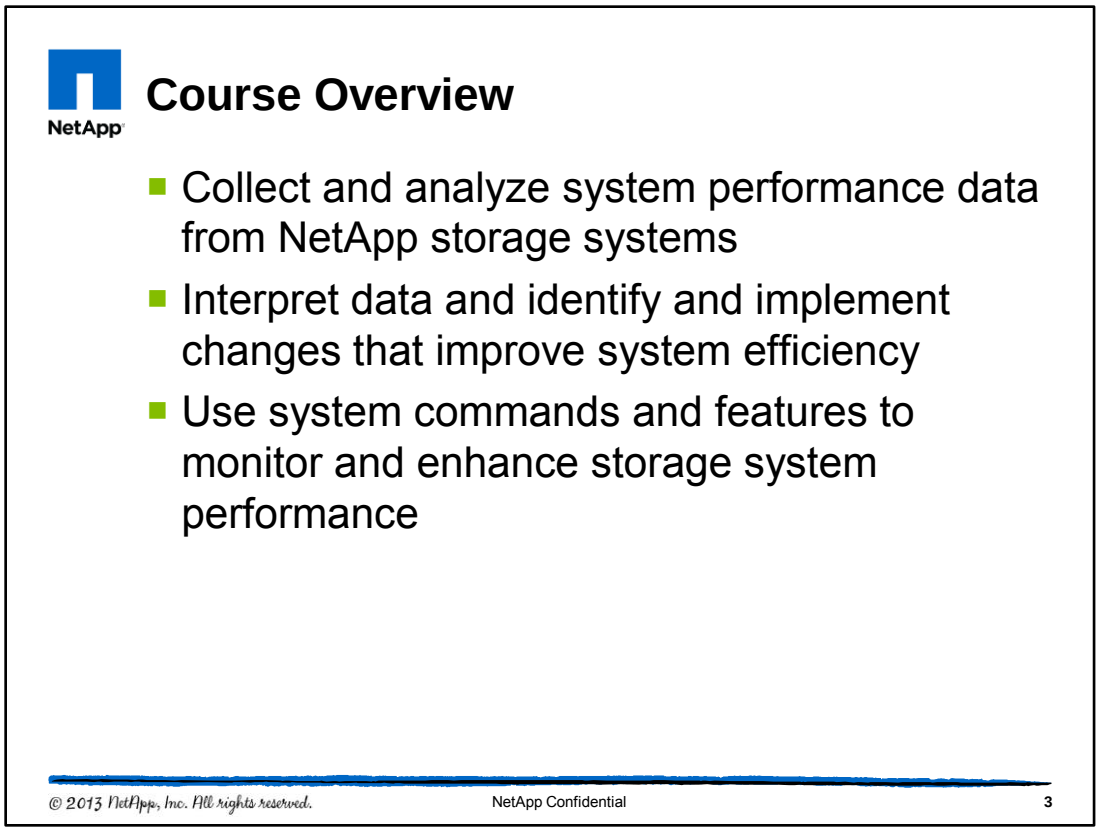


PERFORMANCE ANALYSIS ON CLUSTERED DATA ONTAP

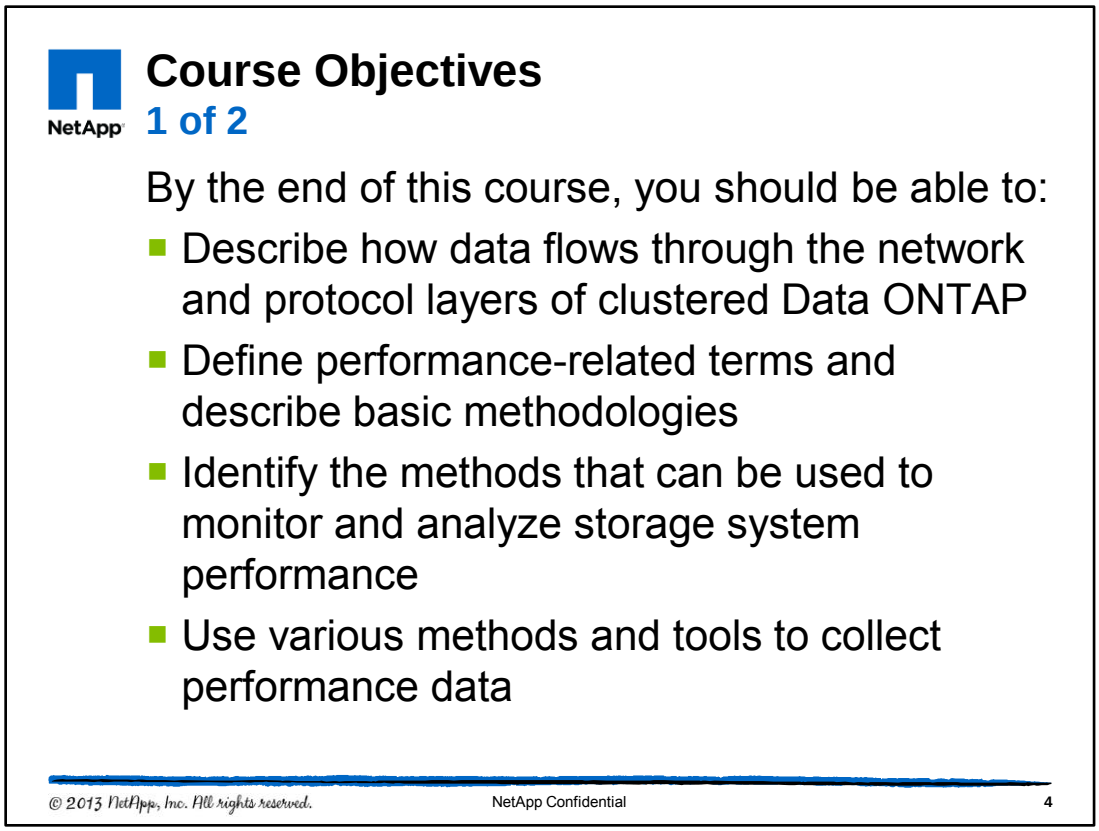


CLASSROOM LOGISTICS

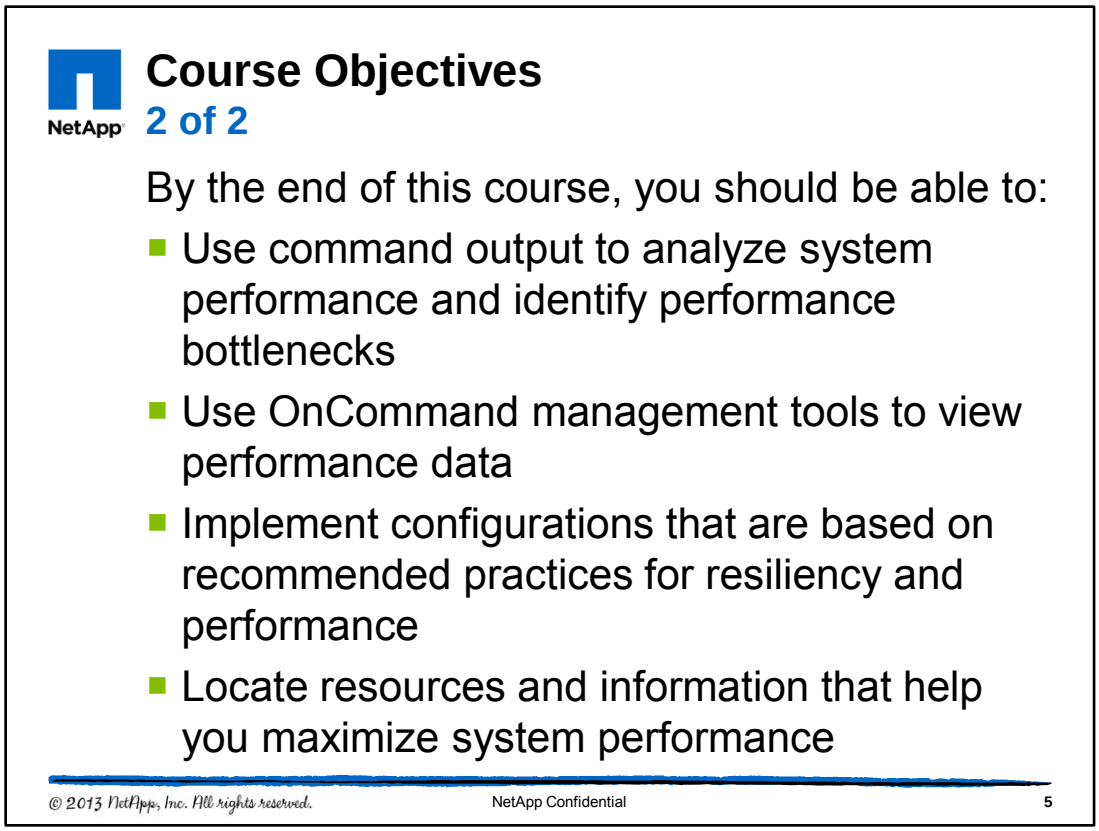


COURSE OVERVIEW

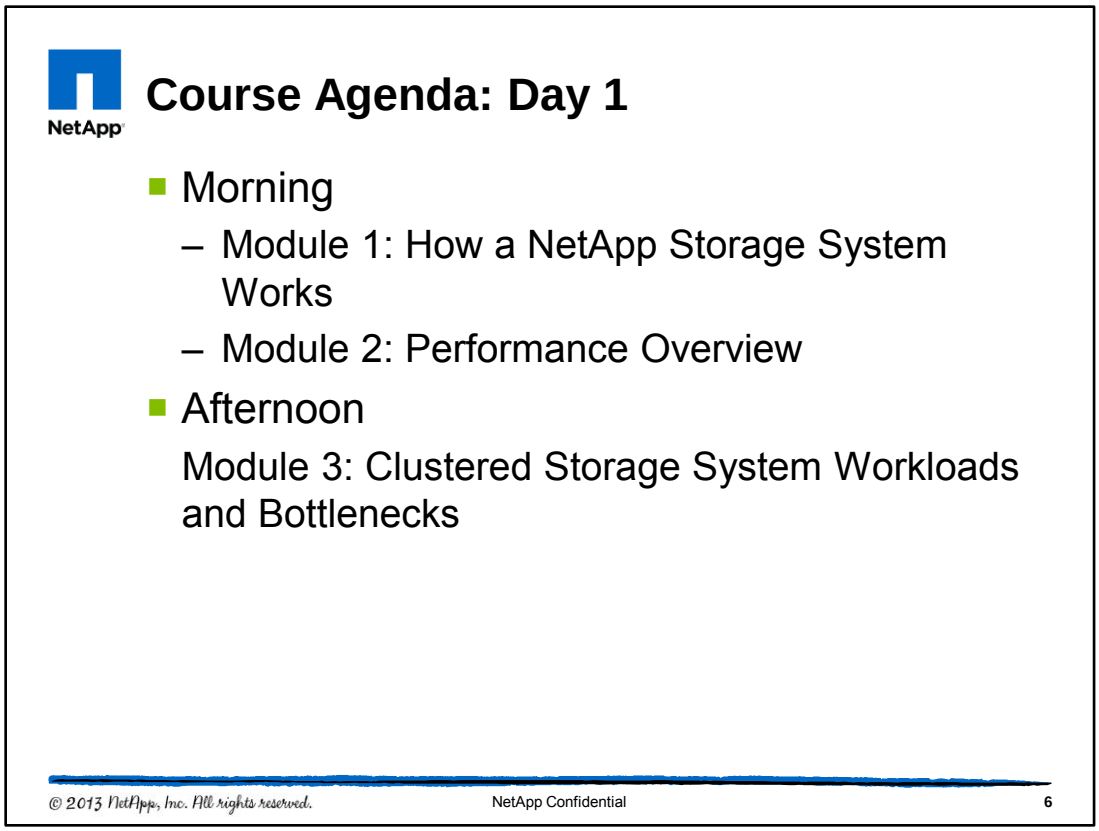
This course provides you with the knowledge and skills that you need to collect and analyze system performance data from NetApp storage systems that are running clustered Data ONTAP. You learn how to interpret data and how to identify and implement changes that improve system efficiency. You also learn how to use system commands and features to monitor and enhance storage system performance using a combination of hands-on labs, case-studies, and technical discussion.



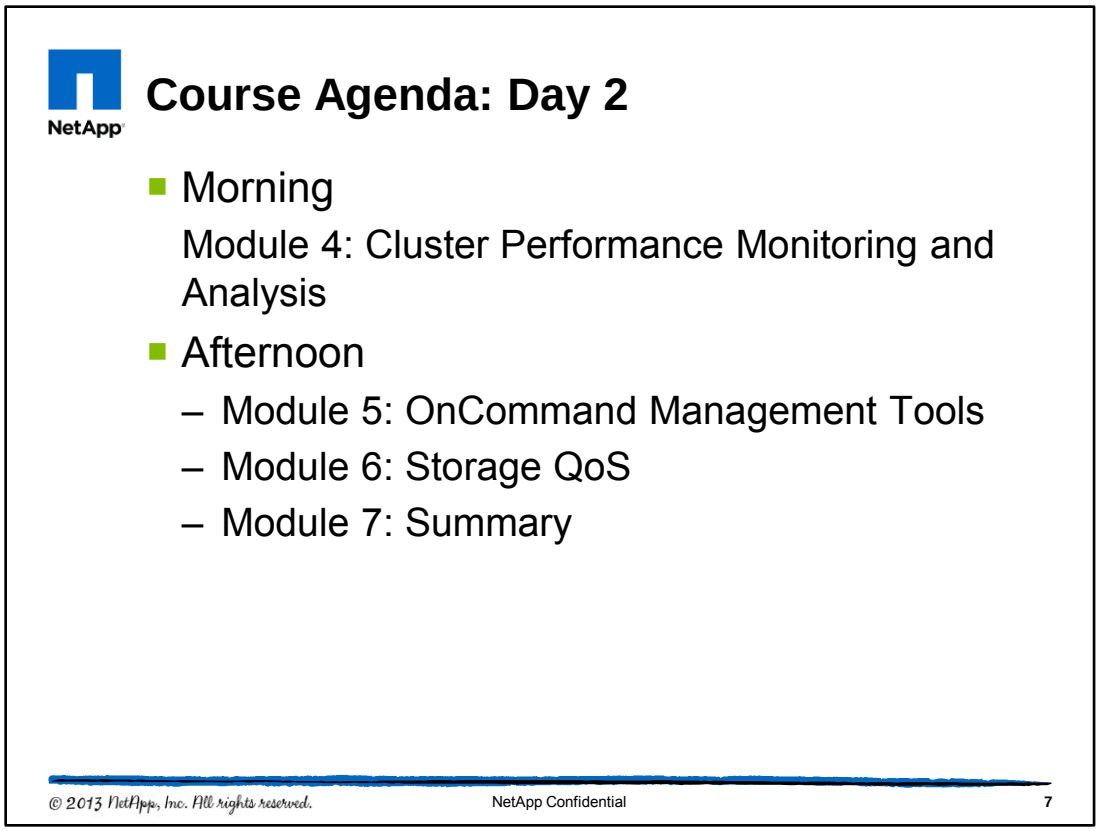
COURSE OBJECTIVES: 1 OF 2



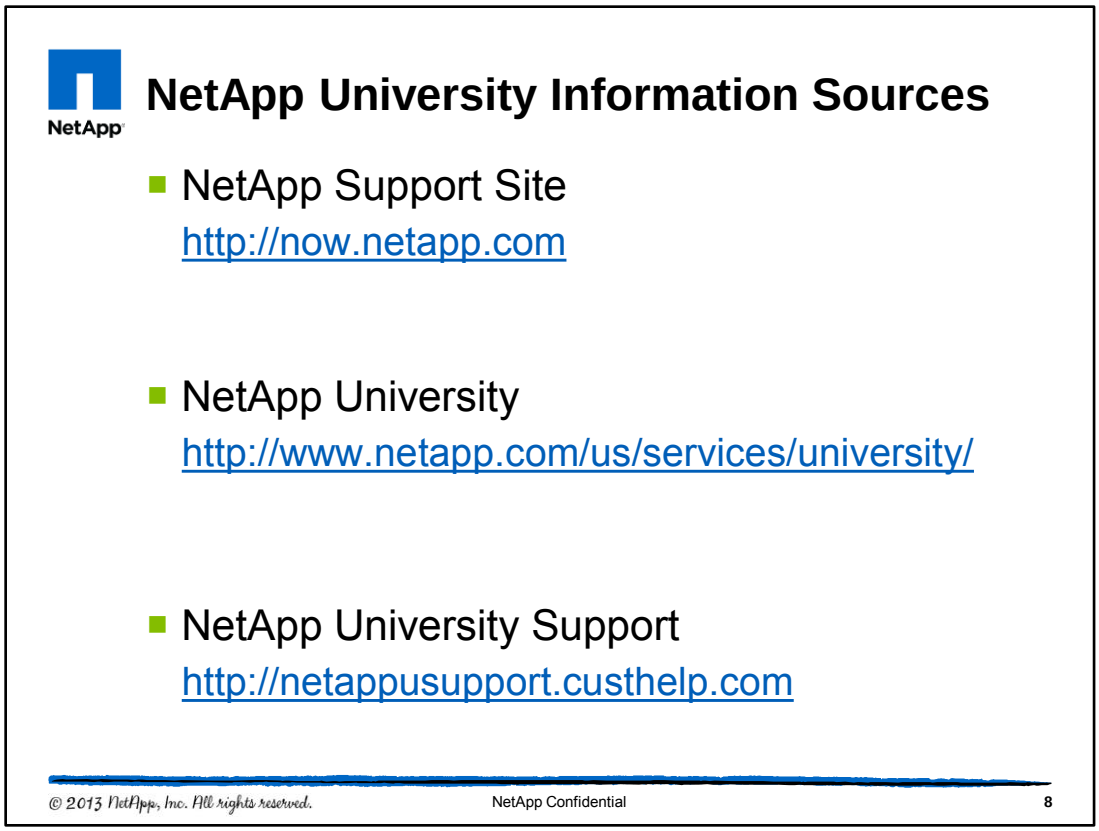
COURSE OBJECTIVES: 2 OF 2



COURSE AGENDA: DAY 1



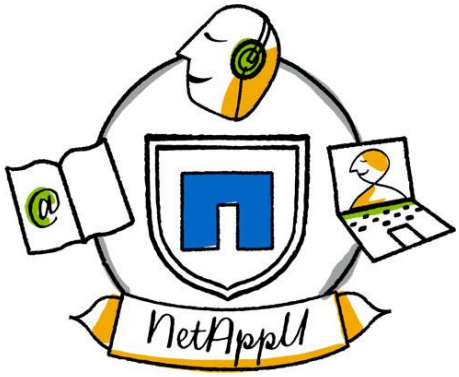
COURSE AGENDA: DAY 2



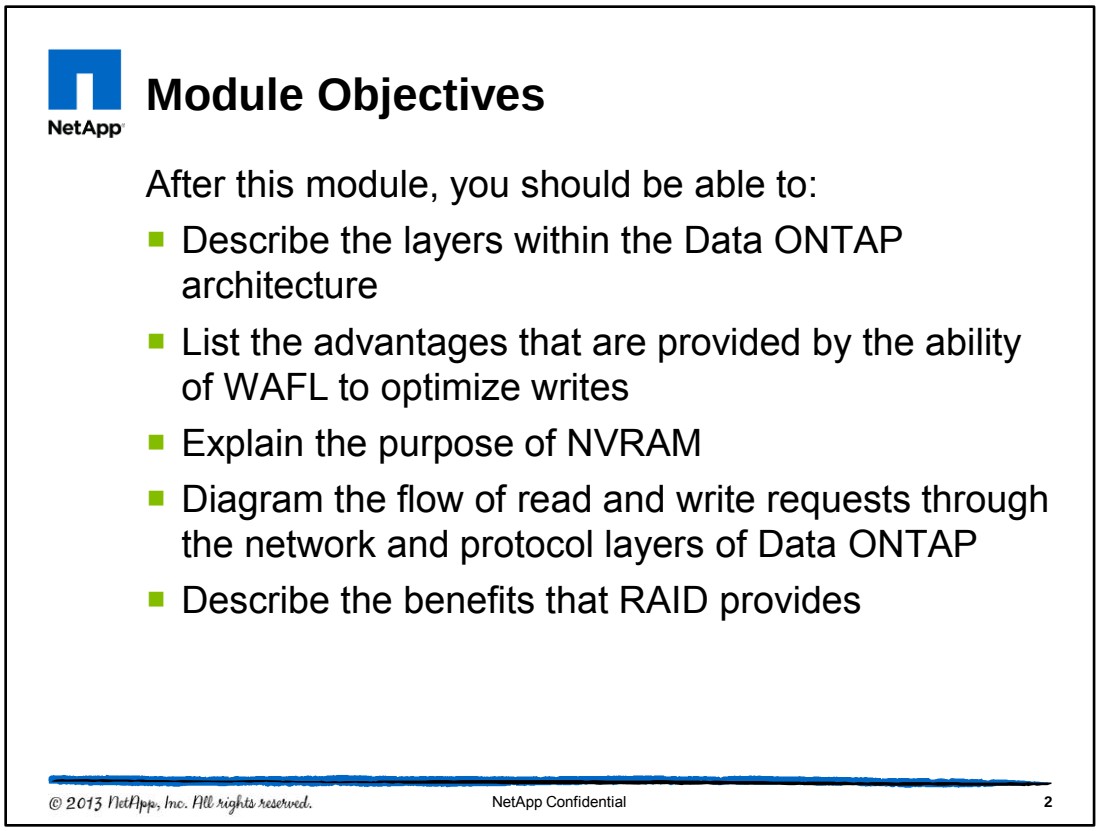
NETAPP UNIVERSITY INFORMATION SOURCES

Module 1

How a NetApp
Storage System Works



MODULE 1: HOW A NETAPP STORAGE SYSTEM WORKS

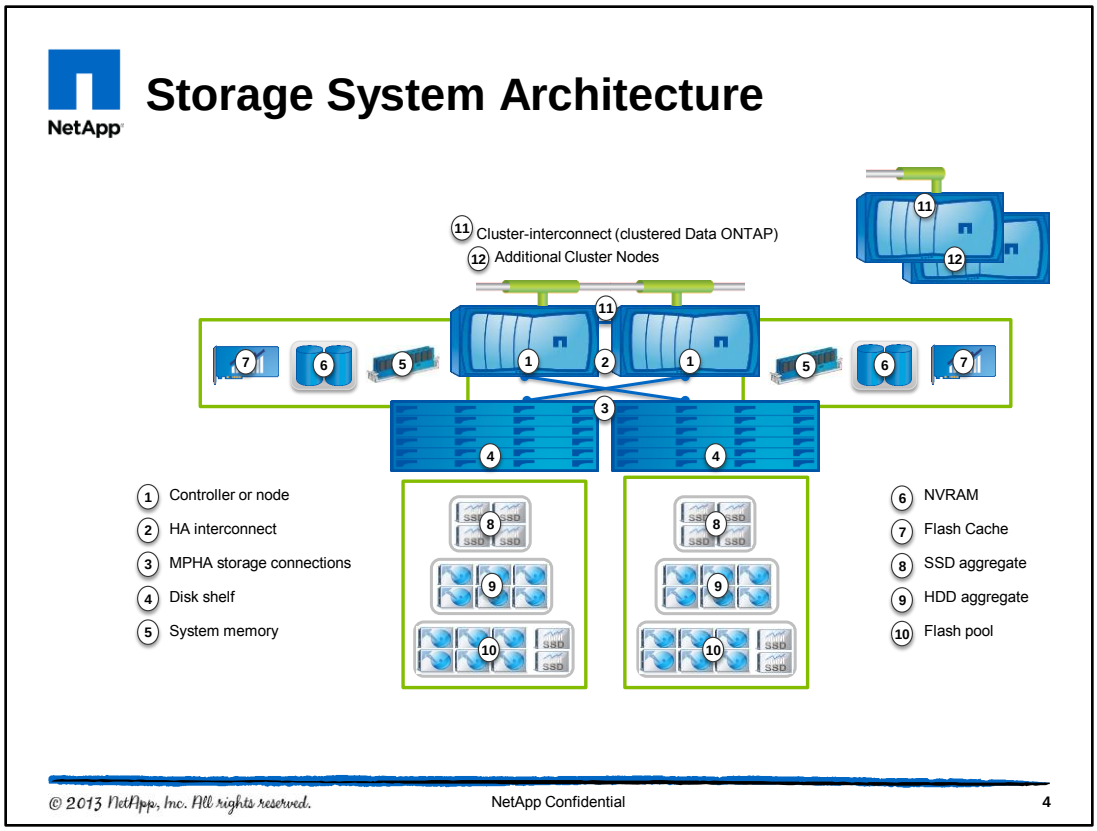


MODULE OBJECTIVES

Lesson 1

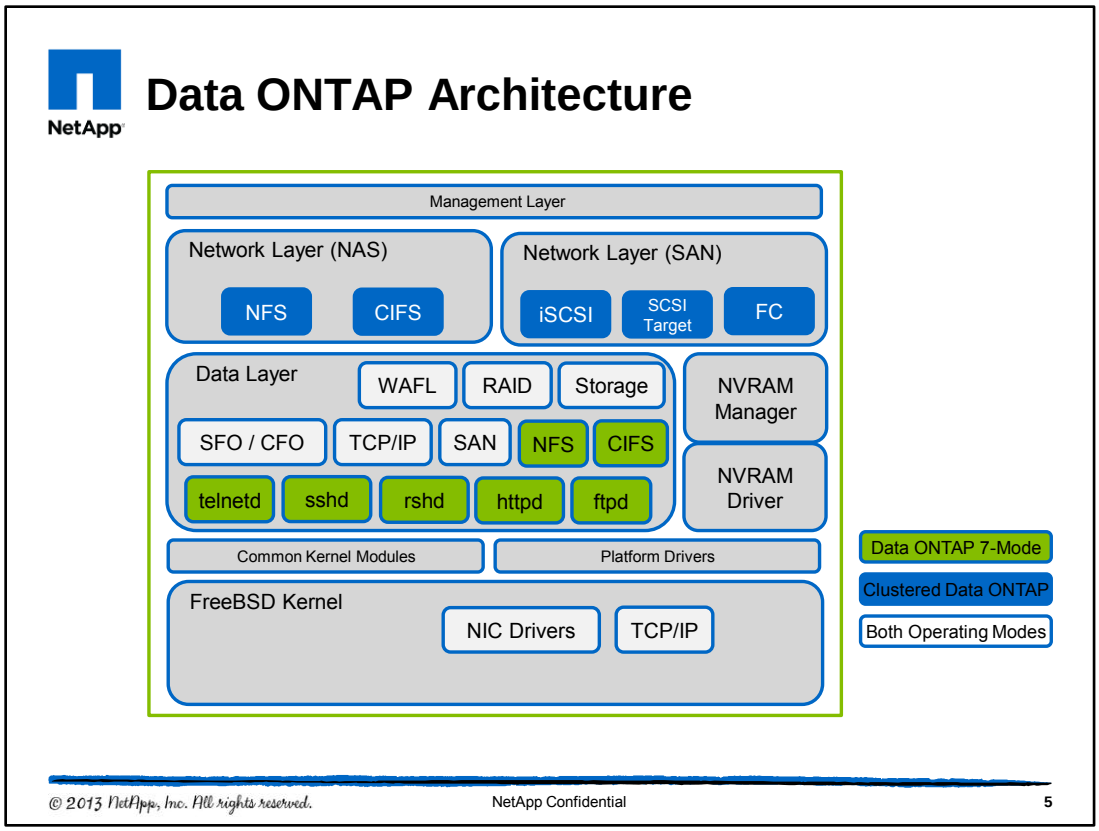
Architecture

LESSON 1: ARCHITECTURE



STORAGE SYSTEM ARCHITECTURE

The NetApp storage system architecture includes multiple components: storage controllers, high-availability interconnect, multipath high-availability storage connections, disk shelves, system memory, NVRAM, Flash Cache modules, solid-state drive (SSD) aggregates, hard-disk-drive (HDD) aggregates, and flash pools. Storage systems that run the clustered Data ONTAP operating system also include cluster-interconnect and multiple cluster nodes.



DATA ONTAP ARCHITECTURE

The Data ONTAP architecture consists of multiple layers, which are built on top of the FreeBSD operating system. Above the FreeBSD kernel is the data layer that includes the WAFL (Write Anywhere File Layout) file system, RAID, storage, failover, and the protocols for Data ONTAP operating in 7-Mode. Also above the FreeBSD kernel is the NVRAM driver and manager. Above these layers is the NAS and SAN networking layer, which includes protocol support for clustered Data ONTAP. Above the networking layer is the Data ONTAP management layer.

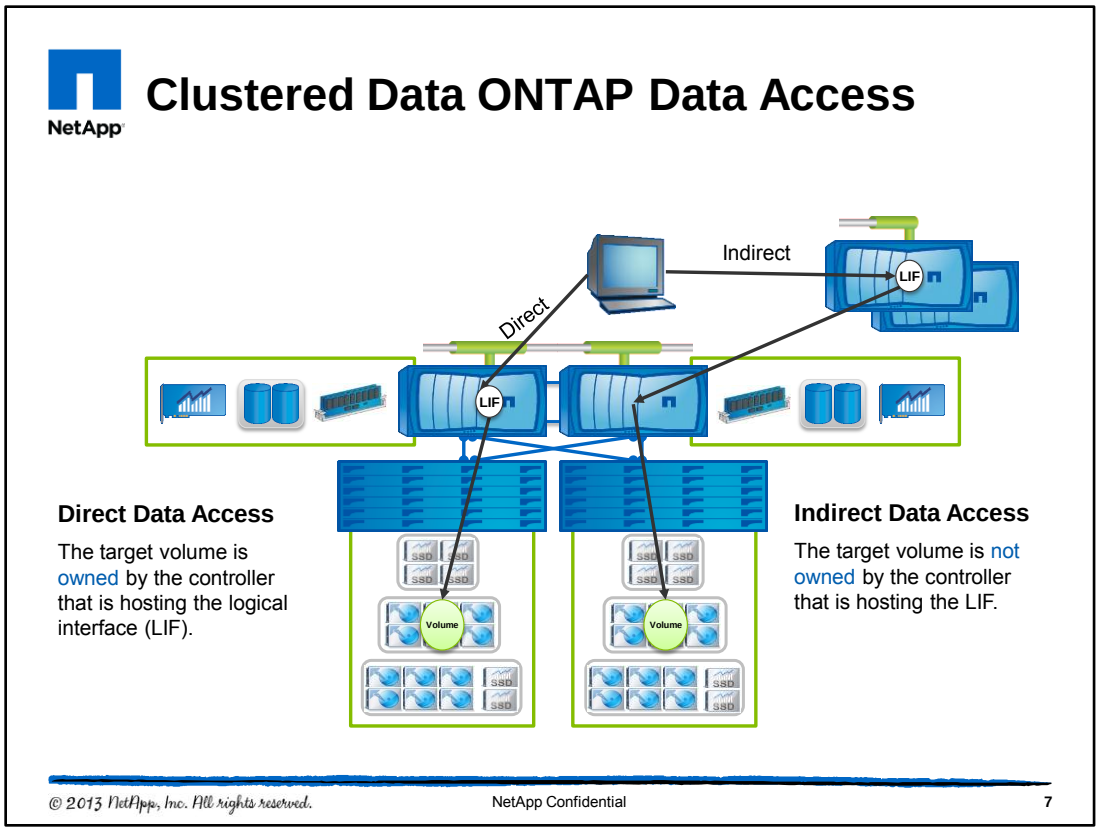
The data layer TCP/IP stack is used for all network layer protocols or, in other words, for all clustered Data ONTAP protocols. It is also used for all 7-Mode protocols. The TCP/IP stack in the FreeBSD kernel is used for traffic for ports for which the clustered Data ONTAP network layer does not have listeners.

NOTE: The clustered session manager (CSM) resides in the common kernel module.

Lesson 2

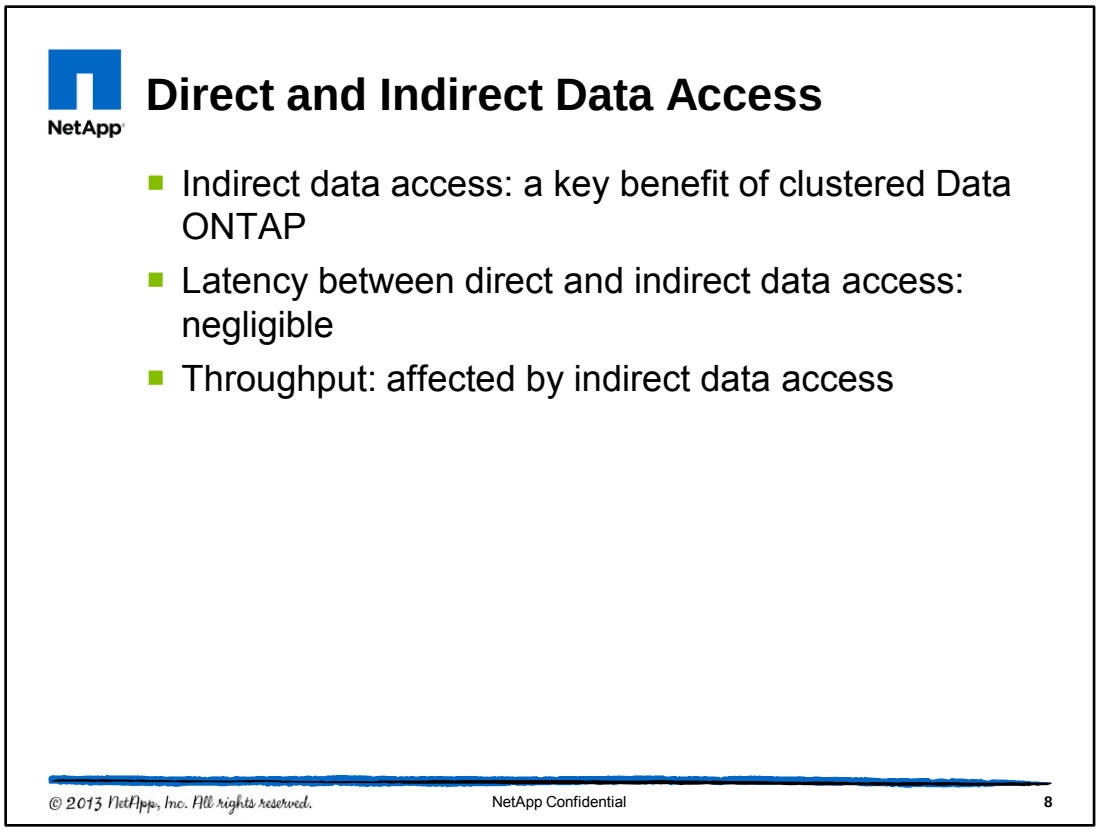
Read Data Access

LESSON 2: READ DATA ACCESS



CLUSTERED DATA ONTAP DATA ACCESS

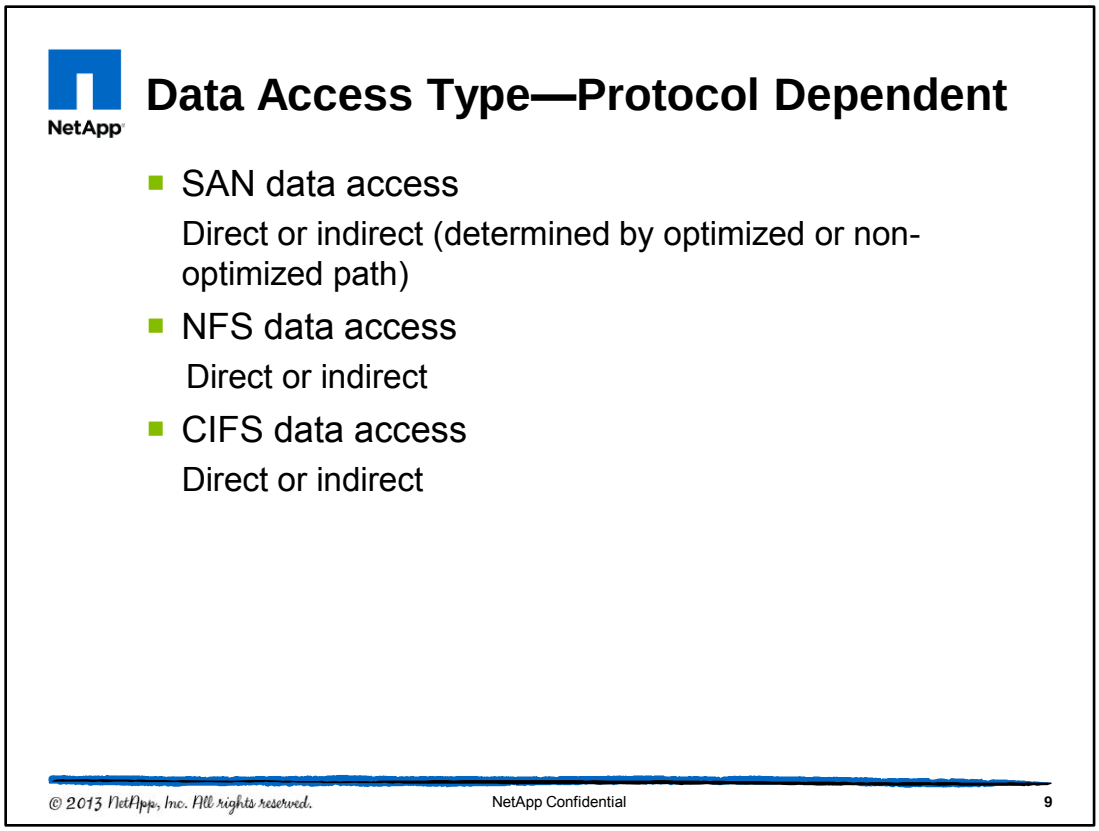
Both clustered Data ONTAP and Data ONTAP operating in 7-Mode support direct data access; however, only clustered Data ONTAP supports indirect data access.



DIRECT AND INDIRECT DATA ACCESS

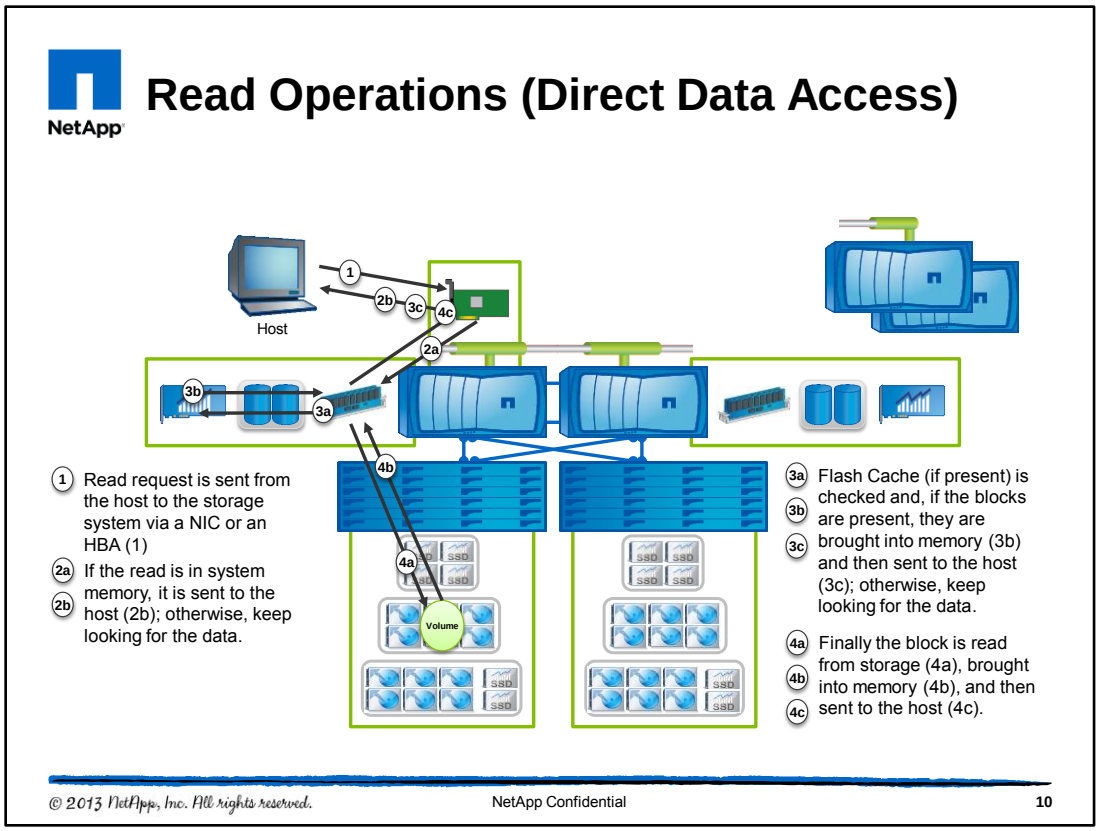
Indirect data access enables you to scale workloads across multiple nodes. The latency between direct and indirect data access is negligible, provided that CPU headroom exists. Throughput can be affected by indirect data access, because additional processing might be required to move data over the cluster-interconnect.

NOTE: the terms latency and throughput will be fully covered in the next module.



DATA ACCESS TYPE—PROTOCOL DEPENDENT

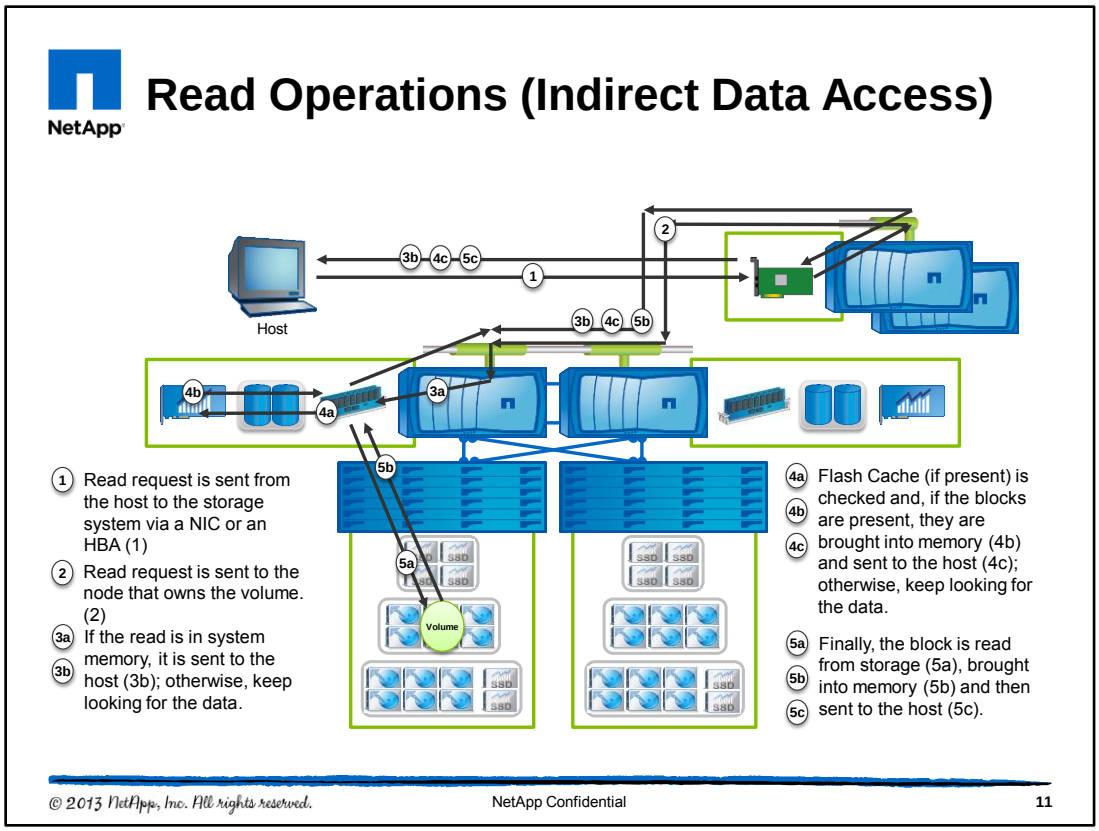
The data access type is protocol dependent. SAN data access can be direct or indirect depending on path selected by Asymmetric Logical Unit Access (ALUA). NFS data access can be direct or indirect, except that pNFS is always direct. CIFS data access can be either direct or indirect.



READ OPERATIONS (DIRECT DATA ACCESS)

Read operations for direct access take the following path through the storage system:

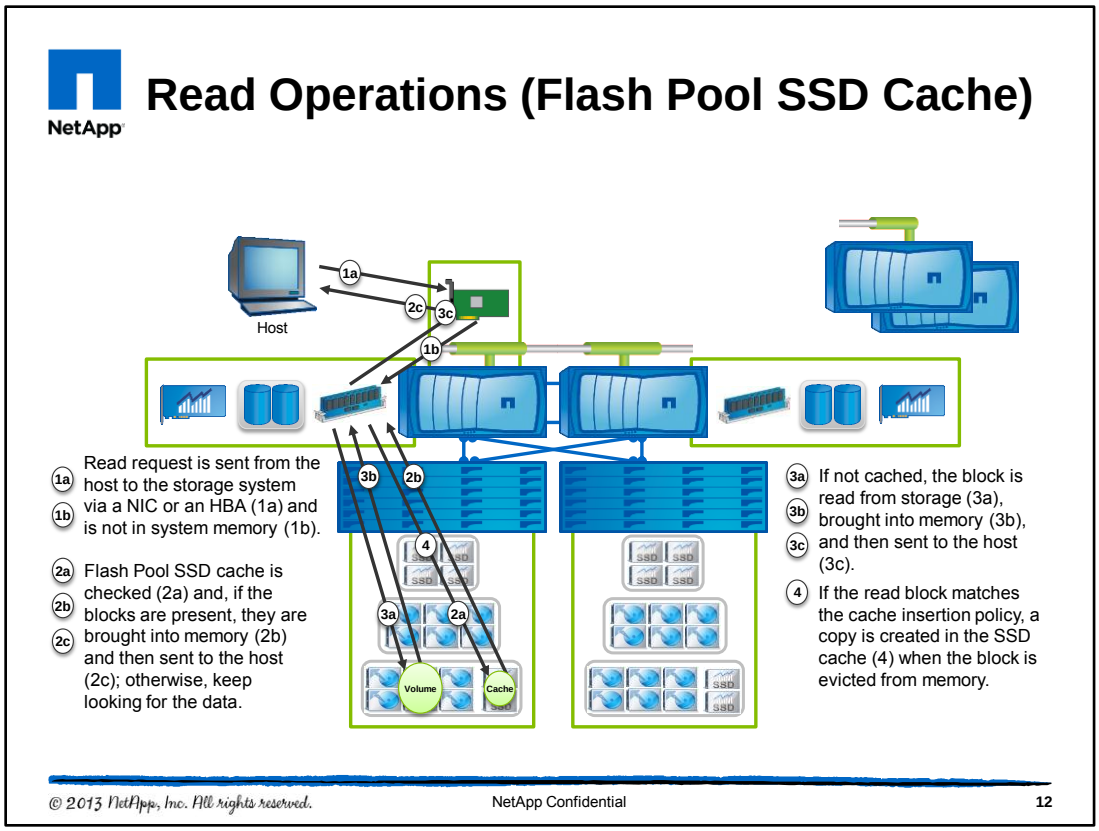
1. The read request is sent from the host to the storage system via a network interface card (NIC) or a host bus adapter (HBA).
2. If the read is in system memory, it is sent to the host; otherwise, keep looking for the data.
3. Flash Cache is checked (if it is present) and, if the blocks are present, they are brought into memory and then sent to the host; otherwise, keep looking for the data.
4. The block is read from storage, brought into memory, and then sent to the host.



READ OPERATIONS (INDIRECT DATA ACCESS)

Read operations for indirect data access take the following path through the storage system:

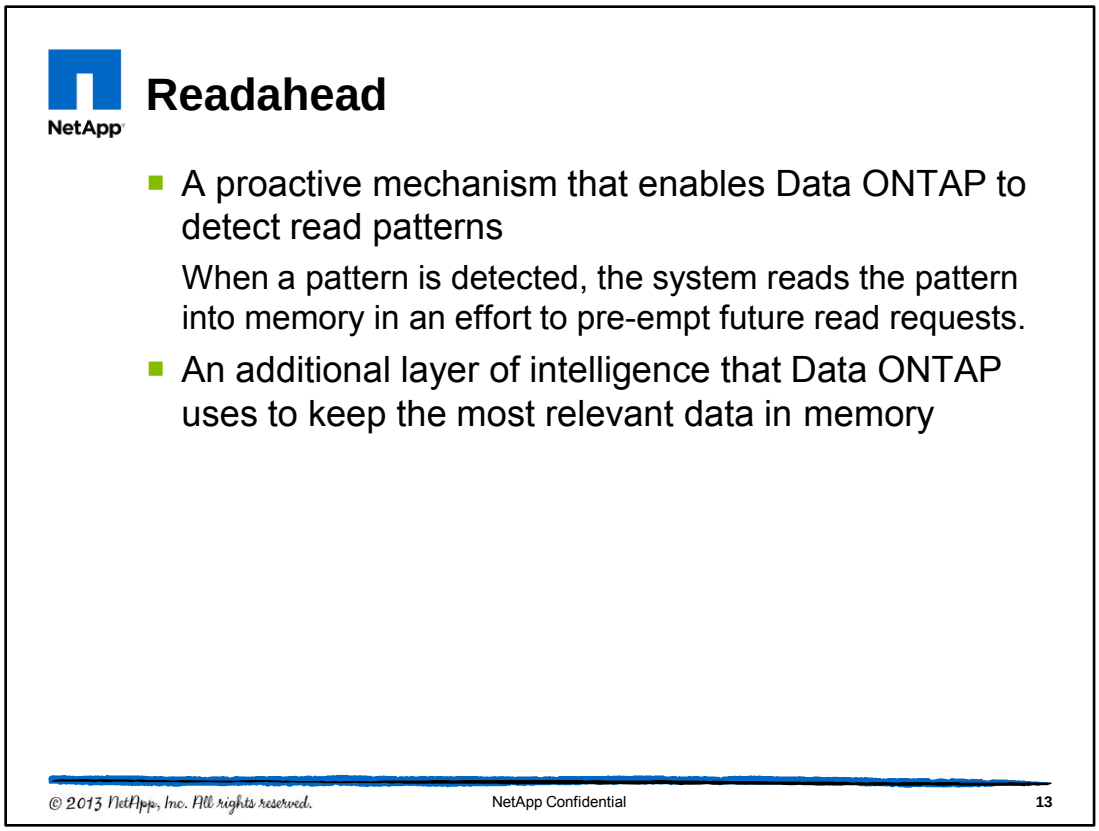
1. The read request is sent from the host to the storage system via a NIC or an HBA.
2. The read request is sent to the storage controller that owns the volume.
3. If the read is in system memory, it is sent to the host; otherwise, keep looking for the data.
4. Flash Cache (if it is present) is checked and, if the blocks are present, they are brought into memory and then sent to the host; otherwise, keep looking for the data.
5. The block is read from storage, brought into memory, and then sent to the host.



READ OPERATIONS (FLASH POOL SSD CACHE)

Read operations that involve Flash Pool SSD cache take the following path through the storage system:

1. The read request is sent from the host to the storage system via a NIC or an HBA and is not in system memory.
2. The Flash Pool SSD drive cache is checked and, if the blocks are present, they are brought into memory and then sent to the host; otherwise, keep looking for the data.
3. If not cached, the block is read from storage, brought into memory, and then sent to the host.
4. If the read block matches the cache insertion policy, a copy is created in the SSD cache when the block is evicted from memory.



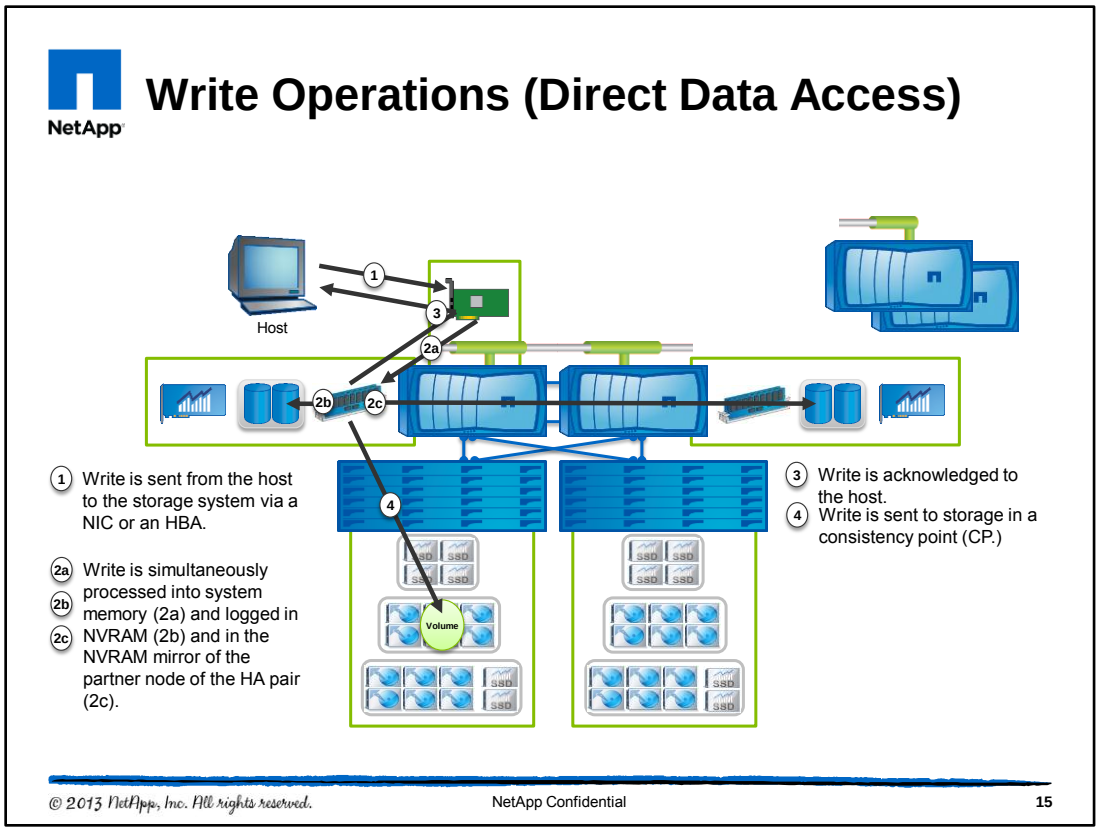
READAHEAD

Readahead enables Data ONTAP to detect read patterns (including long reads, strides, and backward reads). When a pattern is detected, the system reads the pattern into memory, reading more data than was requested in an effort to pre-empt future read requests.

Lesson 3

Write Data Access

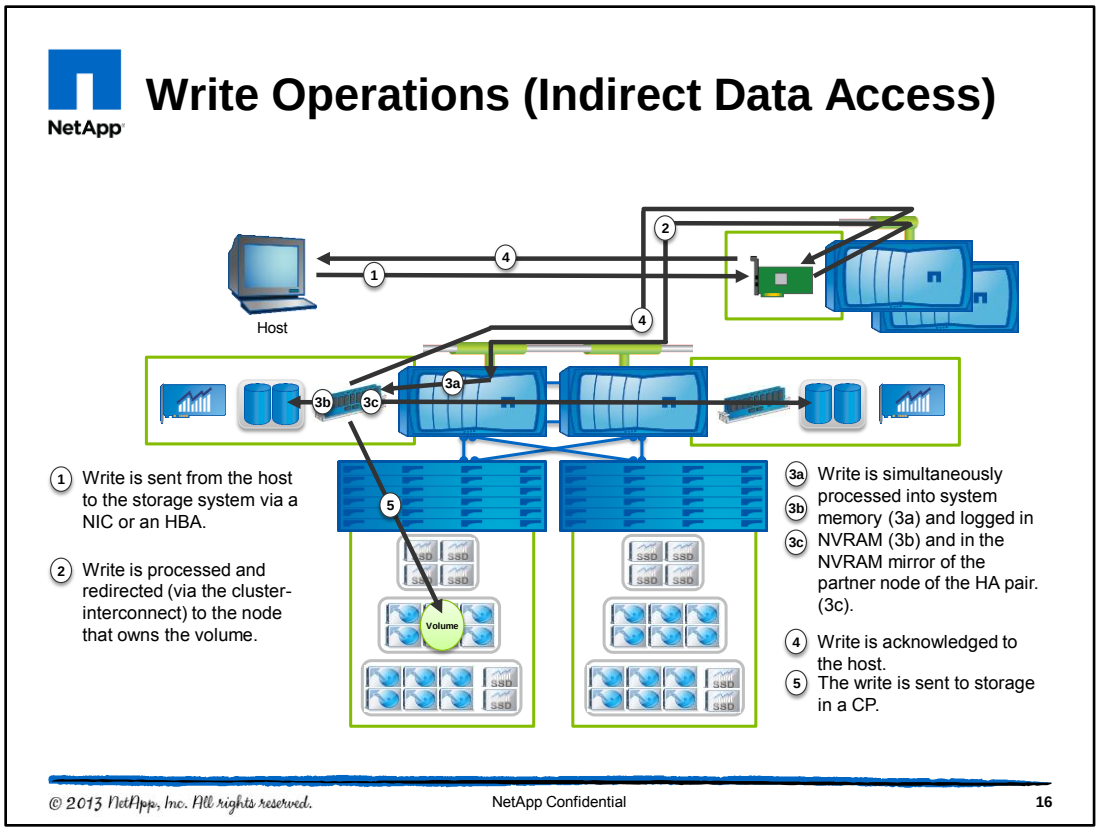
LESSON 3: WRITE DATA ACCESS



WRITE OPERATIONS (DIRECT DATA ACCESS)

Write operations for direct access take the following path through the storage system:

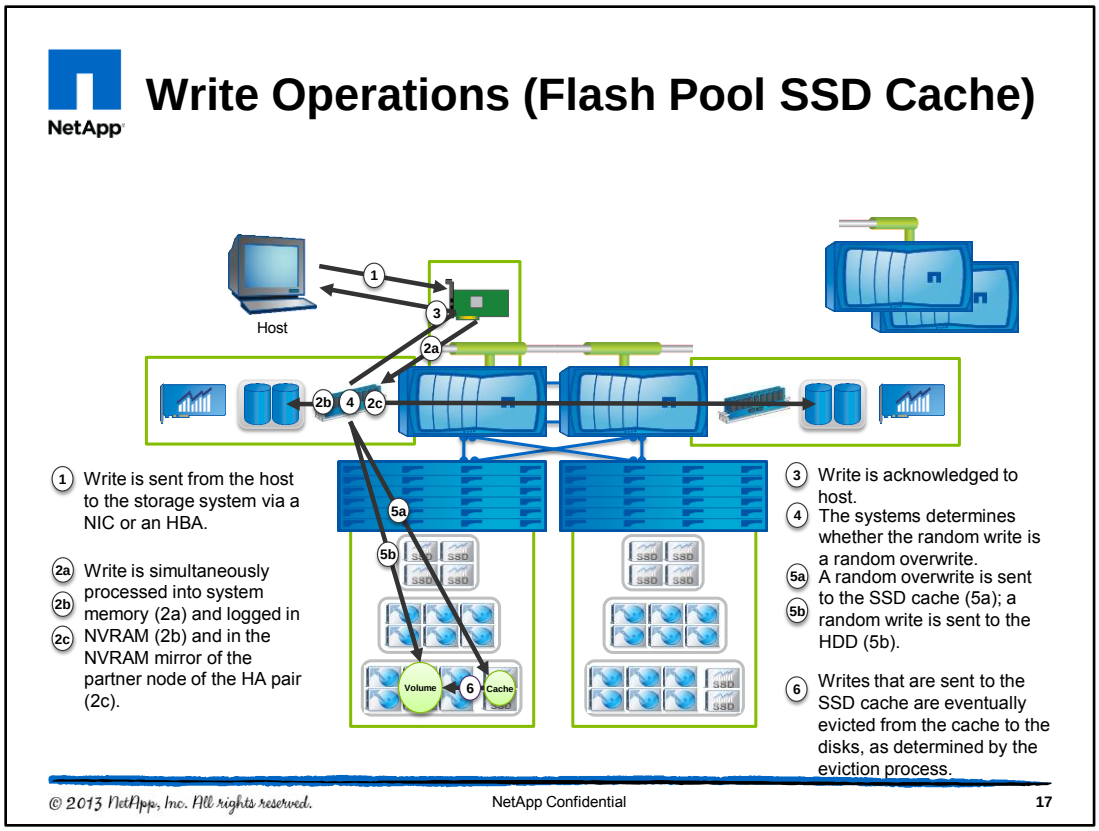
1. The write request is sent from the host to the storage system via a NIC or an HBA.
2. The write is simultaneously processed into system memory and logged in NVRAM and in the NVRAM mirror the partner node of the HA pair.
3. The write is acknowledged to the host.
4. The write is sent to storage in a consistency point (CP).



WRITE OPERATIONS (INDIRECT DATA ACCESS)

Write operations for indirect data access take the following path through the storage system:

1. The write request is sent from the host to the storage system via a NIC or an HBA.
2. The write is processed and redirected (via the cluster-interconnect) to the storage controller that owns the volume.
3. The write is simultaneously processed into system memory and logged in NVRAM and in the NVRAM mirror of the partner node of the HA pair.
4. The write is acknowledged to the host.
5. The write is sent to storage in a CP.



WRITE OPERATIONS (FLASH POOL SSD CACHE)

Write operations that involve the SSD cache take the following path through the storage system:

1. The write request is sent from the host to the storage system via a NIC or an HBA.
2. The write is simultaneously processed into system memory and logged in NVRAM and in the NVRAM mirror of the partner node of the HA pair.
3. The write is acknowledged to the host.
4. The system determines whether the random write is a random overwrite.
5. A random overwrite is sent to the SSD cache; a random write is sent to the HDD.
6. Writes that are sent to the SSD cache are eventually evicted from the cache to the disks, as determined by the eviction process).

For detailed information, see TR-4070: *Flash Pool Design and Implementation Guide.*

Lesson 4

NVRAM and CPs

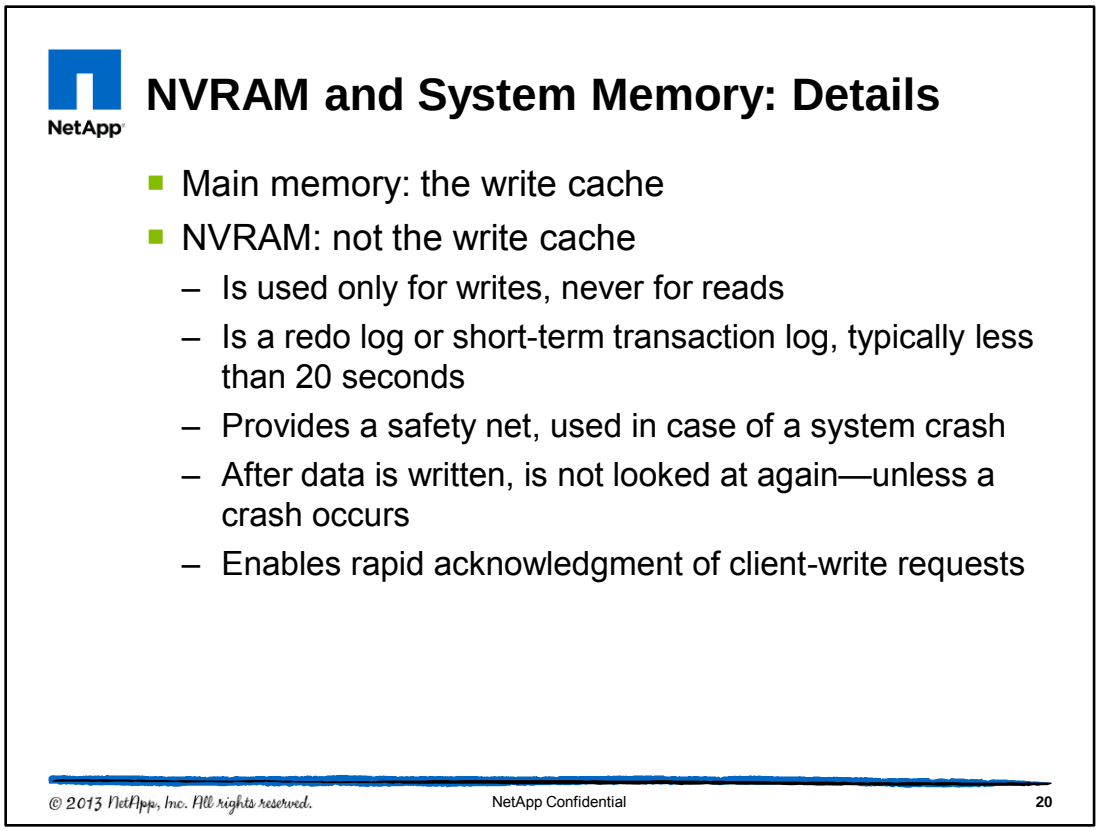
LESSON 4: NVRAM AND CPS

NVRAM and System Memory

- Write operations: sent to disk from memory (not NVRAM) in a CP
- NVRAM (and NVMEM) characteristics:
  - Battery-backed memory
  - Double-buffered journal of write operations
  - Mirrored between storage controllers in an HA pair
- Writes in memory that are logged in NVRAM (and mirrored): persistent.

NVRAM AND SYSTEM MEMORY

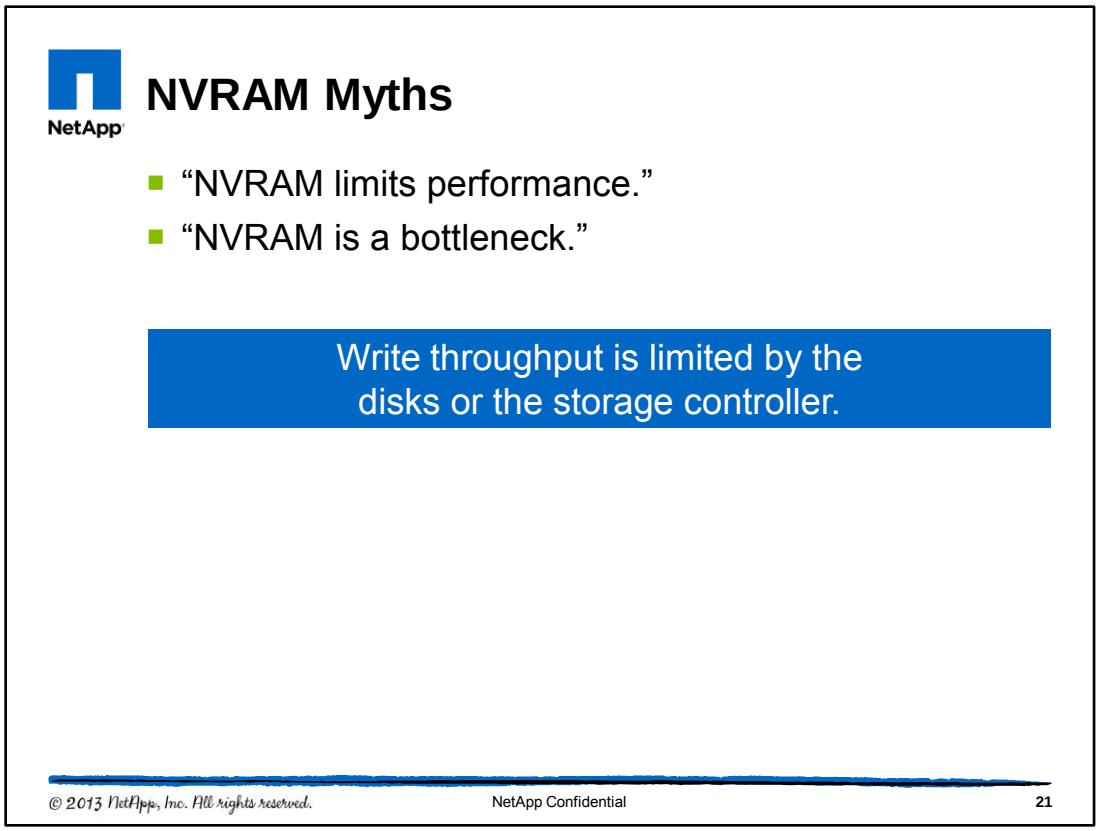
With battery-backed memory, during a power outage, the battery maintain powers and keeps the contents of the memory alive.



NVRAM AND SYSTEM MEMORY: DETAILS

NVRAM is not the write cache; NVRAM is a redo log.

NVRAM provides a safety net for the time between the acknowledgement of a client-write request and the commitment of the data to disk. After data is written to NVRAM, it is not looked at again, unless a crash occurs before a CP is complete. If a crash occurs, the operations in the NVRAM log are repeated; that is, the operations in the log are replayed into system memory.



NVRAM MYTHS

CPs

Certain circumstances trigger a CP:

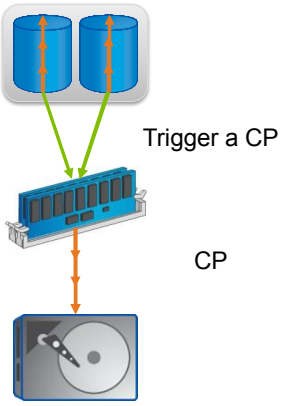
- One of the NVRAM buffers fills up, and it is time to flush the writes to disk (type = F or B).
- A ten-second timer runs out (type = T).
- A resource is exhausted or hits a predefined scenario, and it is time to flush the writes to disk (all other CP types).

NVRAM is very fast.
It is never the performance bottleneck.

CPS

Back-to-Back CPs

- As an NVRAM buffer reaches its capacity (alternating), it signals to memory that it is time to flush the writes in memory to disk.
- If the second buffer reaches capacity while writes are still being sent to disk from the first buffer, the CP cannot occur.
- The CP can occur only after the first flush of writes is complete.



BACK-TO-BACK CPS

Lesson 5

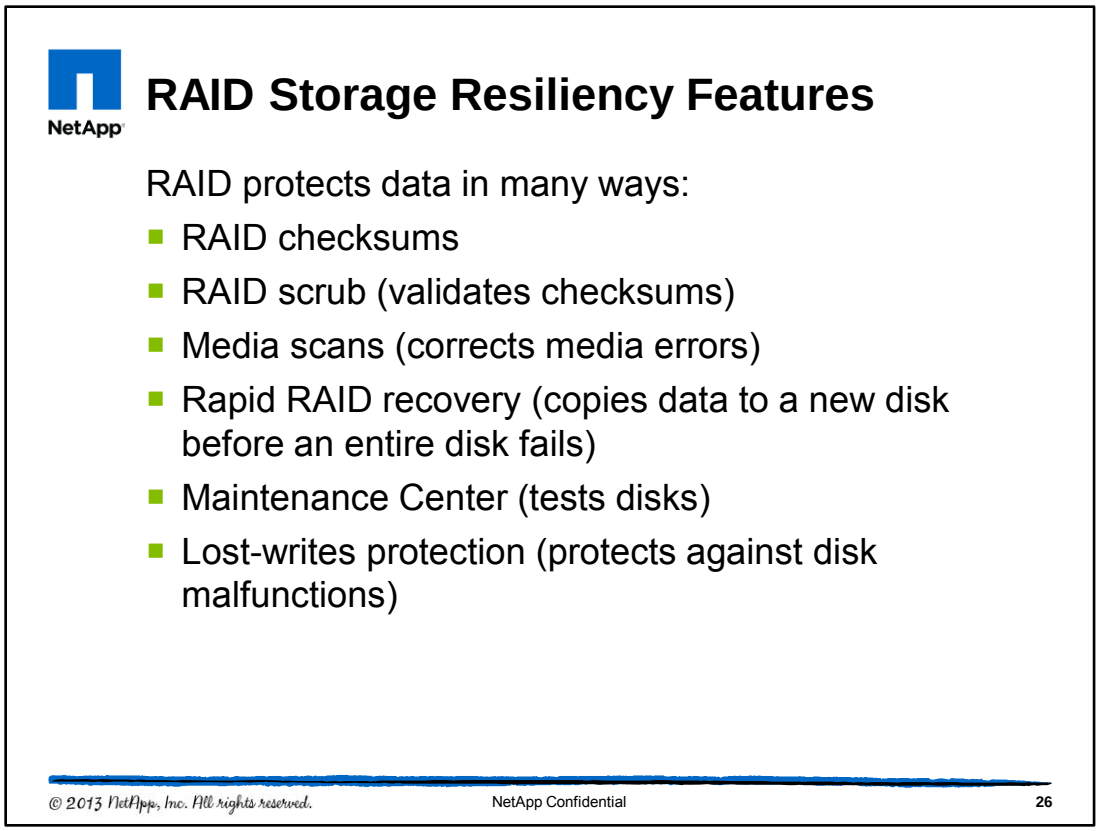
RAID

LESSON 5: RAID

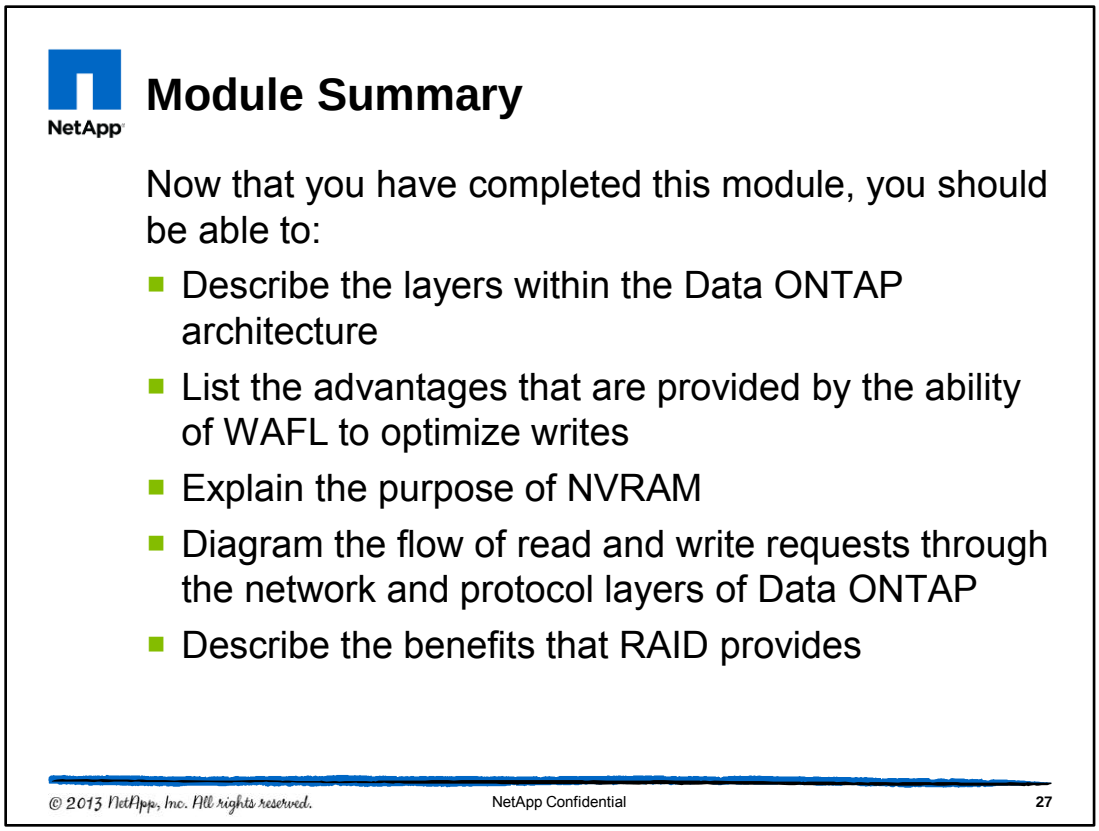
The Value of Software RAID

- Tight integration with WAFL
  - Better write allocation
  - Better handling of failures
- More flexibility
  - Rapid RAID recovery
  - Flexibility in RAID type (RAID-DP technology)
  - Flexible disk layout (across adapters)
  - Better error handling

THE VALUE OF SOFTWARE RAID



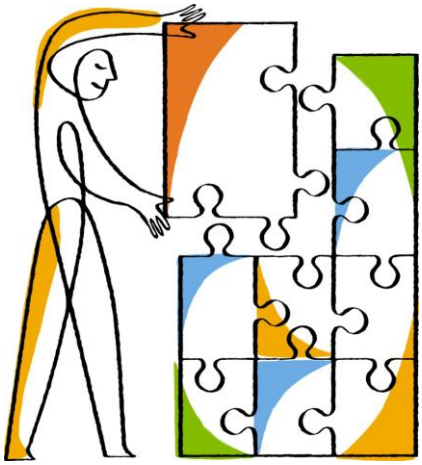
RAID STORAGE RESILIENCY FEATURES



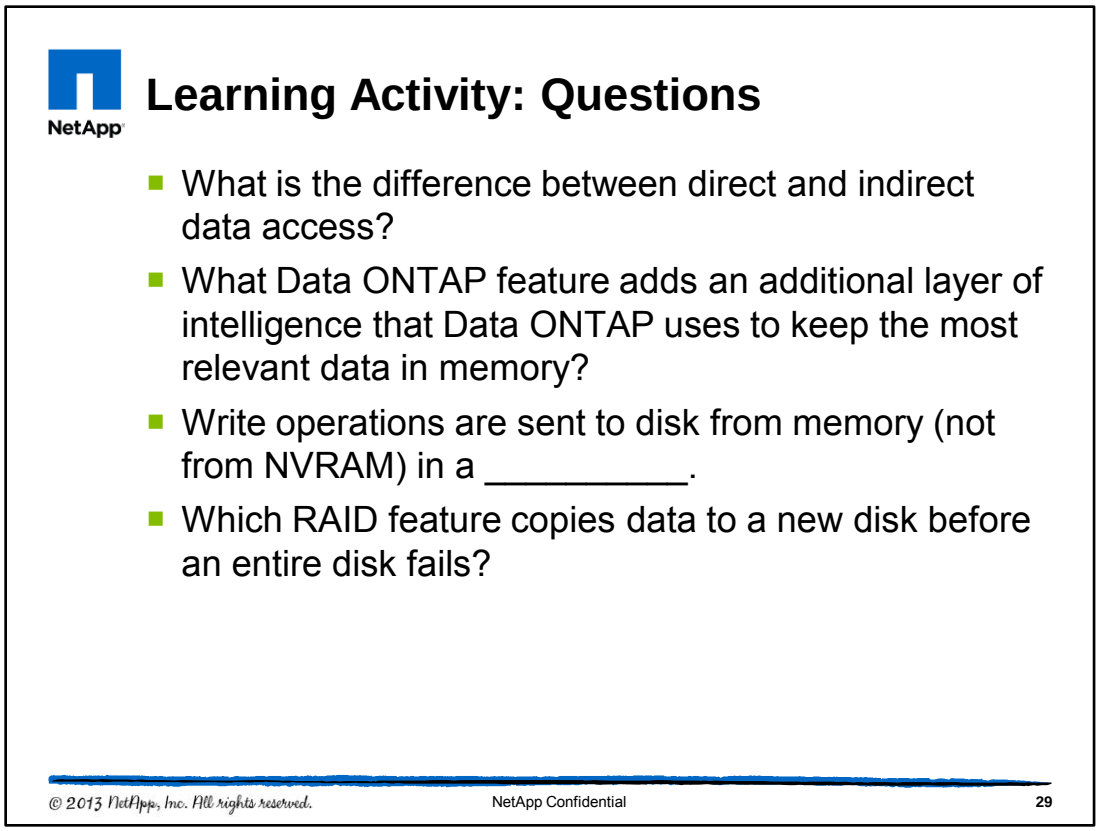
MODULE SUMMARY

Learning Activity Questions

Module 1: How a NetApp Storage System Works



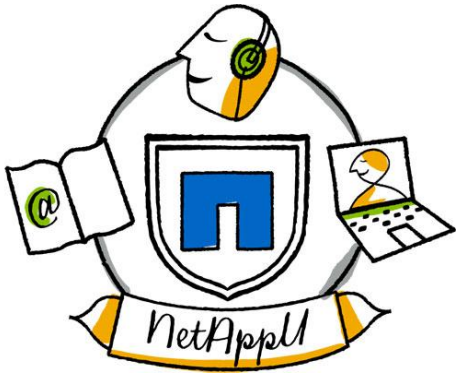
LEARNING ACTIVITY QUESTIONS



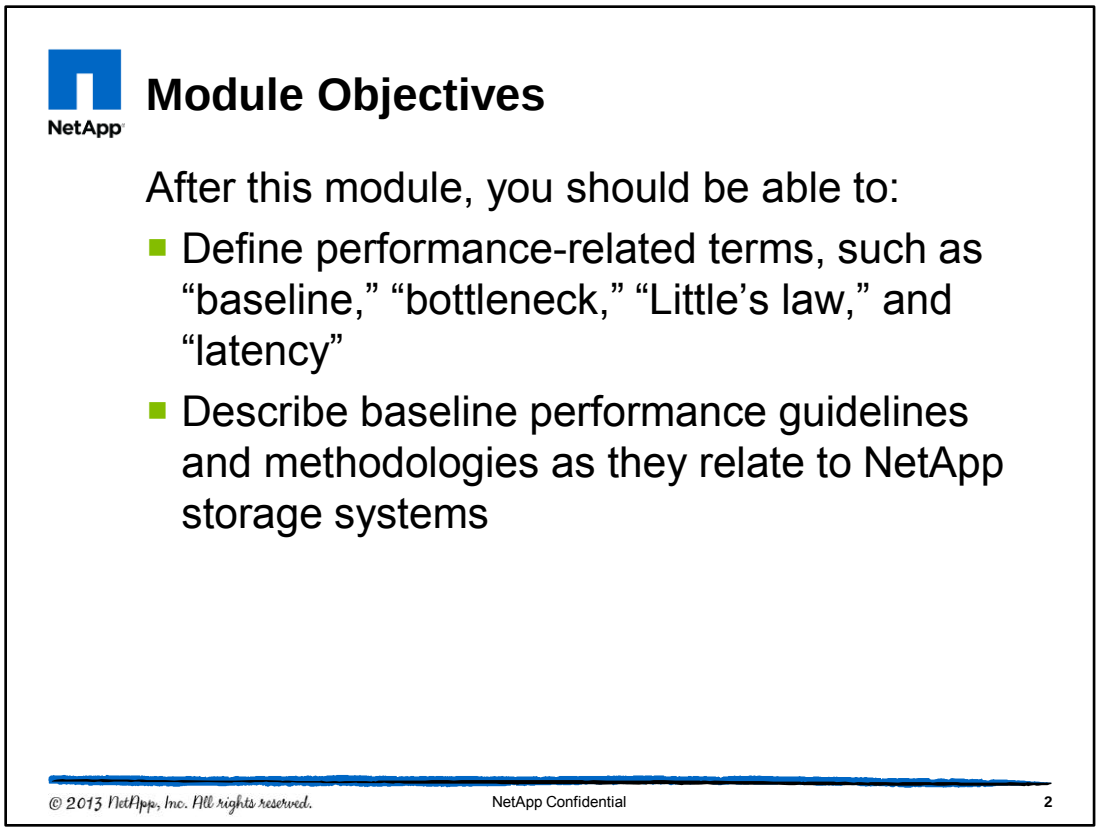
LEARNING ACTIVITY: QUESTIONS

Module 2

Performance Overview



MODULE 2: PERFORMANCE OVERVIEW



MODULE OBJECTIVES

First Rule for Performance Cases

Have No Fear

1 = 

2 = 

3 = 

4 = 

5 = 

6 = 

7 = 

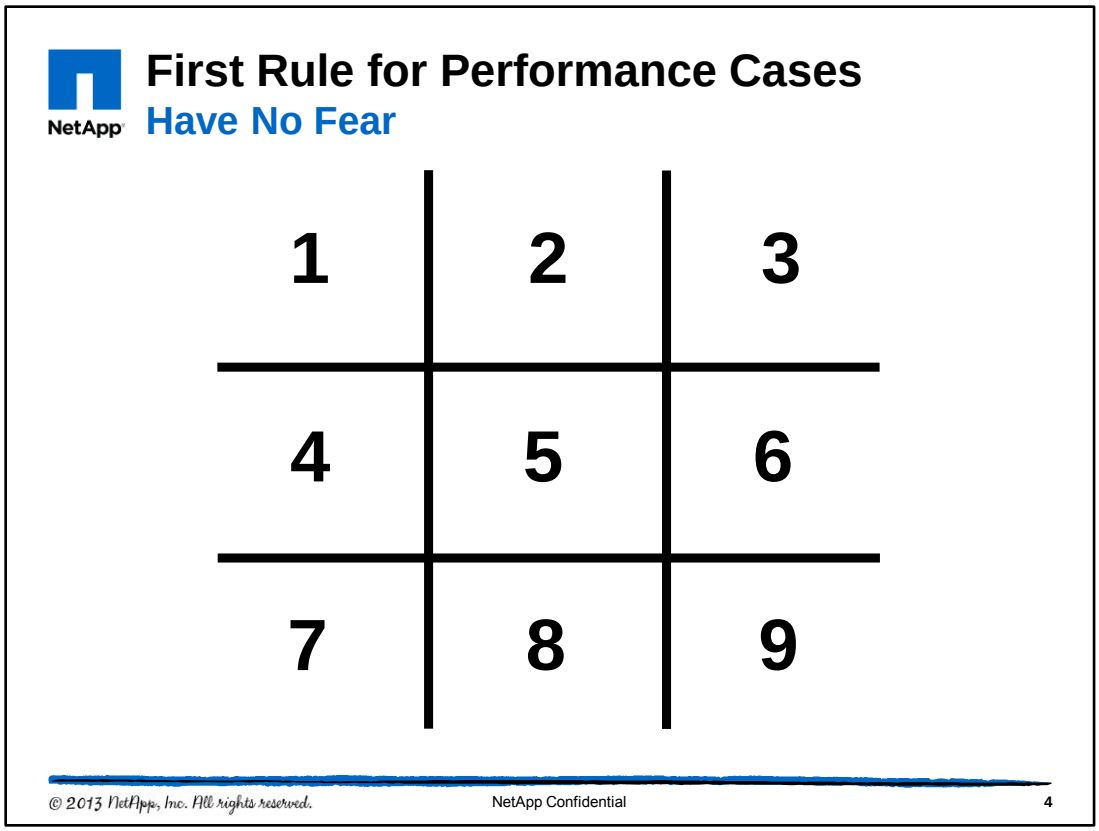
8 = 

9 = 

How long would you need to memorize this code?

5 seconds?

FIRST RULE FOR PERFORMANCE CASES: HAVE NO FEAR



FIRST RULE FOR PERFORMANCE CASES: HAVE NO FEAR

Lesson 1

Basic Terminology

LESSON 1: BASIC TERMINOLOGY

Terminology
"Performance" and "Bottleneck"

- What is performance?

  A comparison between the useful work that is accomplished by a computer system and the time and resources that are required to accomplish the work

- What is a bottleneck?

  A component or resource that hinders the performance or capacity of a system

- What bottlenecks affect a storage system?

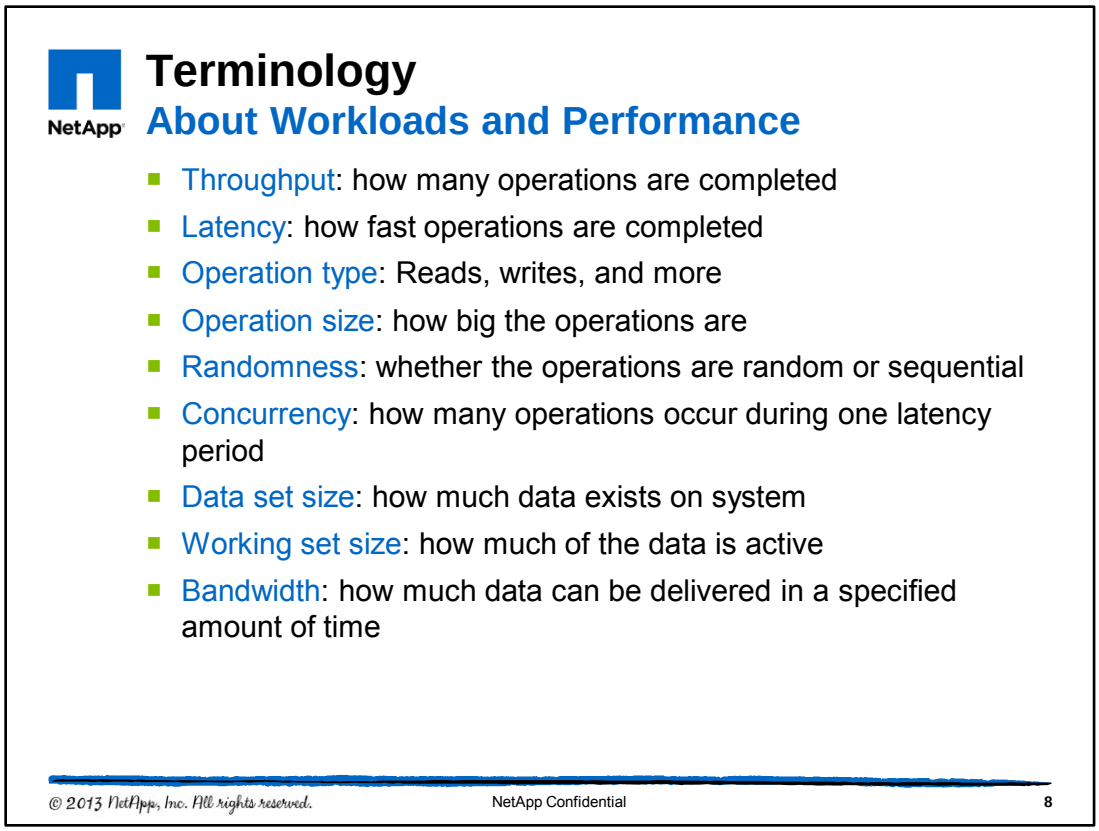
  Storage system (CPU, memory, disk), network, host, and applications

TERMINOLOGY: "PERFORMANCE" AND "BOTTLENECK"

Terminology
About Performance

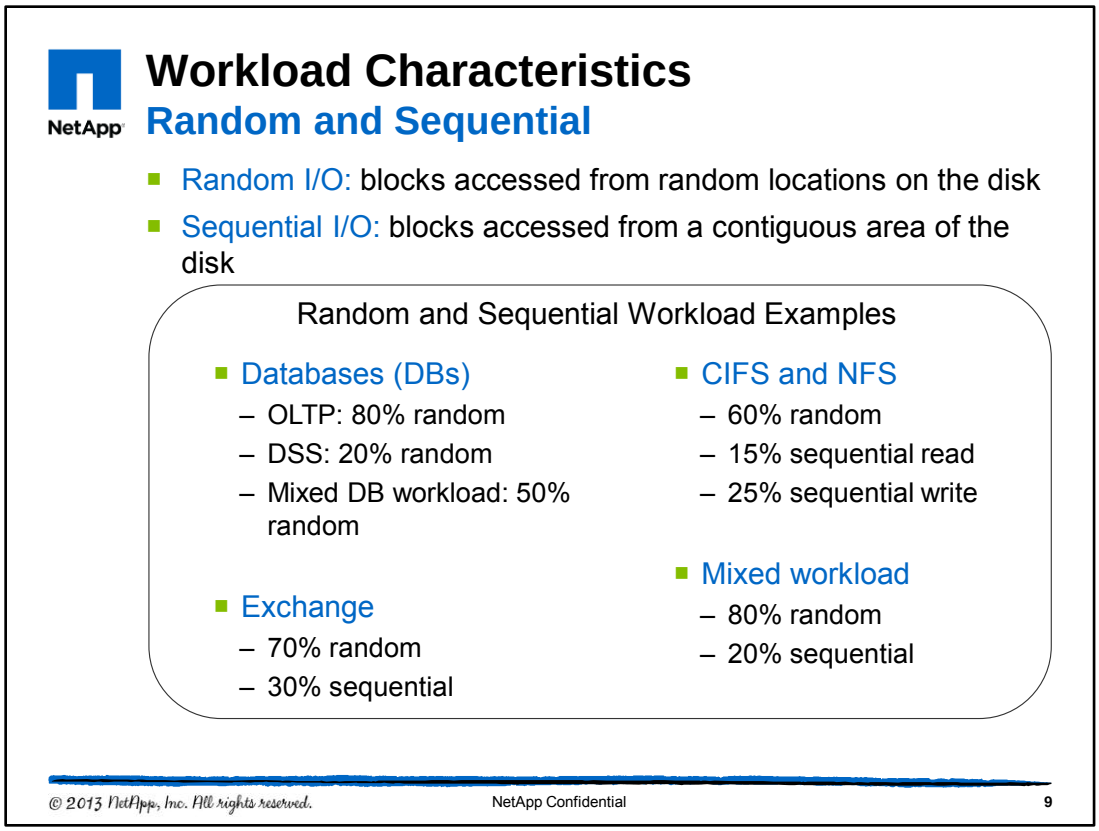
- Baseline: a value or set of values that can serve as a comparison or control
- Benchmark: a controlled workload that is used to measure performance
- Response time: the time that is required to return an answer
- Resource utilization: the percentage of time that a resource is working
- I/O rate: the number of transactions per second or I/O operations per second (IOPS)
- I/O time: the time that is expended to service an I/O event
- Seek time: the time that is required to move the disk drive head to the data
- Saturation: the condition in which a component reaches its maximum throughput handling capability

TERMINOLOGY: ABOUT PERFORMANCE



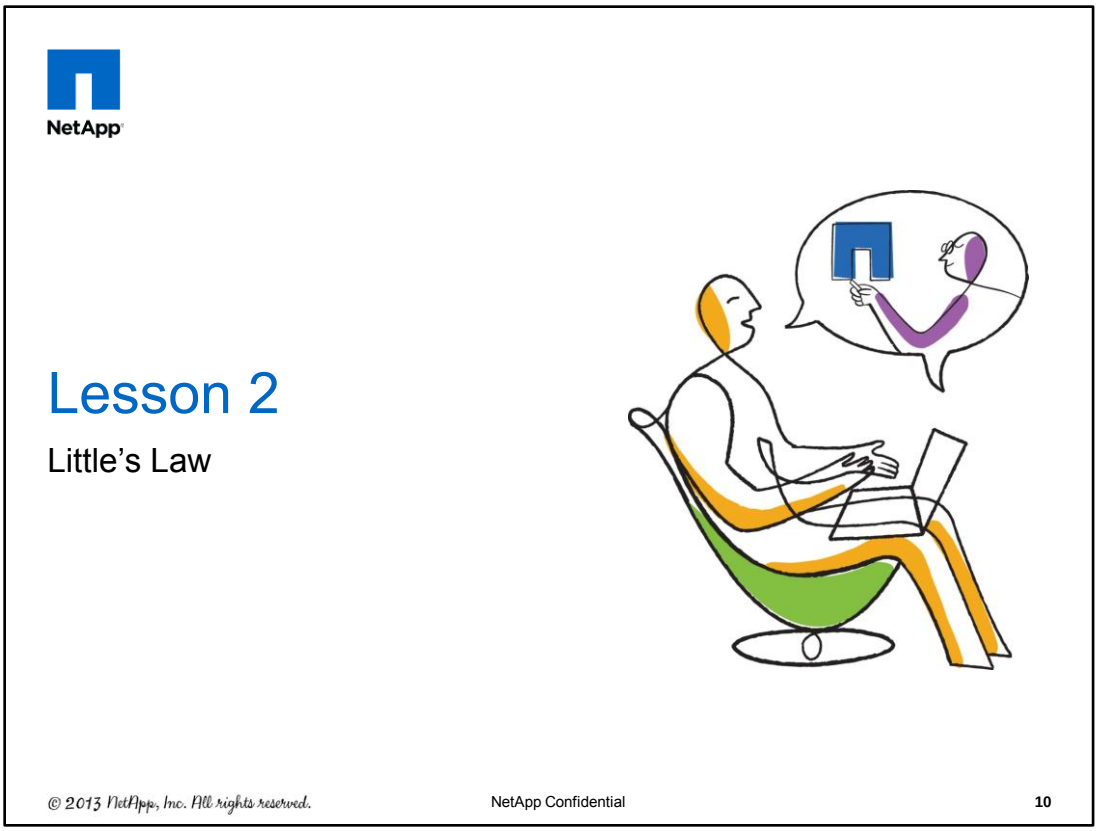
TERMINOLOGY: ABOUT WORKLOADS AND PERFORMANCE

Workload characteristics affect storage system performance and are part of the performance equation.



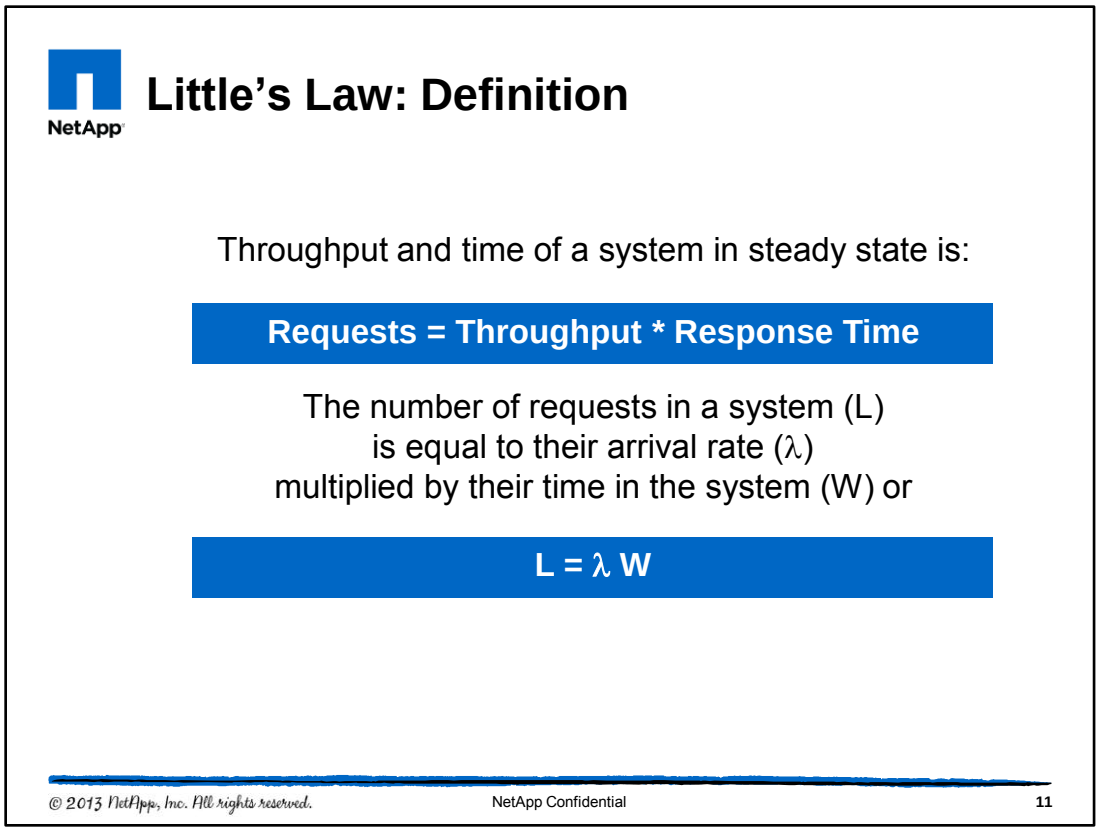
WORKLOAD CHARACTERISTICS: RANDOM AND SEQUENTIAL

Workload characteristics define the type of data access that affects the system. With random activity, the storage system accesses blocks from random locations on the disk. Traditionally, a time penalty is incurred while the disk heads seek and the disk rotates. With sequential activity, the storage system accesses blocks that reside in a contiguous area of the disk.



LESSON 2: LITTLE'S LAW

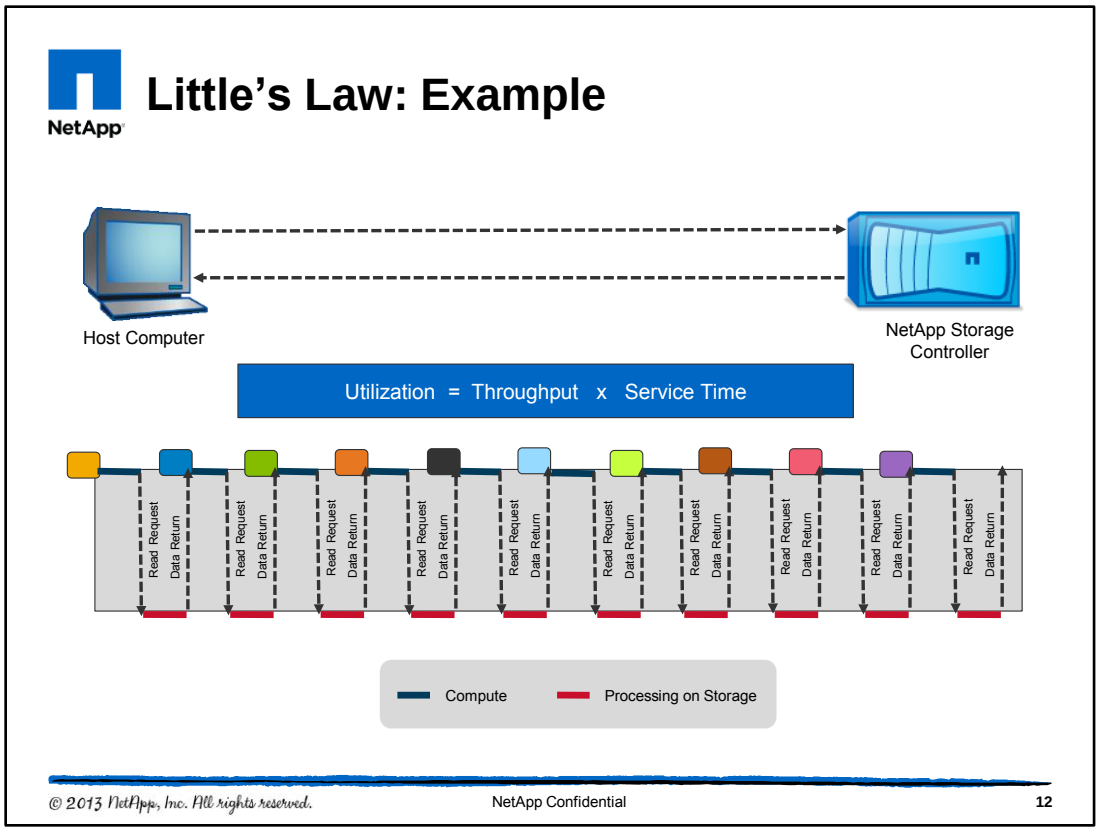
Little's law is a the theorem that was presented by John Little.



LITTLE'S LAW: DEFINITION

Initially, Little's law was presented as a basic manufacturing principle; however, the law can be applied to the performance of any system. Little's law states that the long-term average number of customers (or requests, in this case) in a stable system (L) is equal to the long-term average effective arrival rate (λ) multiplied by the average amount of time that a customer (or request) spends in the system (W). The law is expressed algebraically as "L = λW."

The equation can also be expressed as "requests = throughput x response time." The term "requests" can be replaced by the term "utilization," as in "utilization = throughput x response time." And, the term "response time" can be replaced with the term "service time" or "latency."



LITTLE'S LAW: EXAMPLE

Little's Law describes throughput as work in progress divided by response time. Response time is latency, and latency is consistent, regardless of the work in progress (or queue depth). The first example uses a queue depth of one, indicating that one task is being performed. For this example, assume that the latency is 2.88 ms. Throughput is then calculated as one divided by the response time, or one divided by 2.88 ms. Therefore, the throughput is .35 per ms, or, in other words, approximately one-third of the task was completed in one millisecond.

The second example uses a queue depth to ten and, again, a latency of 2.88 ms. Throughput is then calculated as ten divided by 2.88 ms. Therefore, throughput is 3.5 ms, or, in other words, three and one-half tasks were completed in one millisecond.

As demonstrated, the more tasks in the queue, the better the throughput; and the better the throughput, the better the system performance.

Lesson 3

Performance of Storage System Components

LESSON 3: PERFORMANCE OF STORAGE SYSTEM COMPONENTS

Controller
Limits

- CPU
  - < 85% on one controller
  - < 50% on a controller pair
- Other factors
  - Limit
    - Controller PCIe bus limits
    - Controller memory bus limits
  - Improve
    - Flash Pool, Flash Cache, Flash Accel
    - Solid-state drives (SSD)

CONTROLLER: LIMITS

Disk Shelf
Limits

Transport	Peak Throughput	75% of Peak (Recommended)
1 Gbps FC	120 MBps	90 MBps
2 Gbps FC	240 MBps	180 MBps
4 Gbps FC	480 MBps	360 MBps
3 Gbps SAS (IOM3)	1.2 GBps	0.9 GBps
6 Gbps SAS (IOM6)	2.4 GBps	1.8 GBps

DISK SHELF: LIMITS

Hard Disk Drive
Theoretical Limits

Spindle Speed	Maximum Theoretical Random IOPS	Maximum Theoretical 4KB Random Throughput	Maximum Theoretical 64KB Random Throughput
7200 RPM	240 per spindle	0.9 MBps per spindle	15 Mbps per spindle
10000 RPM	333 per spindle	1.3 MBps per spindle	20 MBps per spindle
15000 RPM	500 per spindle	1.9 MBps per spindle	31 MBps per spindle

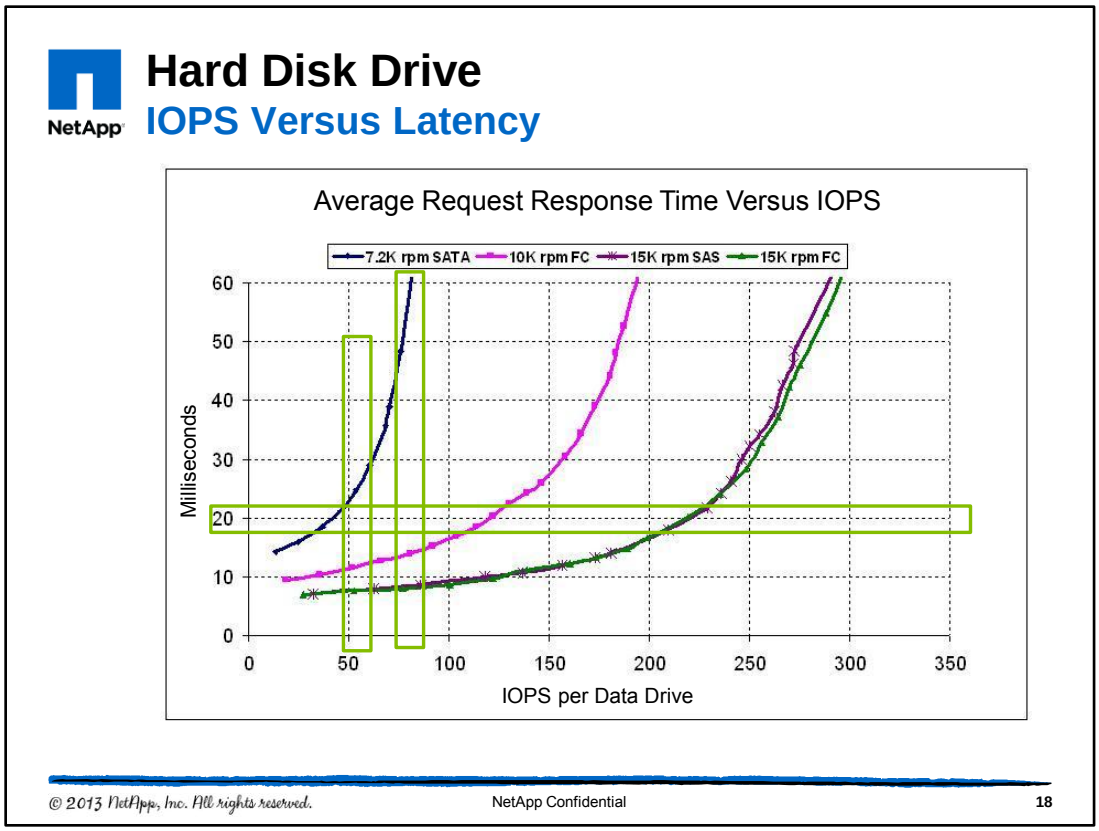
Theoretical throughput is never achieved.

HARD DISK DRIVE: THEORETICAL LIMITS

Hard Disk Drive
Realistic Limits

Workload Type	Typical Measured Peak Throughput per Data Spindle (CPU Limited Configuration)	Target Throughput for Non-Performance Workloads (50% of Peak)	Target Throughput with 112 Spindles (98 Data Spindles)	Target Throughput with 512 Spindles (448 Data Spindles)
Random read	500 KBps	250 KBps	20 MBps	100 MBps
Random write	2.4 MBps	1.2 MBps	110 MBps	530 MBps
Sequential read	6.8 MBps	3.2 MBps	300 MBps	1.4 GBps
Sequential write	7.2 MBps	3.6 MBps	350 MBps	1.6 GBps

HARD DISK DRIVE: REALISTIC LIMITS



HARD DISK DRIVE: IOPS VERSUS LATENCY

This diagram shows drive capability for hard disk drives (HDDs) with different rotational speeds. The diagram answers the question "how many IOPS can be performed per drive within what response time?" For example, if the response time is 20 ms, drives with 7200 RPM have an I/O rate of approximately 40, drives with 10000 RPM have an I/O rate of approximately 120, and drives with 15000 RPM have an I/O rate of approximately 220. You should commit the information in this diagram to memory.

If drives with 7200 RPM are doing 80 or 90 IOPS, the efficiency of the drives must be improved, spindles must be added, or the workload must be moved to faster drives. Conversely, if drives with 15000 RPM are doing 100 IOPS, no action is needed.

In read-intensive environments, solid-state drives (SSDs) provide more latency and throughput benefits than do HDDs. For the latest information about the performance of SSDs, visit netapp.com.

Client

Limits

Transport	Peak Throughput	75% of Peak (Recommended)
1 Gbe	100 - 120 MBps	90 MBps
10 Gbe	1.0 – 1.2 GBps	900 MBps
40 Gbe	~5 GBps	< 4 GBps
1 Gbps FC	120 MBps	90 MBps
2 Gbps FC	240 MBps	180 MBps
4 Gbps FC	480 MBps	360 MBps

CLIENT: LIMITS

Lesson 4

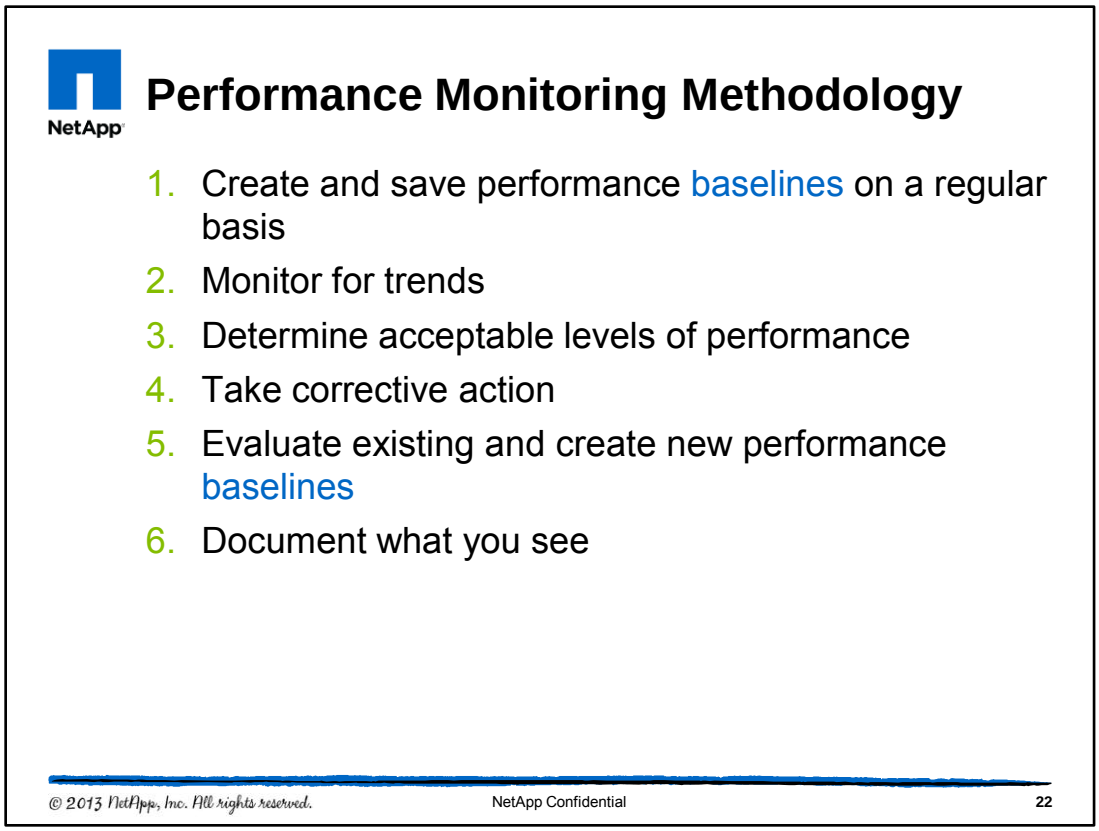
Advanced Performance Analysis

LESSON 4: ADVANCED PERFORMANCE ANALYSIS

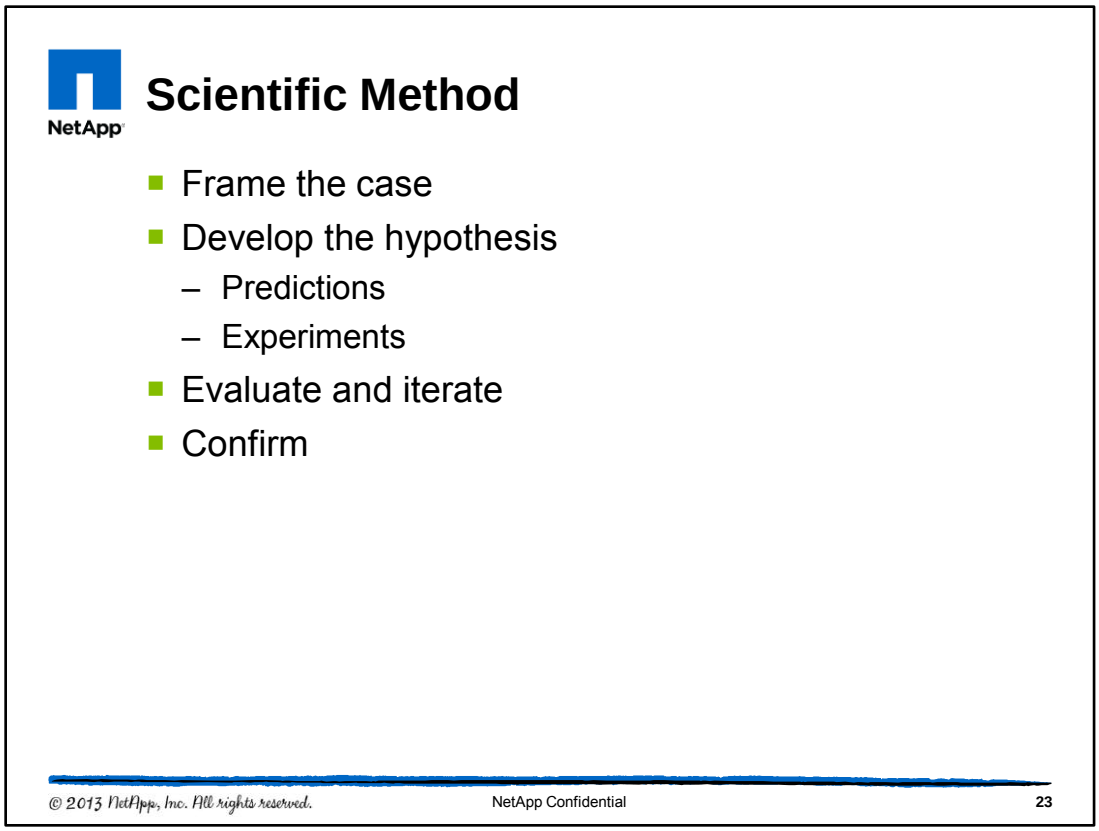
Performance Guidelines

- Know your environment
- Identify the characteristics of your workload
- Recognize possible trade-offs
- Understand the difference between latency and throughput
- Remember Little's Law
- Do not over use resources
- Identify potential bottlenecks
- Design tests carefully
- Understand your end-user applications

PERFORMANCE GUIDELINES



PERFORMANCE MONITORING METHODOLOGY



SCIENTIFIC METHOD

The scientific method is a body of techniques for investigating phenomena and acquiring knowledge as well as for correcting and integrating previous knowledge. The method is based on gathering observable, empirical, and measurable evidence and requires the application of specific principles of reasoning, the collection of data through observation and experimentation, and the formulation and testing of hypotheses. The process must be objective. The goal is to prove whether a theory is true or false.

Framing the case

"Framing the case" is called "characterization." Characterization is the systematic, careful collection of measurements and information about a case. The collection can be accompanied by measurements or estimates of uncertainty. Uncertainty is often estimated by making repeated measurements of the desired quantity. For example, you can count the number of NFS operations that occur each hour and compare the number of actual operations to the number of requests that are possible for the interface. Counts represent only a sample of desired quantities, with an uncertainly that depends upon the sampling method that is used and the number of samples that are collected. It is imperative that you consider the limitations of your data.

Developing the hypothesis

A hypothesis is a suggested explanation of a phenomenon, or, alternately, a reasoned proposal that suggests a correlation between or among a set of phenomena.

Predictions from a hypothesis

Any useful hypothesis enables predications, which are usually obtained through deductive reasoning. You might predict the outcome of an experiment in a laboratory setting or the performance of a phenomenon in nature. Predictions can also involve statistics and probabilities.

To satisfy the requirements of a hypothesis, the outcome of a predication must be unknown. An outcome that is known is a consequence, not a predication. If predictions associated with a hypothesis are not accessible by observation or experience, the hypothesis is not useful.

Experiments

Predictions can be tested by experimentation. If test results contradict the predication, the hypothesis is called into question, and you must seek explanations. When an experiment fails to prove a predication, you should look for fault in the logic or in the test before you conclude that the hypothesis is false.

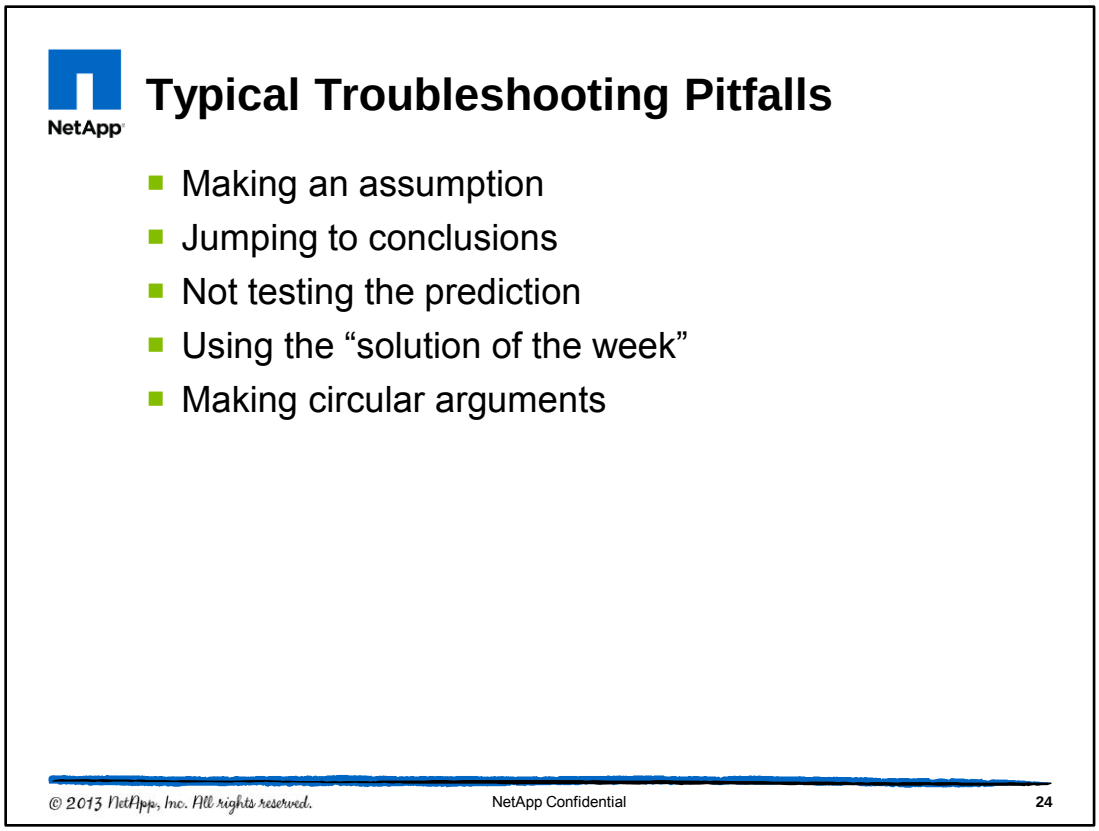
If the results confirm the predictions, the hypothesis is considered to be correct.

Evaluate and iterate

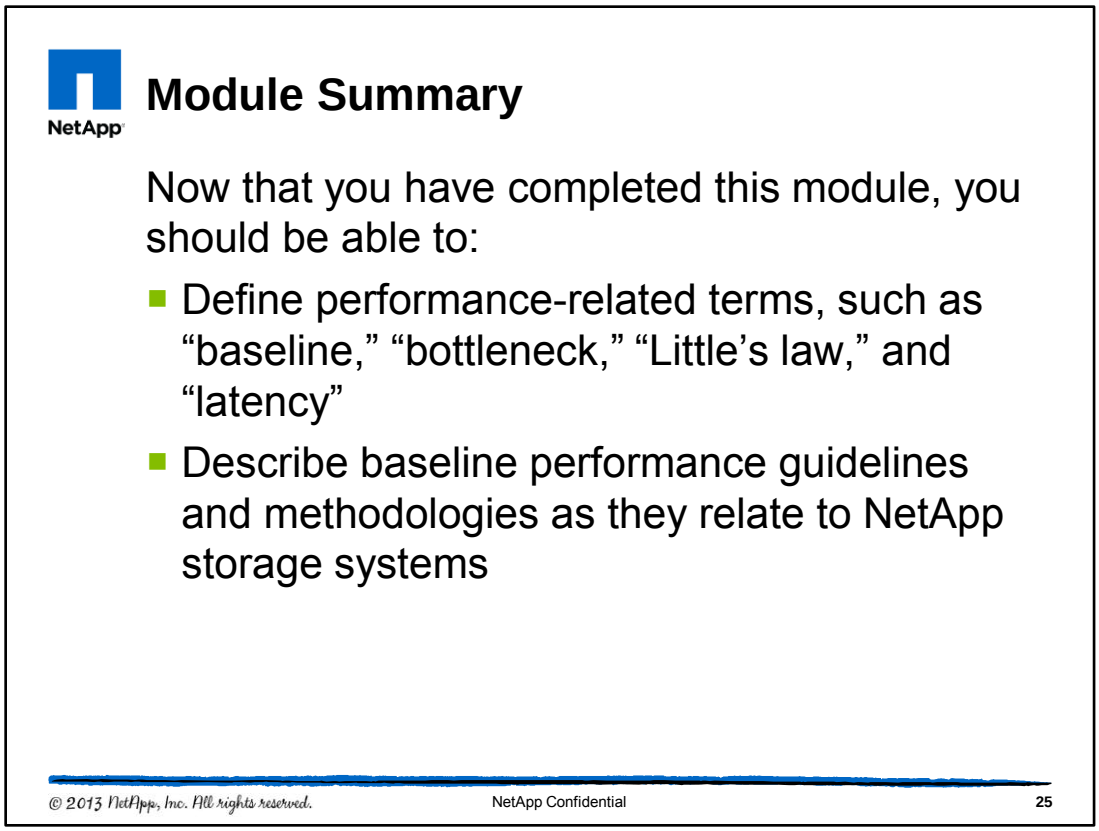
The scientific process is iterative. At any stage, some consideration may lead you to repeat an earlier part of the process. At any point, a hypothesis may be reevaluated, based on new information or on a new understanding of the facts.

Confirm

Each performance case has a social-learning aspect. Communicating about a case enables you to share information with your community. Others learn, and you benefit from peer review.



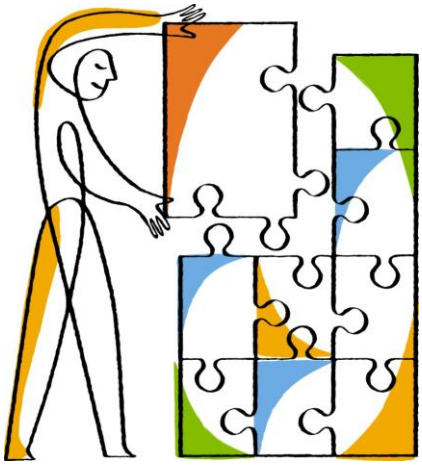
TYPICAL TROUBLESHOOTING PITFALLS



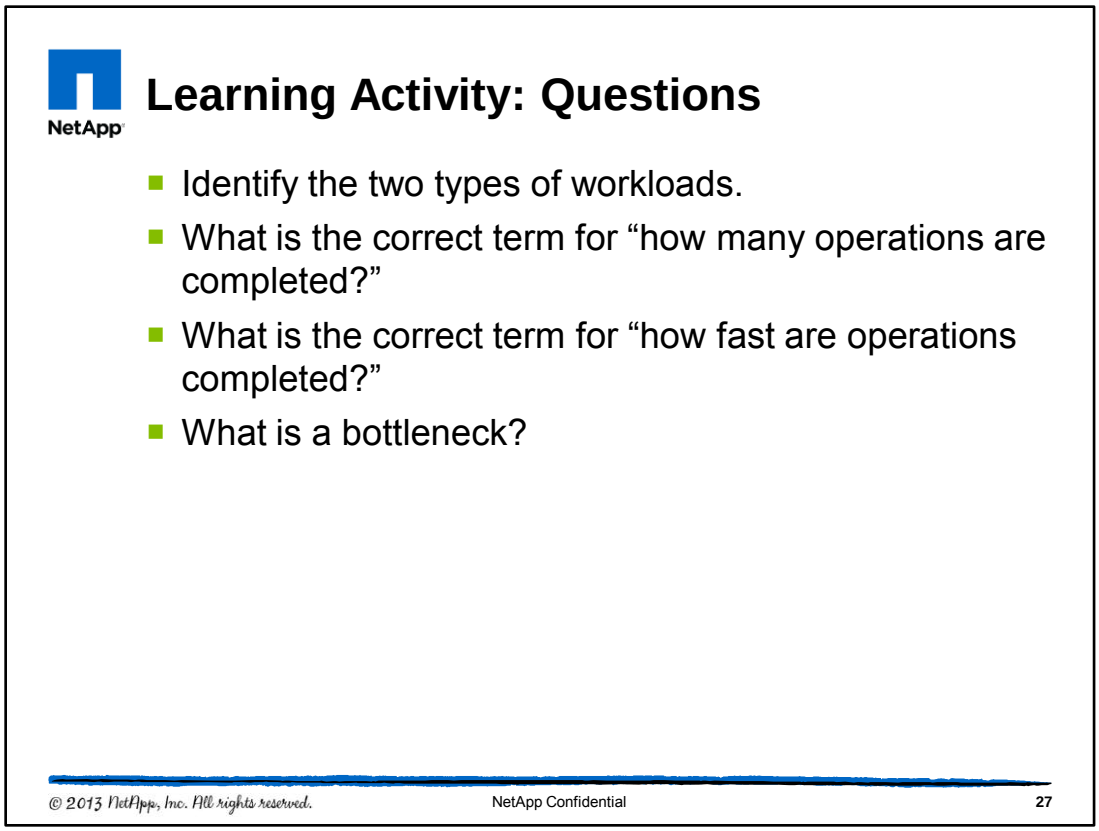
MODULE SUMMARY

Learning Activity Questions

Module 2: Performance Overview



LEARNING ACTIVITY QUESTIONS

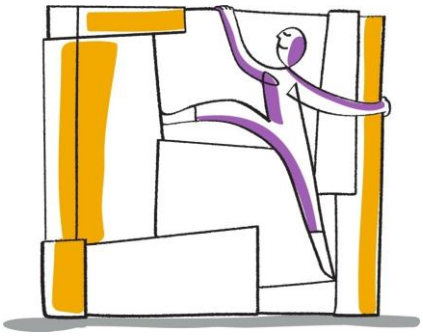


LEARNING ACTIVITY: QUESTIONS

Exercise

Module 2: Performance Overview

Time Estimate: 20 Minutes

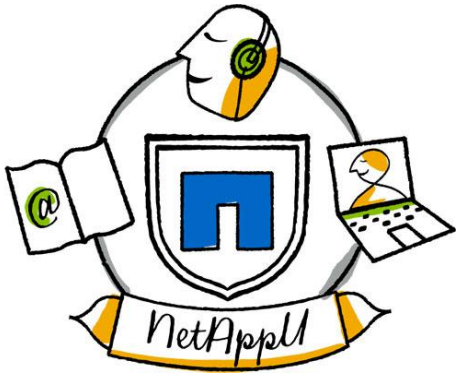


EXERCISE

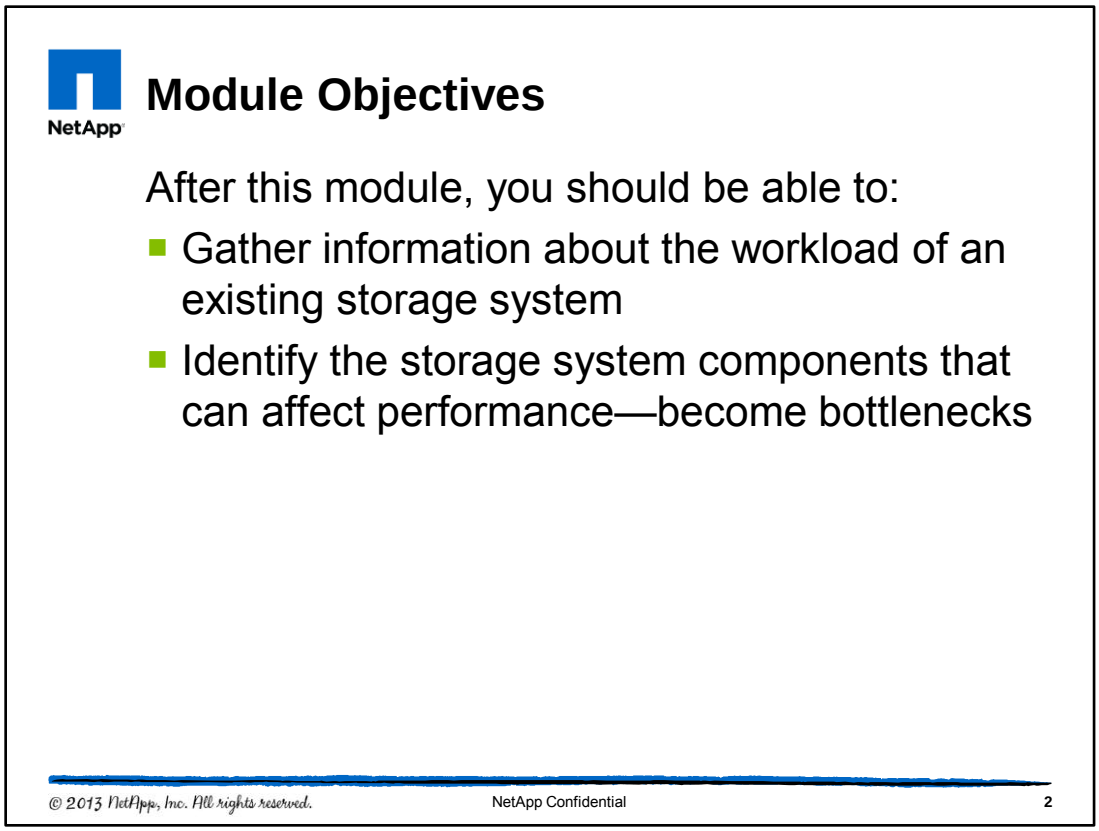
Please refer to your exercise guide.

Module 3

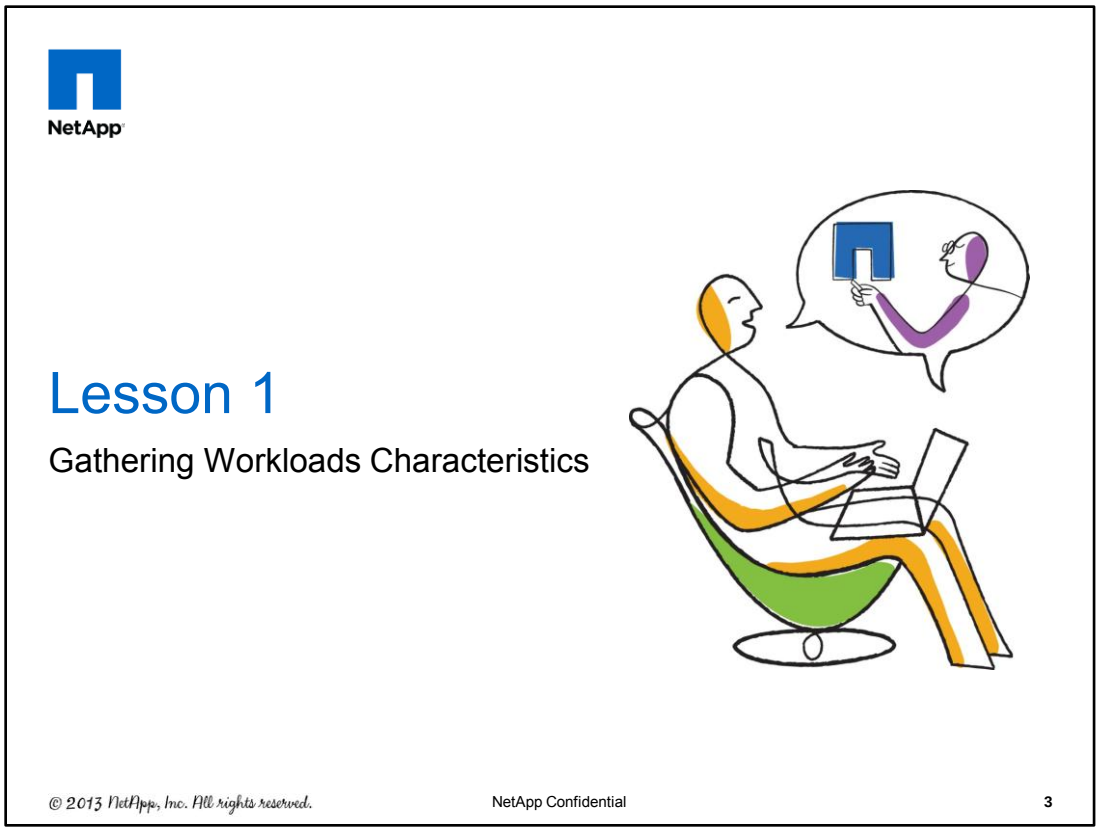
Clustered Storage System
Workloads and Bottlenecks



MODULE 3: CLUSTERED STORAGE SYSTEM WORKLOADS AND BOTTLENECKS

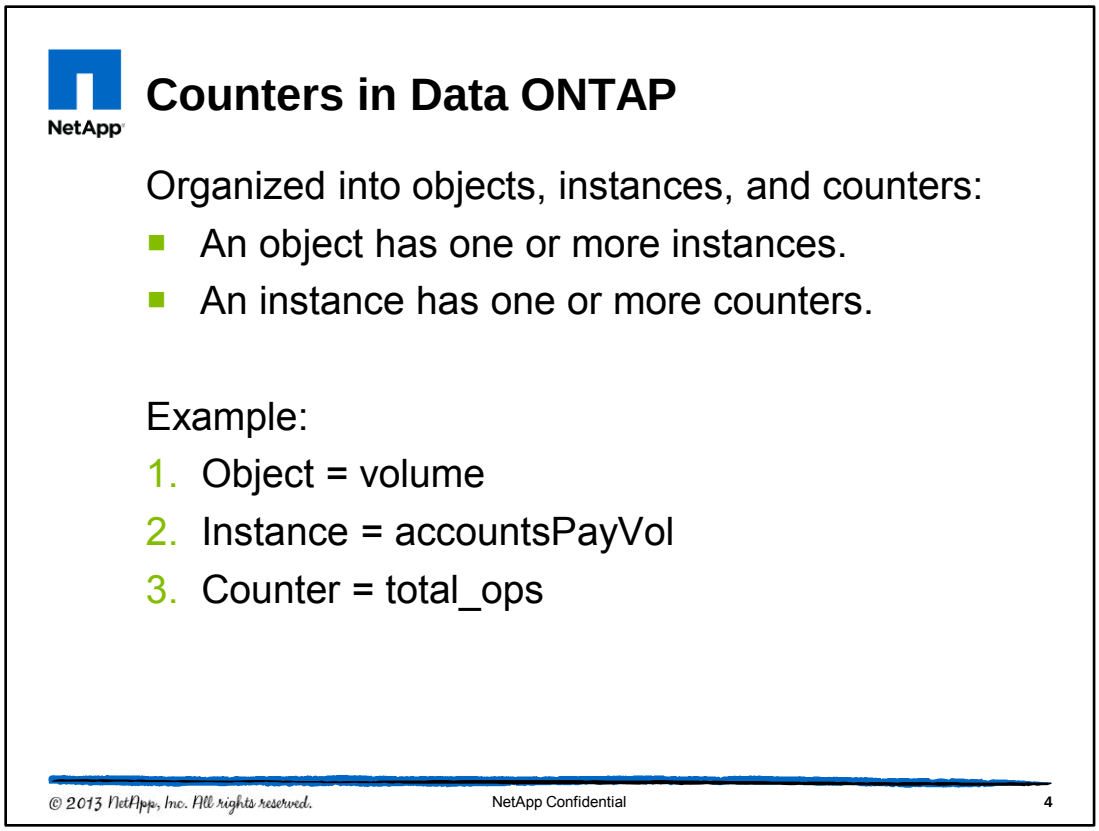


MODULE OBJECTIVES



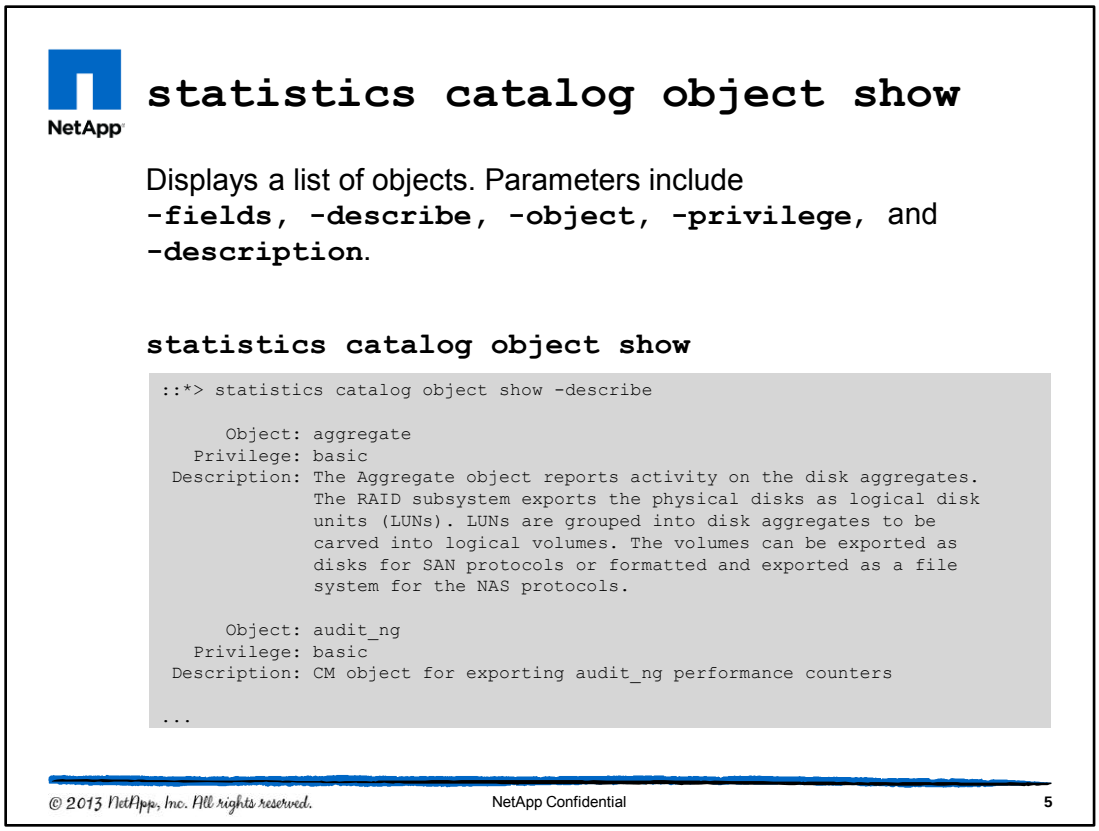
LESSON 1: GATHERING WORKLOADS CHARACTERISTICS

This lesson discusses methods of determining workload characteristics for any given storage environment.



COUNTERS IN DATA ONTAP

In Data ONTAP, a counter is an entity that is displayed as an object, with one or more instances and one or more counters. For example, to display the total operations per second of the accounts payable volume, you specify an object of volume, an instance of accountsPayVol, and a counter of total_ops.



STATISTICS CATALOG OBJECT SHOW

This command displays the names and descriptions of objects about which you can obtain performance data. The displayed data is either node-specific or cluster-wide, depending on which objects are specified.

Parameters:

-fields <fieldname>, ...

Displays the specified field or fields. You can use '-fields ?' to display a list of fields and then choose one or more fields from the list.

-describe

Displays detailed information about each object, including privilege level

-object <text>

Selects the objects for which you want to display information. If you do not specify this parameter, information is displayed for all of the objects.

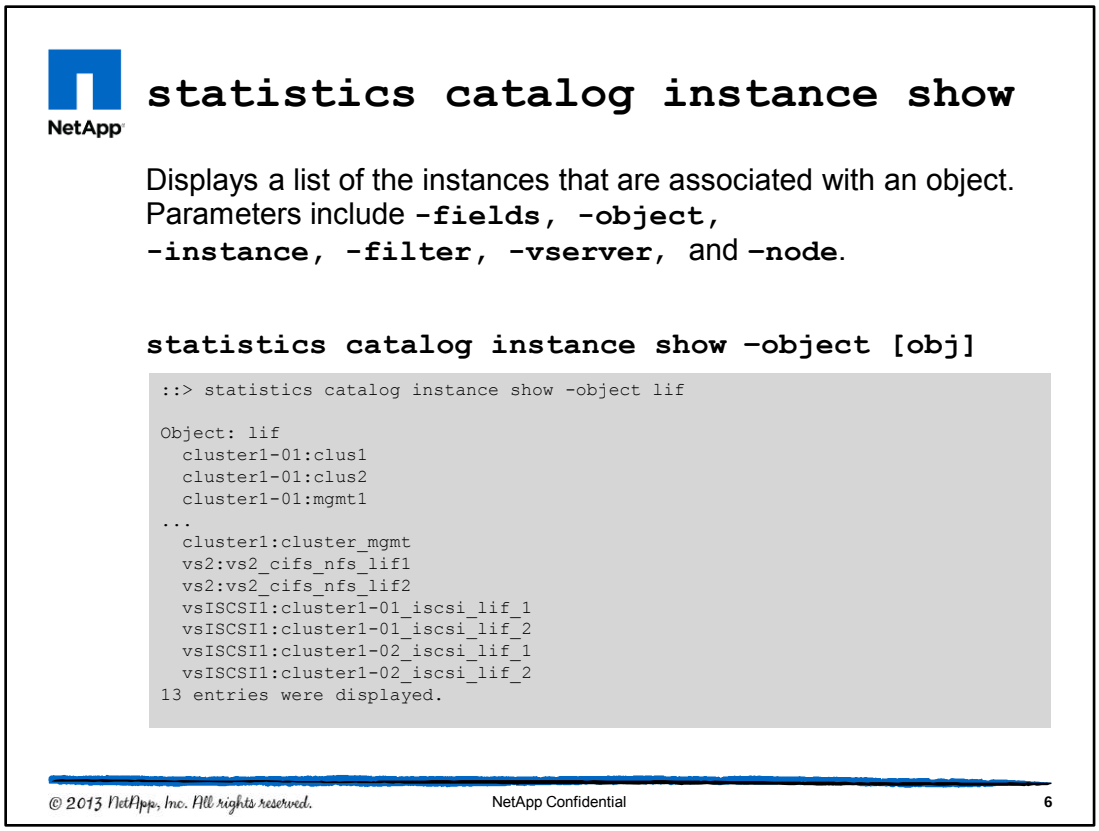
-privilege <text>

(privilege: advanced)

Selects the objects that match the parameter value

-description <text>

Selects the objects that match the parameter value



STATISTICS CATALOG INSTANCE SHOW

This command displays the names of the instances that are associated with the specified object. The displayed data is either node-specific or cluster-wide, depending on the objects specified.

Parameters:

-fields <fieldname>, ...

Displays the specified field or fields. You can use '-fields ?' to display a list of fields and then choose one or more fields from the list.

-object <text>

Selects the object for which you want to display the list of instances. This parameter is required. To view a list of valid object names, type “statistics catalog instance show -object ?” or “statistics catalog object show.”

-instance <text>

Selects the instances that match the parameter value. If you do not specify this parameter, the command displays all instances.

-filter <text>

Selects the instances that match the parameter value. For example, to display instances from vserver1, specify -filter "vserver_name=vserver1".

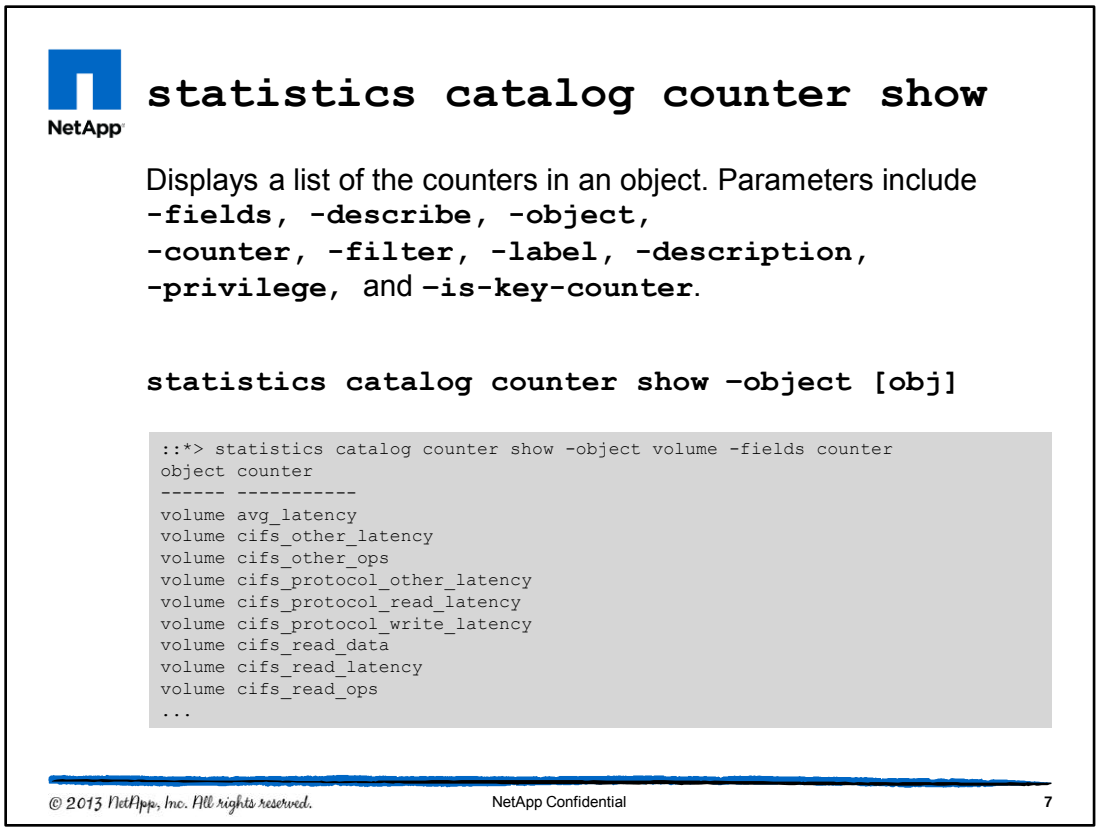
-vserver <vserver name>, ...

Selects the instances that match the parameter value. If you do not specify this parameter, the command displays all of the vserver instances in the cluster.

-node {<nodename>|local}, ...

Selects the instances that match the parameter value. If you do not specify this parameter, the command displays all node instances in the cluster.

NOTE: In discussion, the term “Vserver” has been replaced by the term “SVM.” However, this lesson uses “Vserver,” because the command syntax uses “vserver.”



STATISTICS CATALOG COUNTER SHOW

This command displays the names and descriptions of counters. The displayed data is either node-specific or cluster-wide, depending on the objects specified.

Parameters:

-fields <fieldname>, ...

Displays the specified field or fields. You can use '-fields ?' to display a list of fields and then choose one or more fields from the list.

-describe

Displays d information about each counter, including privilege level, label, and whether the counter is a key counter.

-object <text>

Selects the object for which you want to display the list of counters. This parameter is required. To view a list of valid object names, type “statistics catalog counter show -object ?” or “statistics catalog object show.”

-counter <text>

Selects the counters that match the parameter value. If you do not specify this parameter, the command displays information about all counters.

-filter <text>

Selects the counters that match the parameter value. For example, to display counters from node1, specify -filter "node_name=node1".

-label <text>, ...

Selects the counters that match the parameter value. A label is the name of the bucket to which an array counter belongs.

-description <text>

Selects the counters that match the parameter value.

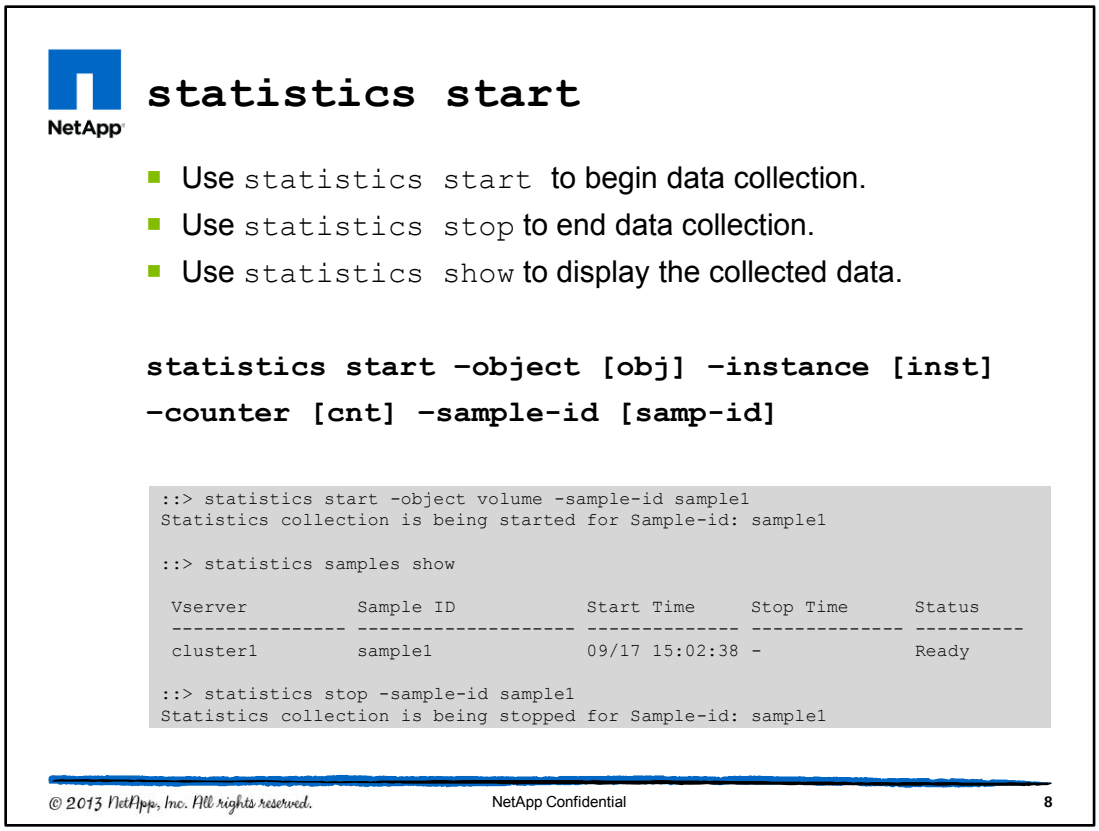
-privilege <text>

(privilege: advanced)

Selects the counters that match the parameter value.

-is-key-counter {true|false}

Selects the counters that are key counters (true) or are not key counters (false). A key counter uniquely identifies an instance across the cluster. The default setting is false. For example, "vserver_name" and "node_name" are key counters because they identify the Vserver or node to which the instance belongs.



STATISTICS START

You can collect more than one data sample at a time.

Parameters:

-object <text>

Selects the objects for which you want to collect data. This parameter is required. To display a list of valid object names, type “statistics catalog object show” at the command prompt. To avoid negatively impacting system performance, select no more than a few objects.

-instance <text>

Selects the instances for which you want to collect data. If you do not specify this parameter, the command collects statistics for all of the instances that are associated with the specified objects.

-counter <text>

Selects the counters for which you want to collect data. If you do not specify this parameter, the command collects statistics for all of the counters in the specified objects.

-sample-id <text>

Specifies an identifier for the data sample. Identifiers must be unique and are restricted to the characters 0-9, a-z, A-Z, and "_". If you do not specify this parameter, the command generates a sample identifier and defines the sample as the default sample for the CLI session. Then, if you run the statistics show command and do not specify the -sample-id parameter, the data from the default sample is displayed. If you run the statistics start command more than once during a CLI session and do not specify the -sample-id parameter on the subsequent runs, the sample that was displayed by the previous run is overwritten. When you close a session, the default sample is not deleted.

-vserver <vserver name>

Selects the vserver for which you want to collect data. If you do not specify this parameter, the command collects statistics for all of the Vservers in the cluster.

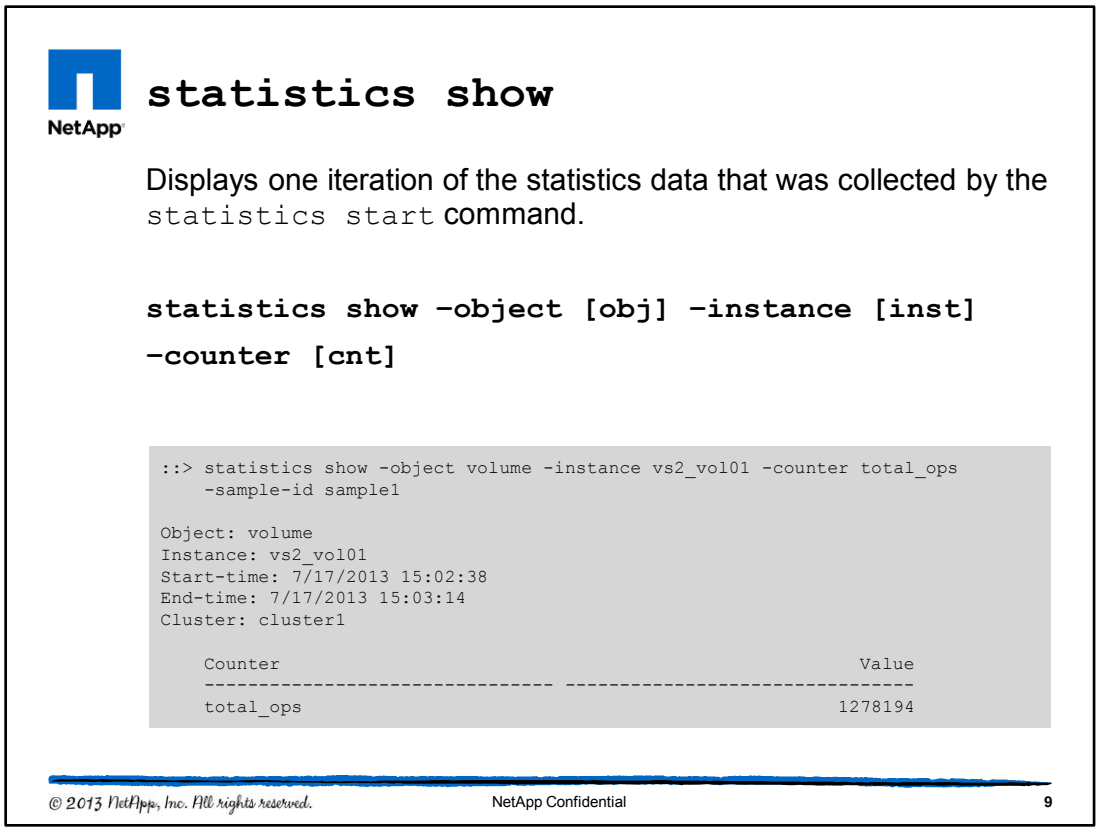
-node {<nodename>|local}

Selects the node for which you want to collect data. If you do not specify this parameter, the command collects statistics for all of the nodes in the cluster.

-filter <text>

(privilege: advanced)

Selects data for the instance that matches the specified filter criteria. For example, to display the instances from node1, specify -filter "node_name=node1".



STATISTICS SHOW

This command displays performance data for a particular period of time. The data is calculated based on the samples that the cluster collects. You use the statistics start and statistics stop commands to collect your data sample. You use the -sample-id parameter to display the sample data.

Parameters:

-fields <fieldname>, ...

Displays data for the specified field or fields. You can use '-fields ?' to display a list of fields and then choose one or more fields from the list

-object <text>

Selects the objects for which you want to display data. To view a list of valid object names, type “statistics show -object ?” or “statistics catalog object show.” To avoid significantly impacting performance, specify no more than a few objects.

-instance <text>

Selects the instances for which you want to display data. If you do not specify this parameter, the command displays statistics for all of the instances that are associated with the specified objects. For example, if you want to display disk-object statistics, you can use this parameter to specify the name of the disk whose statistics you want to view. If you do not specify this parameter, the command displays statistics for all of the disks in the system.

-counter <text>

Selects the counters for which you want to display data.

-node {<nodename>|local}

Selects the nodes for which you want to display data.

-vserver <vserver name>

Selects the Vserver for which you want to display data.

-value <Counter64>

(privilege: advanced)

Selects the data that matches the specified counter value.

-labels <text>, ...

(privilege: advanced)

Selects the data that matches the specified label.

-values <text>, ...

(privilege: advanced)

Displays only the statistics that have the specified values.

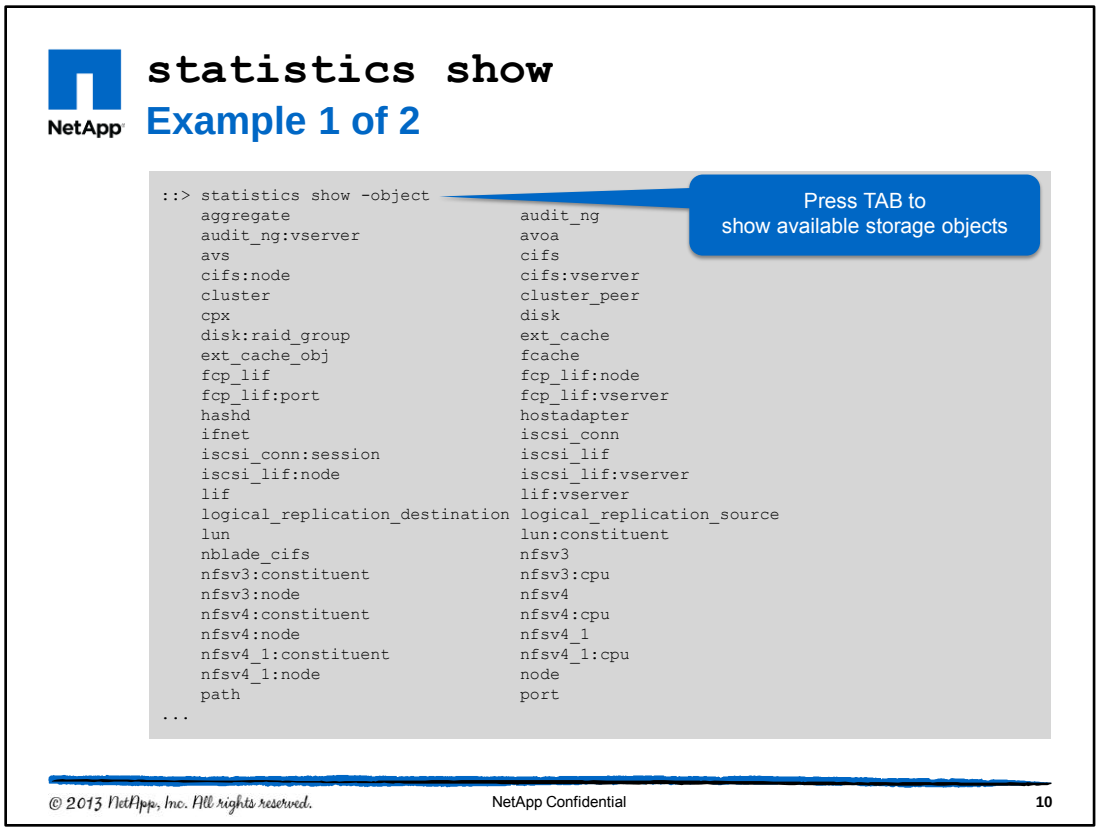
-filter <text>

(privilege: advanced)

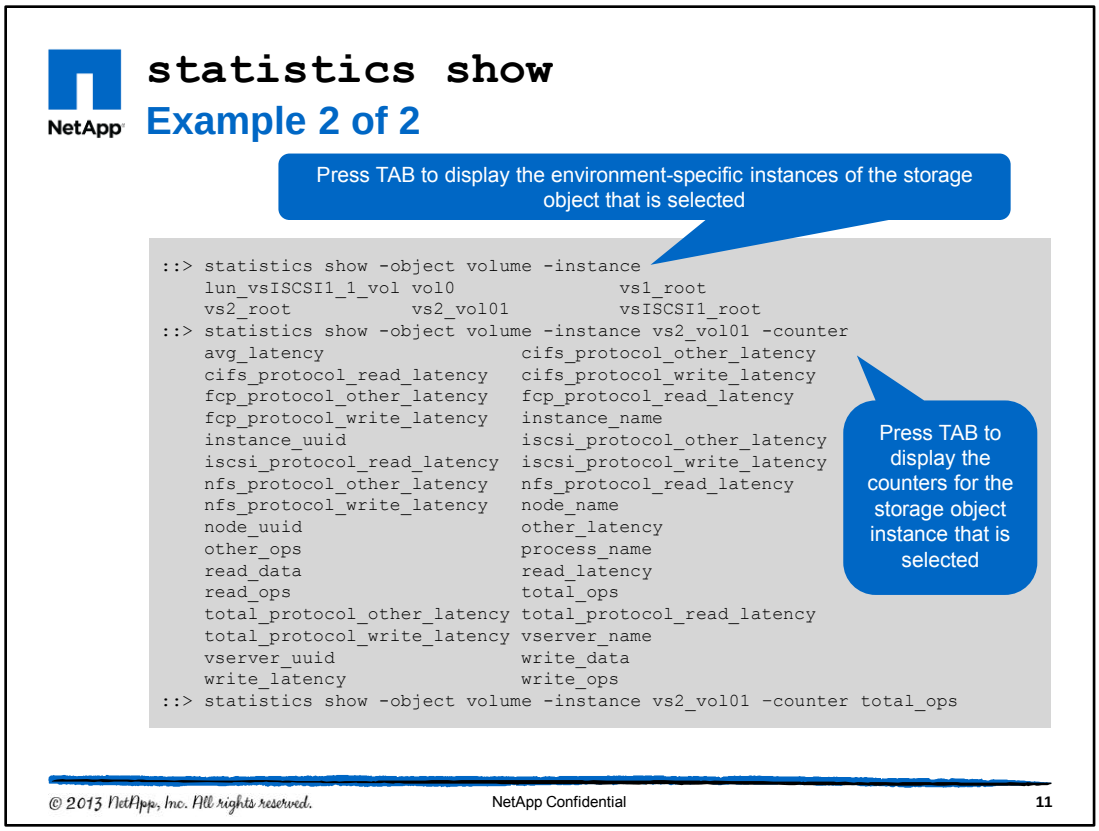
Selects the data for the instance that matches the specified filter criteria. For example, to display the instances for which the total-ops counter is greater than 50, specify -filter "total_ops>50".

-sample-id <text>

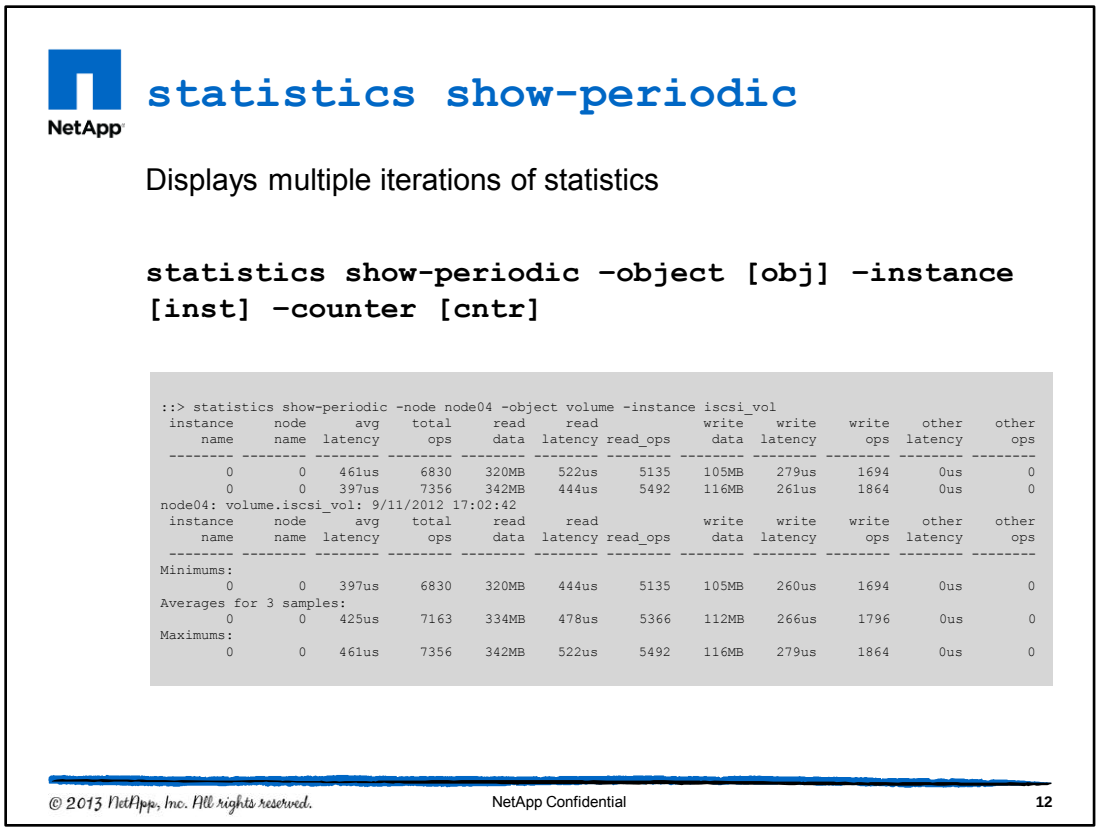
Displays data for the specified sample.



STATISTICS SHOW: EXAMPLE 1 OF 2

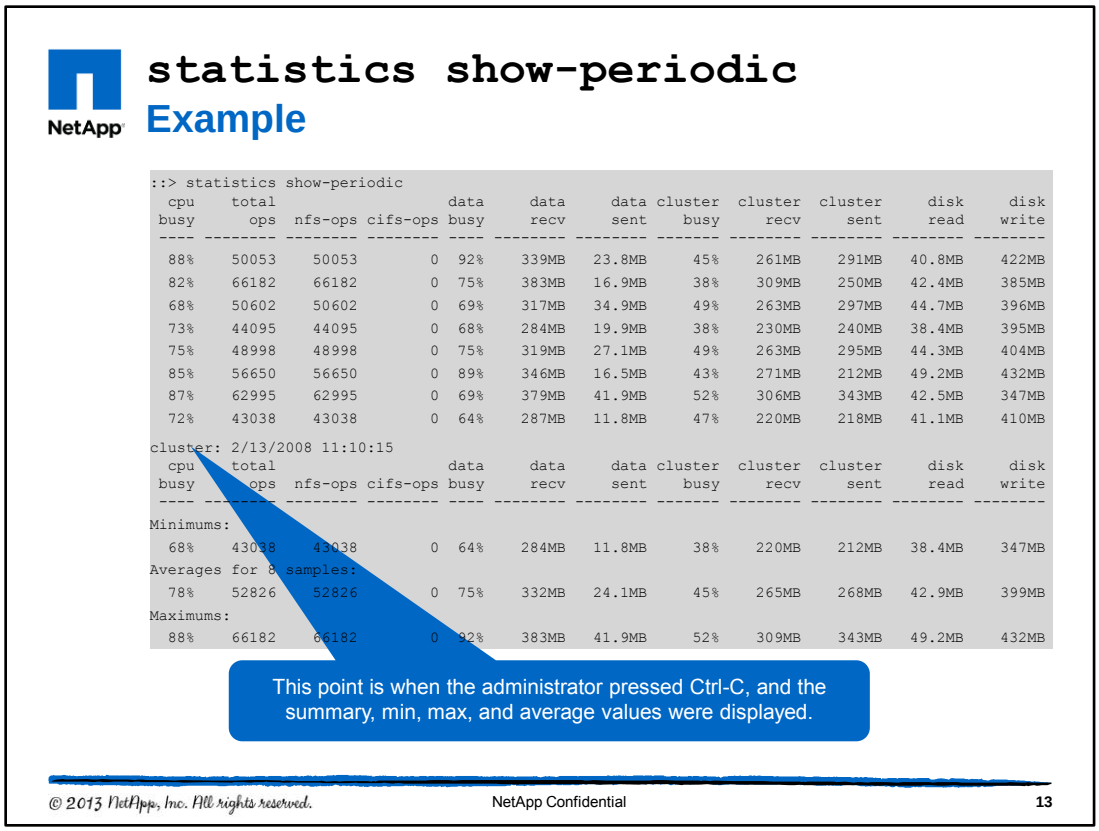


STATISTICS SHOW: EXAMPLE 2 OF 2



STATISTICS SHOW-PERIODIC

The `statistics show-periodic` command uses the same parameters as the `statistics show` command.



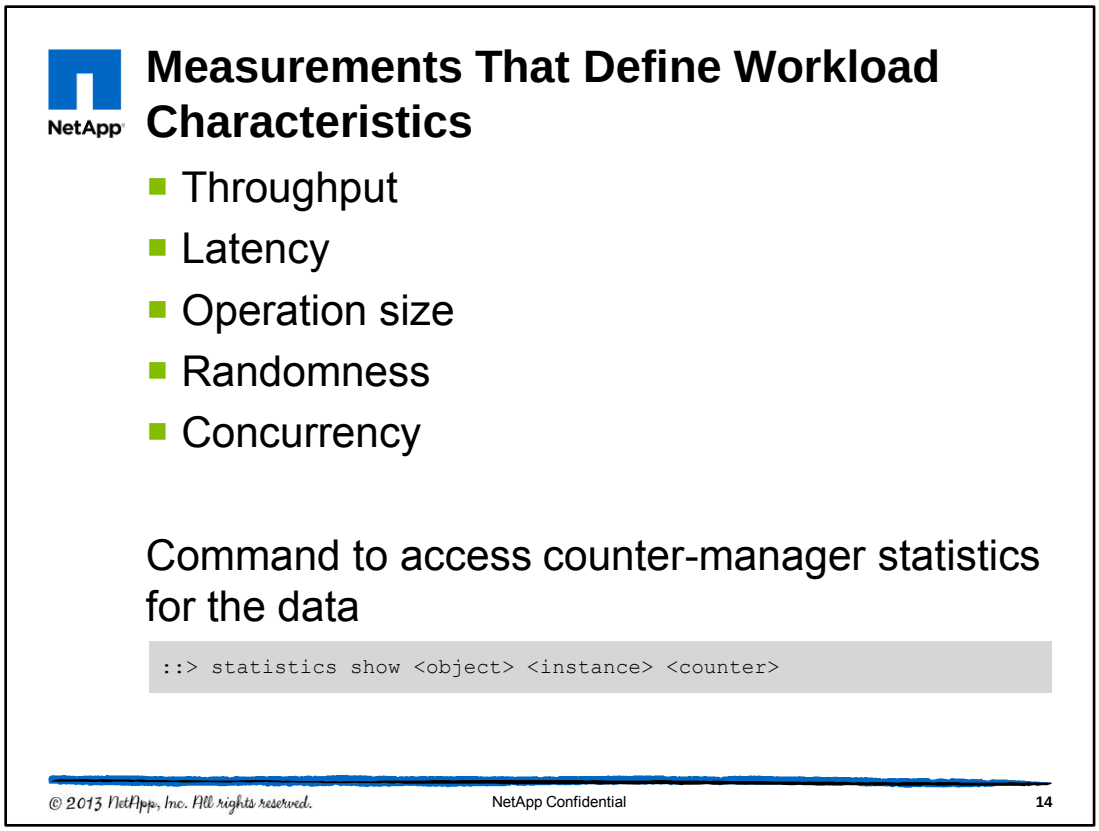
STATISTICS SHOW-PERIODIC: EXAMPLE

The `statistics show-periodic` command runs until Ctrl-C is pressed, with each line of output reporting the stats since the previous line of output (interval). The default interval is one second. When Ctrl-C is pressed, some summary data is presented.

This output can tell you much. If the “cluster busy” values are nonzero, it’s a good indication that the user data isn’t sent over the cluster links. The same is true if “cluster recv” and “cluster sent” values are in the KB range. Therefore, if operations occur with no data sent over the cluster network, the output shows that data is served locally, which is similar to when many reads are performed to LS mirror copies that are on the same nodes as the data logical interfaces (LIFs) that are accessed by the clients. When cluster traffic occurs, the “cluster recv” and “cluster sent” values are in the MB range.

Other good options to use with this command are:

- `statistics periodic –object latency –node node`
- `statistics periodic –object volume –node node –interval 1`
- `statistics show –node node –object volume –counter *latency` (This wildcard shows all the latency counters.)



MEASUREMENTS THAT DEFINE WORKLOAD CHARACTERISTICS

Workload Characteristics
Throughput

Throughput (operations per second)

- NFS example

```
::> statistics show -object nfsv3 -instance * -counter nfsv3_read_ops
    -sample-id sample_nfsv3
::> statistics show -object nfsv3 -instance * -counter nfsv3_write_ops
    -sample-id sample_nfsv3
```

- CIFS example

```
::> statistics show -object cifs -instance * -counter cifs_read_ops
    -sample-id sample_cifs
::> statistics show -object cifs -instance * -counter cifs_write_ops
    -sample-id sample_cifs
```


WORKLOAD CHARACTERISTICS: THROUGHPUT

Workload Characteristics
Latency

Latency (time in milliseconds)

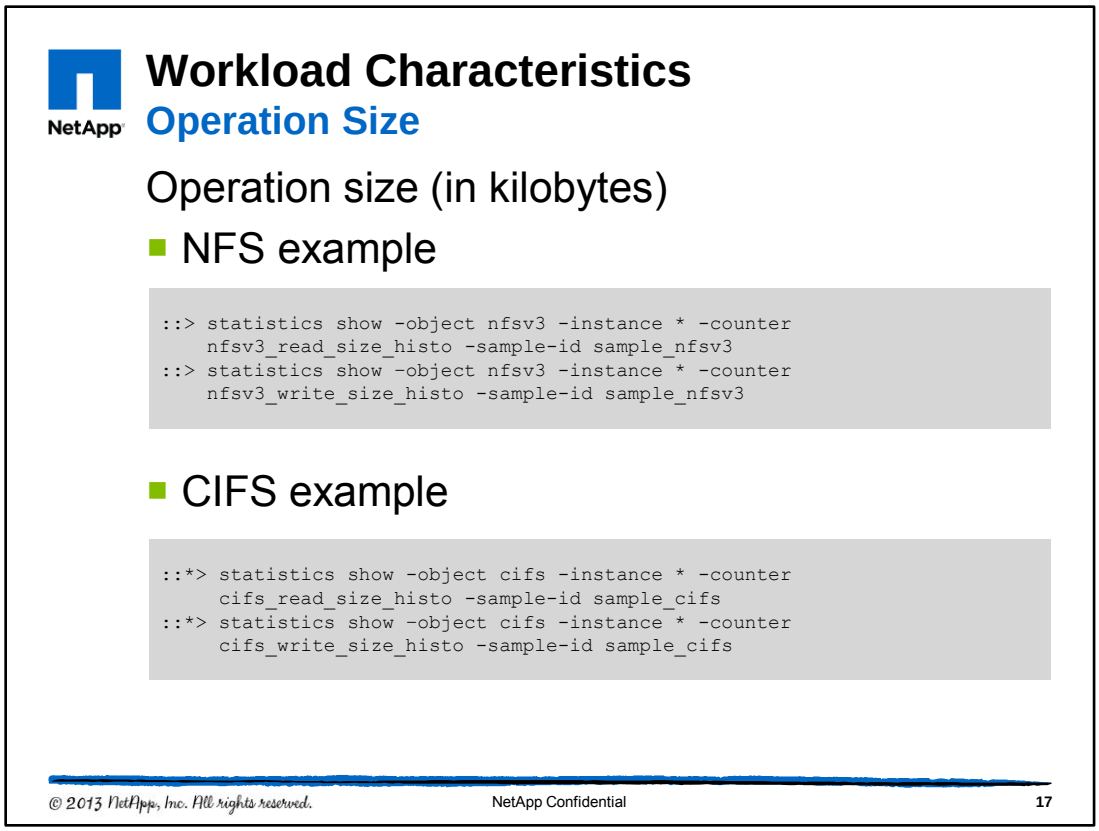
- NFS example

```
::> statistics show -object volume -instance * -counter nfs_read_latency
    -sample-id sample_nfsv3
::> statistics show -object volume -instance * -counter nfs_write_latency
    -sample-id sample_nfsv3
```

- CIFS example

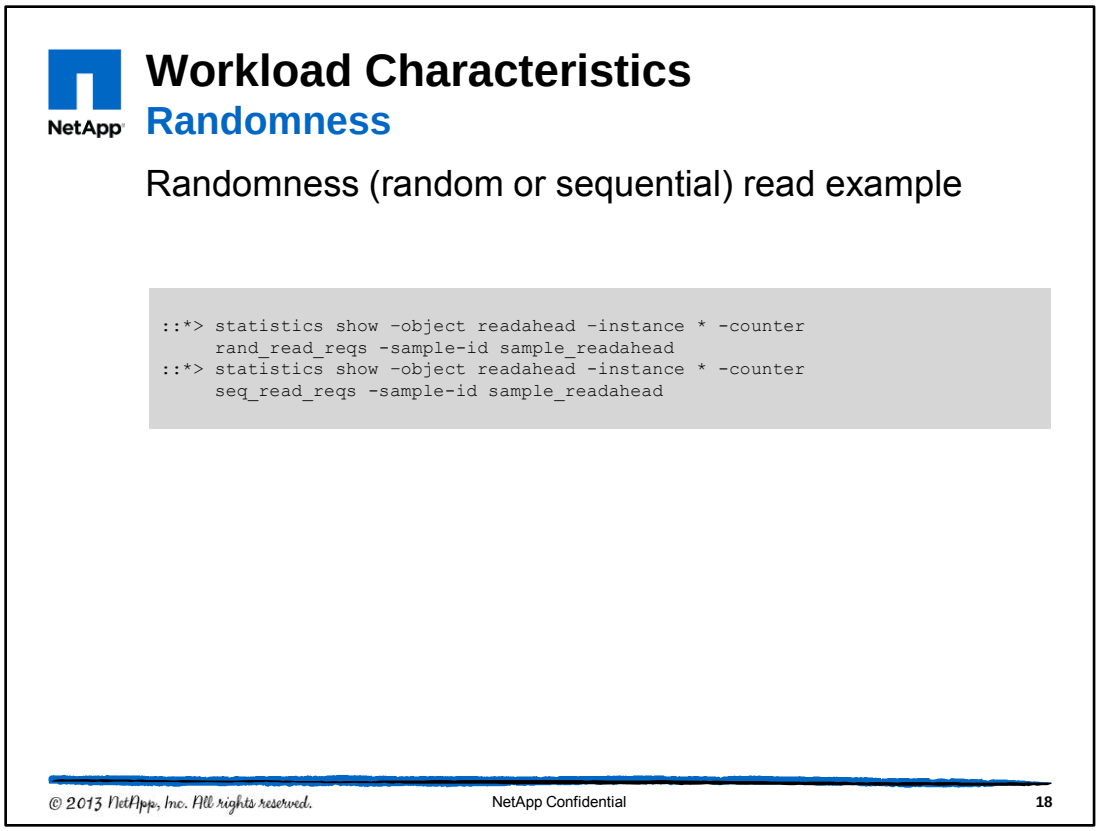
```
::> statistics show -object volume -instance * -counter cifs_read_latency
    -sample-id sample_cifs
::> statistics show -object volume -instance * -counter cifs_write_latency
    -sample-id sample_cifs
```


WORKLOAD CHARACTERISTICS: LATENCY



WORKLOAD CHARACTERISTICS: OPERATION SIZE

cifs_read_size_histo and cifs_write_size_histo are diagnostic privilege level counters and will only display if the sample was collected while in the diagnostic privilege level.



WORKLOAD CHARACTERISTICS: RANDOMNESS

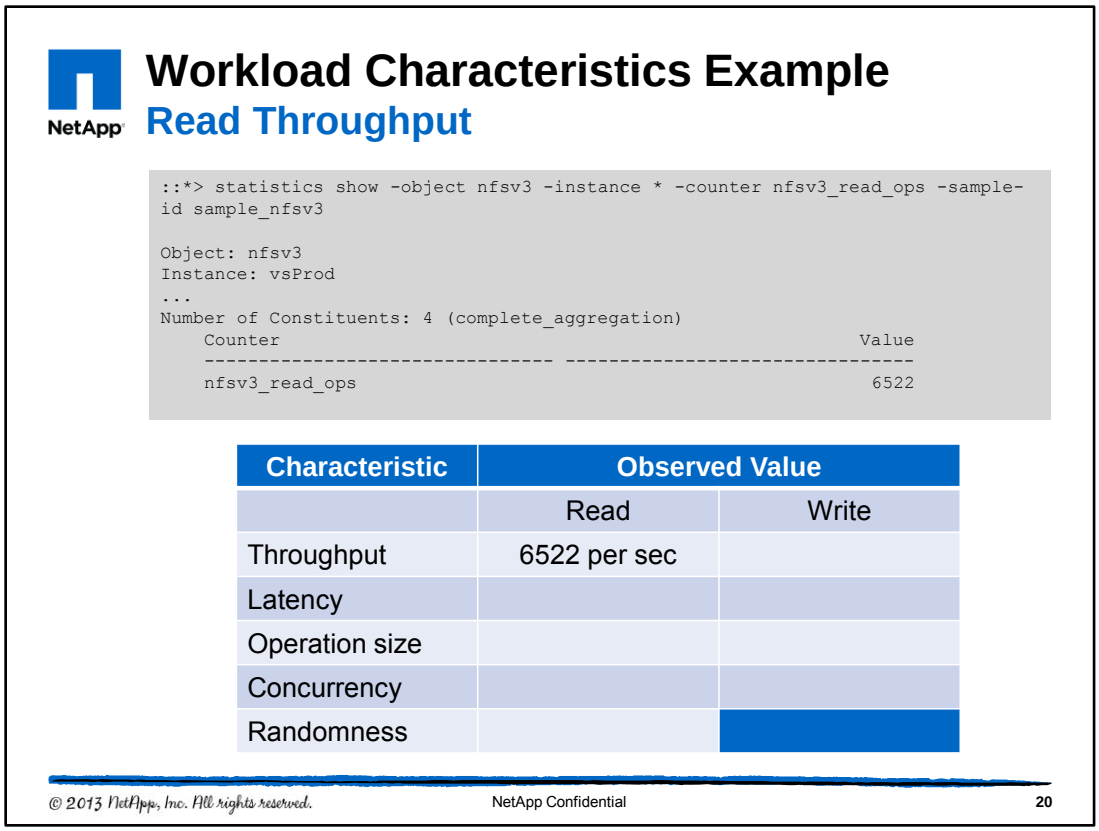
rand_read_reqs and seq_read_reqs are diagnostic privilege level counters and will only display if the sample was collected while in the diagnostic privilege level.

Workload Characteristics
Concurrency

Not a specific counter but can be calculated by using the formula throughput x latency:

- Uses the numbers from the throughput and latency counters
- Produces a value that identifies the number of operations that occur within the latency window
  - Think of the axiom: the larger the number, the “better” the result
  - Consider the result in relation to operation size.

WORKLOAD CHARACTERISTICS: CONCURRENCY



WORKLOAD CHARACTERISTICS EXAMPLE: READ THROUGHPUT

This example shows the process of determining the workload characteristics of a storage system:

- Read throughput
- Write throughput
- Read latency
- Write latency
- Read operation size
- Write operation size
- Read and write concurrency
- Random read
- Sequential read

Workload Characteristics Example
Write Throughput

```
::*> statistics show -object nfsv3 -instance * -counter nfsv3_write_ops -sample-
id sample_nfsv3

Object: nfsv3
Instance: vsProd
...
Number of Constituents: 4 (complete_aggregation)
    Counter                                                     Value
    -------------------------------- --------------------------------
    nfsv3_write_ops                                               721
```

Characteristic	Observed Value	
	Read	Write
Throughput	6522 per sec	721 per sec
Latency		
Operation size		
Concurrency		
Randomness		

WORKLOAD CHARACTERISTICS EXAMPLE: WRITE THROUGHPUT

Workload Characteristics Example
Read Latency

```
::*> statistics show -object volume -instance * -counter nfs_read_latency -
sample-id sample_nfsv3

Object: volume
Instance: vsProd_vol09
...
    Counter                                                     Value
    -------------------------------- --------------------------------
    nfs_read_latency                                       2882.40us
```

Characteristic	Observed Value	
	Read	Write
Throughput	6522 per sec	721 per sec
Latency	2.88 ms	
Operation size		
Concurrency		
Randomness		

WORKLOAD CHARACTERISTICS EXAMPLE: READ LATENCY

Workload Characteristics Example

Write Latency

```
::*> statistics show -object volume -instance * -counter nfs_write_latency -
sample-id sample_nfsv3

Object: volume
Instance: vsProd_vol09
...
    Counter                                                     Value
    -------------------------------- --------------------------------
    nfs_write_latency                                      1352.58us
```

Characteristic	Observed Value	
	Read	Write
Throughput	6522 per sec	721 per sec
Latency	2.88 ms	1.35 ms
Operation size		
Concurrency		
Randomness		

WORKLOAD CHARACTERISTICS EXAMPLE: WRITE LATENCY

Workload Characteristics Example

Read Operation Size

```
::*> statistics show -object nfsv3 -instance * -counter nfsv3_read_size_histo -
sample-id sample_nfsv3

Object: nfsv3
Instance: vsProd
...
    Counter                                                     Value
    -------------------------------- ----------------------------------
    nfsv3_read_size_histo                                           -
...
                                <=4KB                           356789
```

Characteristic	Observed Value	
	Read	Write
Throughput	6522 per sec	721 per sec
Latency	2.88 ms	1.35 ms
Operation size	4K	
Concurrency		
Randomness		

WORKLOAD CHARACTERISTICS EXAMPLE: READ OPERATION SIZE

Workload Characteristics Example

Write Operation Size

```
::*> statistics show -object nfsv3 -instance * -counter nfsv3_write_size_histo -
sample-id sample_nfsv3

Object: nfsv3
Instance: vsProd
...
    Counter                                                     Value
    -------------------------------- ----------------------------------
    nfsv3_write_size_histo                                             -
...
                                <=4KB                             12345
```

Characteristic	Observed Value	
	Read	Write
Throughput	6522 per sec	721 per sec
Latency	2.88 ms	1.35 ms
Operation size	4K	4K
Concurrency		
Randomness		

WORKLOAD CHARACTERISTICS EXAMPLE: WRITE OPERATION SIZE

Workload Characteristics Example

Read and Write Concurrency

Concurrency = Throughput x Latency

```
Read:  6522 per sec * 0.00288 (2.88 ms) = 18.8
Write:  721 per sec * 0.00135 (1.35 ms) = 0.97
```

Characteristic	Observed Value	
	Read	Write
Throughput	6522 per sec	721 per sec
Latency	2.88 ms	1.35 ms
Operation size	4K	4K
Concurrency	18.8	0.97
Randomness		

WORKLOAD CHARACTERISTICS EXAMPLE: READ AND WRITE CONCURRENCY

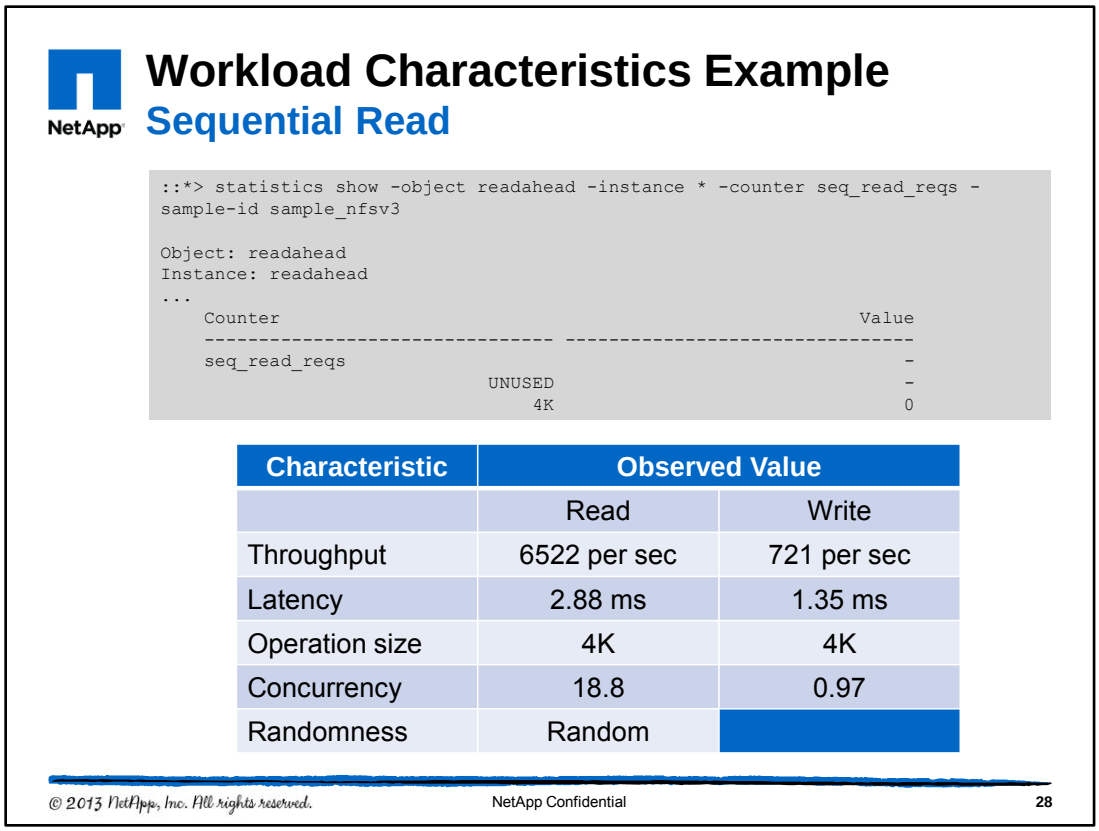
Workload Characteristics Example
Random Read

```
::*> statistics show -object readahead -instance * -counter rand_read_reqs -
sample-id sample_nfsv3

Object: readahead
Instance: readahead
...
    Counter                                                     Value
    -------------------------------- --------------------------------
    rand_read_reqs                                                 -
                                UNUSED                             -
                                    4K                            99
```

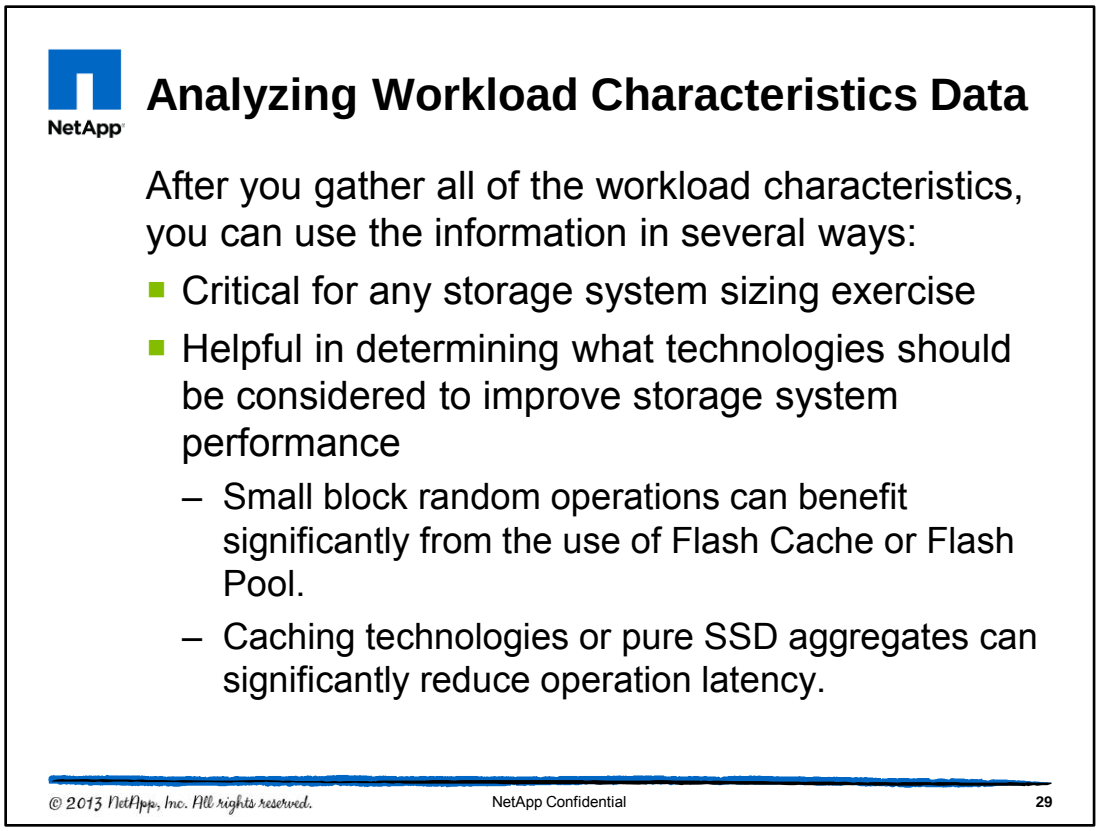
Characteristic	Observed Value	
	Read	Write
Throughput	6522 per sec	721 per sec
Latency	2.88 ms	1.35 ms
Operation size	4K	4K
Concurrency	18.8	0.97
Randomness	Random	

WORKLOAD CHARACTERISTICS EXAMPLE: RANDOM READ



WORKLOAD CHARACTERISTICS EXAMPLE: SEQUENTIAL READ

The characteristics of the example workload can be defined as many more reads than writes, small operations, some concurrency, and random reads.



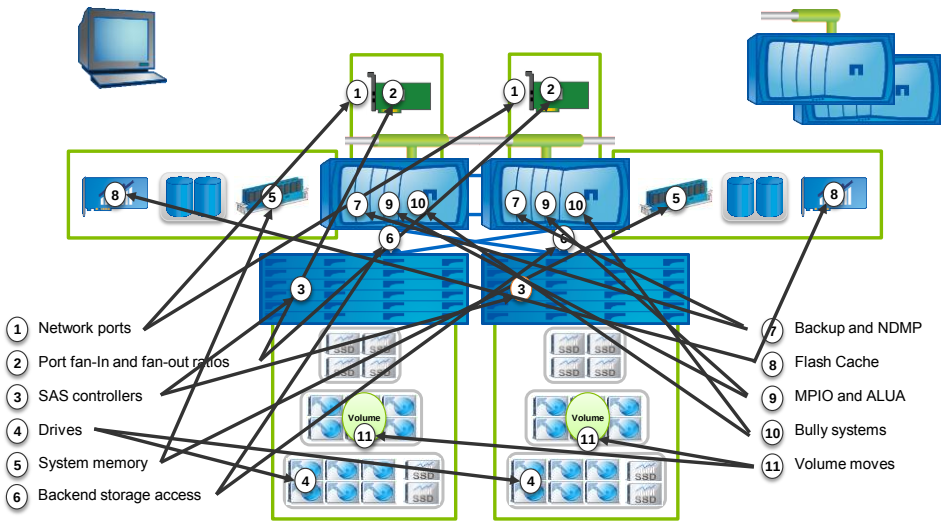
ANALYZING WORKLOAD CHARACTERISTICS DATA

Lesson 2

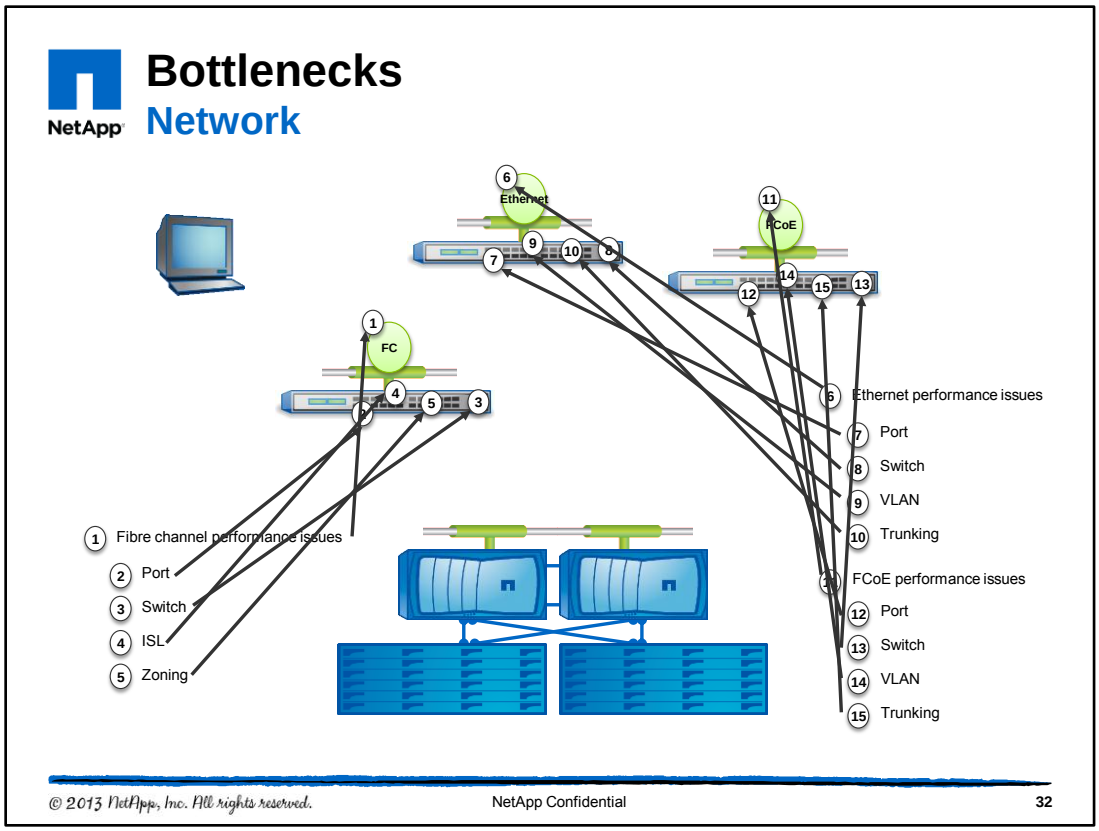
Identifying Storage System Bottlenecks

LESSON 2: IDENTIFYING STORAGE SYSTEM BOTTLENECKS

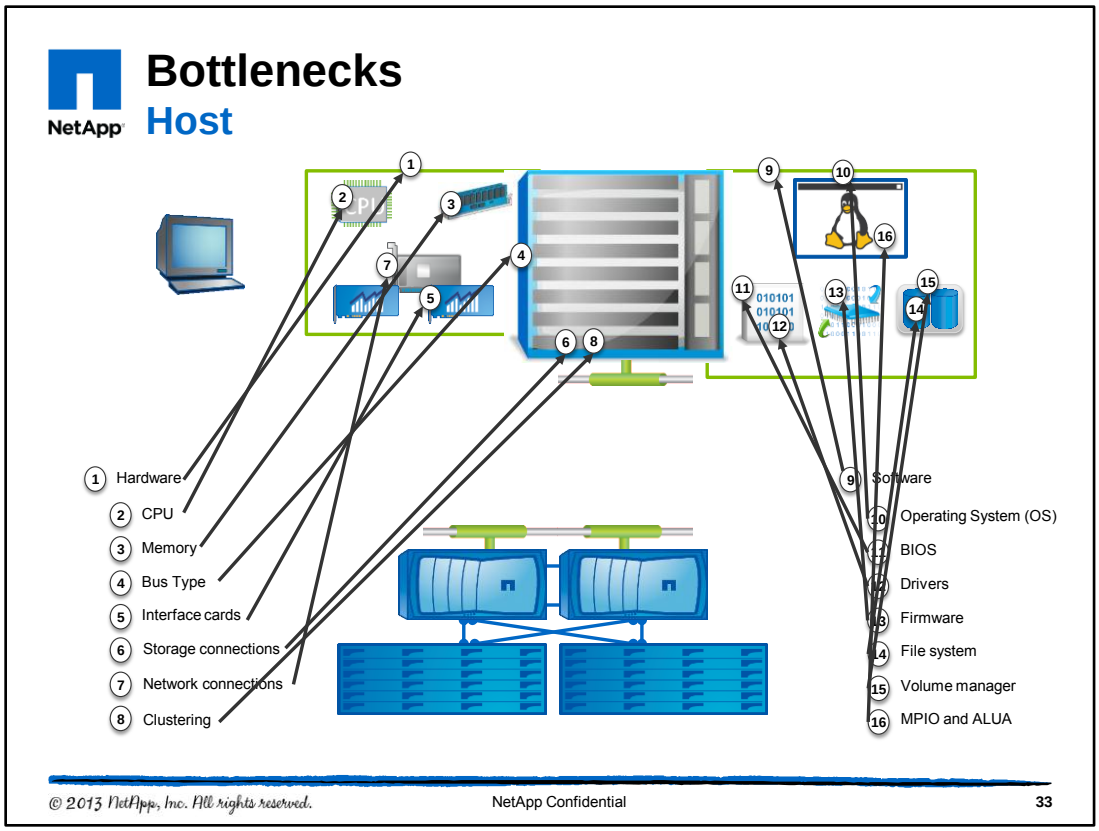
Bottlenecks
Storage System



BOTTLENECKS: STORAGE SYSTEM

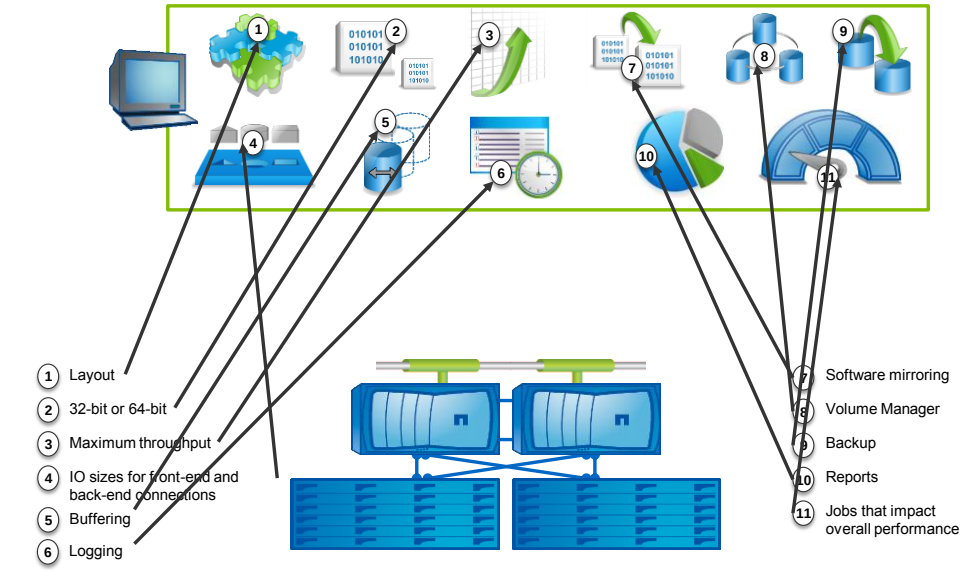


BOTTLENECKS: NETWORK



BOTTLENECKS: HOST

Bottlenecks
Application



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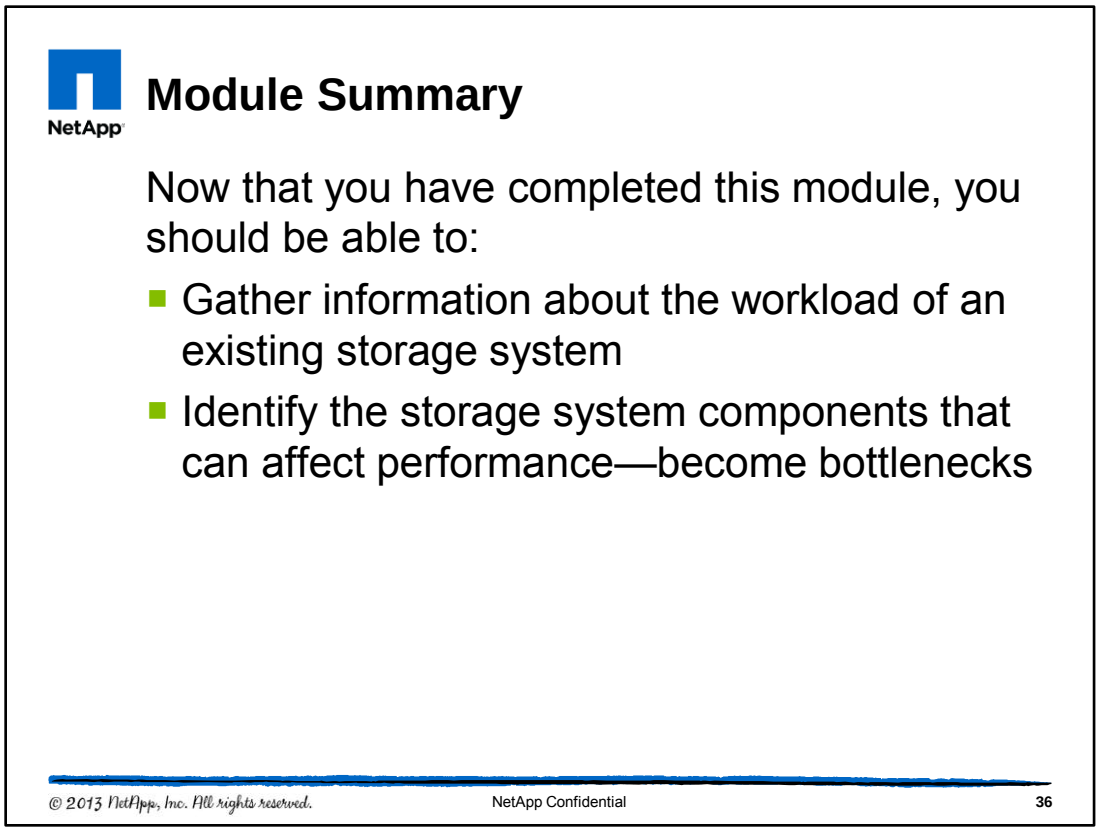
BOTTLENECKS: APPLICATION

Storage System Bottlenecks
Summary

- Storage system
  - Network ports
  - Memory and Flash Cache
  - SAS controllers
  - Drives (type, size, speed, number)
  - MPIO and ALUA
  - Port fan-In and fan-out ratios
  - Bully systems
  - Backend storage access
  - Volume moves
  - Backup and NDMP
- Network
  - FC performance issues (port, switch, ISL, zoning)
  - Ethernet performance issues (port, switch, VLAN, trunking)
  - FCoE performance issues (port, switch, ISL, zoning)
- Host
  - Hardware (CPU, memory, bus type, interface cards, storage connections, network connections, clustering)
  - Software (OS, BIOS, drivers, firmware, file system, volume manager, MPIO and ALUA)
- Applications
  - Layout
  - 32-bit or 64-bit
  - Maximum throughput
  - IO sizes for front-end and back-end connections
  - Buffering
  - Logging
  - Software mirroring
  - Volume Manager
  - Backup
  - Reports
  - Jobs that impact overall performance

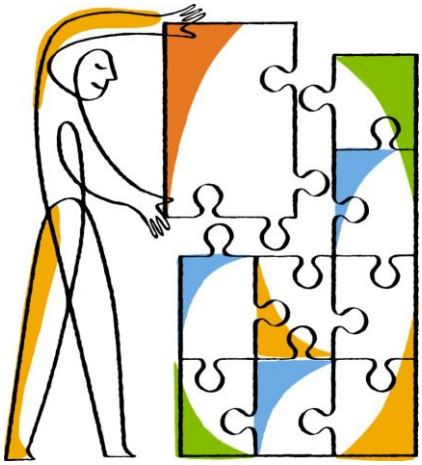
STORAGE SYSTEM BOTTLENECKS: SUMMARY



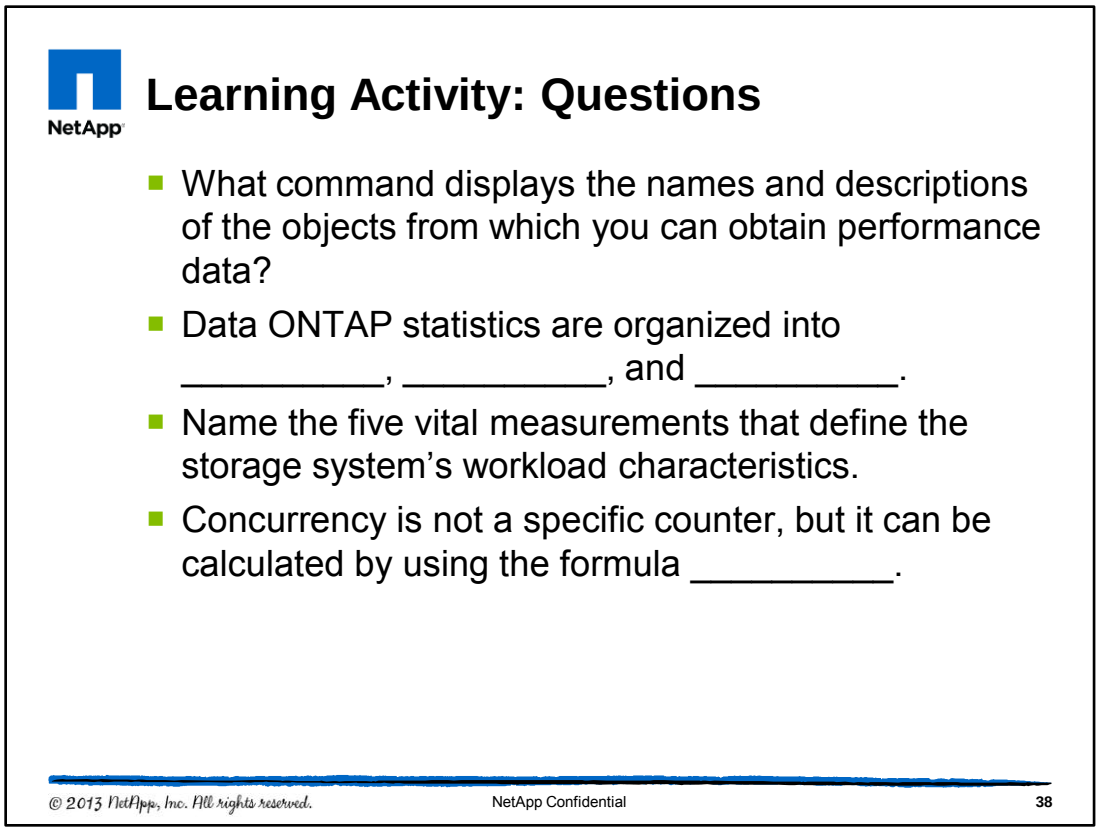
MODULE SUMMARY

Learning Activity Questions

Module 3: Clustered Storage System Workloads and Bottlenecks



LEARNING ACTIVITY QUESTIONS

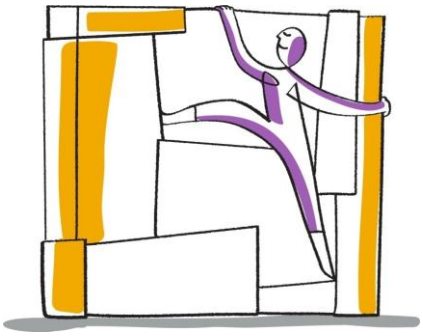


LEARNING ACTIVITY: QUESTIONS

Exercise

Module 3: Clustered Storage System Workloads and Bottlenecks

Time Estimate: 90 Minutes

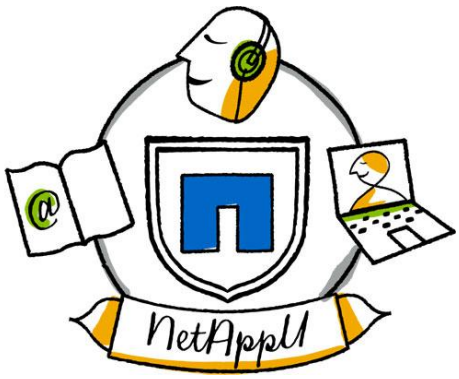


EXERCISE

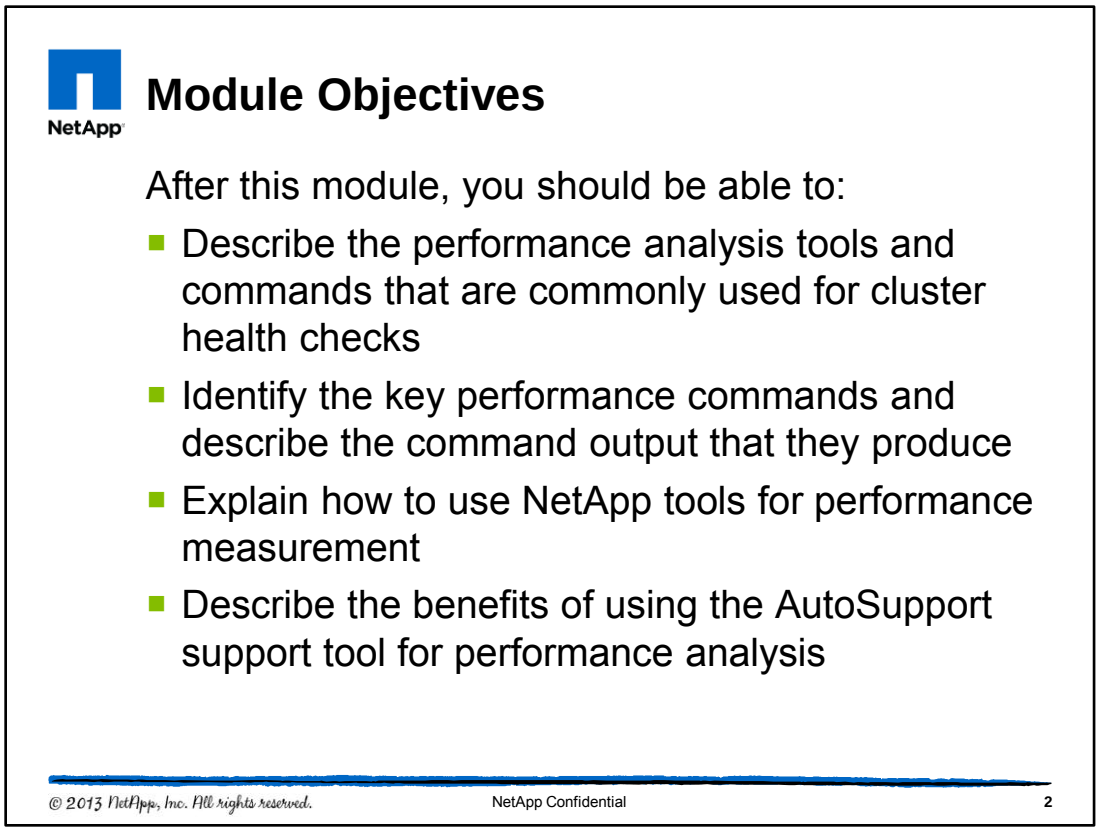
Please refer to your exercise guide.

Module 4

Cluster Performance Monitoring and Analysis



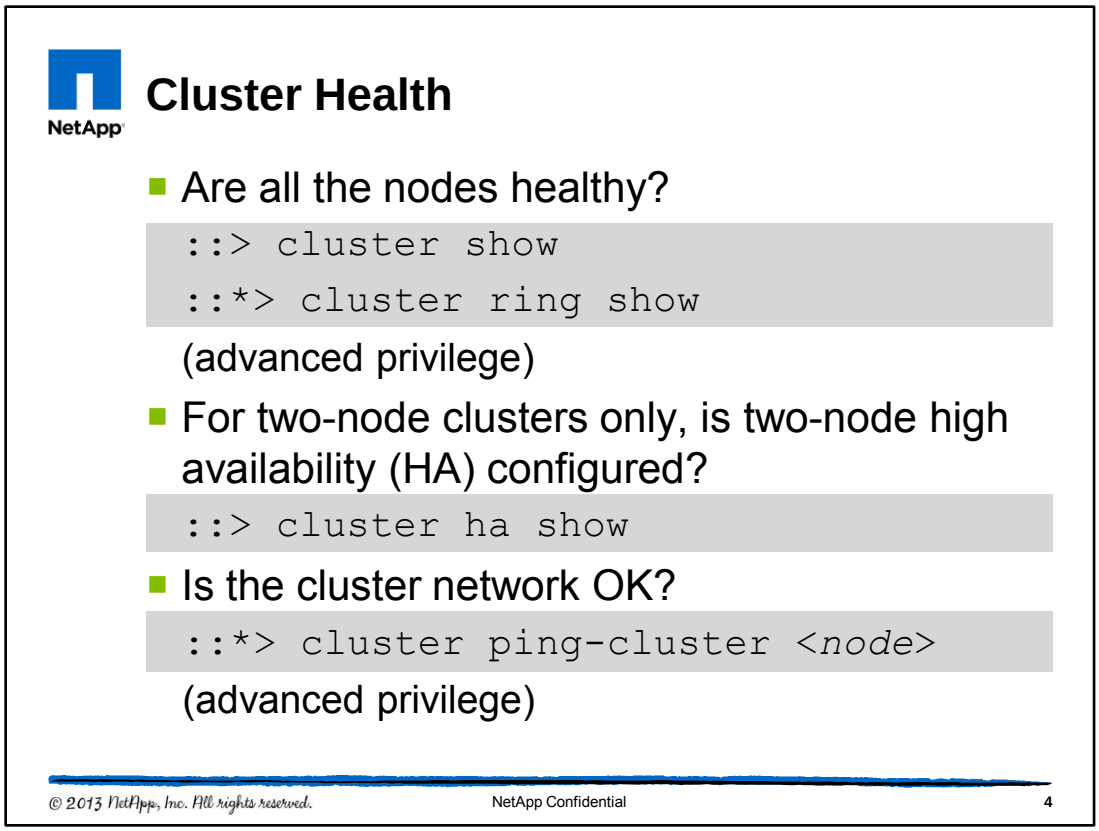
MODULE 4: CLUSTER PERFORMANCE MONITORING AND ANALYSIS



MODULE OBJECTIVES

LESSON 1: HEALTH CHECKS

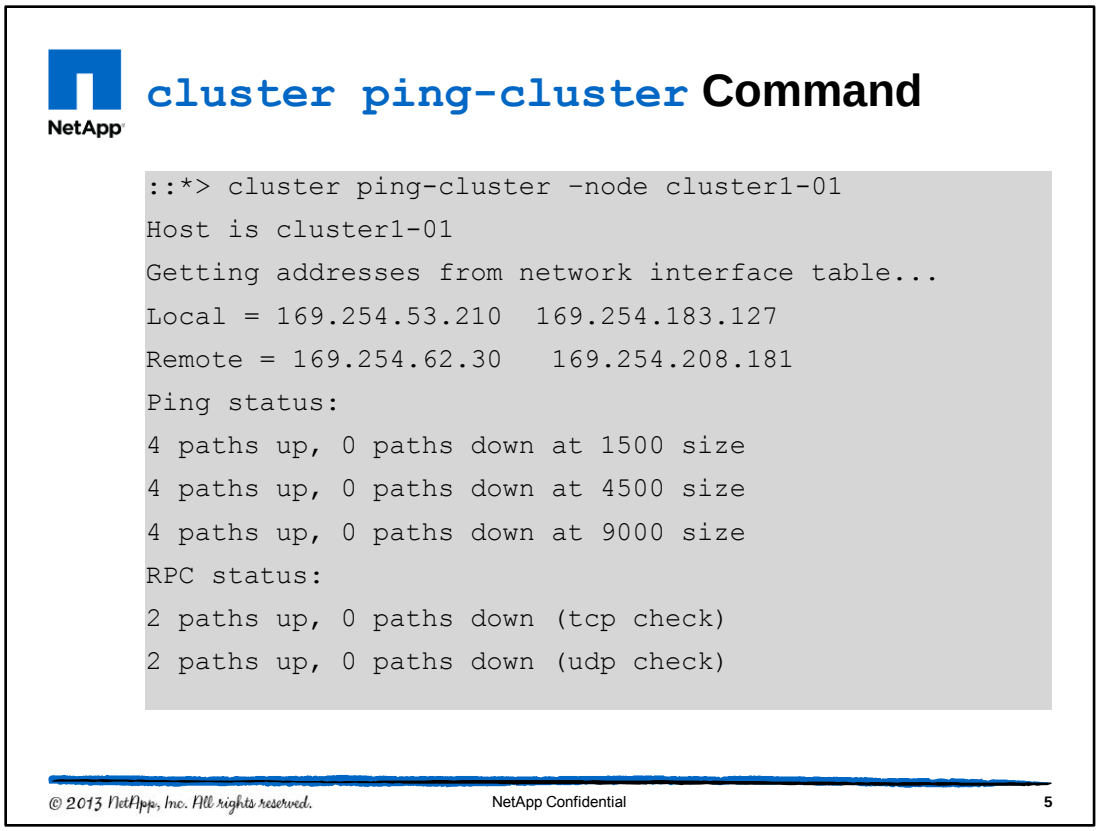
This lesson discusses methods of determining the health of a clustered storage system.



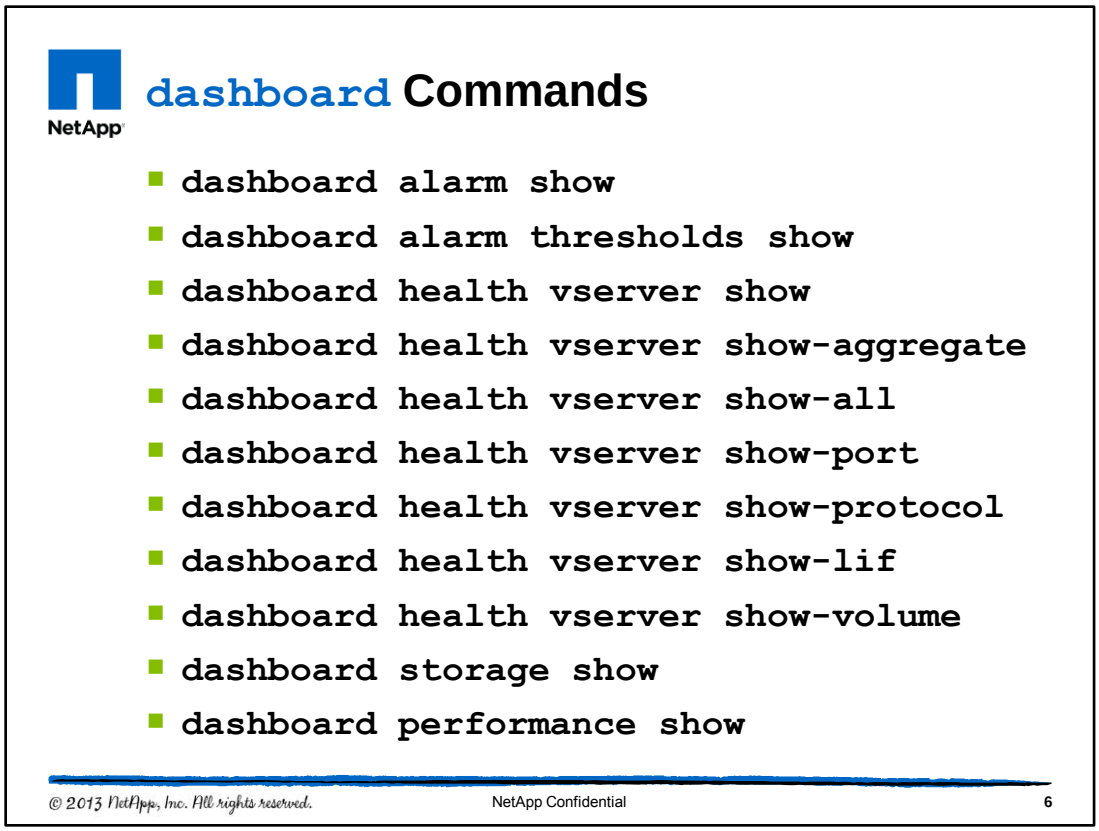
CLUSTER HEALTH

The cluster commands provide a quick check on the health of the cluster. Remember that a two-node cluster must have two-node high availability (HA) enabled. If this step is forgotten, problems arise, especially during storage failover (SFO).

The `cluster ping-cluster` command is a great way to ensure that all the cluster ports and cluster LIFs are working properly.

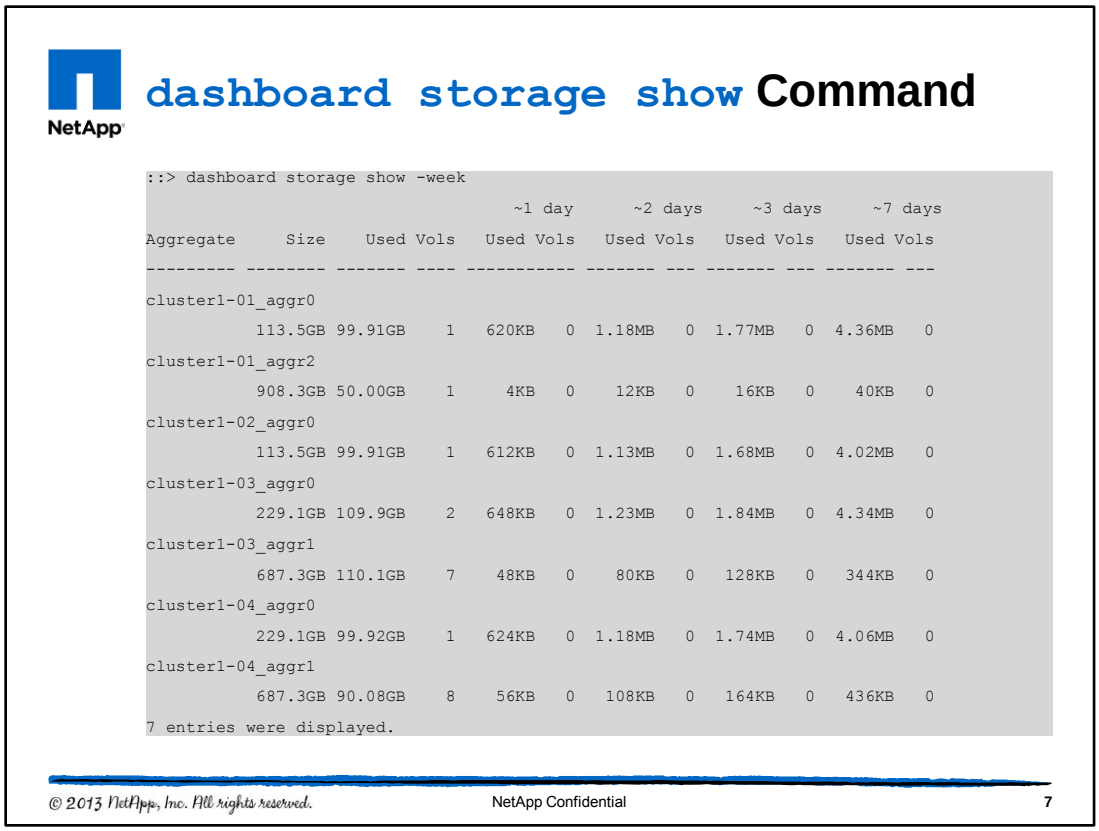


CLUSTER PING-CLUSTER COMMAND



DASHBOARD COMMANDS

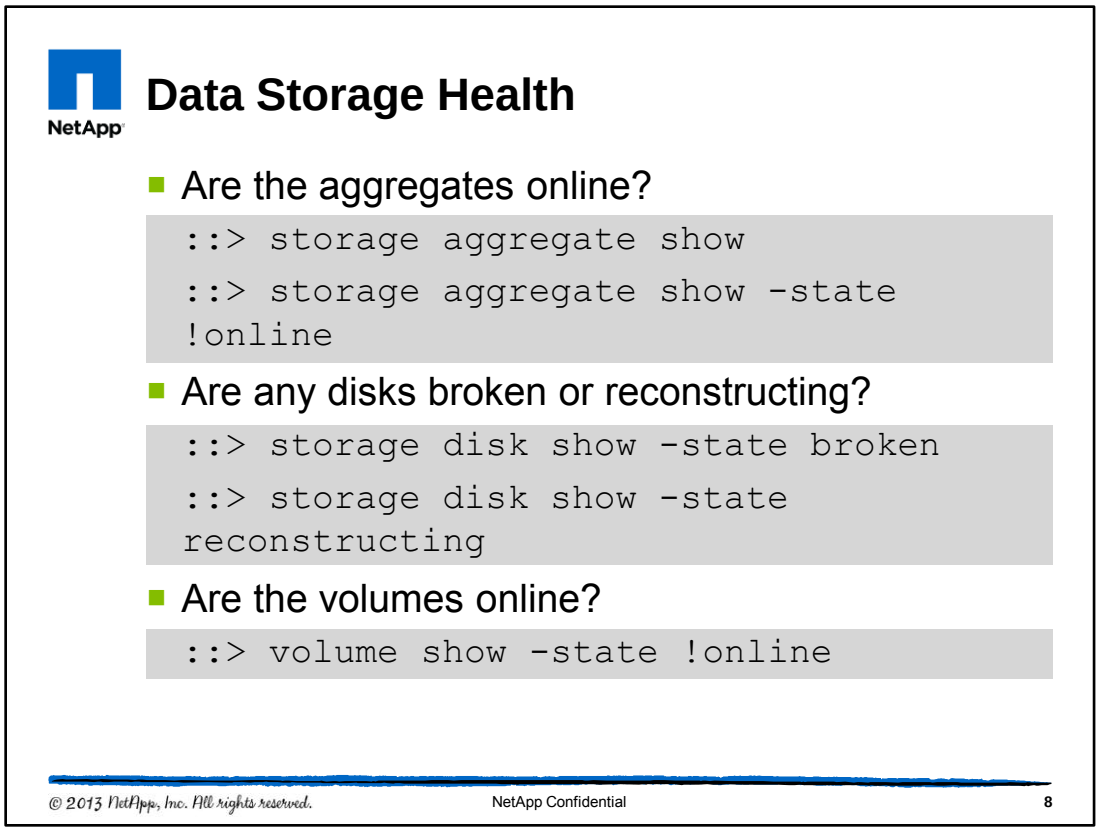
The `dashboard` commands provide quick views of the nodes and the cluster.



DASHBOARD STORAGE SHOW COMMAND

By default, the storage dashboard displays the:

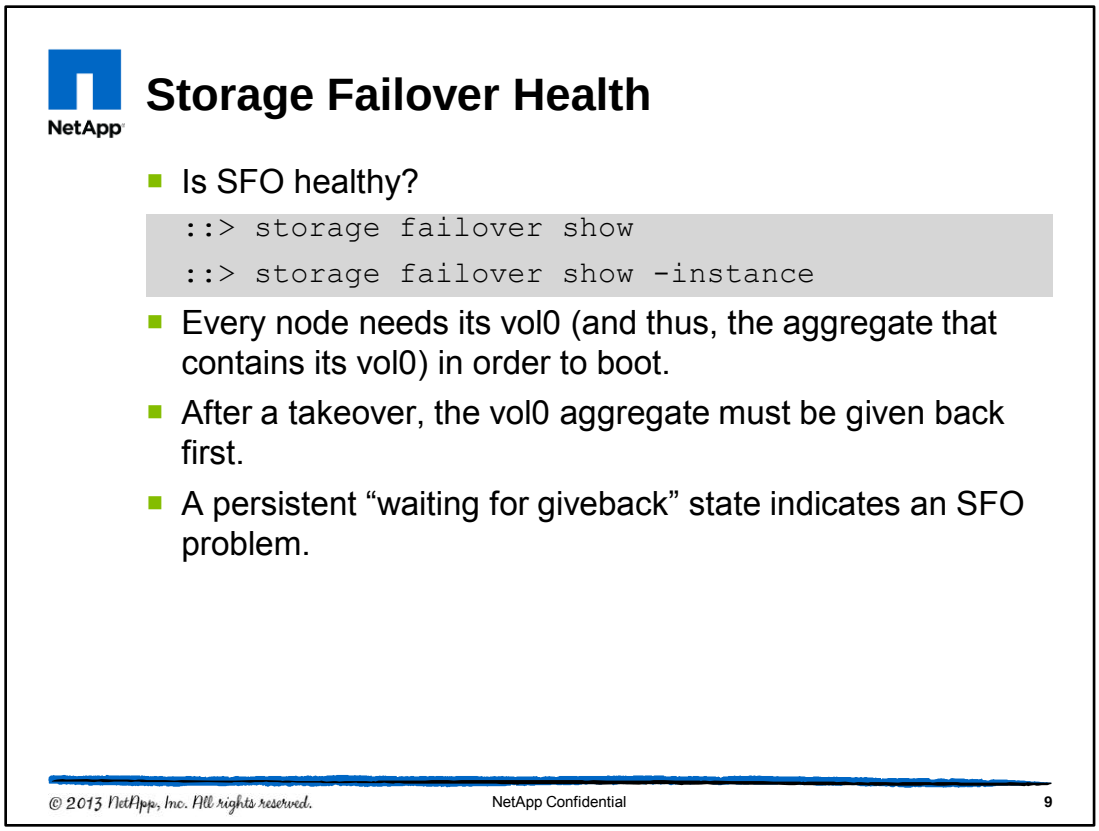
- Aggregate name
- Aggregate size, in GB
- Aggregate available space, in GB
- Aggregate used space, in GB
- Percentage of space that is used
- Number of volumes
- Four-hour change in used size
- Four-hour change in number of volumes
- Eight-hour change in used size
- Eight-hour change in number of volumes
- Operational status



DATA STORAGE HEALTH

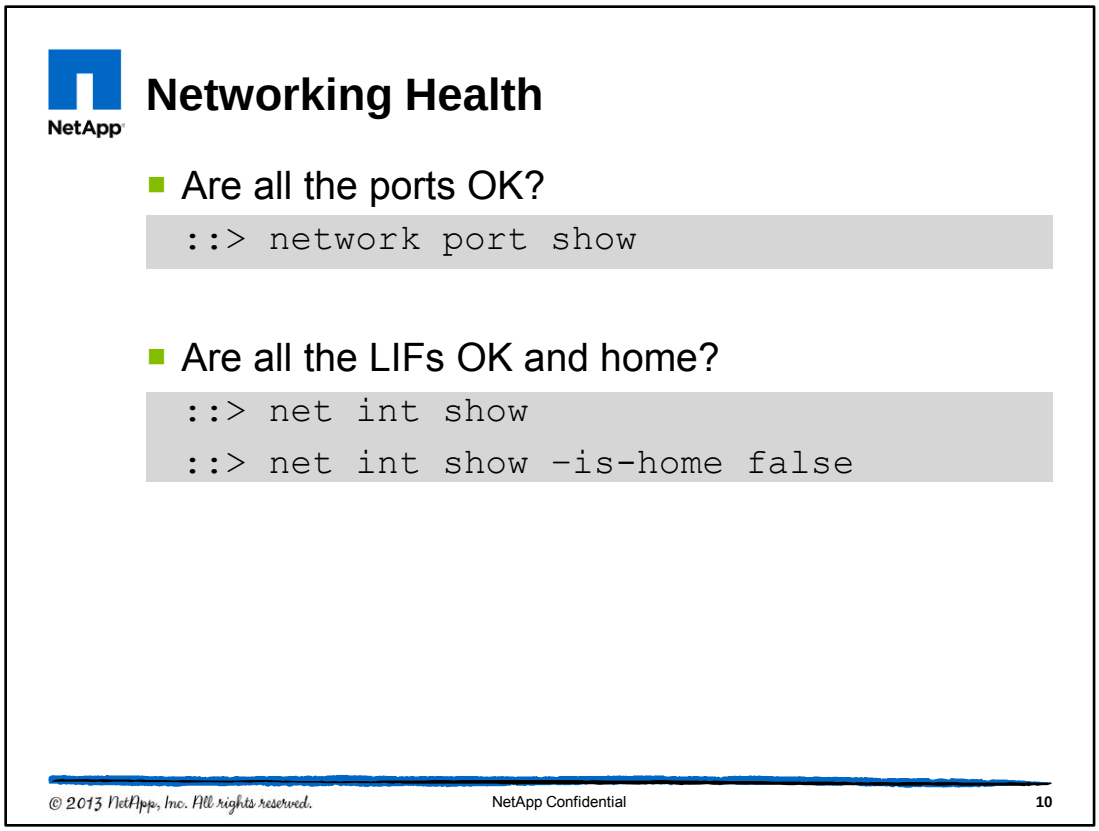
For the most part, the commands on this slide are self-explanatory. Most `show` commands provide a view of what's happening in a particular area of the cluster. Also, most `show` commands have some powerful query capabilities that, if you take the time to learn them, can help you to pinpoint potential problems.

In the `volume show -state !online` command, the exclamation point means "not" (negation). Therefore, this command shows all volumes that do not have a state of "online." Because you'll want to know about other states that exist, it's important to use `!online` rather than `offline`.



STORAGE FAILOVER HEALTH

When the aggregates of one node fail over to the HA partner node, the aggregate that contains the vol0 volume of that node goes, too. Each node needs its vol0 to boot, so when the rebooted node begins to boot, the first thing that happens is that it signals the partner to do a giveback of that one aggregate and then waits for that to happen. If SFO is working properly, giveback happens quickly, the node has its vol0 and can boot, and when it gets far enough in its boot process, the rest of the aggregates are given back. If problems exist, you probably see the rebooted node go into a “waiting for giveback” state. If this happens, it’s possible that its aggregates are stuck in a transition state between the two nodes and might not be owned by either node. If this happens, contact NetApp Global Support.

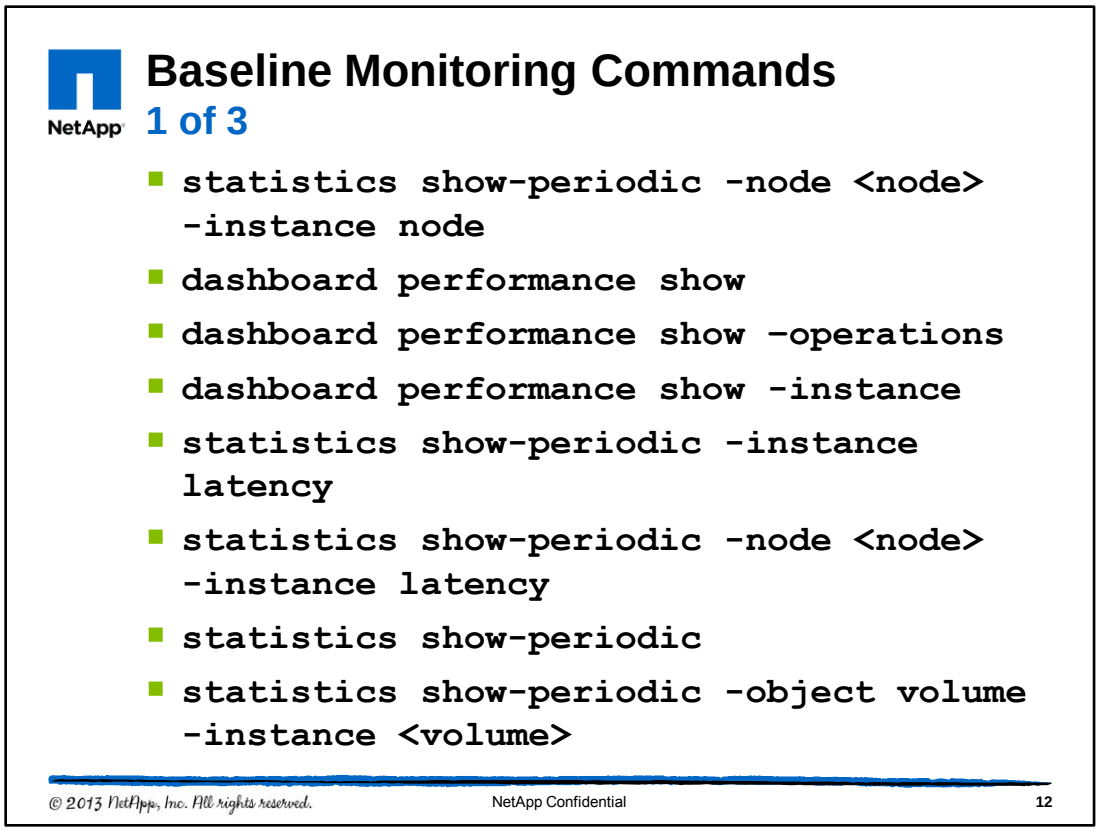


NETWORKING HEALTH

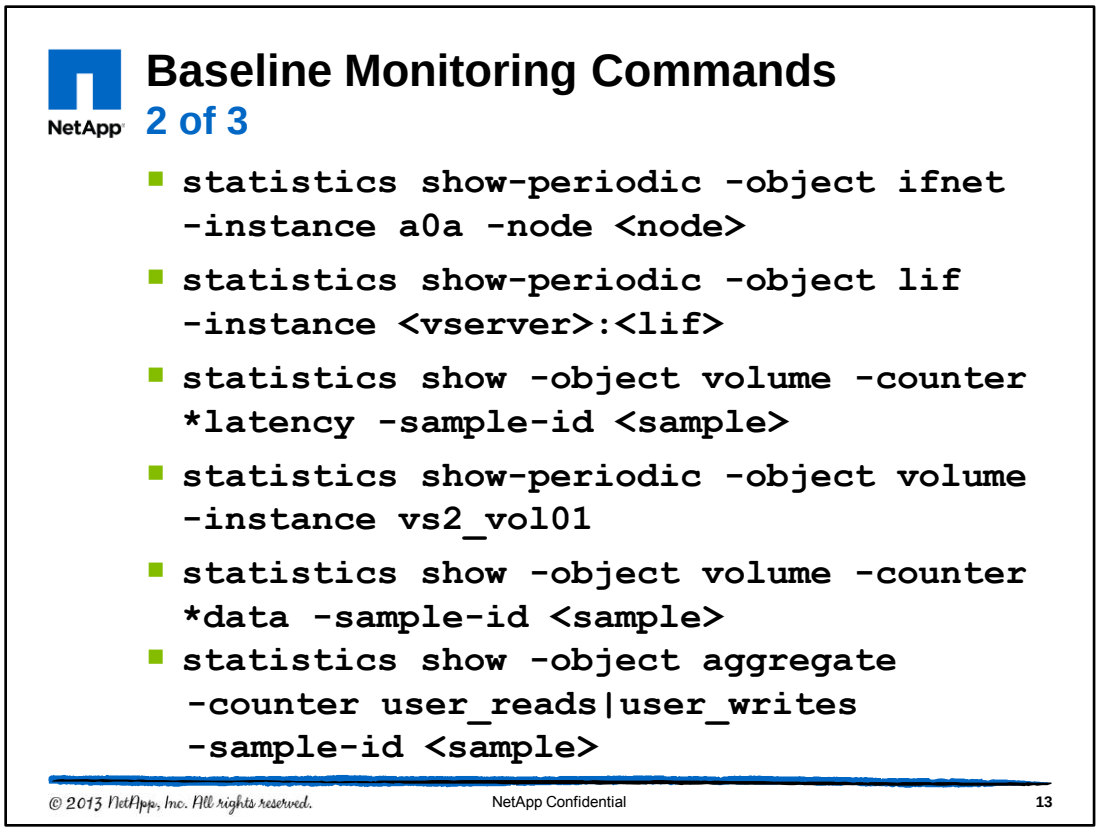
You must verify that all the network ports, including the cluster ports, are OK. If those ports are fine, verify that the LIFs are working properly, and note which ones are home and which ones aren't home. If the LIFs are not home, it doesn't mean that a problem exists, but this condition might give you a sense of what's happening.

LESSON 2: BASELINE PERFORMANCE MONITORING

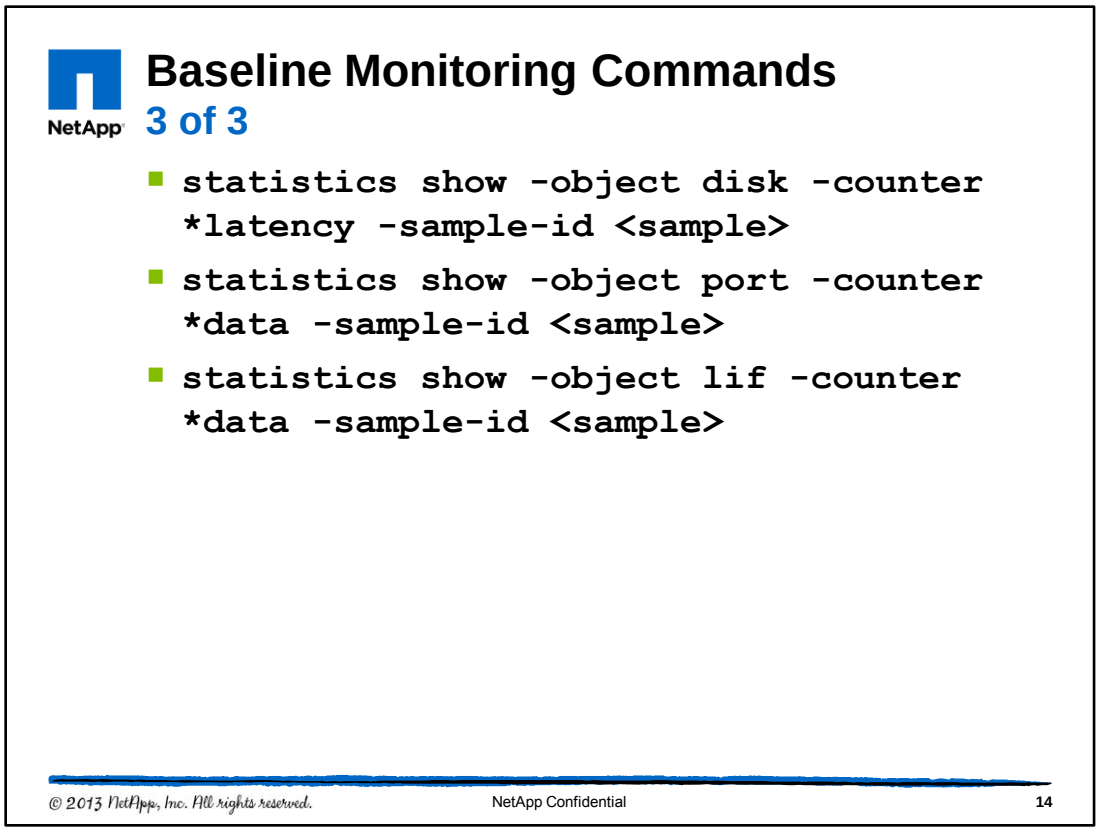
This lesson discusses baseline performance monitoring for any given clustered storage system.



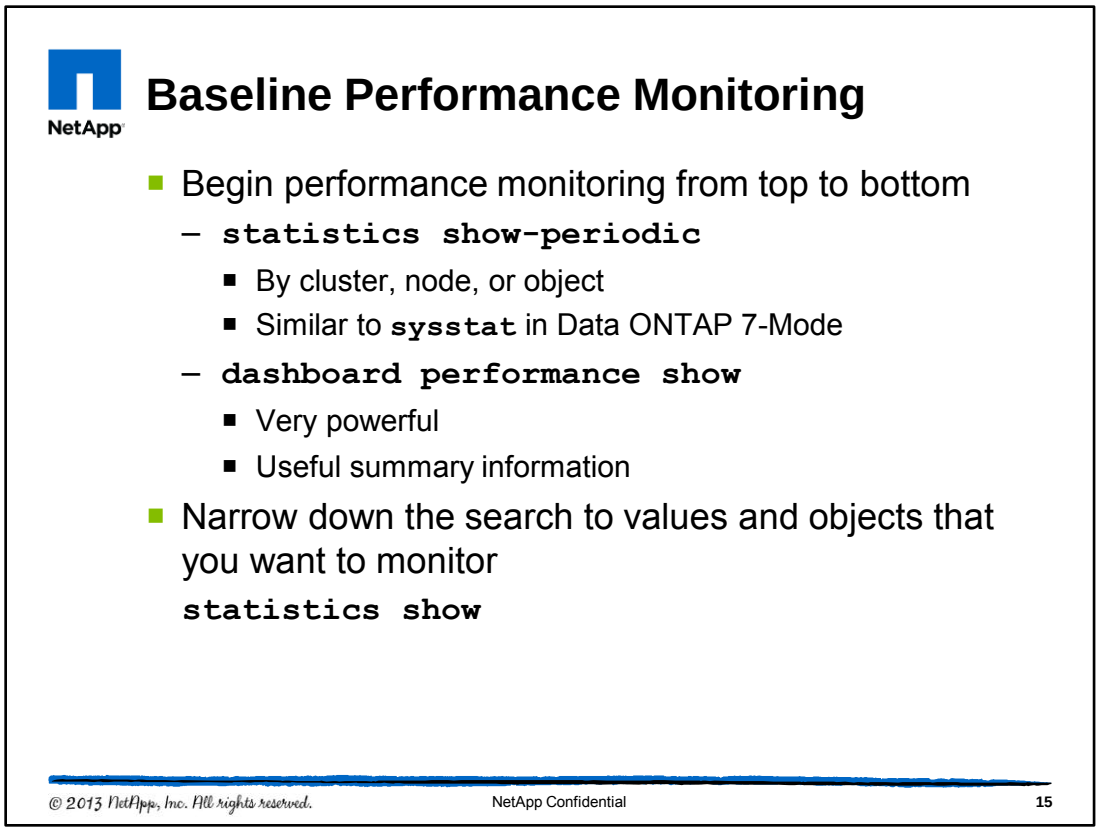
BASELINE MONITORING COMMANDS: 1 OF 3



BASELINE MONITORING COMMANDS: 2 OF 3

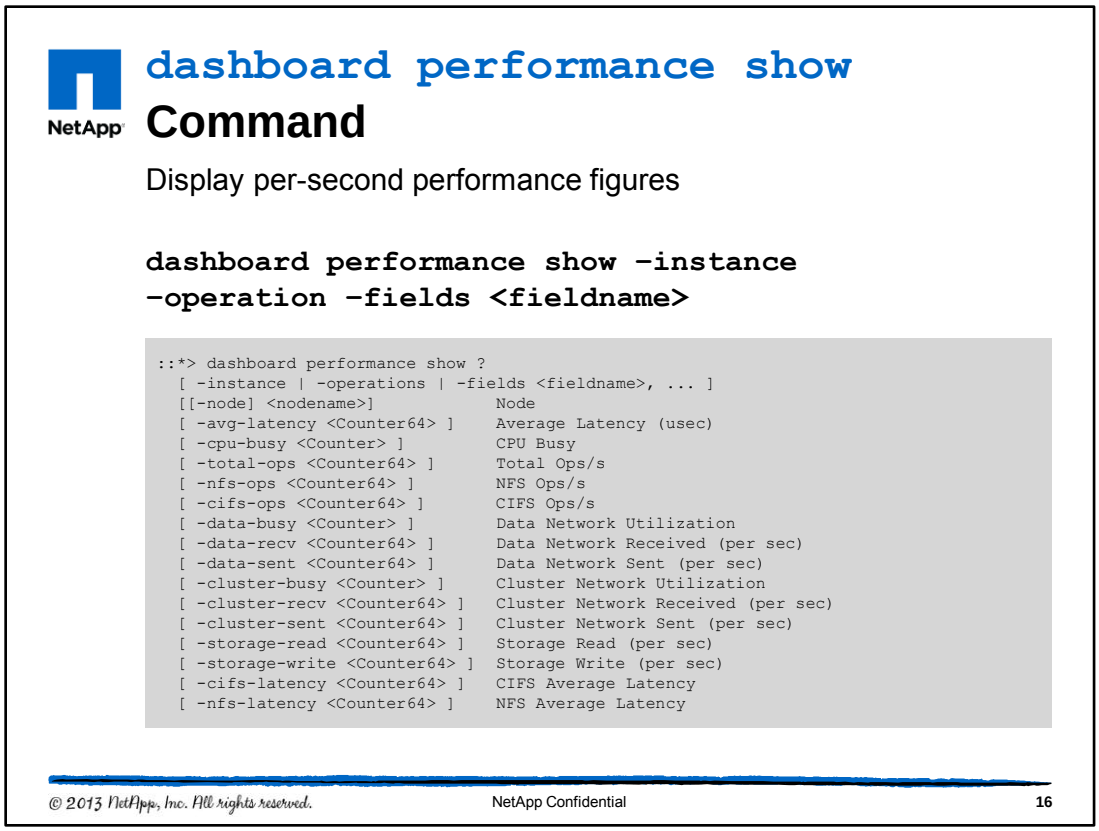


BASELINE MONITORING COMMANDS: 3 OF 3

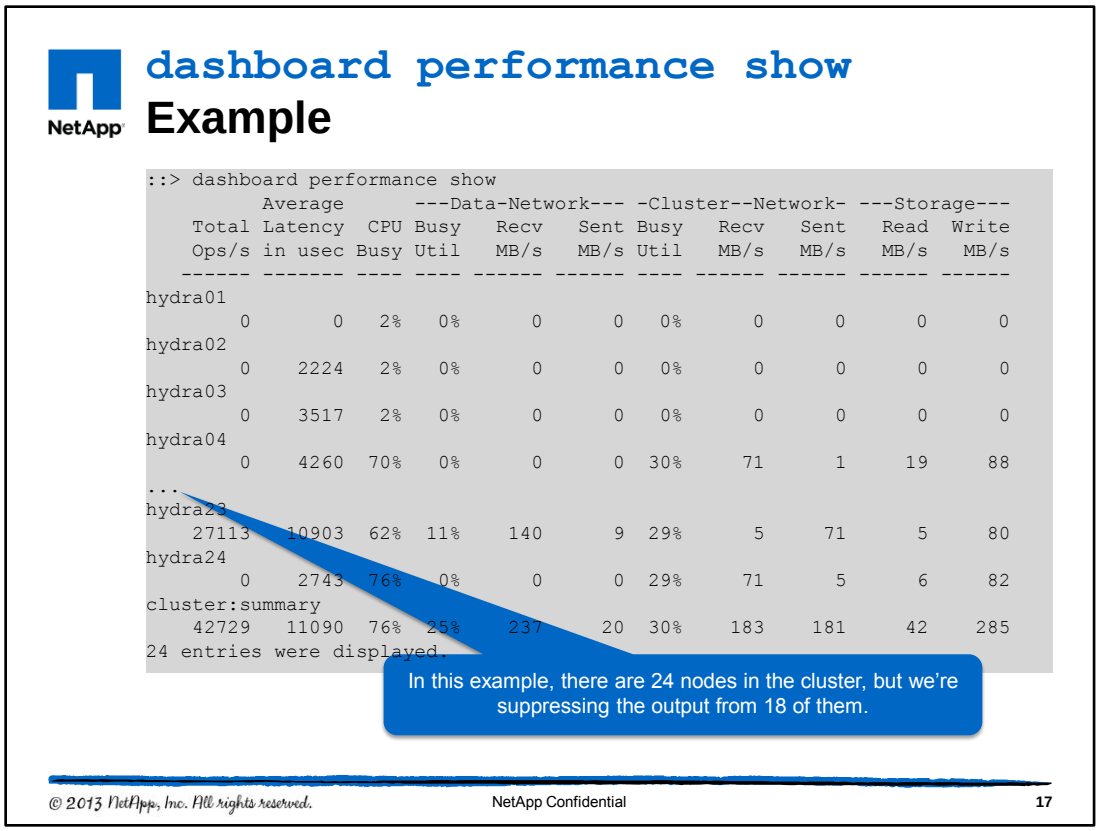


BASELINE PERFORMANCE MONITORING

Top to bottom (cluster down to node component).



DASHBOARD PERFORMANCE SHOW: COMMAND



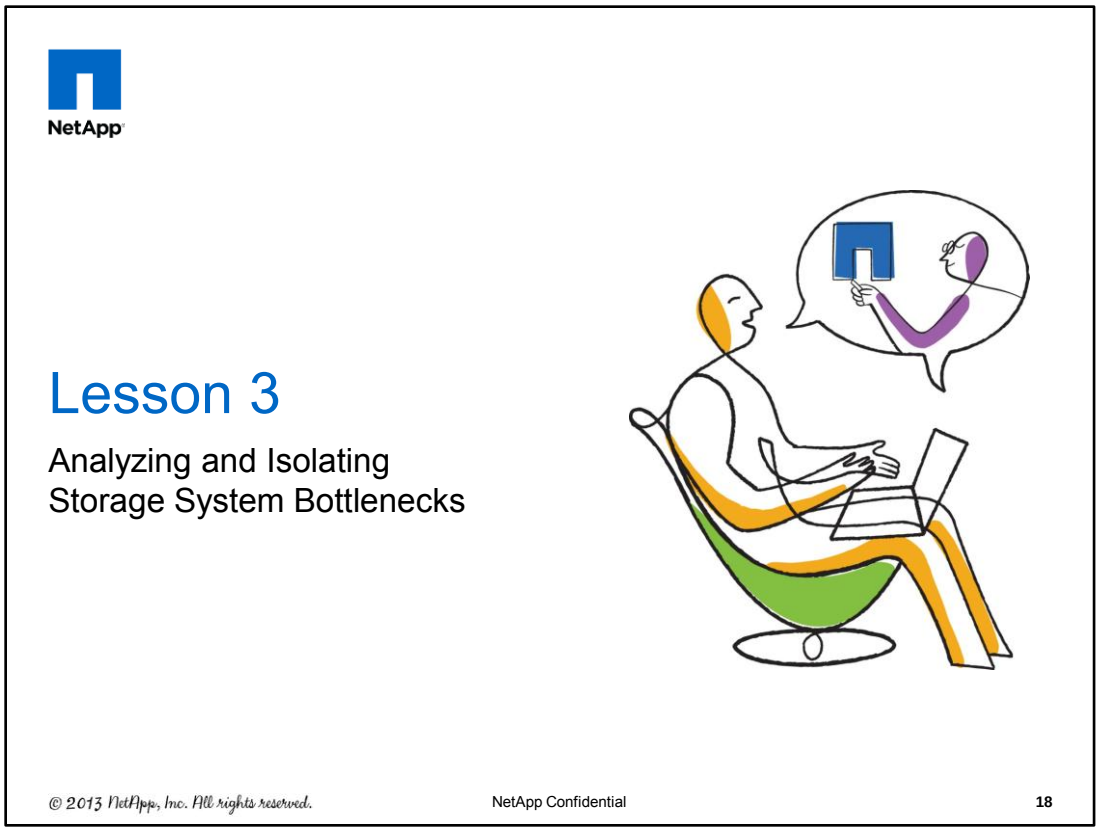
DASHBOARD PERFORMANCE SHOW: EXAMPLE

By default, the performance dashboard displays the following information about system and cluster performance:

- Node name or cluster summary
- Average operation latency, in microseconds
- Total number of operations
- Percentage of data network use
- Data that is received on the data network, in MBps
- Data that is sent on the data network, in MBps
- Percentage of cluster network use
- Data that is received on the cluster network, in MBps
- Data that is sent on the cluster network, in MBps
- Data that is read from storage, in MBps
- Data that is written to storage, in MBps

This command can display a wide range of performance information. See the reference page for the command for further details.

This performance view can be used in conjunction with `statistics show -node <node> -object <object>` to get more detailed statistics.



LESSON 3: ANALYZING AND ISOLATING STORAGE SYSTEM BOTTLENECKS

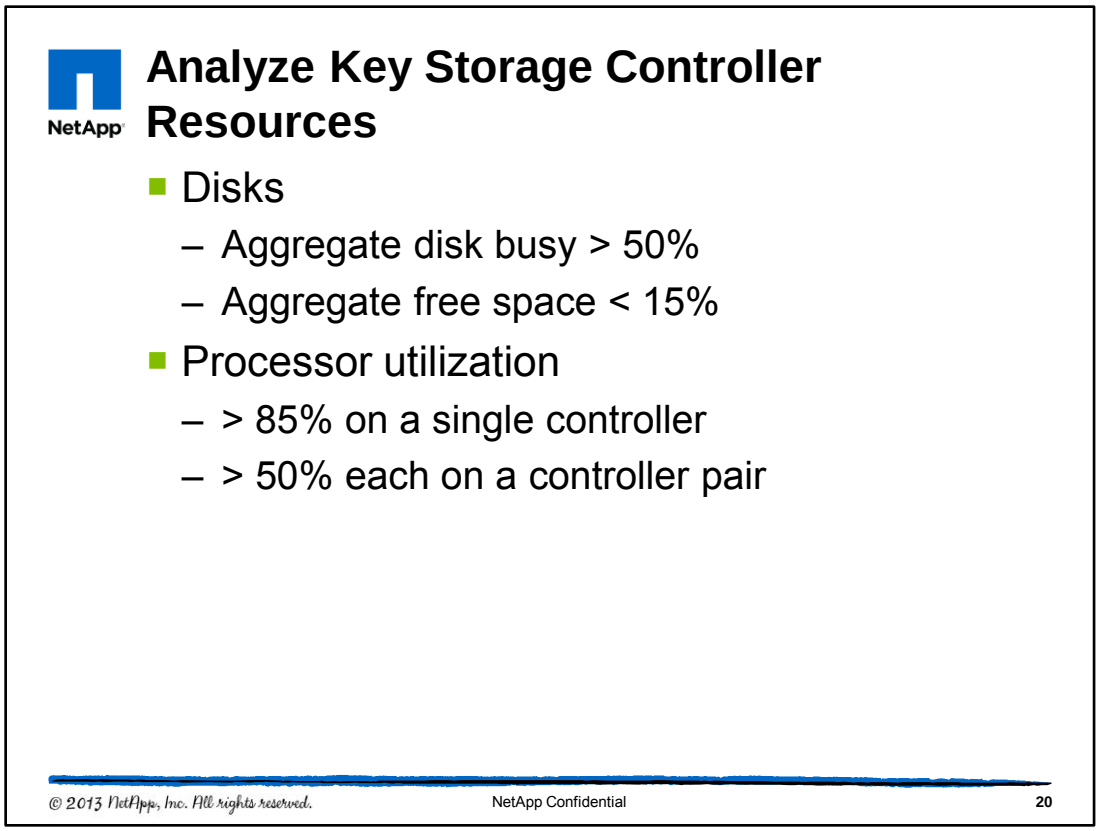
This lesson discusses methods of analyzing and isolating storage system bottlenecks for any given clustered storage system.

Analyzing Storage System Bottlenecks

- Use top-to-bottom baseline process
  - `statistics show-periodic`
  - `dashboard performance show`
  - `statistics show`
- Analyze key storage controller resources
  - Disk
  - Processor utilization
- Define workload characteristics when analyzing client performance problems

```
statistics show –object [obj]
–instance [inst] –counter [cnt]
```


ANALYZING STORAGE SYSTEM BOTTLENECKS



ANALYZE KEY STORAGE CONTROLLER RESOURCES

LESSON 4: COMMON PERFORMANCE TOPICS

This lesson analyzes common performance topics as they relate to the clustered Data ONTAP storage system. Aggregate free space, CPU and memory headroom, disk-bound configurations, and cache hits are covered.

Aggregate Free Space

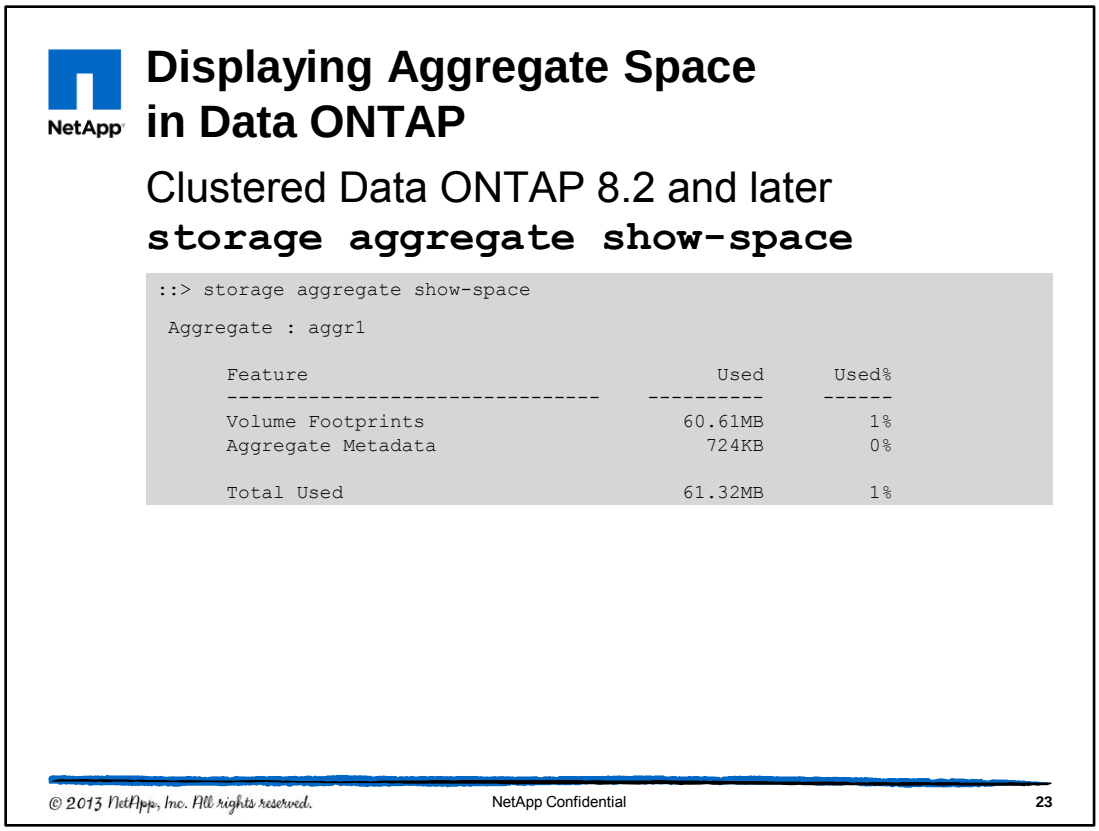
WAFL (Write Anywhere File Layout) free space recommendation:

- For data sets with a low rate of change, 3% free space in the aggregate is recommended; otherwise, allow 5% free space.
- This space is used primarily for metadata.
- Insufficient free space pushes data into the WAFL reserve.

WAFL reserve:

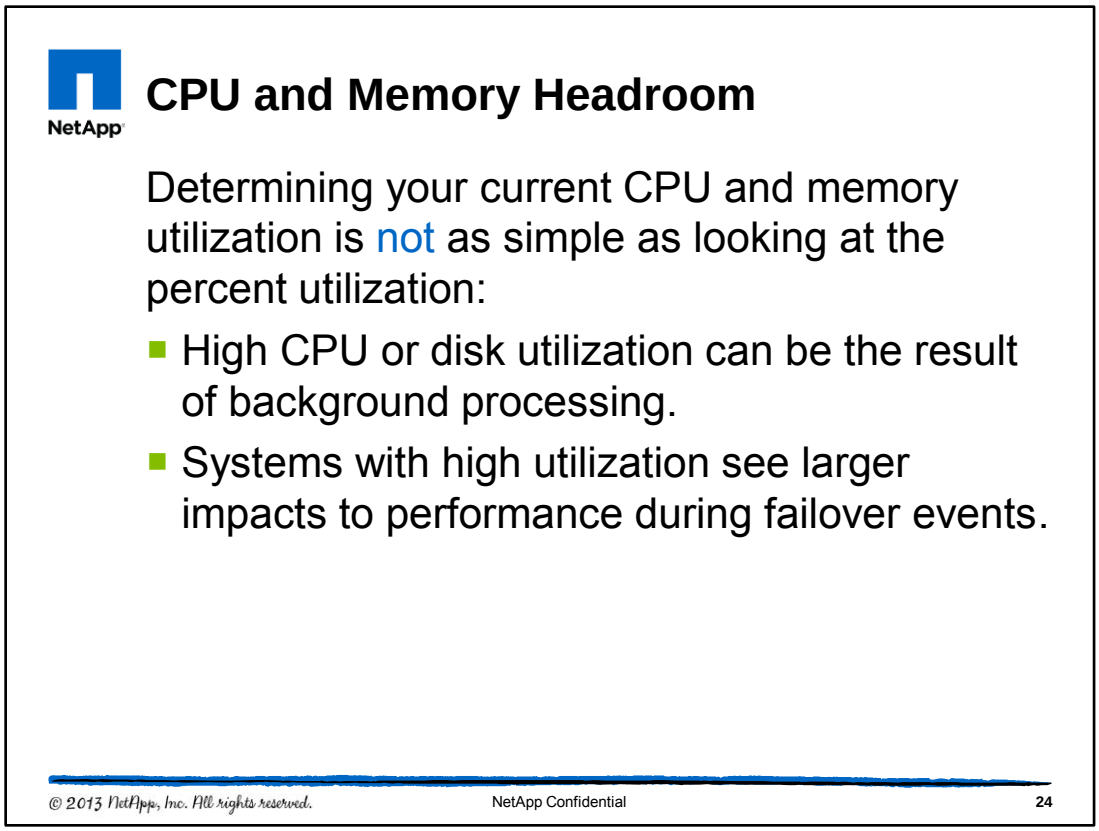
- Allocate 10% aggregate capacity for the WAFL reserve.
- The reserve ensures that WAFL can keep open allocation areas for long-term write performance.

AGGREGATE FREE SPACE



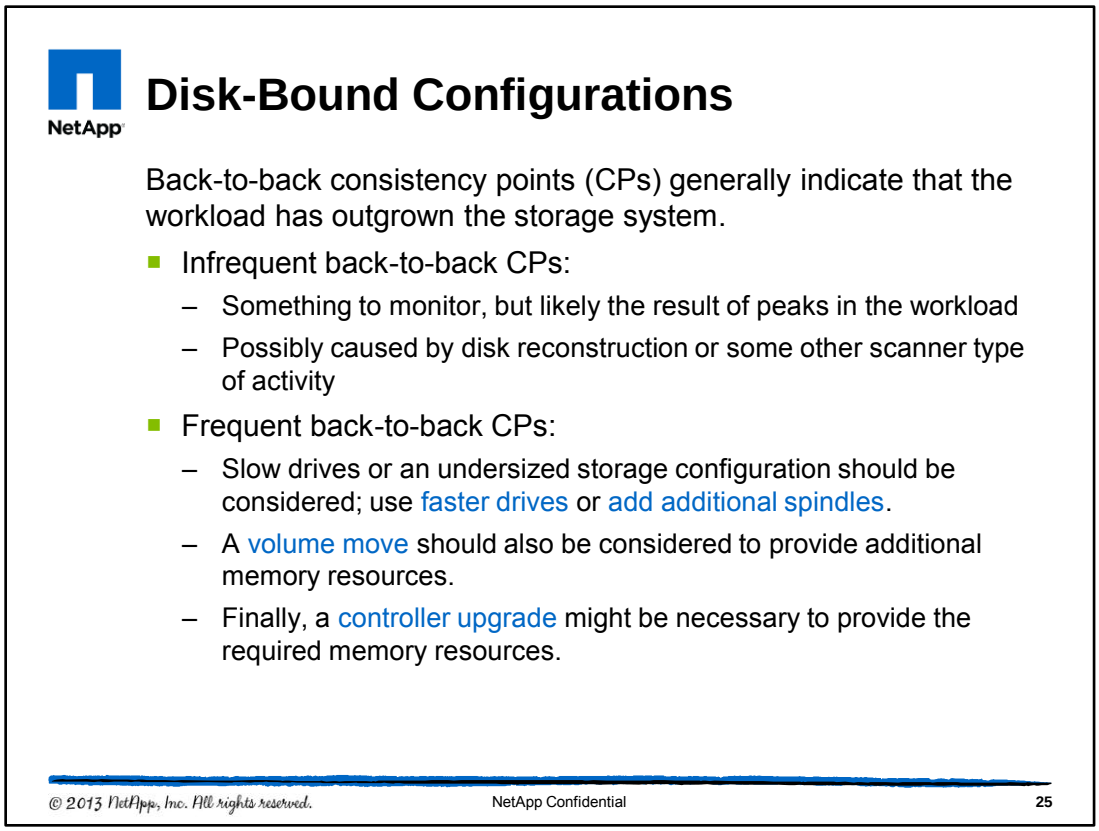
DISPLAYING AGGREGATE SPACE IN DATA ONTAP

To display aggregate space in clustered Data ONTAP 8.2 and later, use the `storage aggregate show-space` command.



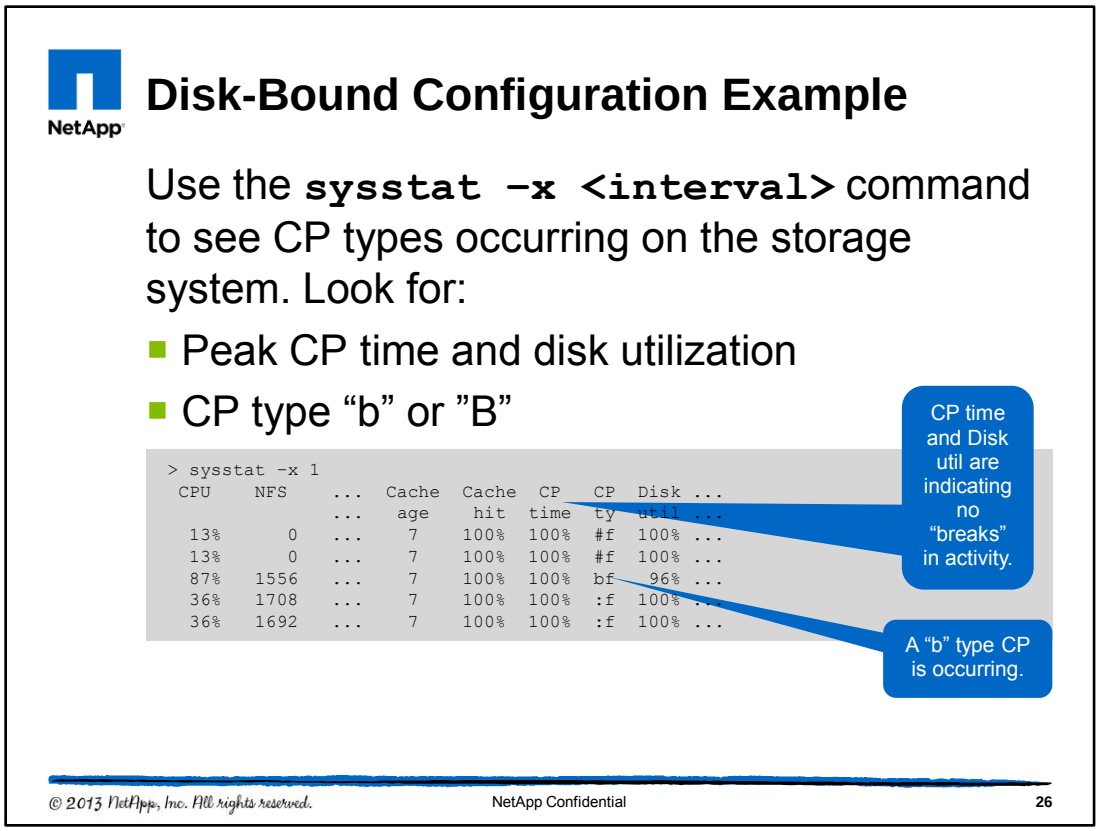
CPU AND MEMORY HEADROOM

Determining your current CPU and memory utilization is *not* as simple as looking at the percent utilization. High CPU or disk utilization can be the result of background processing because the system consumes idle system resources for background operations. Systems with high utilization see larger impacts to performance during failover events because the surviving controller must now host its own workload and the workload from the HA partner.



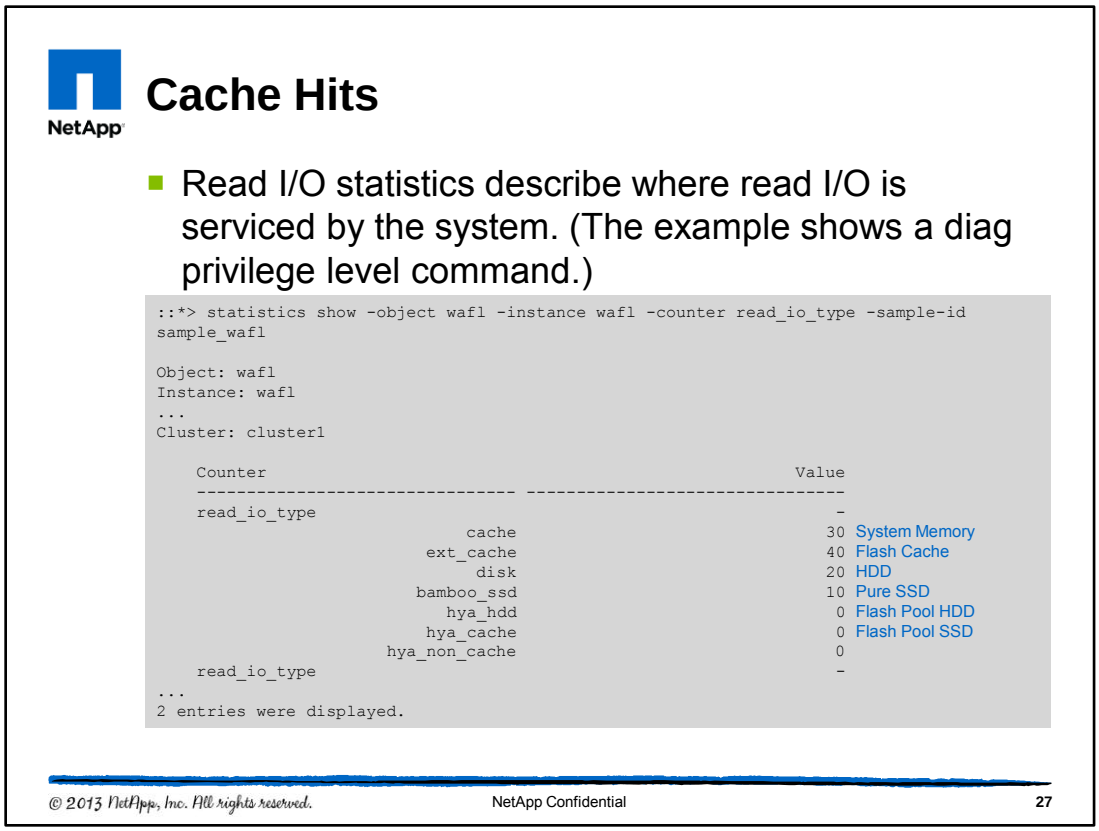
DISK-BOUND CONFIGURATIONS

Back-to-back consistency points (CPs) generally indicate that the workload has outgrown the storage system. Infrequent back-to-back CPs are something to monitor, but it is likely to be the result of peaks in the workload, which might be caused by disk reconstruction or some other scanner type of activity. Frequent back-to-back CPs might be the result of slow drives or an undersized storage configuration; use faster drives or add additional spindles. A volume move from the hot aggregate to a lesser utilized aggregate should also be considered. As a last resort, a controller upgrade might be necessary to provide the memory resources required by the workload.



DISK-BOUND CONFIGURATION EXAMPLE

Use the `sysstat –x <interval>` command to see CP types that are occurring on the storage system. Look for peak CP time and disk utilization, and also look for “b” or ”B” type CPs that are occurring. Remember to use the `system node run` command when running this command on a clustered Data ONTAP system.

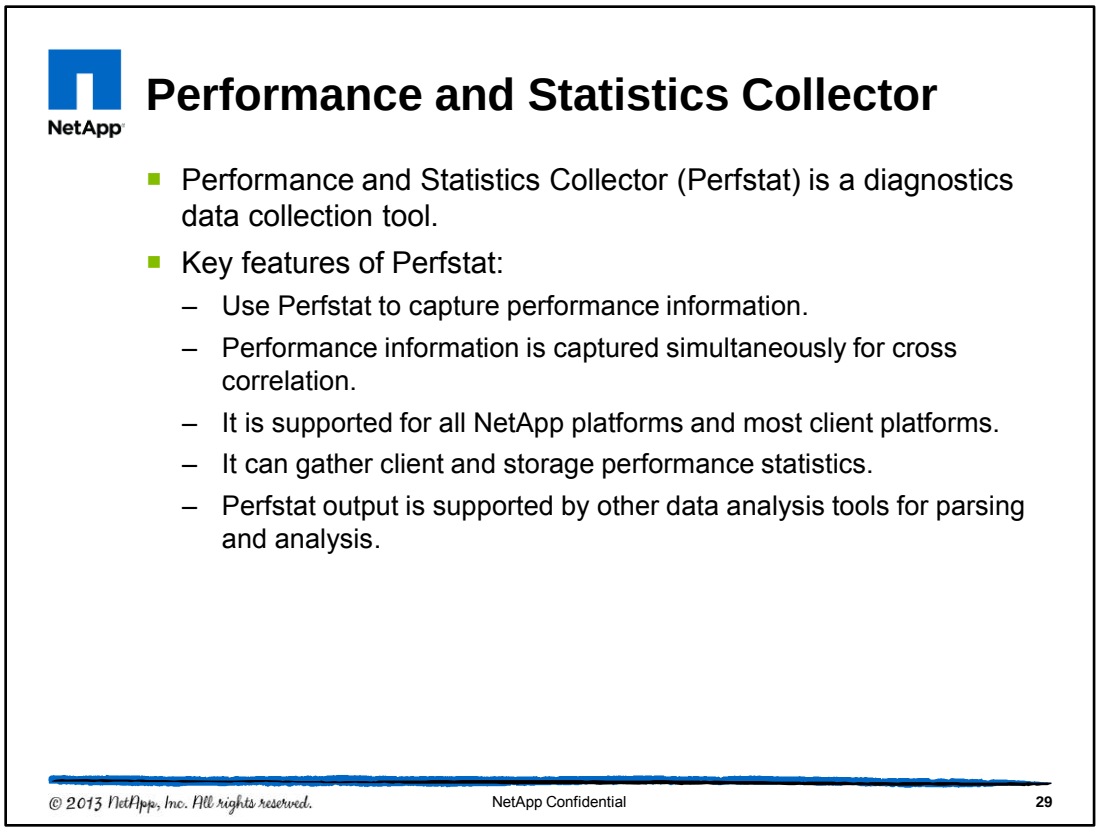


CACHE HITS

Read I/O statistics describe where read I/O is serviced by the system. A special diag privilege of the `statistics show` command displays cache hits for system memory, Flash Cache, hard disks, solid-state drives (SSDs), hard disks in a Flash Pool, and SSDs in a Flash Pool.

LESSON 5: KEY PERFORMANCE TOOLS

This lesson introduces the clustered Data ONTAP operating system performance tools.

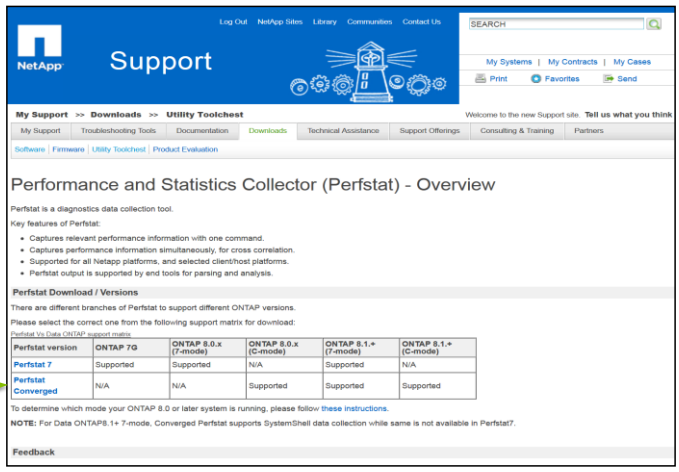


PERFORMANCE AND STATISTICS COLLECTOR

One of the most important performance and statistics collection tools is Perfstat.

Perfstat Download

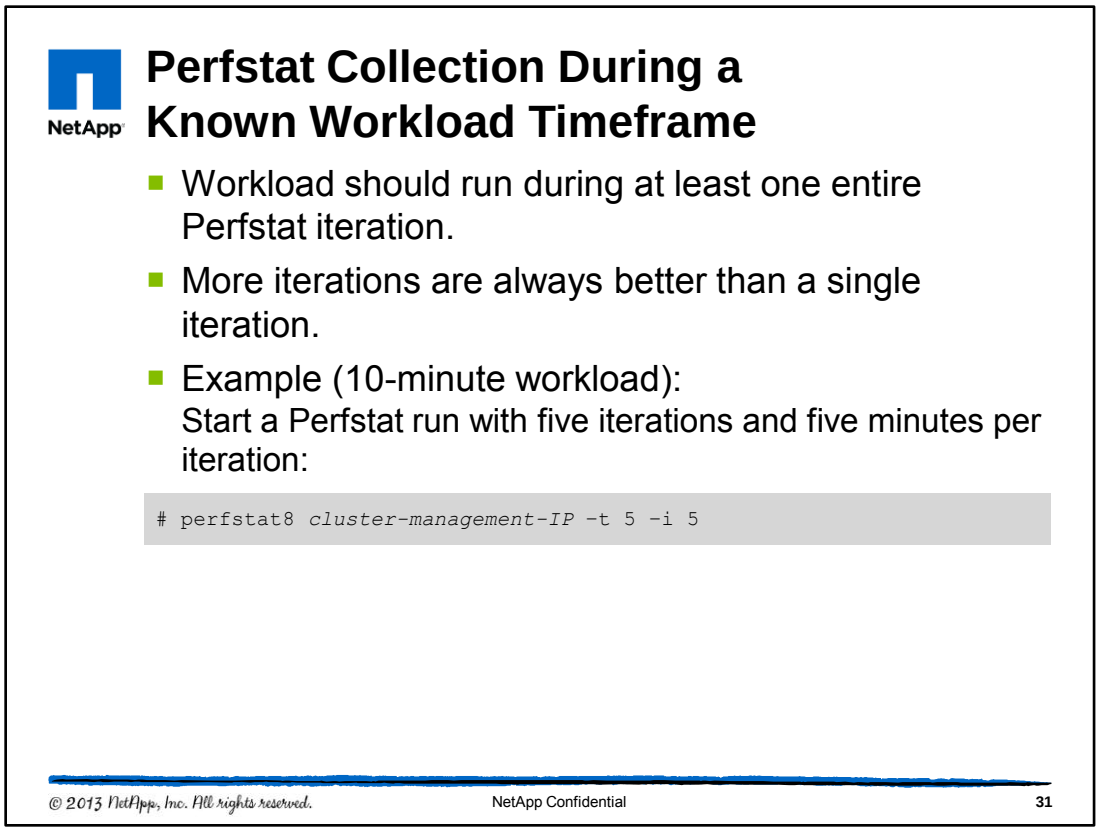
Perfstat is available from the ToolChest page of the NetApp Support site.



Remember to always run the latest version of Perfstat.

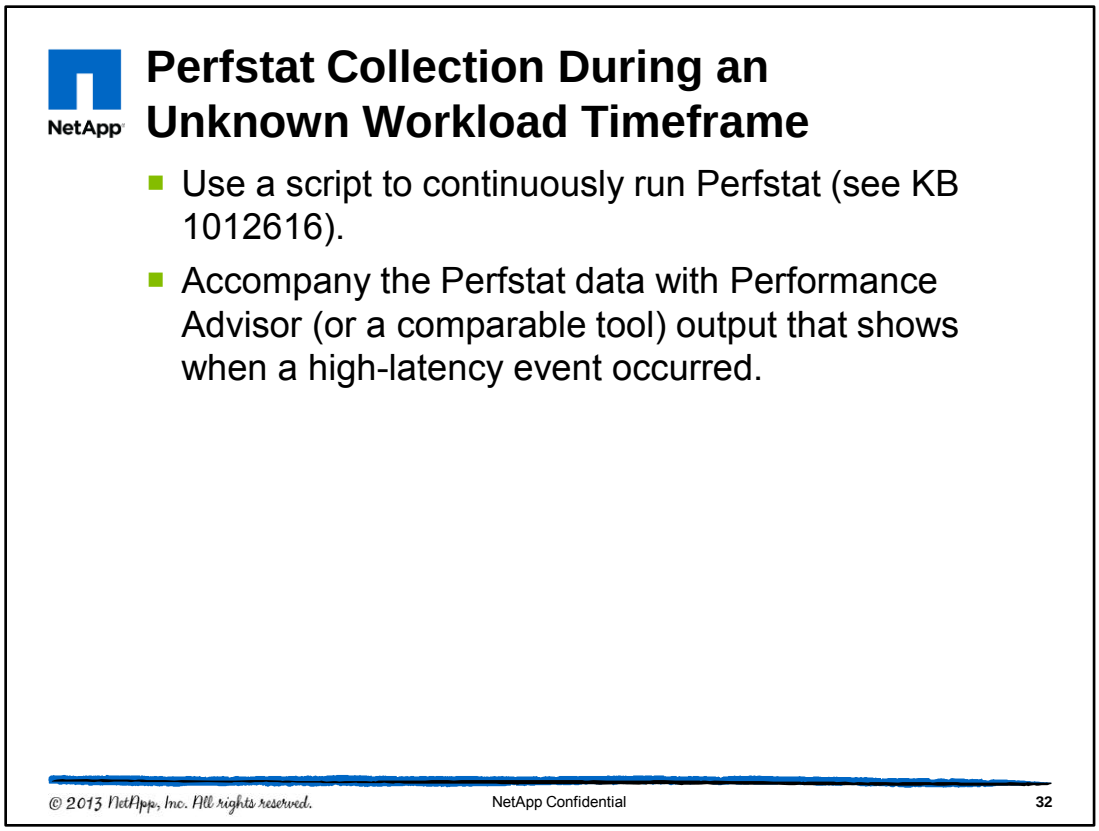
PERFSTAT DOWNLOAD

Remember, when collecting performance data for a NetApp support case, always run the latest version of Perfstat.



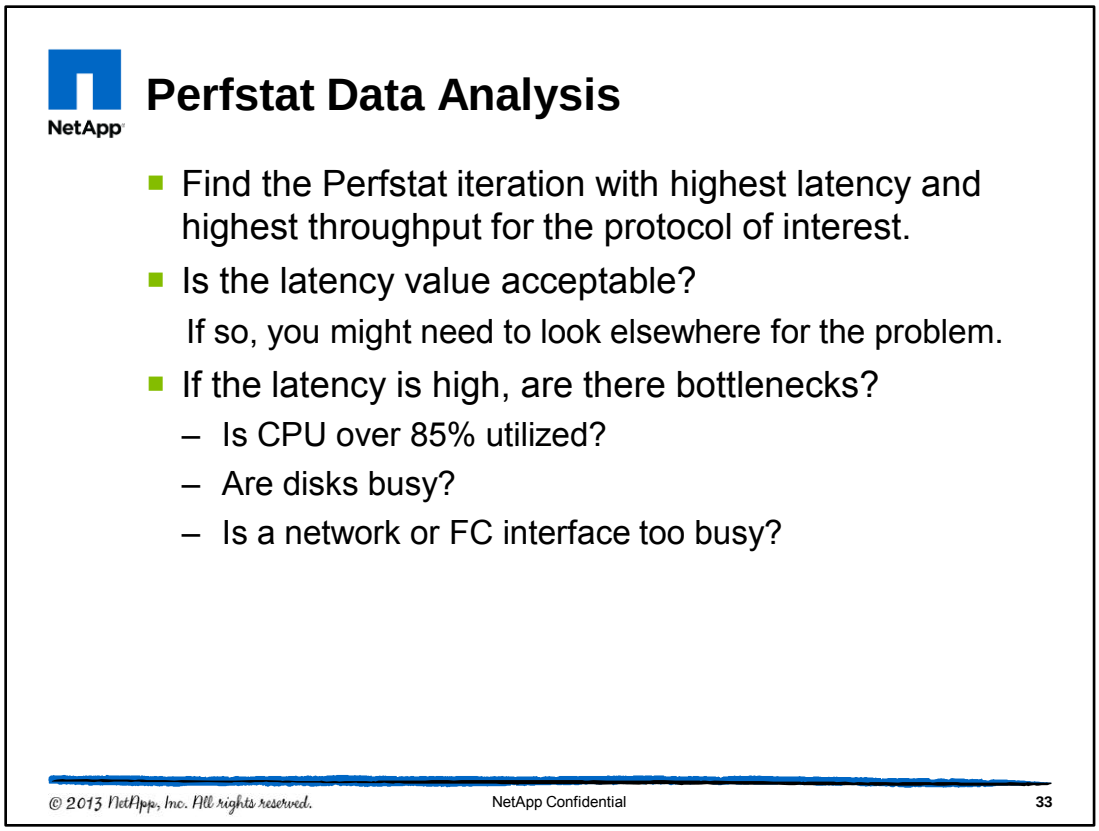
PERFSTAT COLLECTION DURING A KNOWN WORKLOAD TIMEFRAME

Follow these guidelines when collecting Perfstat data during a known workload timeframe. The workload should run during at least one entire Perfstat iteration, and more iterations are always better than a single iteration. This example includes a 10-minute workload. First, start a Perfstat run with five iterations and five minutes per iteration. The first iteration captures workload data as the workload is getting ramped up. The workload starts sometime in the second iteration and runs during the entire third iteration. The workload finishes during the fourth iteration. Following these guidelines ensures that the entire workload is captured.



PERFSTAT COLLECTION DURING AN UNKNOWN WORKLOAD TIMEFRAME

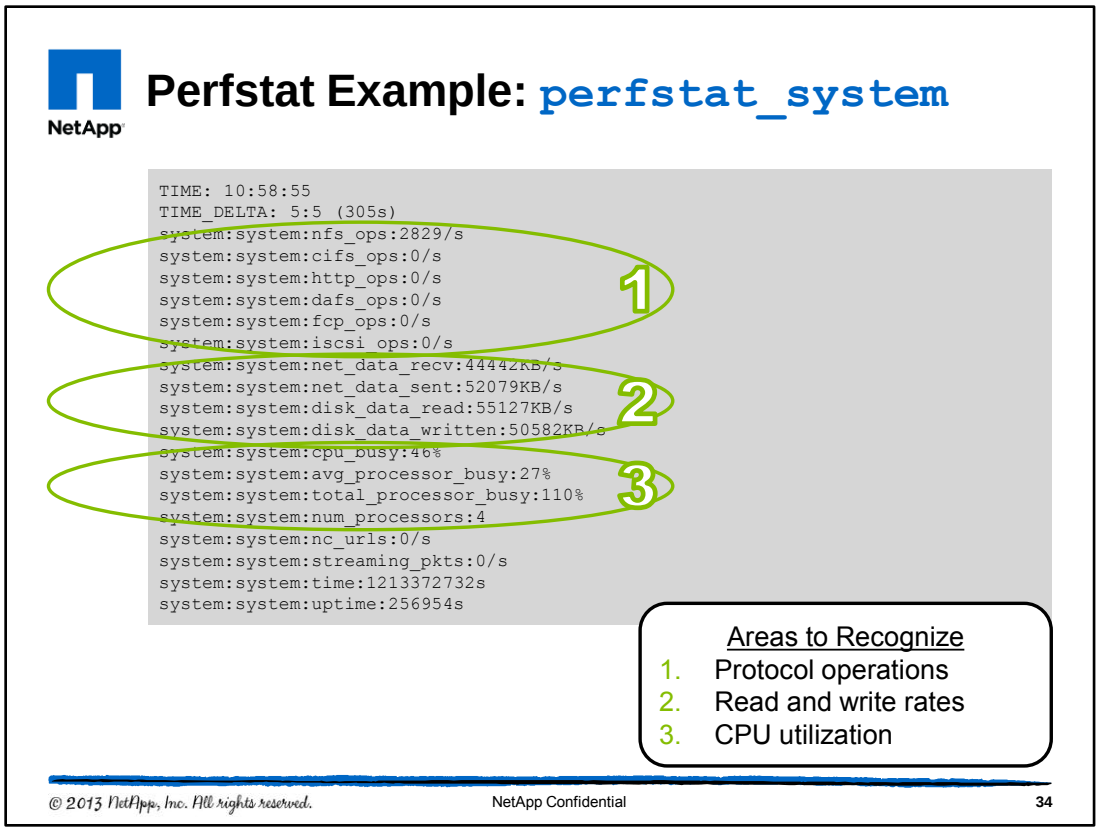
Collecting Perfstat data during an unknown workload timeframe requires either the use of a script to continuously run Perfstat or a tool such as the Performance Advisor to execute Perfstat during a user-defined alert that can be set up to automate the Perfstat execution.



PERFSTAT DATA ANALYSIS

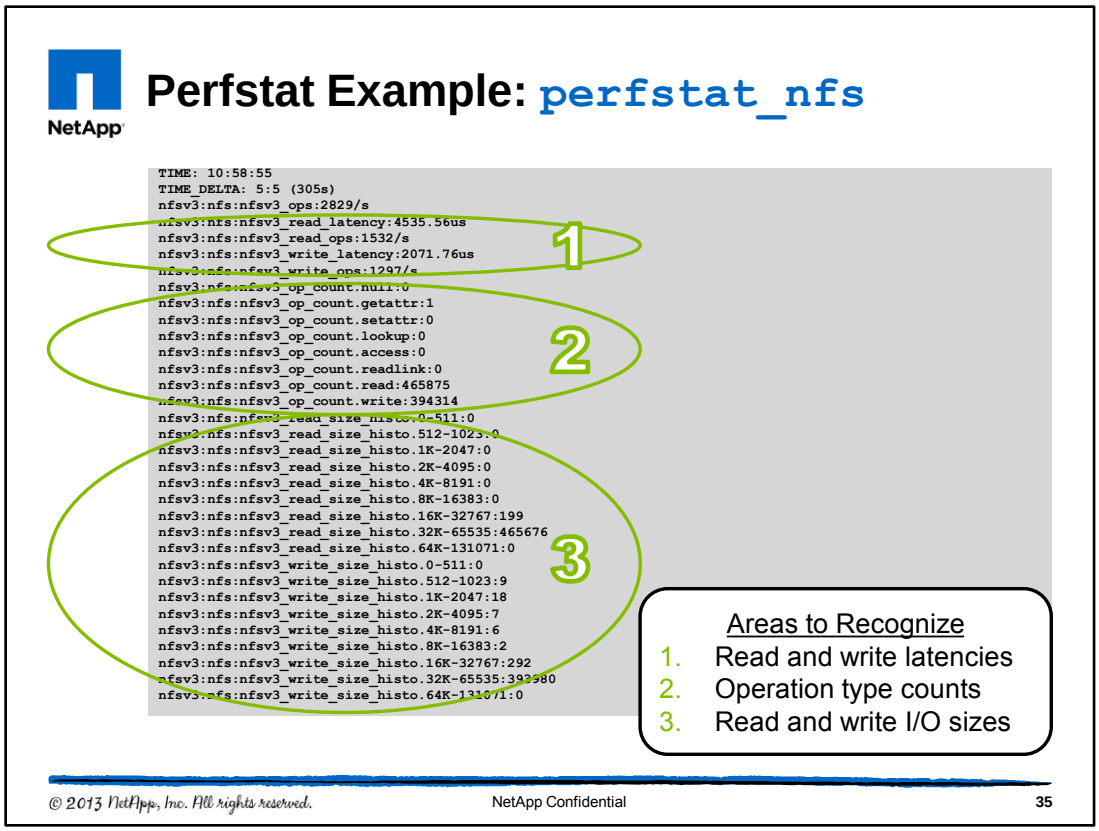
When analyzing Perfstat data, find the Perfstat iteration with the highest latency and highest throughput for the protocol of interest. Is the latency value acceptable? If so, you might need to look at some of the other potential components or resources that might be hindering the performance. If the latency is high, are there bottlenecks? Is CPU over 85% utilized? Are the disks busy? Remember to refer to the Disk IOPS Versus Latency chart in the previous module. Is a network or FC interface too busy?

By pursuing each of these questions, you can isolate the potential problem more easily.



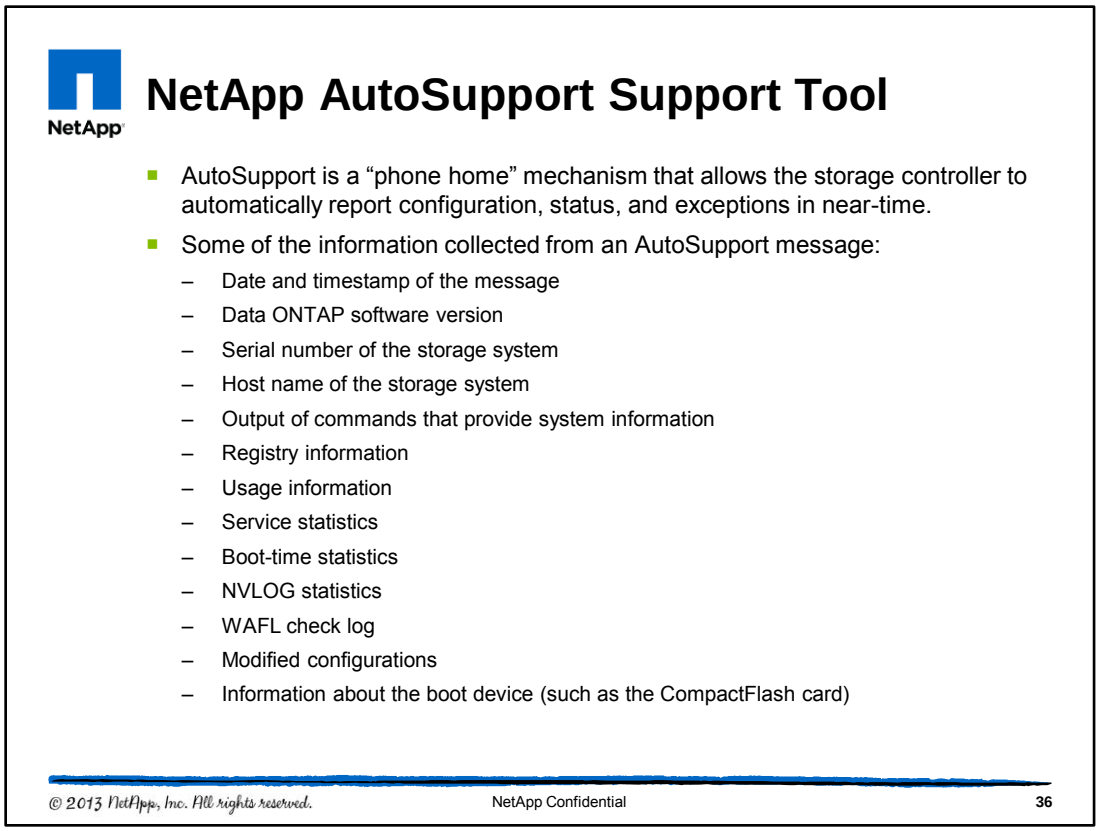
PERFSTAT EXAMPLE: PERFSTAT_SYSTEM

This example shows Perfstat system output. There are a few areas that you should recognize from the output. First, notice the protocol operations. This example shows 100% NFS OPS. Next, notice the read and write rates, and finally, the CPU utilization.



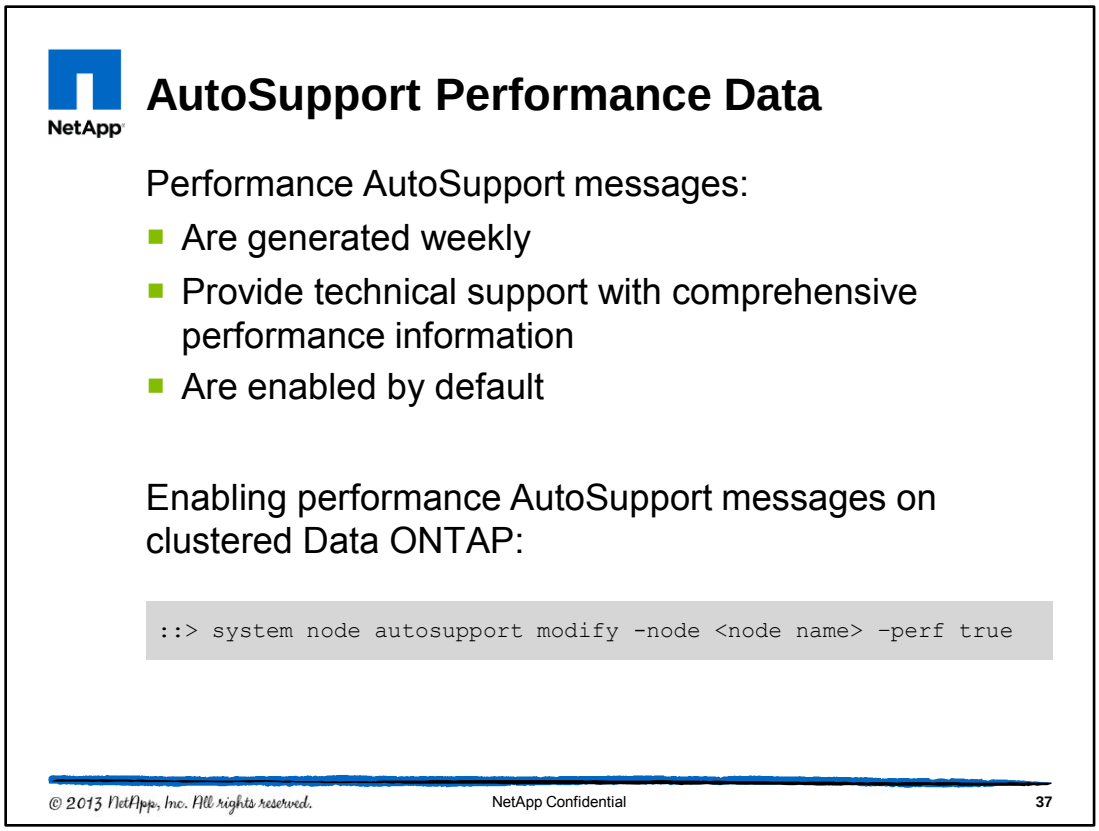
PERFSTAT EXAMPLE: PERFSTAT_NFS

This example shows Perfstat NFS output. Note these areas in the output. First, notice the read and write latencies. Next, notice the operation type counts, and finally, the read and write I/O sizes.



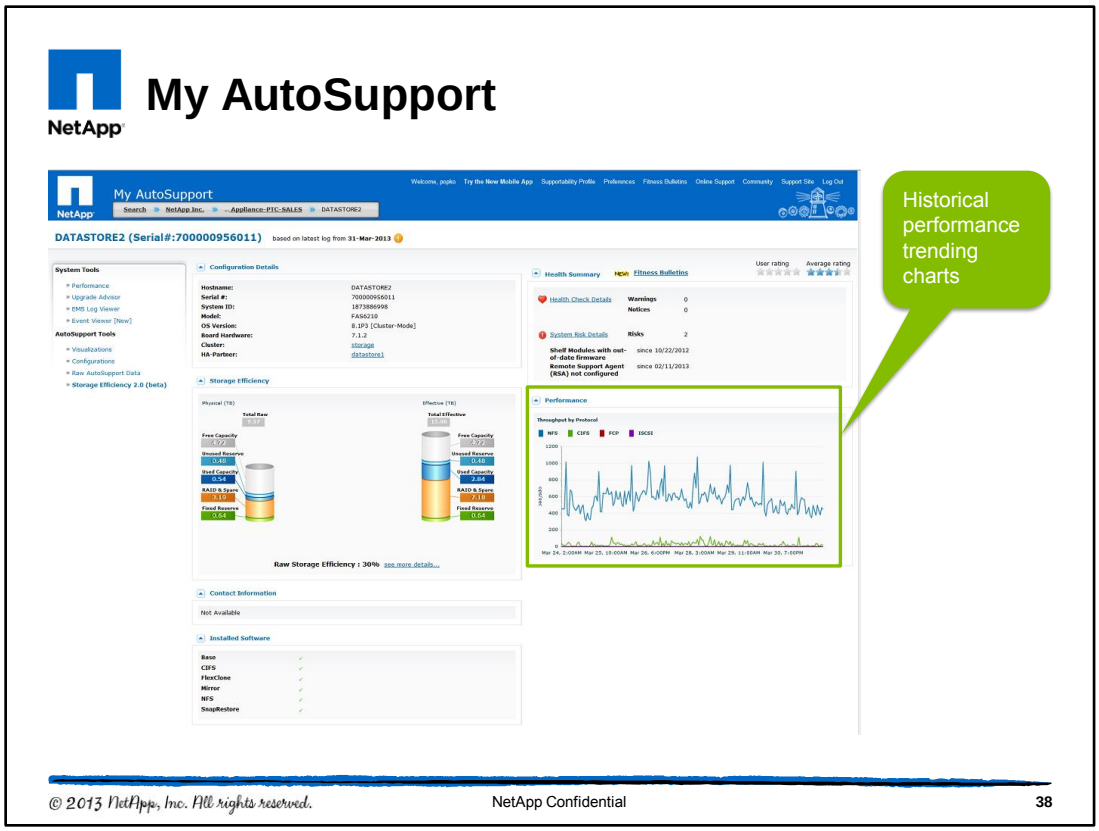
NETAPP AUTOSUPPORT SUPPORT TOOL

AutoSupport is an integrated and efficient monitoring and reporting feature. It’s one of the most important troubleshooting tools for any NetApp storage system, and it can aid in providing performance-related information when no other baseline information is available. Some of the information that is collected in an AutoSupport message includes usage information, service statistics, boot-time statistics, and NVLOG statistics. Most of the commands introduced in this course are also part of every AutoSupport payload.



AUTOSUPPORT PERFORMANCE DATA

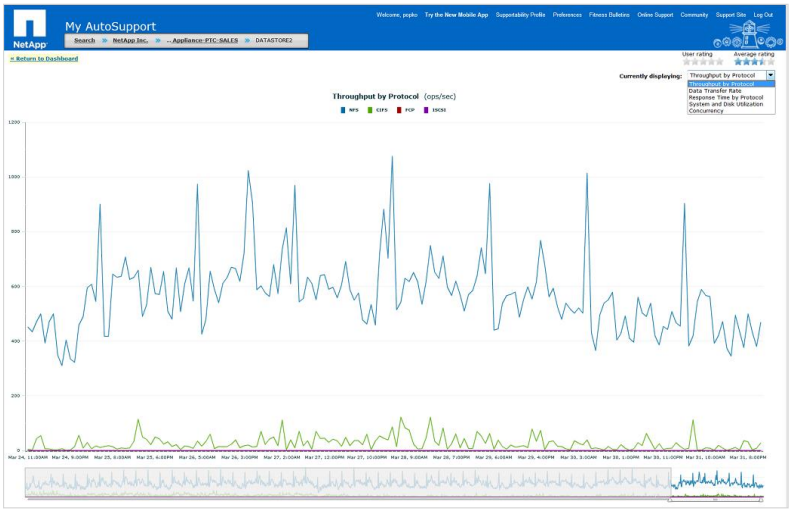
NetApp technical support personnel use AutoSupport performance messages to monitor and track the performance of the system and, as indicated, offer recommendations to improve performance. Performance messages can be quite large, so by default they are sent only to technical support. A basic set of performance statistics is collected using an hourly granularity, which is a suitable granularity for trending. For example, these statistics are used to display the performance graphs for the storage system in My AutoSupport. The AutoSupport performance message is enabled (or true) by default. If a system has AutoSupport performance messaging disabled, you can enable it by entering the `system node autosupport modify` command.



MY AUTOSUPPORT

My AutoSupport is a web-based application that extends the capability of the AutoSupport system and helps you to improve the operational and storage efficiency of your NetApp storage system. Performance information, if available, is displayed on the dashboard.

My AutoSupport: Performance View



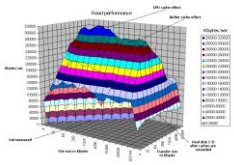
MY AUTOSUPPORT: PERFORMANCE VIEW

Click the performance data to bring up a larger view of the performance information on the dashboard. A drop-down list enables you to choose throughput by protocol, data transfer rate, response time by protocol, system and disk utilization, or concurrency. This information can be very useful when you are diagnosing performance-related problems, or when you are trying to get an idea of baseline performance for a particular storage system.

Workload Generators

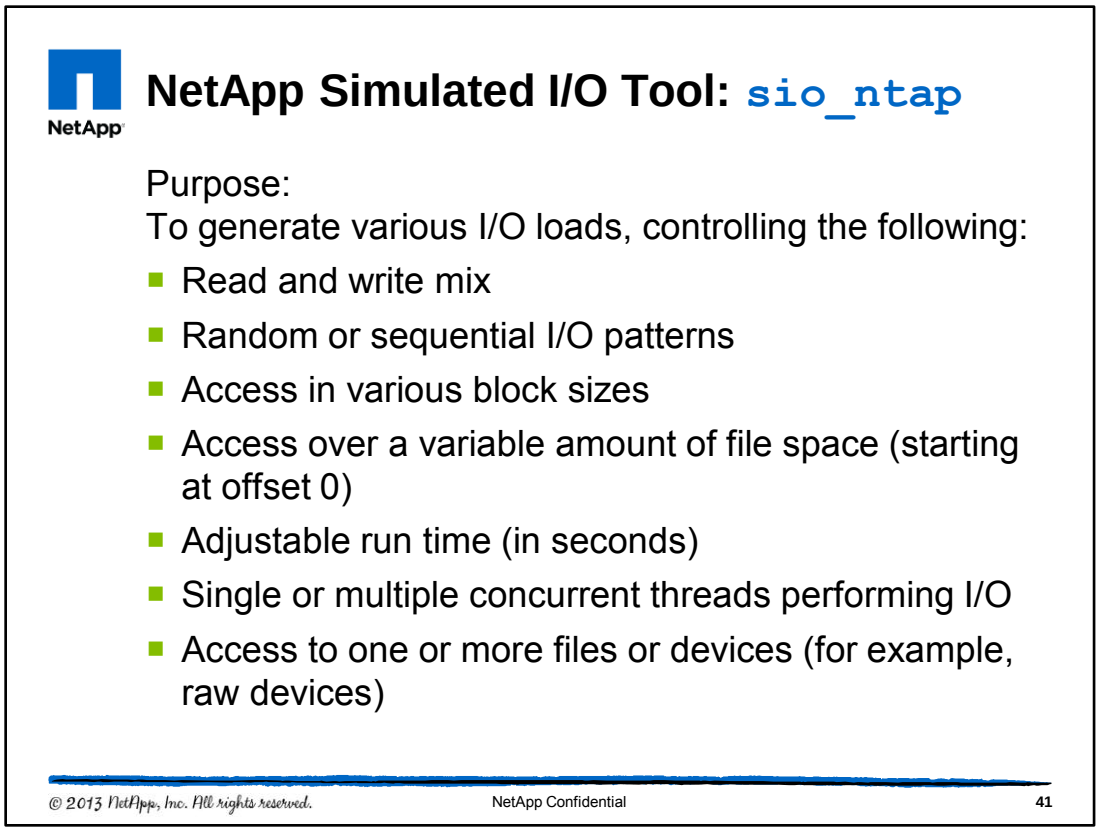
- SIO (simulated I/O) tool
  - Created by NetApp to generate artificial I/O workloads against any device
- Iometer
  - Read and write workload generator, available from SourceForge (open source)

- IOzone
  - File system benchmark tool
  - Generates and measures a variety of file operations
  - Ported to many machines and runs under many operating systems



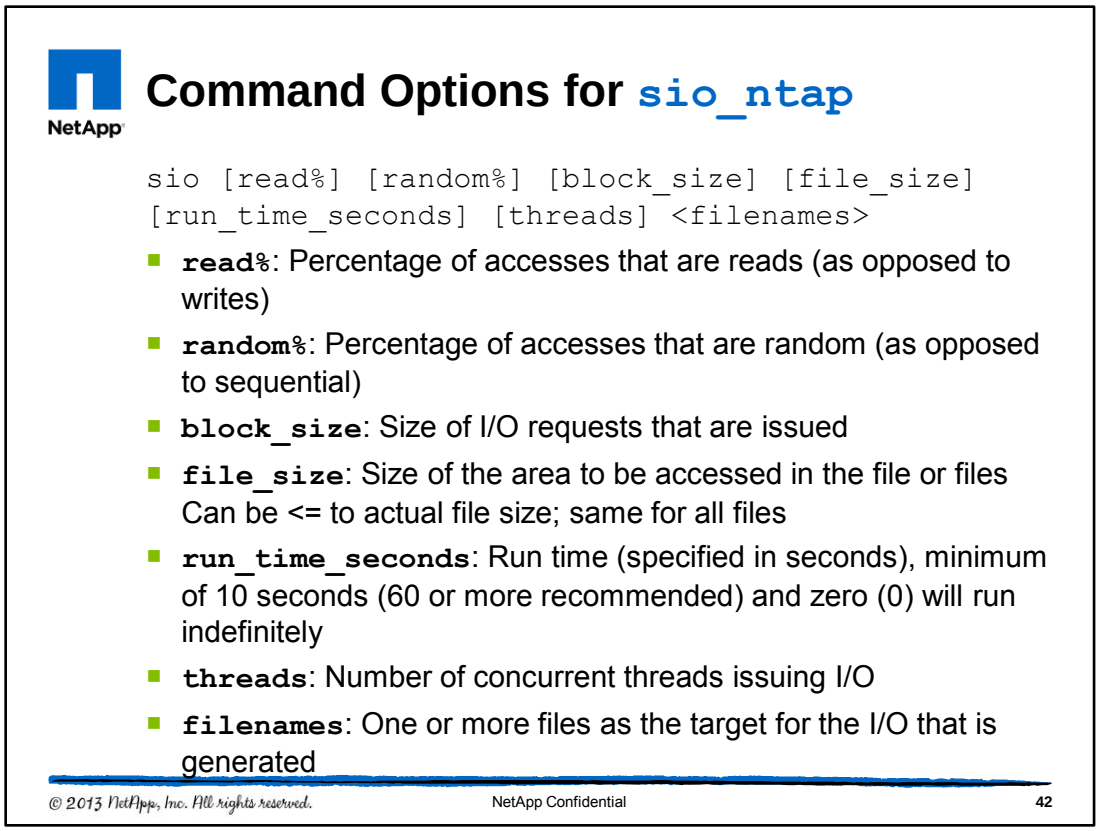
WORKLOAD GENERATORS

Workload generators are tools that attempt to simulate load on a system. A number of I/O workload generators attempt to simulate application I/O to test performance characteristics of a system. SIO (an abbreviation for simulated I/O) is a tool that NetApp created to generate artificial I/O workloads. Iometer and IOzone are similar tools that simulate I/O workloads. This lesson focuses on SIO.



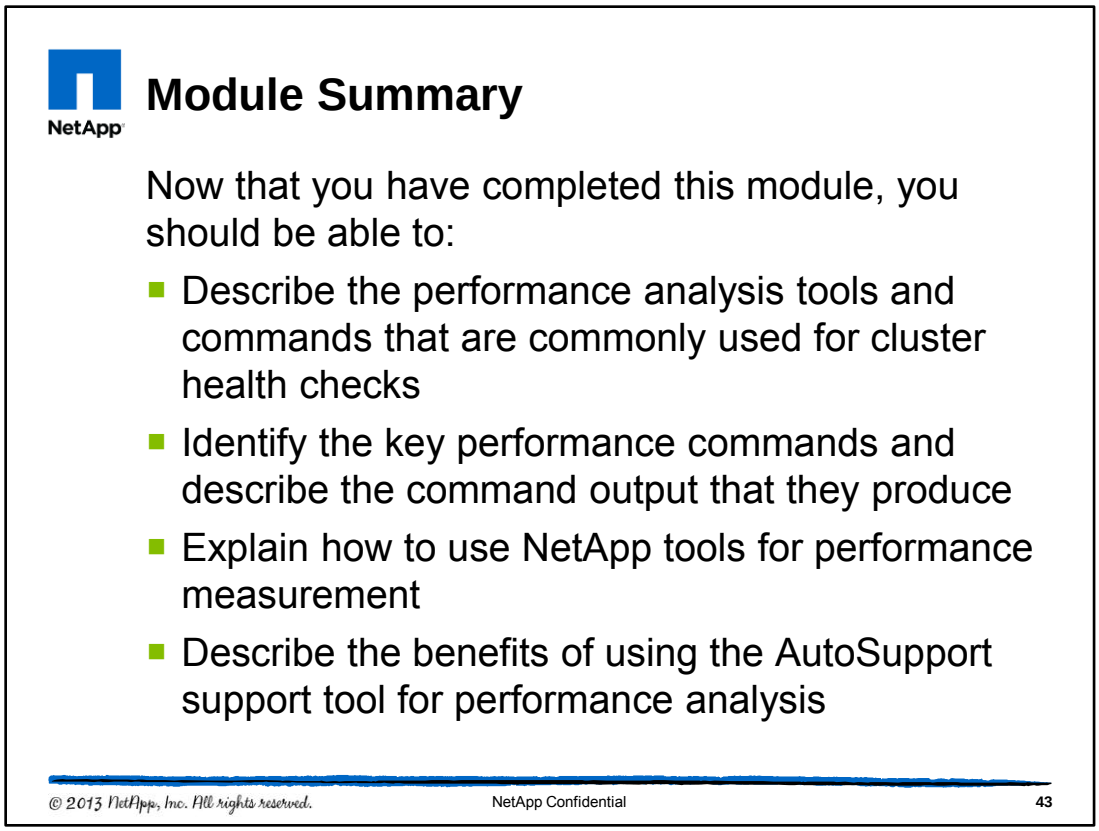
NETAPP SIMULATED I/O TOOL: SIO_NTAP

SIO's main purpose is to create I/O workloads that can emulate many different application workloads.



COMMAND OPTIONS FOR SIO_NTAP

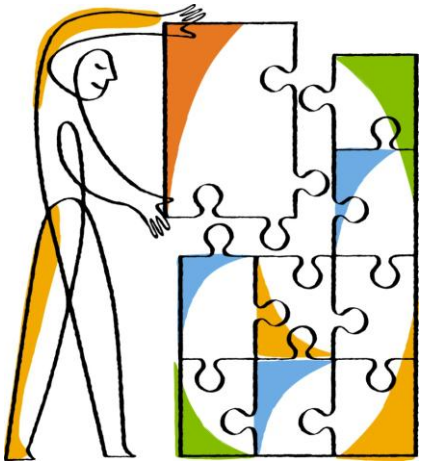
SIO supports a number of different parameters for manipulating the simulated workload's characteristics.



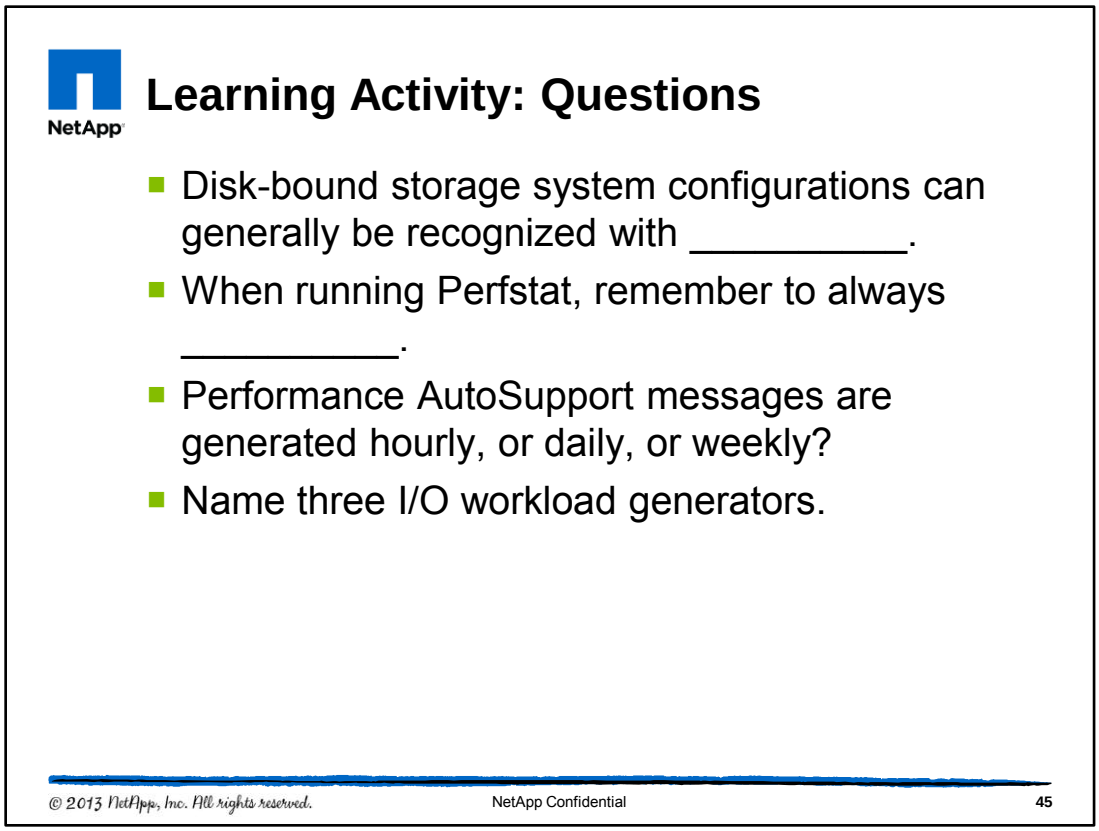
MODULE SUMMARY

Learning Activity Questions

Module 4: Cluster Performance Monitoring and Analysis



LEARNING ACTIVITY QUESTIONS

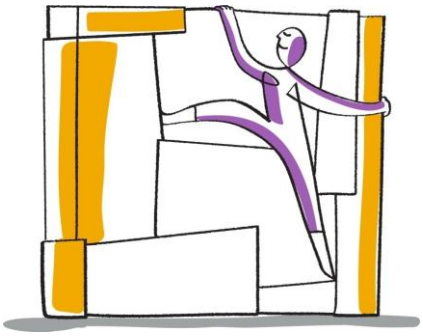


LEARNING ACTIVITY: QUESTIONS

Exercise

Module 4: Cluster Performance Monitoring and Analysis

Time Estimate: 120 Minutes

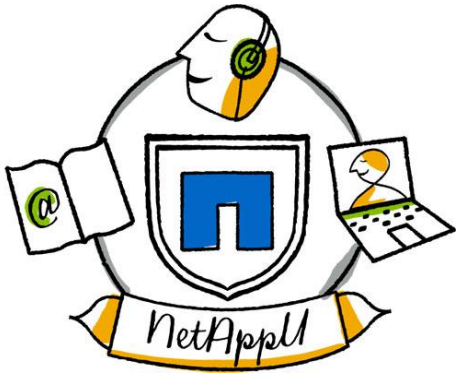


EXERCISE

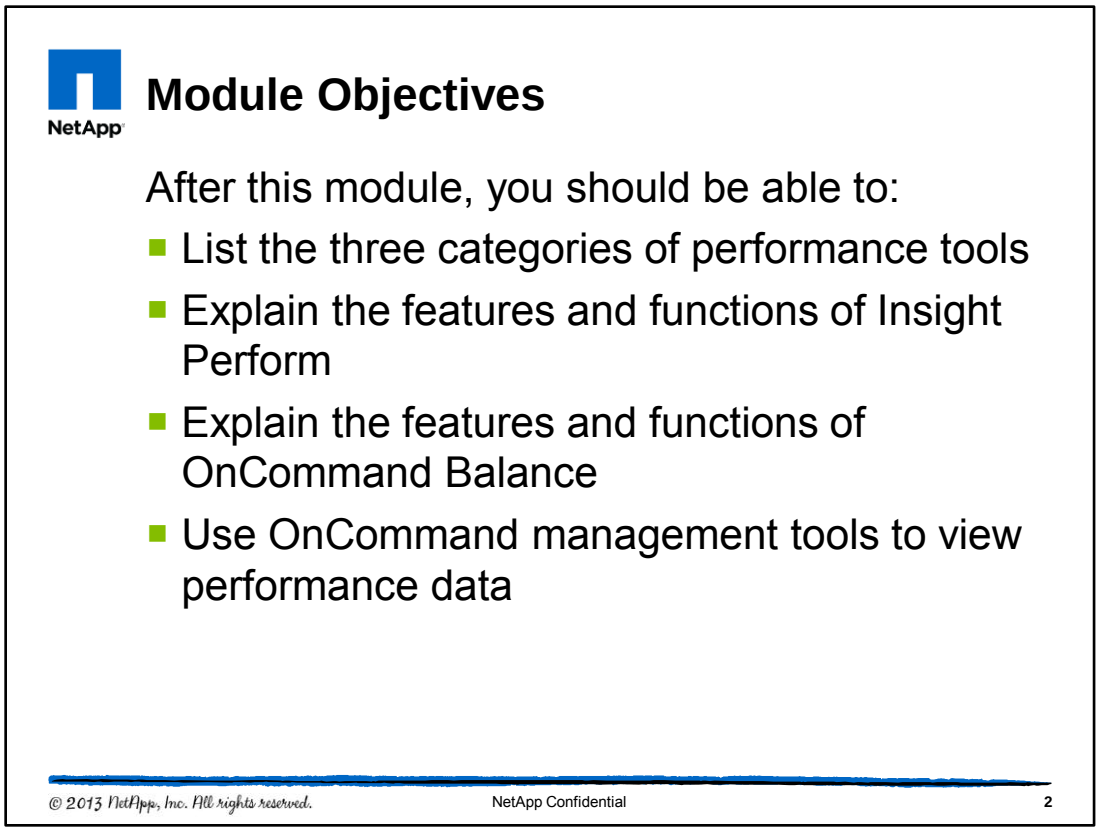
Please refer to your exercise guide.

Module 5

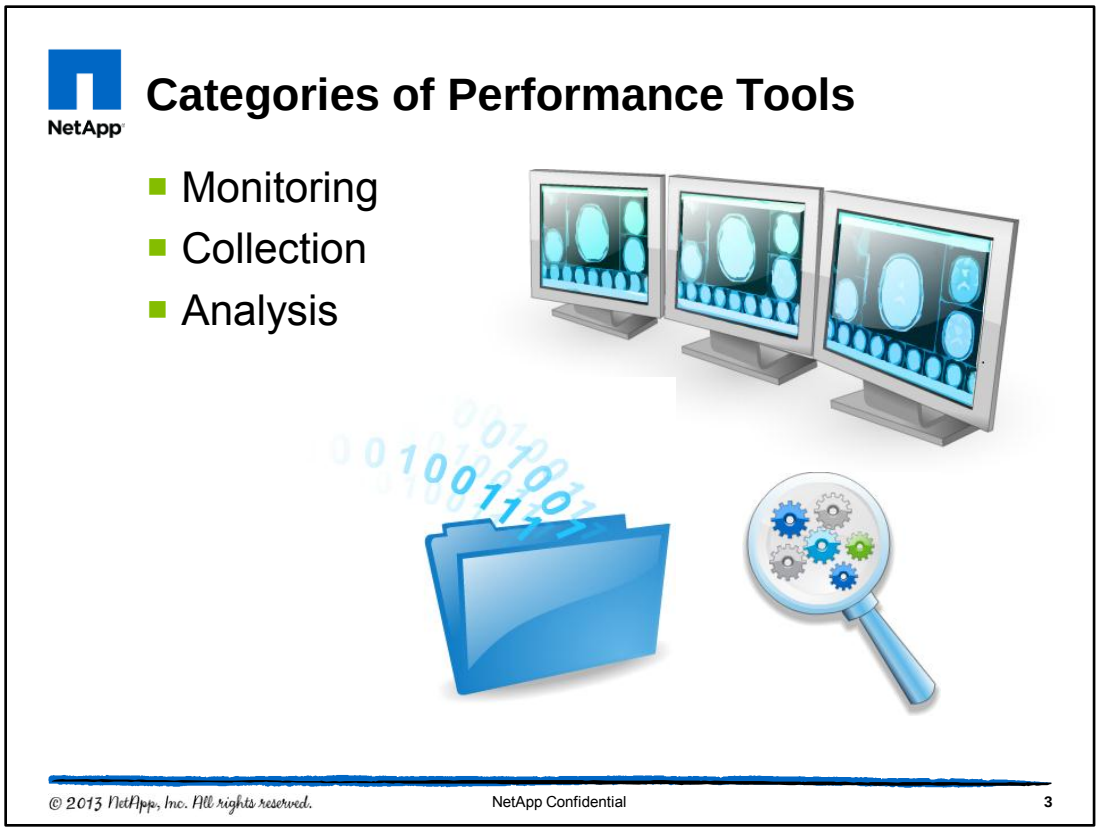
OnCommand Management Tools



MODULE 5: ONCOMMAND MANAGEMENT TOOLS



MODULE OBJECTIVES



CATEGORIES OF PERFORMANCE TOOLS

Performance tools can be divided into three categories: monitoring, collection, and analysis. You have reviewed a number of performance commands that can be executed on the Data ONTAP CLI. Most of the commands are in the monitoring category, but a few are in the collection category.

LESSON 1: ONCOMMAND INSIGHT

This lesson introduces OnCommand Insight and takes a look at the features and functions that OnCommand Insight provides.

What OnCommand Insight Provides

- 100% agentless, read-only access to storage, both SAN and NAS, and virtual server devices
- Multivendor and multiprotocol support
- End-to-end physical and logical visibility
- Performance analysis and optimization
- Risk identification and avoidance
- Built-in tools for root-cause analysis, capacity planning, and monitoring
- Tracking of capacity trends and forecasting
- Flexible enterprise and business-level reporting

NOTE: Insight does not provide provisioning or active management of devices.

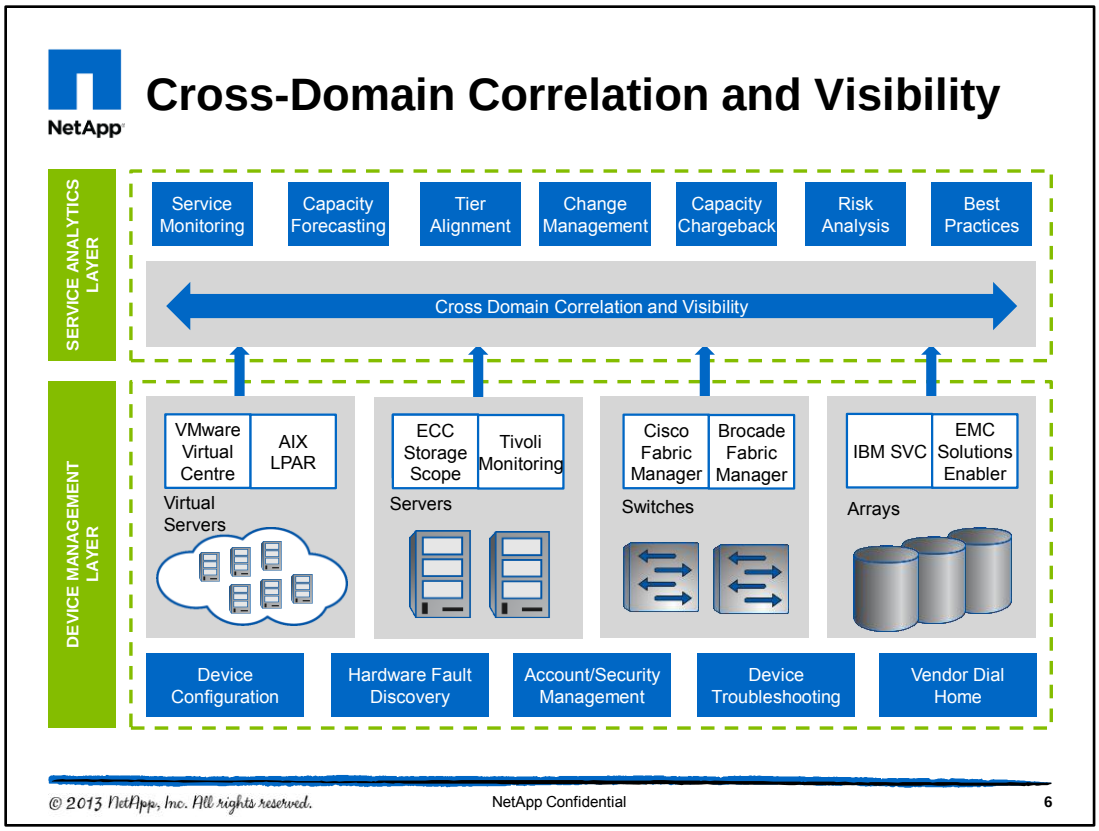
WHAT ONCOMMAND INSIGHT PROVIDES

OnCommand Insight is a suite of storage management software:

- Extends data-center automation—by providing agentless, heterogeneous, service-level views of both SAN and NAS storage environments
- Provides end-to-end data-center visibility—by discovering and gathering inventory data in real time from switches and multivendor storage arrays and identifying hosts
- Helps you manage storage proactively—by automatically correlating discovered data with application-relevant storage service paths
- Identifies all of the storage resources in the service path for an application
- Monitors changes to the storage environment as the changes are made
- Assesses the impact of changes on relevant services and applications, provides alerts about changed information, and provides root-cause analysis for faster troubleshooting

Because Insight is agentless, it does not provide host information. However, if EMC ECC (Enterprise Content Center) or Tivoli is in the environment, Insight can see host information. Insight also does not perform storage provisioning. You can plan for provisioning or create tasks to provision, but you cannot use Insight for active management.

After you add data sources are added to your Insight installation, you can identify relationships between the devices, view the paths in a topology view, and apply policies to devices and paths.



CROSS-DOMAIN CORRELATION AND VISIBILITY

The Insight configuration management system is specifically for the storage domain. The system sits logically above the device management layer, pulling information from physical and virtual server environments, from the storage network, and from storage systems. Insight then analyzes the information and correlates it into service paths. Service paths represent end-to-end data access between a host or virtual host and a volume.

Lesson 2

OnCommand Insight Perform

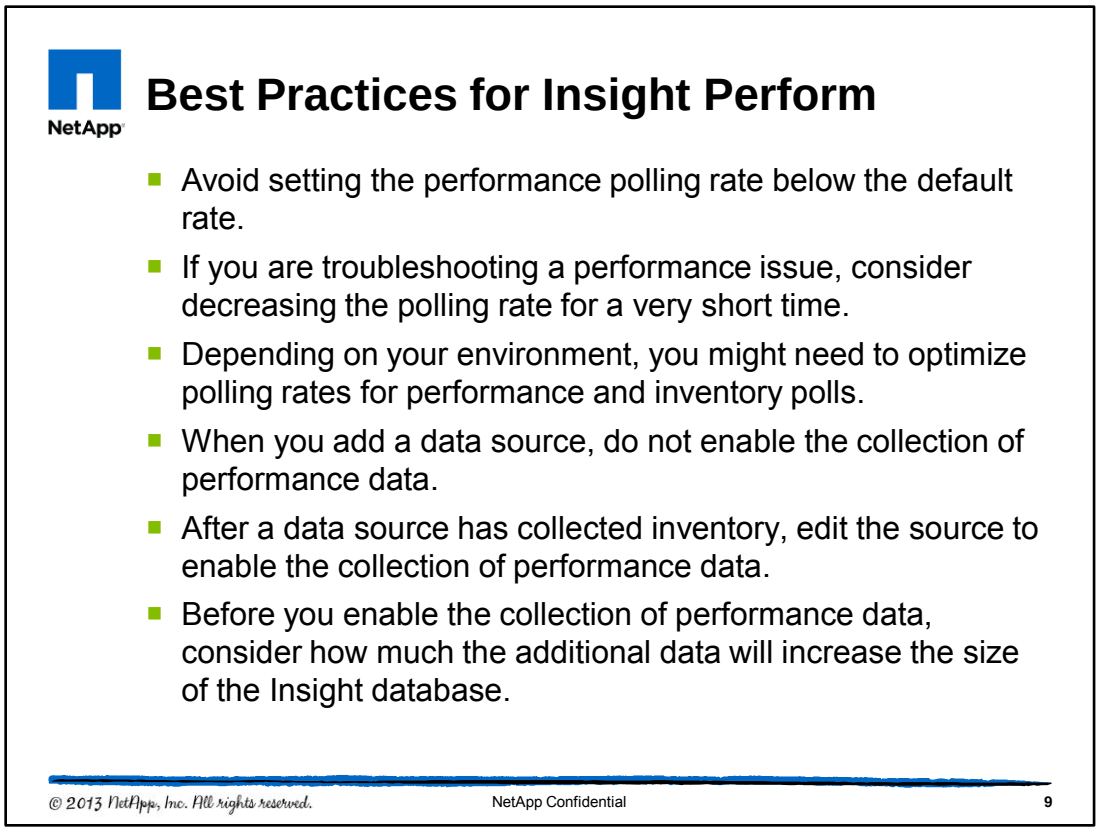
LESSON 2: ONCOMMAND INSIGHT PERFORM

What Insight Perform Does

Insight Perform collects and maintains service performance information that helps administrators

- Manage storage resources and services
- Manage SAN infrastructure resources
- Optimize virtual server and virtual machine (VM) resources
- Reclaim over utilized and under utilized storage resources
- Optimize and manage tiers
- Analyze storage-virtualization efficiency
- Optimize the virtual-host environment
- Improve load balancing
- Troubleshoot performance-related congestion and contention
- Improve resource utilization to optimize services

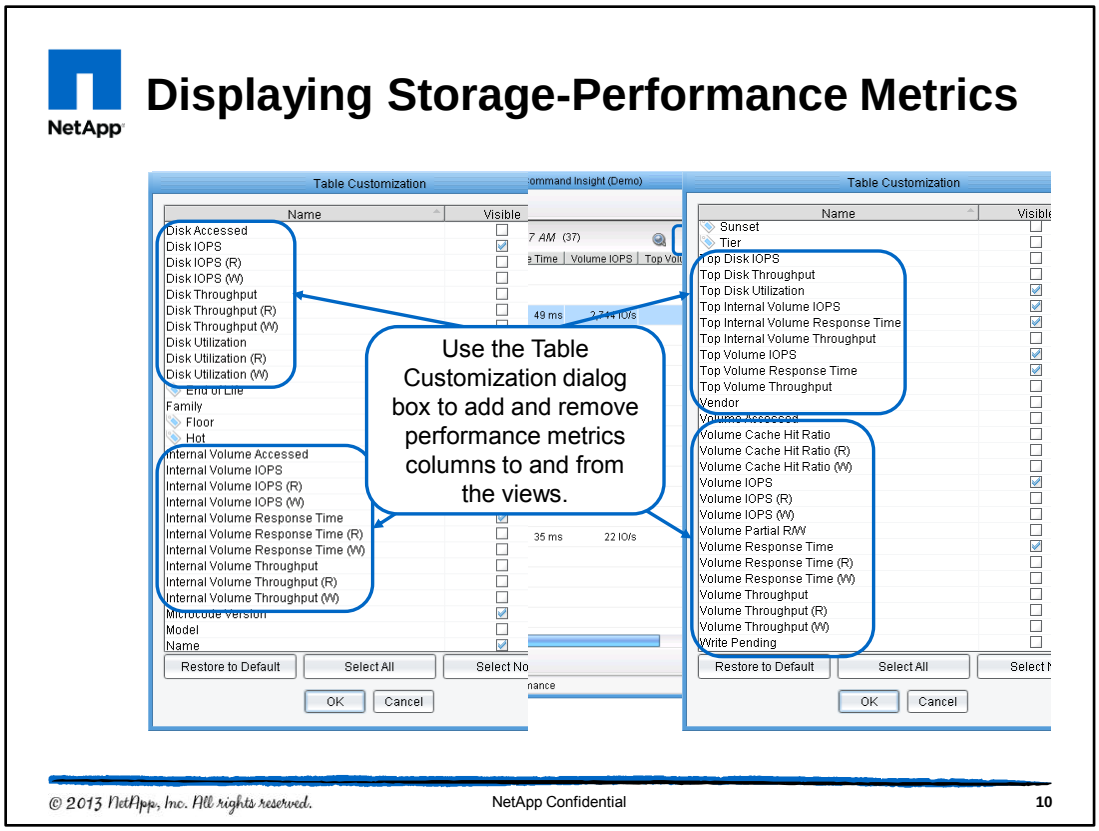
WHAT INSIGHT PERFORM DOES



BEST PRACTICES FOR INSIGHT PERFORM

By setting the performance polling rate below the default, you avoid placing an unnecessarily heavy load on the device that is trying to respond to the polls.

If you decrease the polling rate (as you are troubleshooting an issue), be sure to return to the original polling rate after you resolve the issue.



DISPLAYING STORAGE-PERFORMANCE METRICS

Insight Perform retains performance metrics for 14 days, after which it rolls the metrics into a histogram.

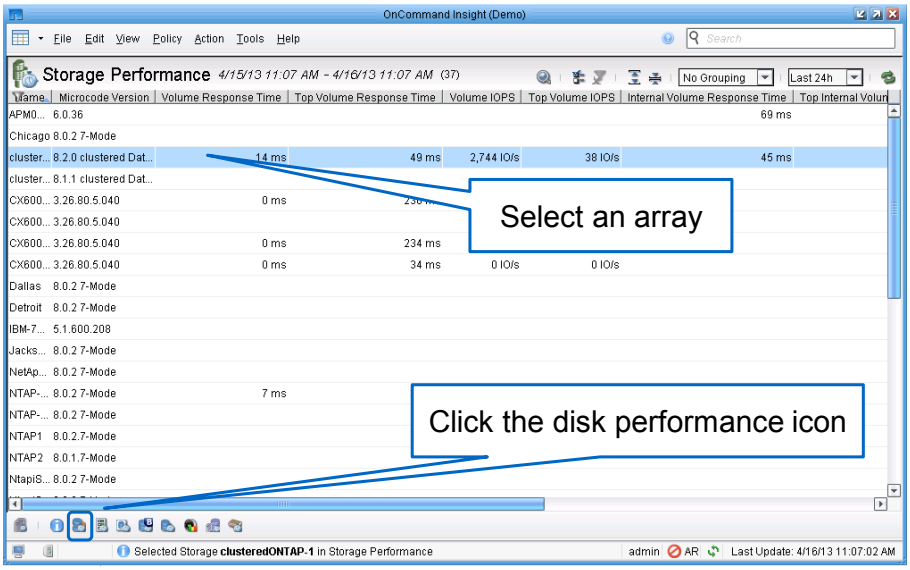
During the extract, transform, load (ETL) process, Insight Perform uploads some performance information to the data warehouse This information is used for analysis and enterprise-level reporting. In the data warehouse, performance data is aggregated with capacity information from Insight Plan to provide for reporting of capacity versus IOPS at the enterprise, array, volume, internal volume, and disk levels. The combination of performance data and capacity data provides unique information about how the capacity is being accessed, how often it is being accessed, and which workloads (applications) are accessing it. From the performance and capacity data, you can also determine how applications and business entities (the owners of the applications) are using storage and VM resources.

Performance metrics are displayed in the Storage Performance table.

To add or remove columns to and from the Storage Performance table, you use the Table Customization dialog box. To open the Table Customization dialog box, in the Storage Performance table, click the table customization icon.

In the dialog box, select the checkboxes of the items that you want to add and clear the checkboxes of the items that you want to remove.

Selecting Arrays

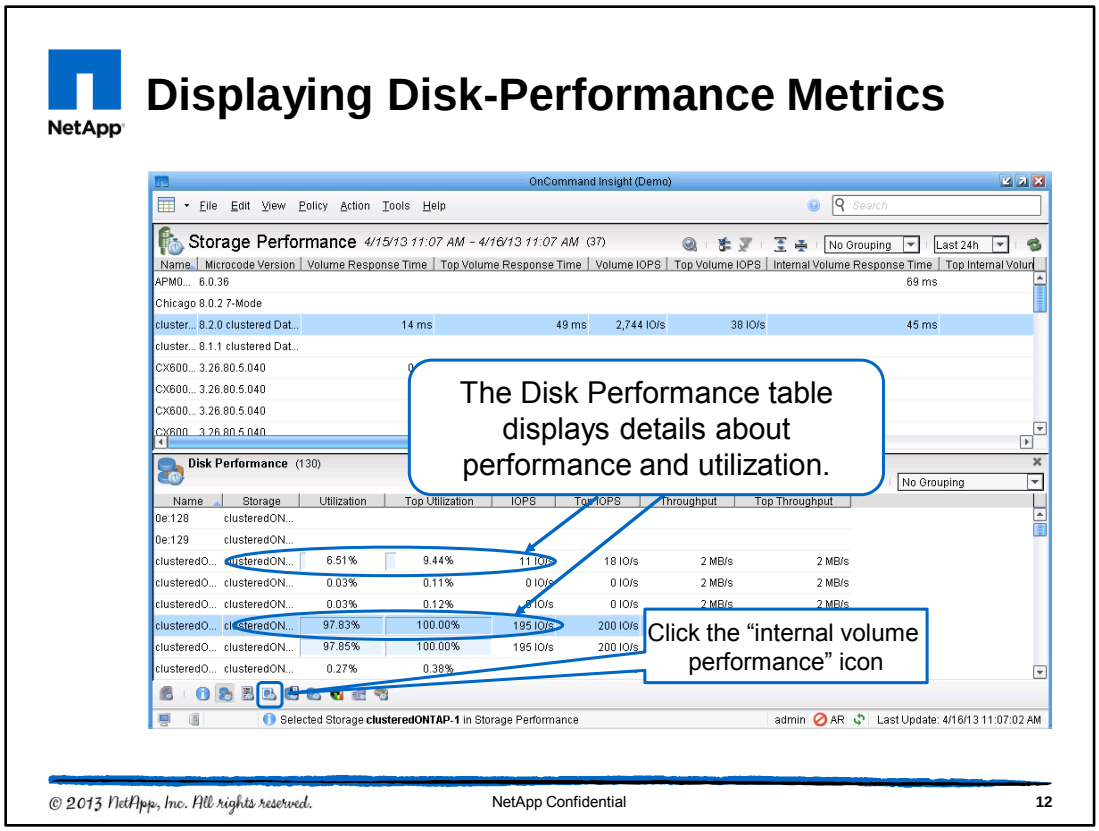


SELECTING ARRAYS

Insight Perform collects performance information from many vendor arrays. Most of the information that is reported from the arrays is in the same format.

To review the performance information collected and displayed for a clustered Data ONTAP array, do the following:

1. In the Storage Performance table, select a clustered Data ONTAP array.
2. Click the disk performance icon to display information about disks.



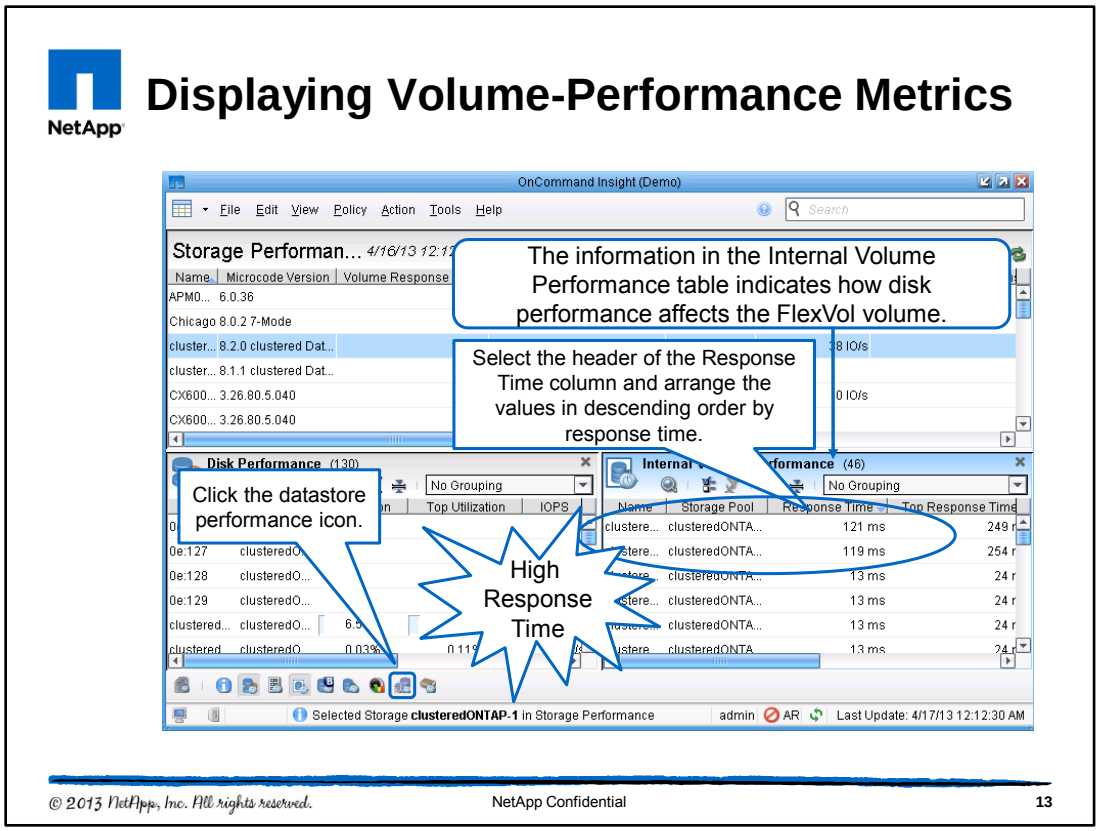
DISPLAYING DISK-PERFORMANCE METRICS

The Disk Performance table displays detailed disk-performance information for the NetApp arrays that you select. You can add and remove items to and from the table, just as you did with the Storage Performance table.

You can use disk-performance information to quickly identify disks that have high and low usage and to optimize the disks in the storage pools.

If you select multiple arrays in the Storage Performance table, all of the disks from the selected arrays are listed in the Disk Performance table. For example, you can sort by the utilization or top utilization columns to review the performance of all of the disks in the cluster at the same time.

To display information about volumes, click the “internal volume performance” icon.

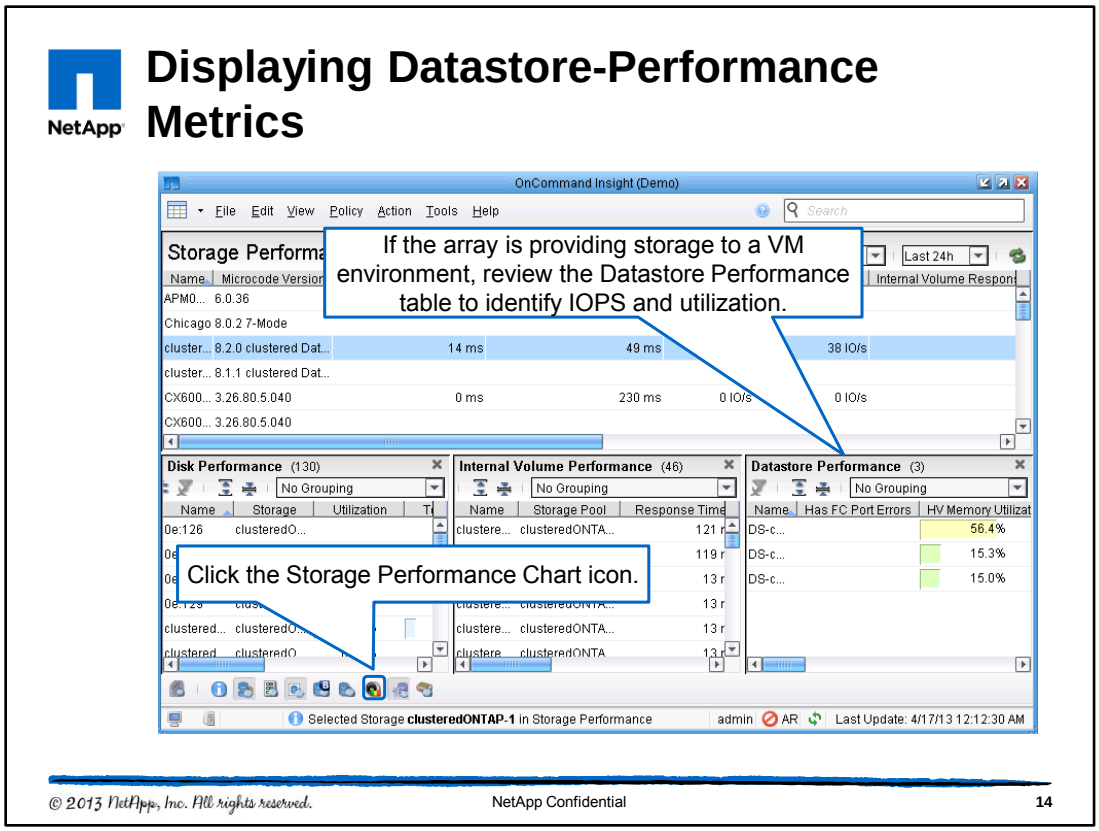


DISPLAYING VOLUME-PERFORMANCE METRICS

The Internal Volume Performance table displays response time, throughput, and IOPS for the FlexVol volumes of the clustered Data ONTAP array that you selected. If you selected multiple arrays, you can see all of the FlexVol volumes in the cluster.

If you select the header of Response Time column, you can sort the table, so that the volumes are listed by response time (highest to lowest). You can use the scroll bar to display additional volumes.

To display information about datastores, click the datastore performance icon.

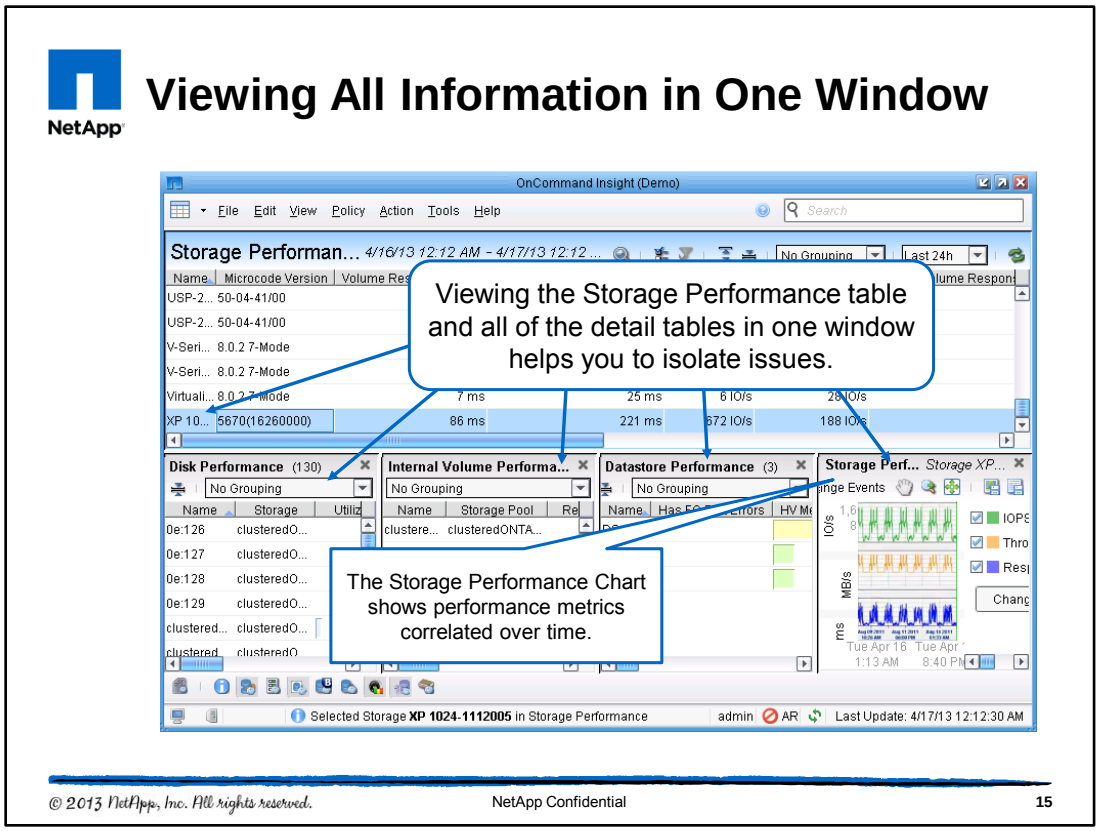


DISPLAYING DATASTORE-PERFORMANCE METRICS

Assume that you selected an array that provides storage to a VM environment. In this case, Insight Perform increases the amount of performance information that is provided about the virtual environment.

The Datastore Performance table displays performance information, including virtual machine disk (VMDK) IOPS, VMDK throughput, and latency. The table also provides information about the CPU and memory utilization for the hypervisor. Using the slidebar, you can review storage performance metrics for each hypervisor.

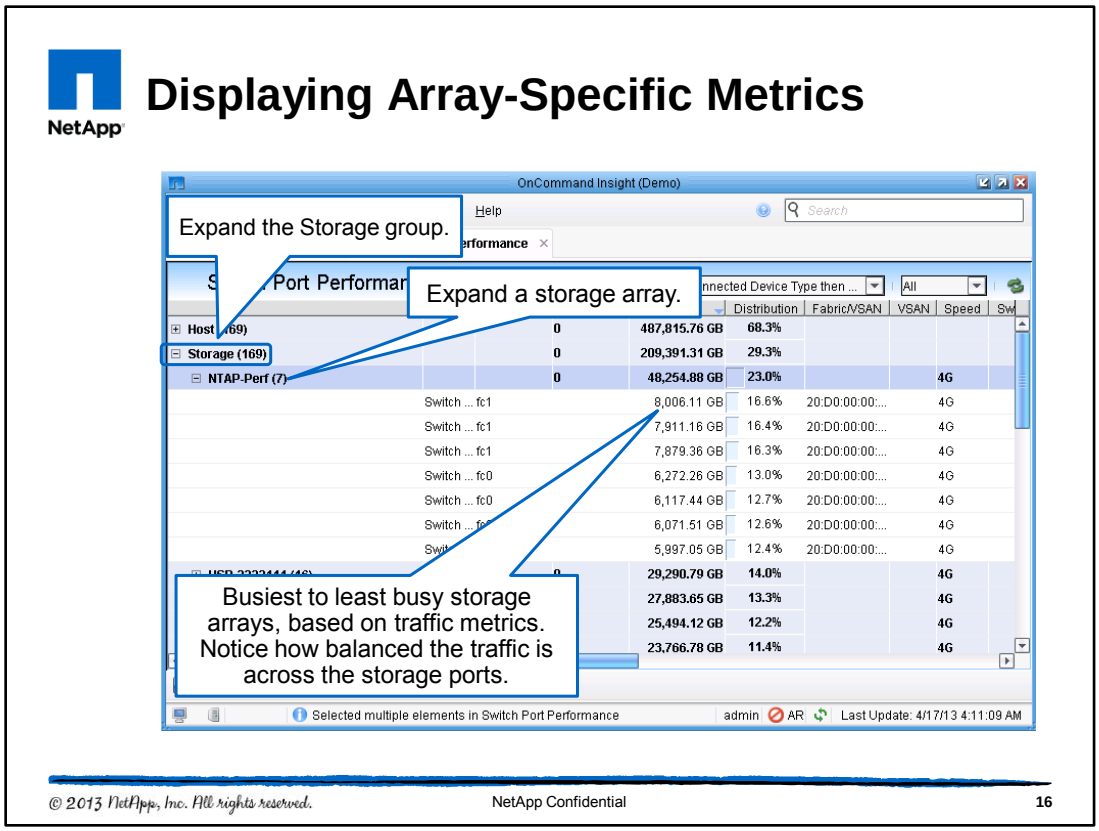
To view information about trends, click the “storage performance chart” icon.



VIEWING ALL INFORMATION IN ONE WINDOW

You can use the Storage Performance chart to identify and analyze performance trends and to develop your understanding of how performance metrics are related.

The window is crowded, so the details of the program information can be difficult to review. But, being able to see all of the information in one window can help you identify and isolate issues. Then, you can select one or more tables and one or more columns, sort the information, and navigate to the details that you need.



DISPLAYING ARRAY-SPECIFIC METRICS

Expand first the Storage group and then a storage array.

The Value column indicates how traffic is balanced across the storage ports.

Scroll to the bottom of the Storage list. You might be surprised to find that some expensive tier 1 arrays are hardly being accessed. You can move the applications that are accessing the expensive tiers to less expensive tier 2 or tier 3 arrays, and you can archive any application that you no longer need. Then, to further reduce the cost of storage, you can optimize, repurpose, or decommission arrays.

NOTE: The least busy arrays *might* be the arrays that contain the most storage. However, the storage is likely to be dead, rather than active. An array that is 80% full might be less than 20% used.

Lesson 3

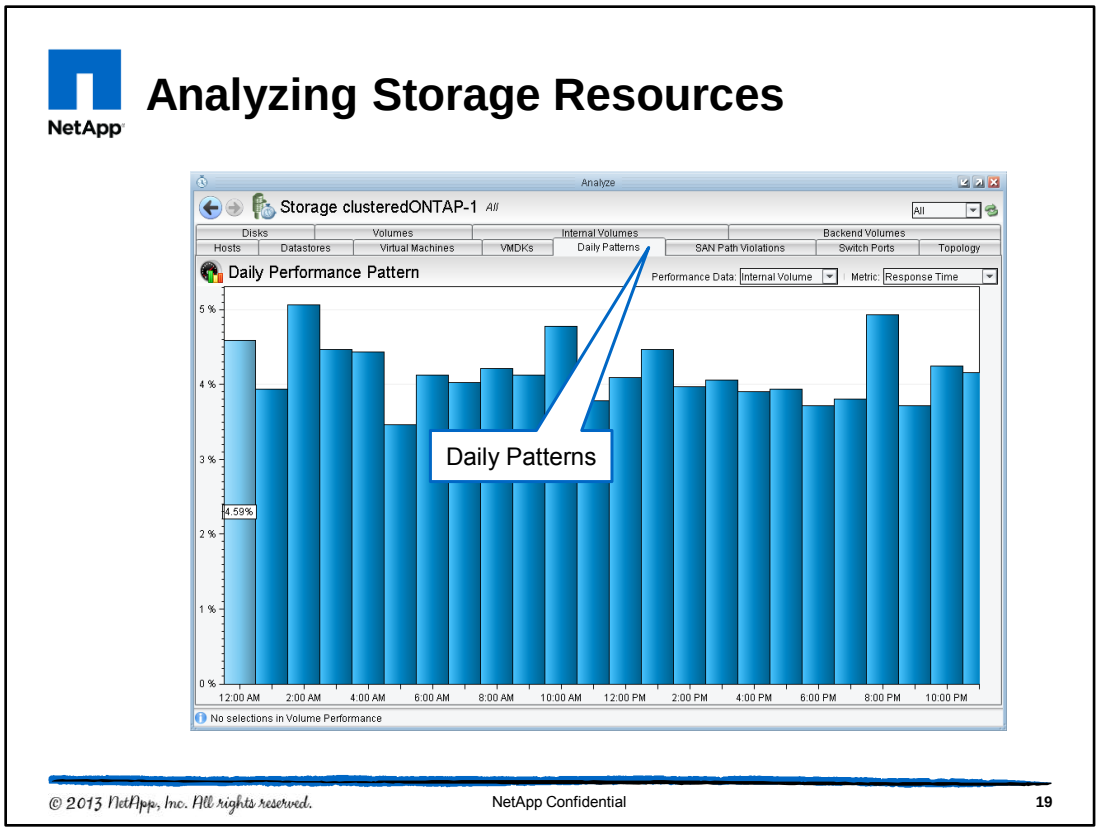
Analyzing Performance with OnCommand Insight Perform

LESSON 3: ANALYZING PERFORMANCE WITH ONCOMMAND INSIGHT PERFORM

Tools for Analyzing Functionality

Function	Tool	Description
Analyze	Insight Perform	Analyze the performance of storage resources that have been affected by a violation
Analyze contention	Insight Perform	Determine the reasons for poor performance and identify where performance is degraded
Analyze storage pools	Insight Assure	Analyze a storage pool and assess its status relative to thin-provisioning policies

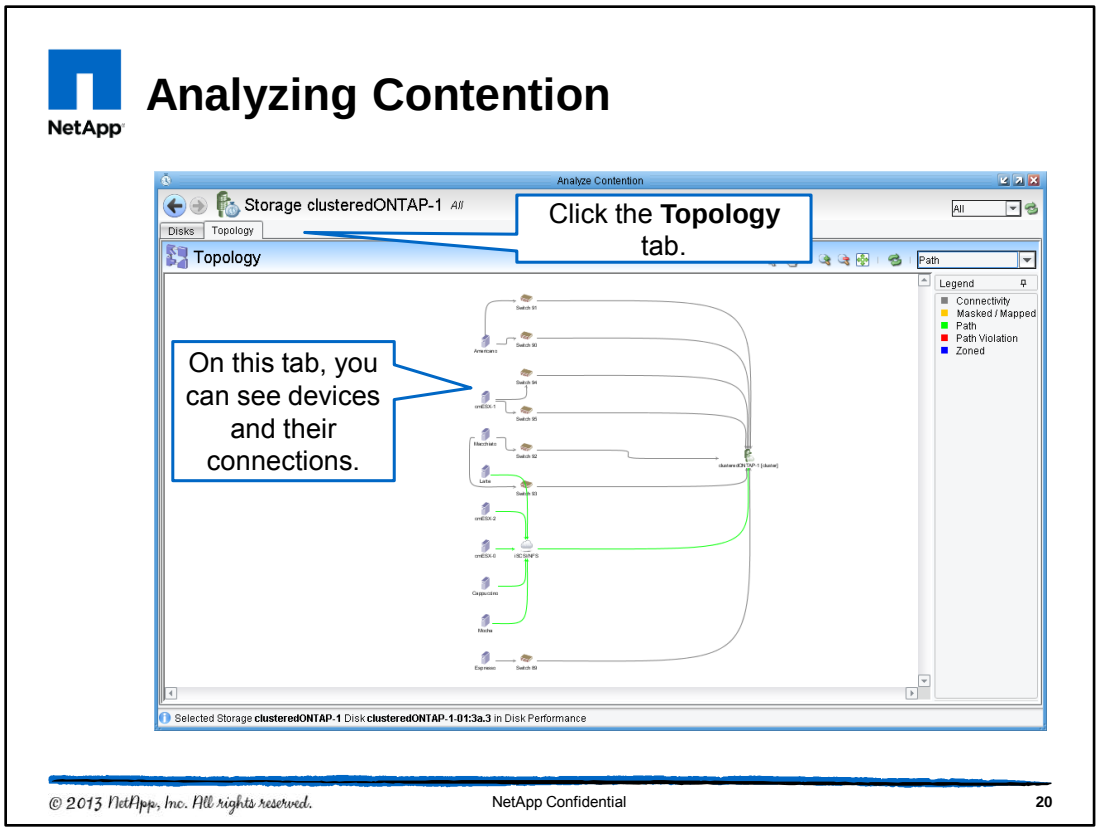
TOOLS FOR ANALYZING FUNCTIONALITY



ANALYZING STORAGE RESOURCES

To analyze storage resources for a clustered Data ONTAP array:

1. Right-click the array, and select **Analyze**.
   The Analyze dialog box is displayed, with the Disks tab selected by default. You click each of the tabs, in turn, to view information about the array from various perspectives.
2. Click the **Volumes** tab.
   From this tab, you can review the performance of volumes and internal volumes.
3. Click the **Hosts** tab.
   From this tab, you can view the performance of the storage that is related to the hosts and also the performance of internal ESX servers.
4. Click the **Daily Patterns** tab.
   From this tab, you can view performance patterns for disks, internal volumes, volumes, and back-end volumes. You can also review metrics such as response time, IOPS, and throughput.



ANALYZING CONTENTION

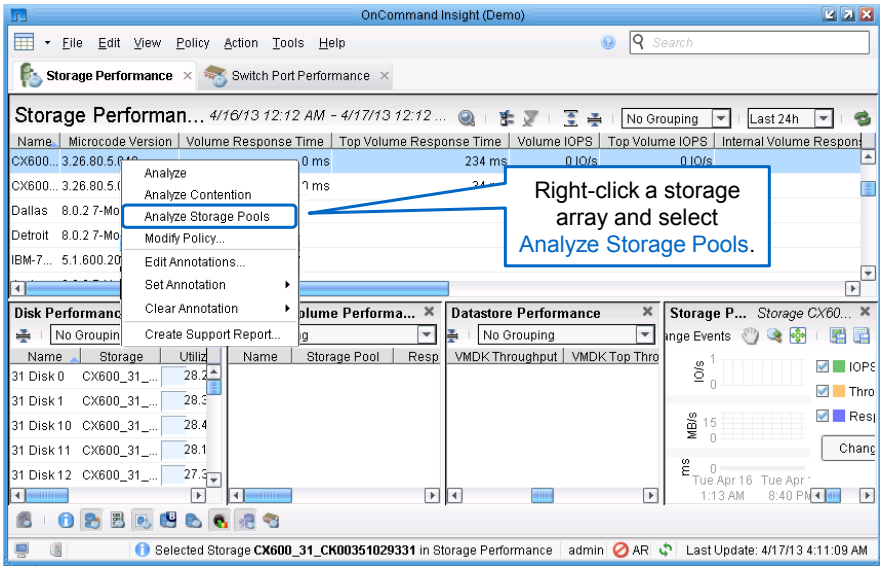
The Analyze Contention dialog box enables you to determine the reasons for poor performance and to identify where performance is degraded.

To analyze contention:

1. Right-click a storage array that is performing poorly and select **Analyze Contention**.
   The Analyze Contention dialog box is displayed. The Disks tab, which contains the Disk Performance table, is selected.
2. Review the performance data for the applications that are listed on the Disks tab.
   In this example, three applications are running on the storage array. Two applications, Consumer Feedback and Heat Loss Calculations, are from different business units but use storage from the same disks. These two applications are causing high utilization. The QA application has acceptable utilization.
3. Click the **Topology** tab.
   This tab provides a diagram of the hosts that are using the array, as well as the various topologies involved.

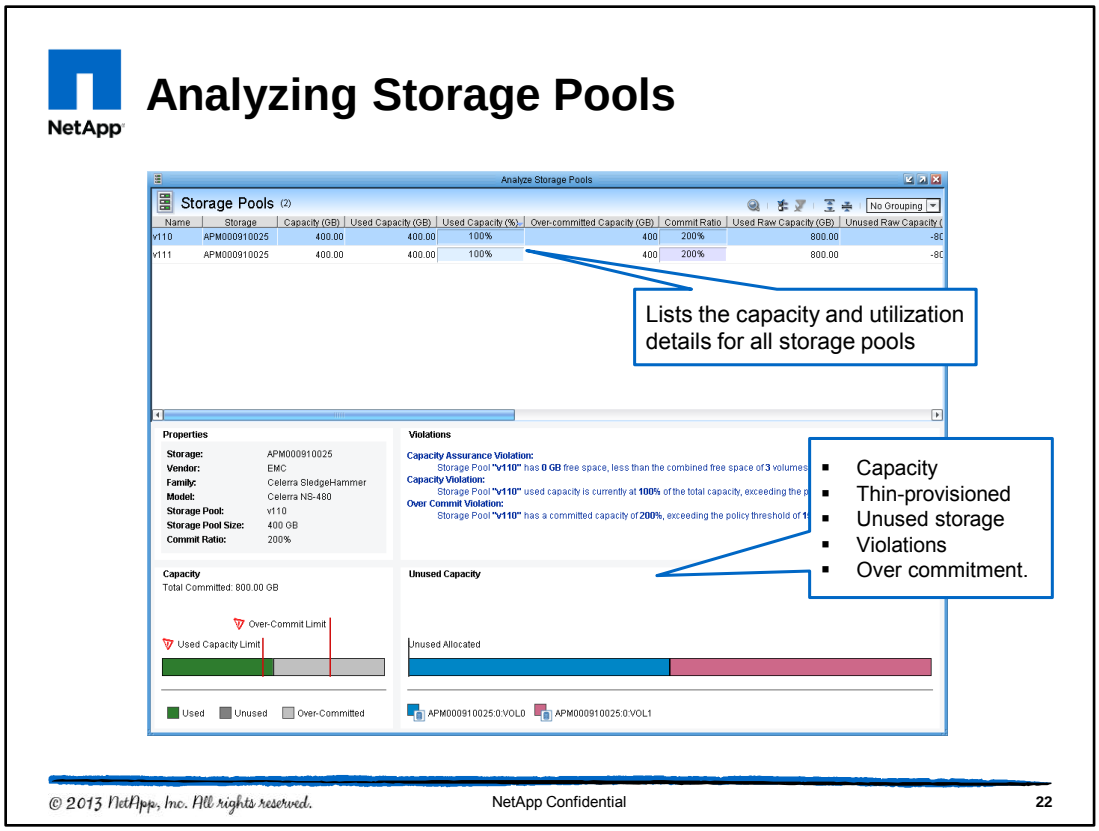
Using the information from the Analyze Contention dialog box, you have identified an issue and can now move one of the applications to a volume that uses other disks.

Selecting a Storage Pools Option



SELECTING A STORAGE POOLS OPTION

In the Storage Performance table, right-click a storage array that includes thin-provisioned storage pools and select **Analyze Storage Pools**.



ANALYZING STORAGE POOLS

Using the Analyze Storage Pools dialog box, you can determine how close a thin-provisioned storage pool is to reaching its policy limit.

The Storage Pools summary pane provides performance and configuration information about:

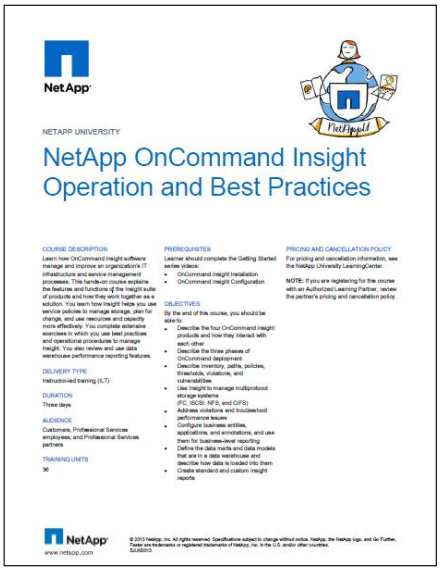
- Storage pools
- Thin provisioning
- Used storage versus the overcommitment rate
- Violations of thin provisioning policies

Using data from the Analyze Storage Pools dialog box, you can review all storage pools and troubleshoot thin-provisioning issues. You can also use this dialog box, instead of the Violations Browser pane, to proactively review thin-provisioning violations and determine how close the storage pool is to reaching the policy limits.

Additional Training
OnCommand Insight

For in-depth, hands-on training on OnCommand Insight, visit the NetApp Learning Center and enroll in NetApp OnCommand Insight Operations and Best Practices

- Instructor-led training (ILT)
- Three days


NETAPP UNIVERSITY

NetApp OnCommand Insight Operation and Best Practices

COURSE DESCRIPTION

Learn how OnCommand Insight software manage and improve an organization's IT infrastructure and service management processes. This hands-on course explains the features and functions of the Insight suite of products and how they work together as a solution. You learn how Insight helps you use service policies to manage storage, plan for change, and use resources and capacity more effectively. You complete extensive exercises in which you use best practices and operational procedures to manage Insight. You also review and use data warehouse performance reporting features.

DELIVERY TYPE

Instructor-led training (ILT)

DURATION

Three days

AUDIENCE

Customers, Professional Services employees, and Professional Services partners

TRAINING UNITS

36

PREREQUISITES

Learner should complete the Getting Started series videos:

- OnCommand Insight Installation
- OnCommand Insight Configuration

OBJECTIVES

By the end of this course, you should be able to:

- Describe the four OnCommand Insight products and how they interact with each other
- Describe the three phases of OnCommand deployment
- Describe inventory, paths, policies, thresholds, violations, and vulnerabilities
- Use Insight to manage multiprotocol storage systems (FC, iSCSI, NFS, and CIFS)
- Address violations and troubleshoot performance issues
- Configure business entities, applications, and annotations, and use them for business-level reporting
- Define the data marts and data models that are in a data warehouse and describe how data is loaded into them
- Create standard and custom Insight reports

PRICING AND CANCELLATION POLICY

For pricing and cancellation information, see the NetApp University LearningCenter.

NOTE: If you are registering for this course with an Authorized Learning Partner, review the partner's pricing and cancellation policy.

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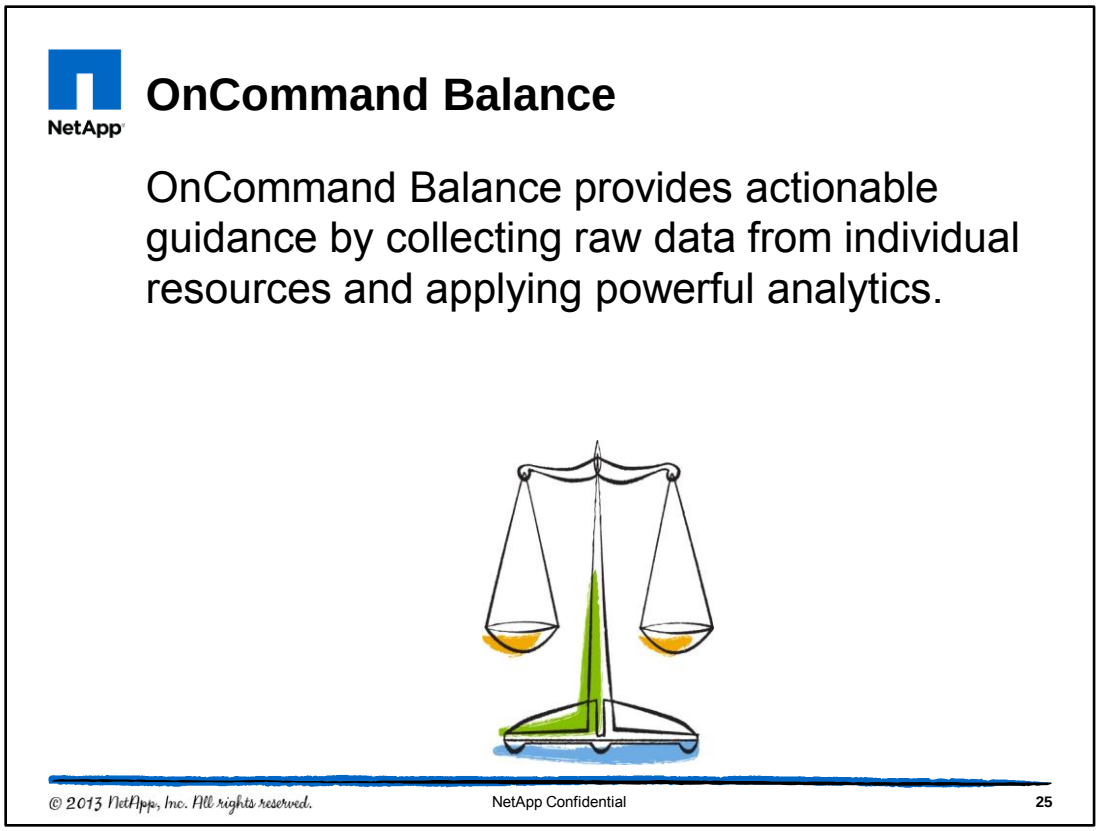
ADDITIONAL TRAINING: ONCOMMAND INSIGHT

Lesson 4

OnCommand Balance

LESSON 4: ONCOMMAND BALANCE

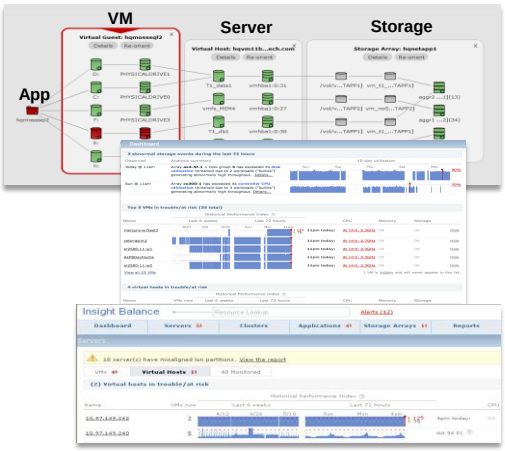


ONCOMMAND BALANCE

OnCommand Balance provides directions to optimize the performance and capacity of shared infrastructures. Unlike some products that simply deliver statistics, OnCommand Balance provides actionable guidance by collecting raw data from individual resources and applying powerful analytics. It's the analytics that provide the intelligence, giving actionable information and directions that are beyond the capabilities of a dashboard.

Features of OnCommand Balance

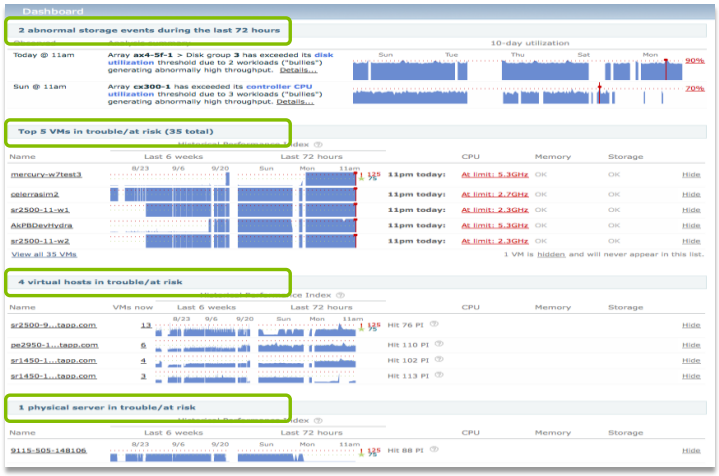
- Troubleshoot issues
  - Visibility: Is it VM, server, storage?
  - Which workloads are victims and which are bullies?
- Optimize performance
  - How much headroom do I have?
  - Where can I put my VM or application for best performance?
- Predict problems
  - How can I proactively avoid bottlenecks?
  - How can I avoid issues?



FEATURES OF ONCOMMAND BALANCE

OnCommand Balance helps in three areas of performance analysis: troubleshooting, optimization, and problem prediction.

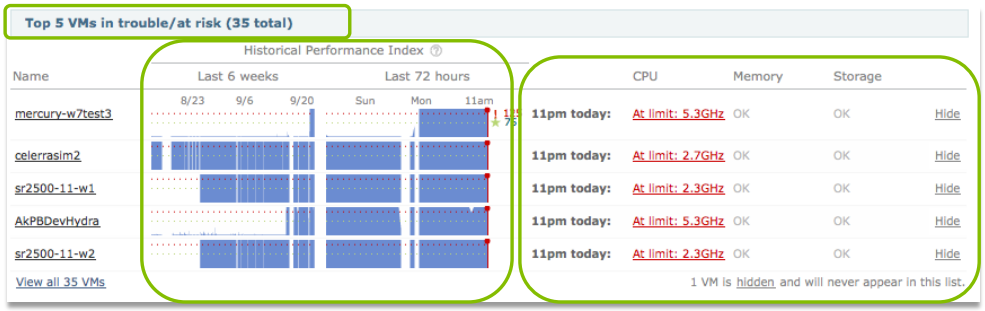
OnCommand Balance
Dashboard



ONCOMMAND BALANCE: DASHBOARD

With one glance, administrators can see which resources are experiencing contention and other performance problems and which of their analytics or key performance indicators have exceeded their thresholds.

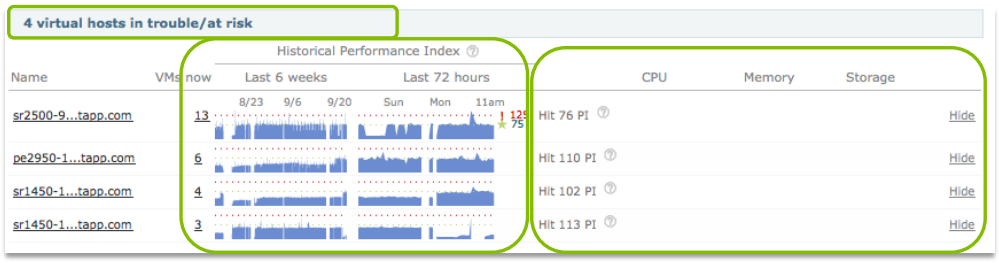
OnCommand Balance
VM Alerts



- Identify poorly performing VMs
- Identify the root causes of performance issues and quickly locate under-provisioned VMs (CPU, memory, and storage)

ONCOMMAND BALANCE: VM ALERTS

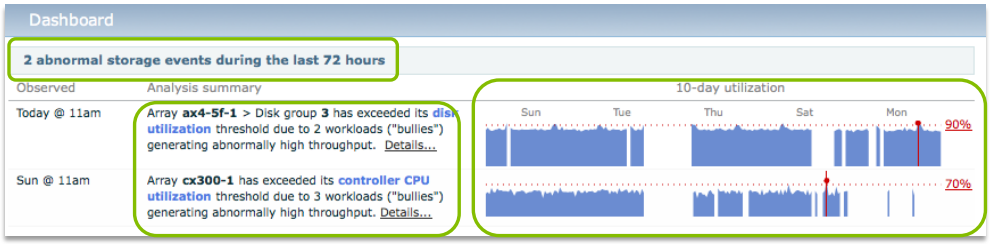
OnCommand Balance
Virtual Host Alerts



- Identify poorly performing virtual hosts, including under-provisioned or misconfigured hosts
- Identify the root causes of performance issues and quickly locate under-provisioned hosts (CPU, memory, and storage)
- Identify VM workloads for offloading, making resource management extremely efficient

ONCOMMAND BALANCE: VIRTUAL HOST ALERTS

OnCommand Balance
Storage Alerts

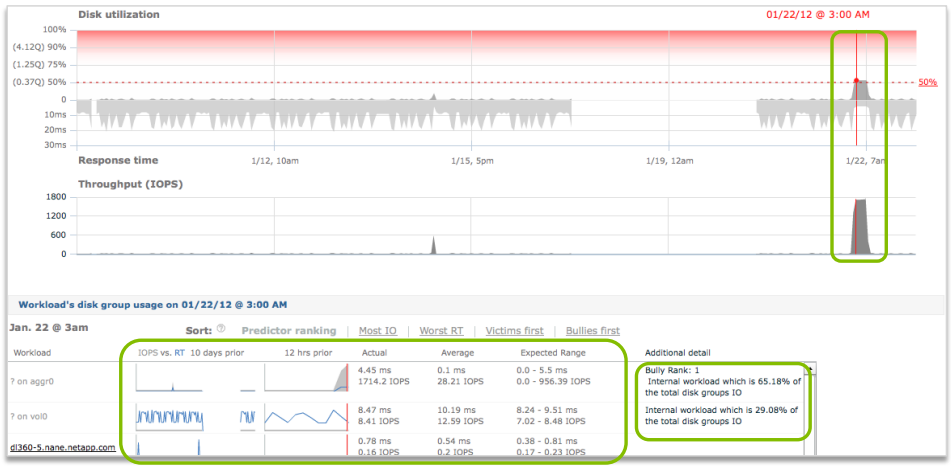


- Alerts on abnormal events are provided.
- Analysis identifies the root cause (bully) of a performance issue and the affected VMs or hosts (victims).

ONCOMMAND BALANCE: STORAGE ALERTS

The storage health panel alerts administrators to abnormal storage events and lists the arrays that have experienced a performance alert in the last 72 hours. The display includes a 10-day utilization chart for alerting analytics, alert explanations, and links for access to detailed analyses.

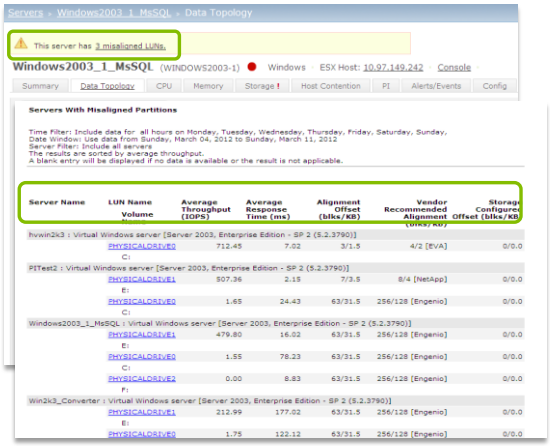
OnCommand Balance
Workload Alerts



ONCOMMAND BALANCE: WORKLOAD ALERTS

As a result of disk scrubbing, Balance can display the internal workload of a disk group. This visibility helps administrators understand how application workloads are impacted by internal workloads.

OnCommand Balance
Server Alerts



- Detect misaligned LUNs before I/O issues occur
- Identify whether misaligned LUNs are impacting performance
- See through server and storage virtualization
- Help ensure that the layout of the VMware environment is safe
- Can be viewed in the GUI or in a report

ONCOMMAND BALANCE: SERVER ALERTS

OnCommand Balance detects misaligned LUNS and partitions that can lead to performance degradation. With just one click, you can display a detailed analysis of the misaligned LUNS (the LUN, average throughput and response time, and manufacturer's recommended alignment configurations).

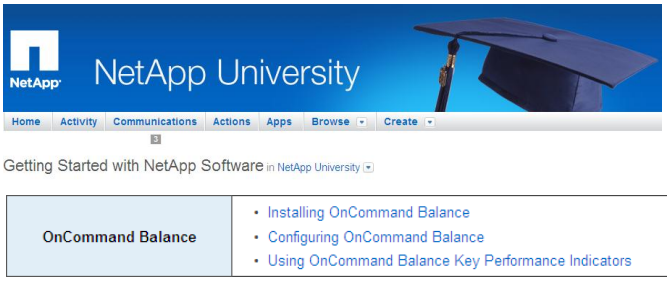
OnCommand Balance can be leveraged to predict and resolve performance problems, optimize workloads, plan capacity to ensure the best possible performance level for the lowest cost, and manage the infrastructure service that supports your applications.

Additional Training

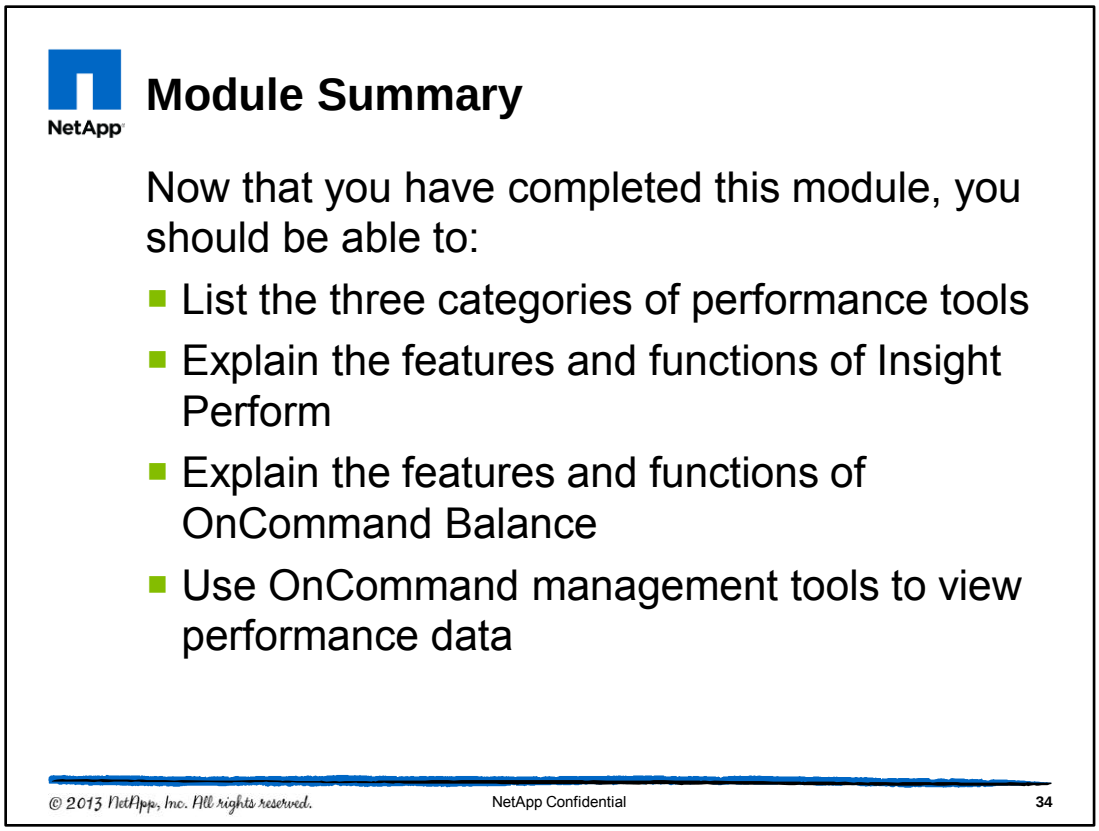
OnCommand Balance

For in-depth training on OnCommand Balance, visit the NetApp Learning Center and enroll in the NetApp OnCommand Balance Getting Started Series.

http://www.netapp.com/gettingstarted



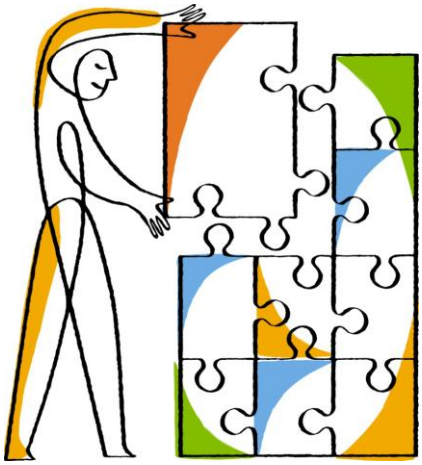
ADDITIONAL TRAINING: ONCOMMAND BALANCE



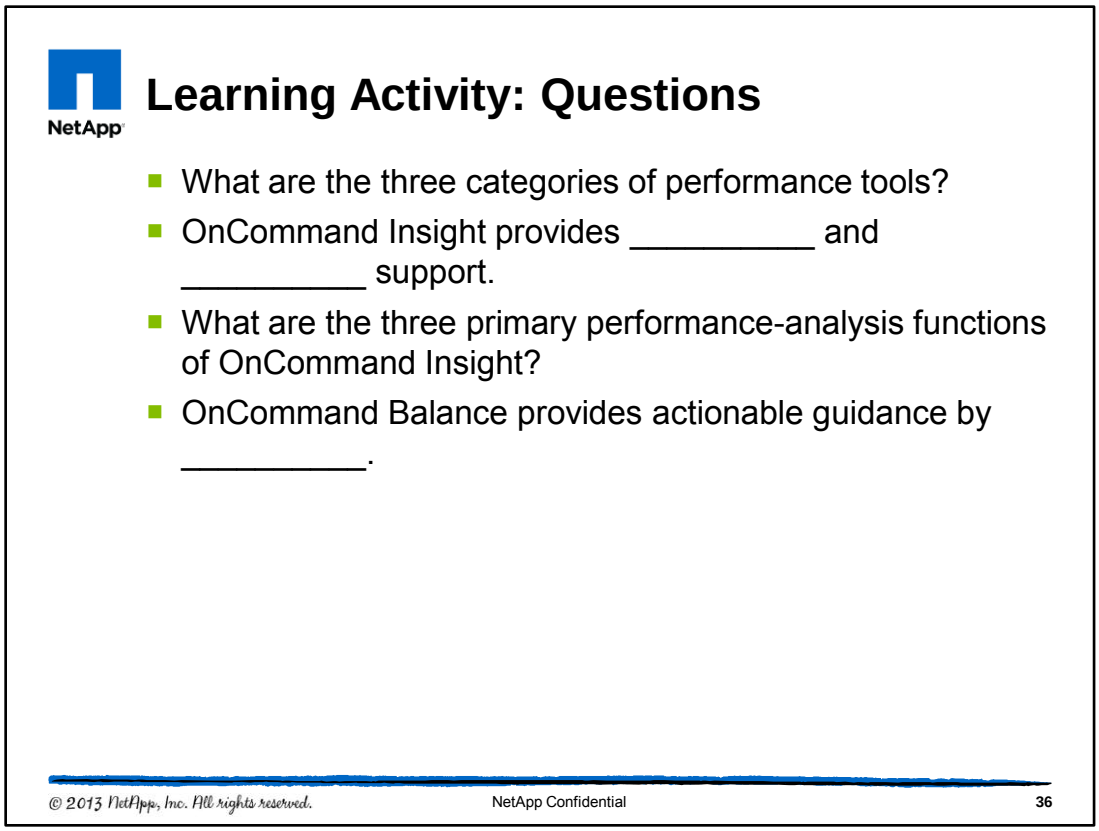
MODULE SUMMARY

Learning Activity Questions

Module 5: OnCommand Management Tools



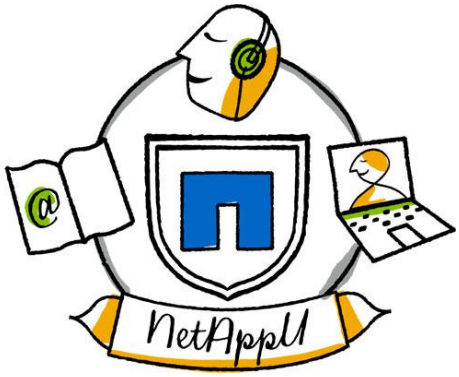
LEARNING ACTIVITY QUESTIONS



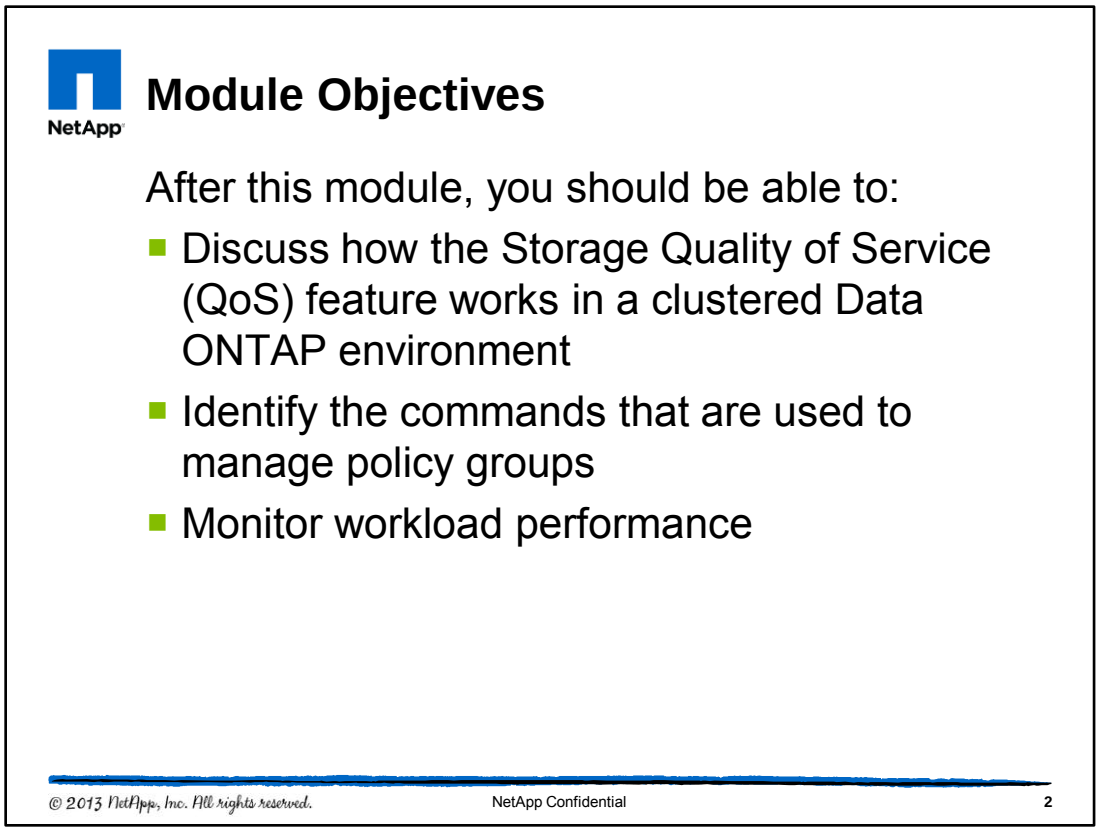
LEARNING ACTIVITY: QUESTIONS

Module 6

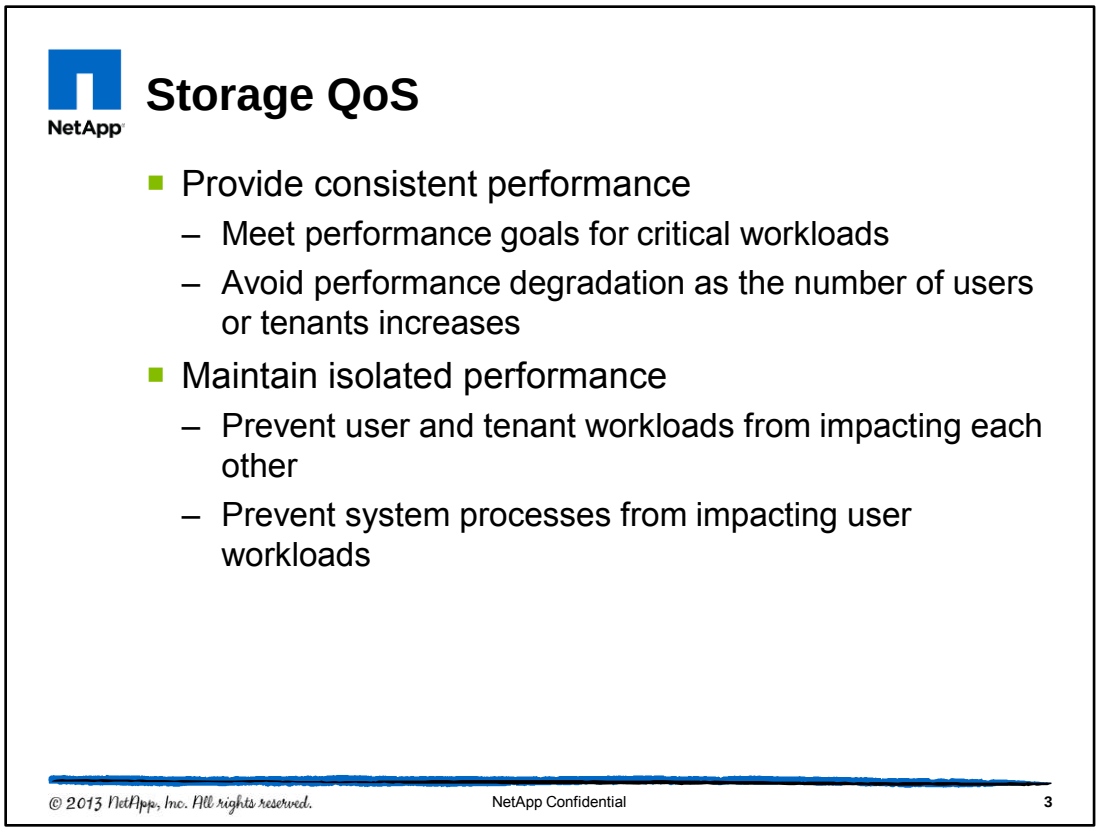
Storage QoS



MODULE 6: STORAGE QOS



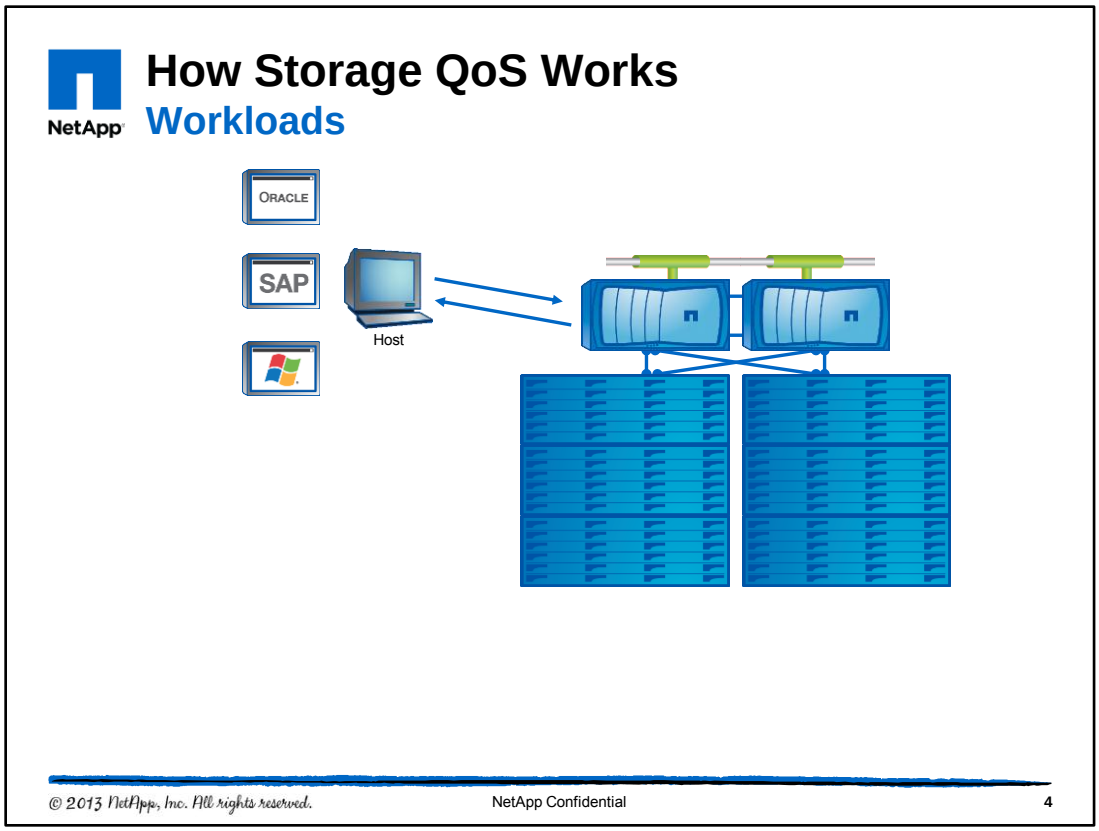
MODULE OBJECTIVES



STORAGE QOS

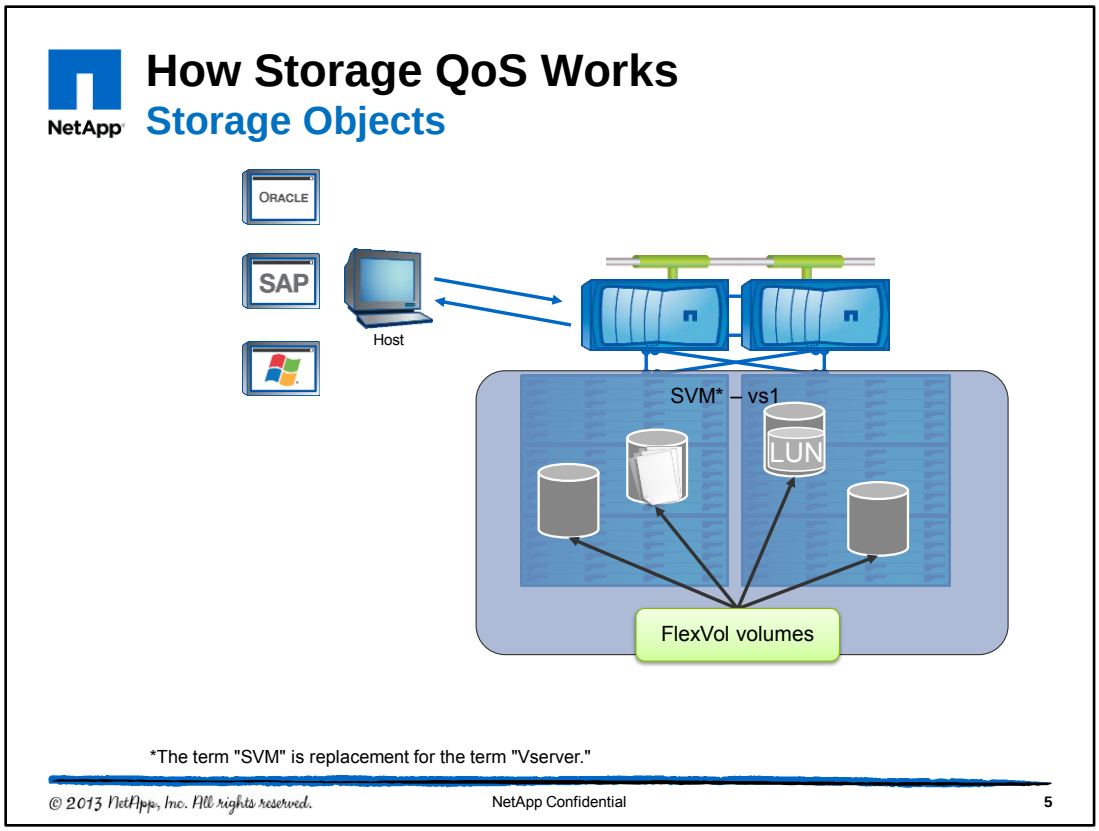
The Storage Quality of Service (QoS) feature of clustered Data ONTAP 8.2 enables administrators to reactively limit throughput to workloads and proactively monitor workload performance. To accomplish these tasks, administrators associate workloads with QoS policy groups.

NOTE: The Storage QoS feature does not guarantee service levels. It is designed to set throughput limits.



HOW STORAGE QOS WORKS: WORKLOADS

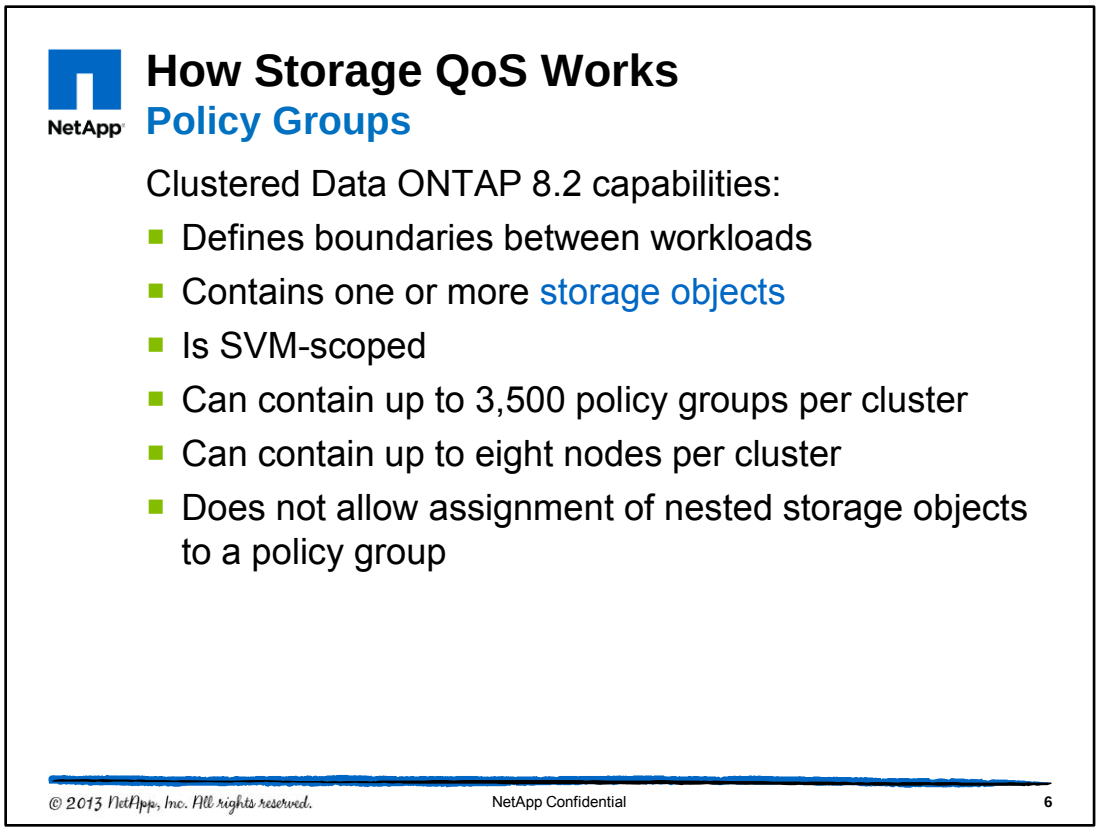
A workload is the input and output operations of a storage object.



HOW STORAGE QOS WORKS: STORAGE OBJECTS

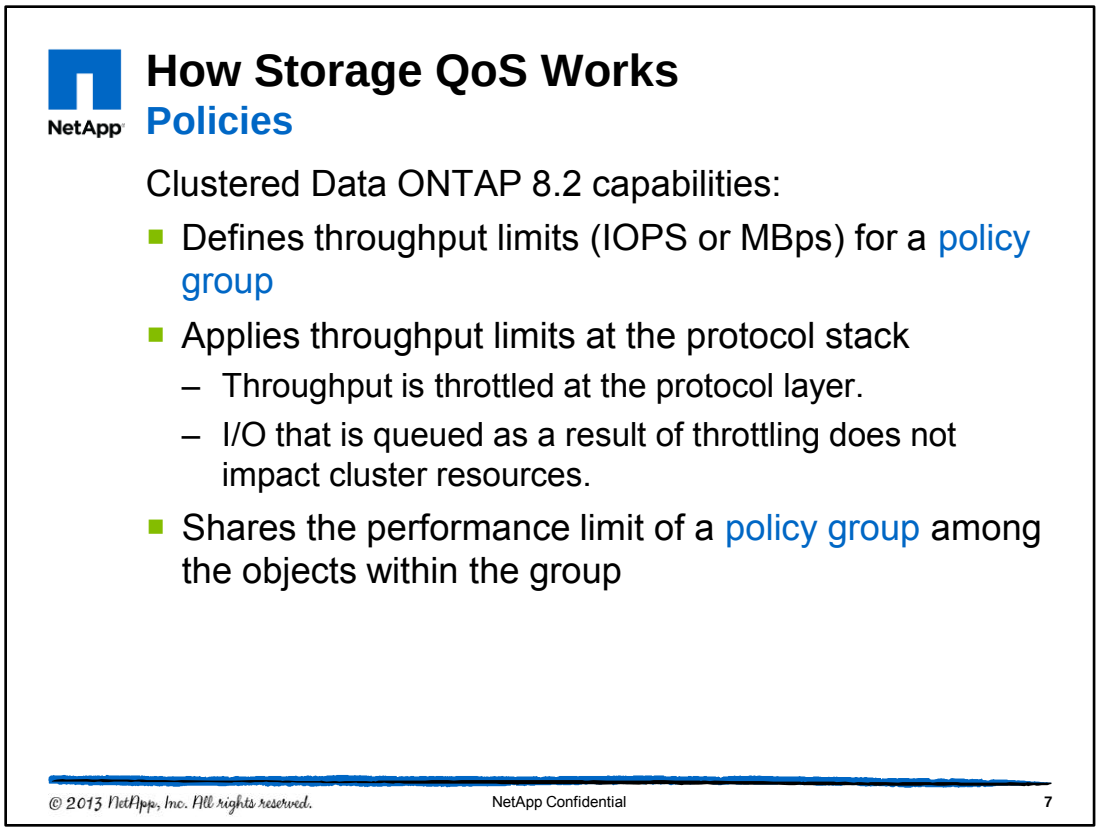
A storage object is a storage virtual server (SVM) with FlexVol volumes, a FlexVol volume, a LUN, or a file (which typically represents a virtual machine).

NOTE: The term “SVM” is a replacement for the term “Vserver”: two terms, one meaning. This course uses both “SVM” and “Vserver.”



HOW STORAGE QOS WORKS: POLICY GROUPS

By associating workloads with QoS policy groups, administrators can monitor workload performance and identify the level of performance of each workload. They can then associate policy groups with higher performing workloads. Thereby, they can throttle the higher performing workloads, make resources available to underperforming workloads, and improve overall performance.



HOW STORAGE QOS WORKS: POLICIES

When objects share a policy group, each object shares in the performance limit of the group, as opposed to each object having its own performance limit.

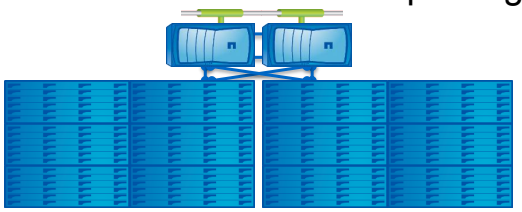
When to Use Storage QoS

- Reactively respond to problem workloads

  Throttle workloads that are performing beyond SLAs
- Proactively prevent workloads from becoming a problem

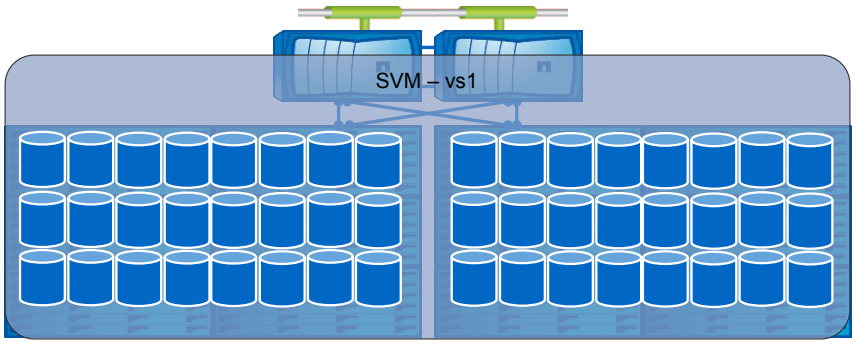
  Set workload limits before problems occur
- Isolate tenant workloads

  Prevent user and tenant workloads from impacting each other



WHEN TO USE STORAGE QOS

When to Use Storage QoS
Reactive

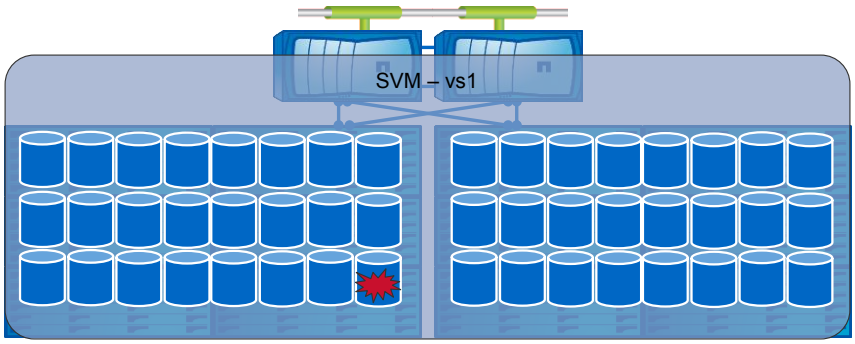


Reactive Scenario

- Storage administrator has not set QoS policies.

WHEN TO USE STORAGE QOS: REACTIVE

When to Use Storage QoS
Reactive

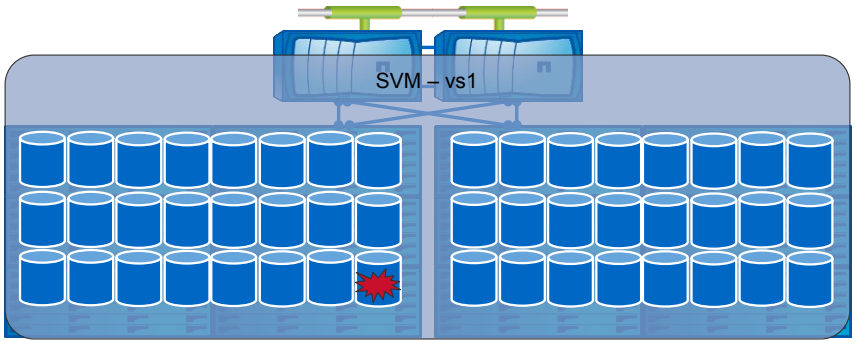


Reactive Scenario

- Storage administrator has not set QoS policies.
- A workload impacts the performance of other workloads.

WHEN TO USE STORAGE QOS: REACTIVE

When to Use Storage QoS
Reactive



Reactive Scenario

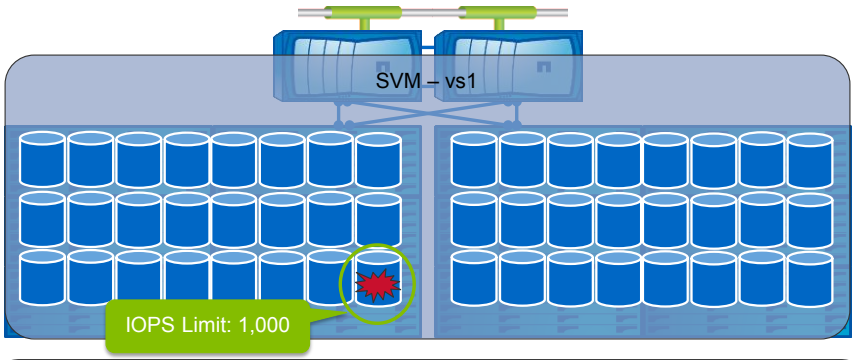
- Storage administrator has not set QoS policies.
- A workload impacts the performance of other workloads.

Solution

- Use Data ONTAP statistics to identify the problem workload.

WHEN TO USE STORAGE QOS: REACTIVE

When to Use Storage QoS
Reactive



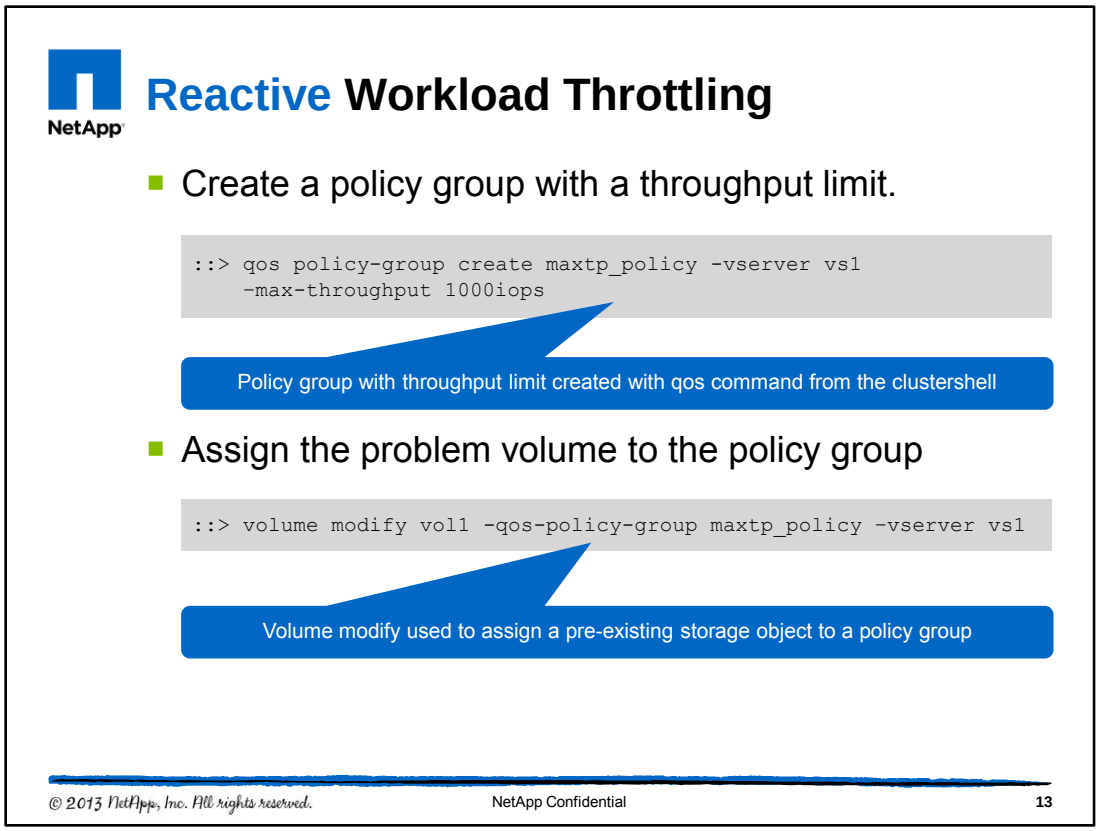
Reactive Scenario

- Storage administrator has not set QoS policies.
- A workload impacts the performance of other workloads.

Solution

- Use Data ONTAP statistics to identify the problem workload.
- Isolate the problem workload by assigning it to a policy group with a throughput limit.

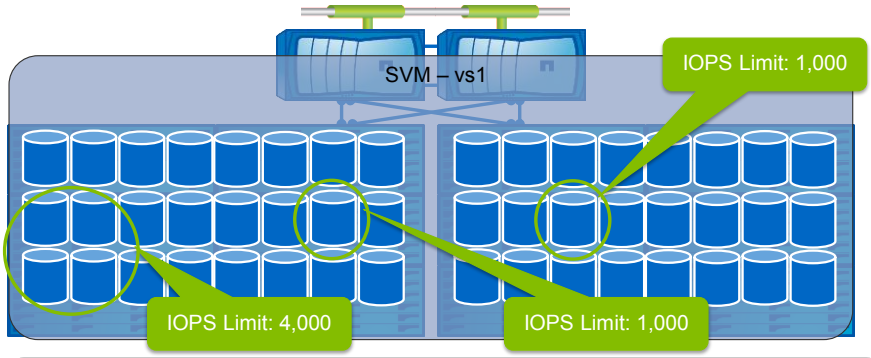
WHEN TO USE STORAGE QOS: REACTIVE



REACTIVE WORKLOAD THROTTLING

The command line uses “vserver,” rather than “SVM.”

When to Use Storage QoS
Proactive



Proactive Scenario

- Storage administrator proactively sets QoS policies with throughput limits.
- New volumes are associated to a policy during the volume create.

WHEN TO USE STORAGE QOS: PROACTIVE

The use of QoS policies with throughput limits ensures that new and possible runaway workloads do not negatively impact performance.

Proactive Workload Throttling

- Create a policy group with a throughput limit.

```
::> qos policy-group create prevent_policy -vserver vs1
    -max-throughput 1000iops
```

- Create a volume and assign it to the new policy group.

```
::> volume create -vserver vs1 -volume vol1 -aggregate aggr1
    -qos-policy-group prevent_policy
```

- Monitor the application workload.

```
::> qos statistics workload performance show
```

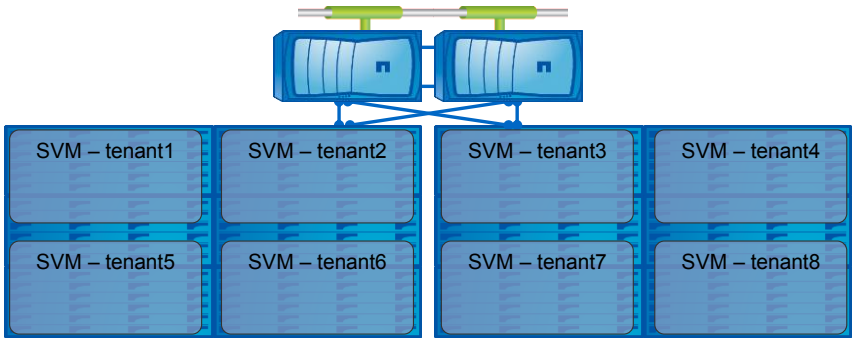
- Modify the throughput limit of the policy.

```
::> qos policy-group modify prevent_policy -max-throughput 3000iops
```


PROACTIVE WORKLOAD THROTTLING

When to Use Storage QoS

Tenant Isolation



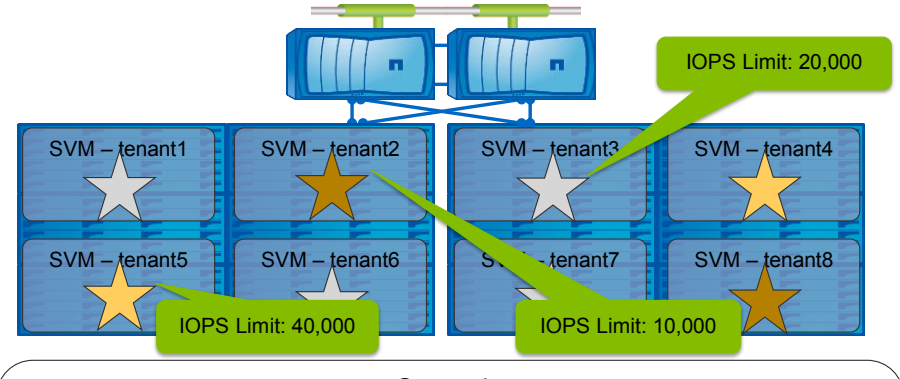
Scenario

- Each tenant (SVM) is isolated.

WHEN TO USE STORAGE QOS: TENANT ISOLATION

When to Use Storage QoS

Tenant Isolation



Scenario

- Each tenant (SVM) is isolated.
- A QoS policy group is created for each SVM.
- QoS policy group performance limits are based on service levels (example: gold = 40,000 IOPS, silver = 20,000 IOPS, and bronze = 10,000 IOPS).

WHEN TO USE STORAGE QOS: TENANT ISOLATION

Tenant Isolation Workload Throttling

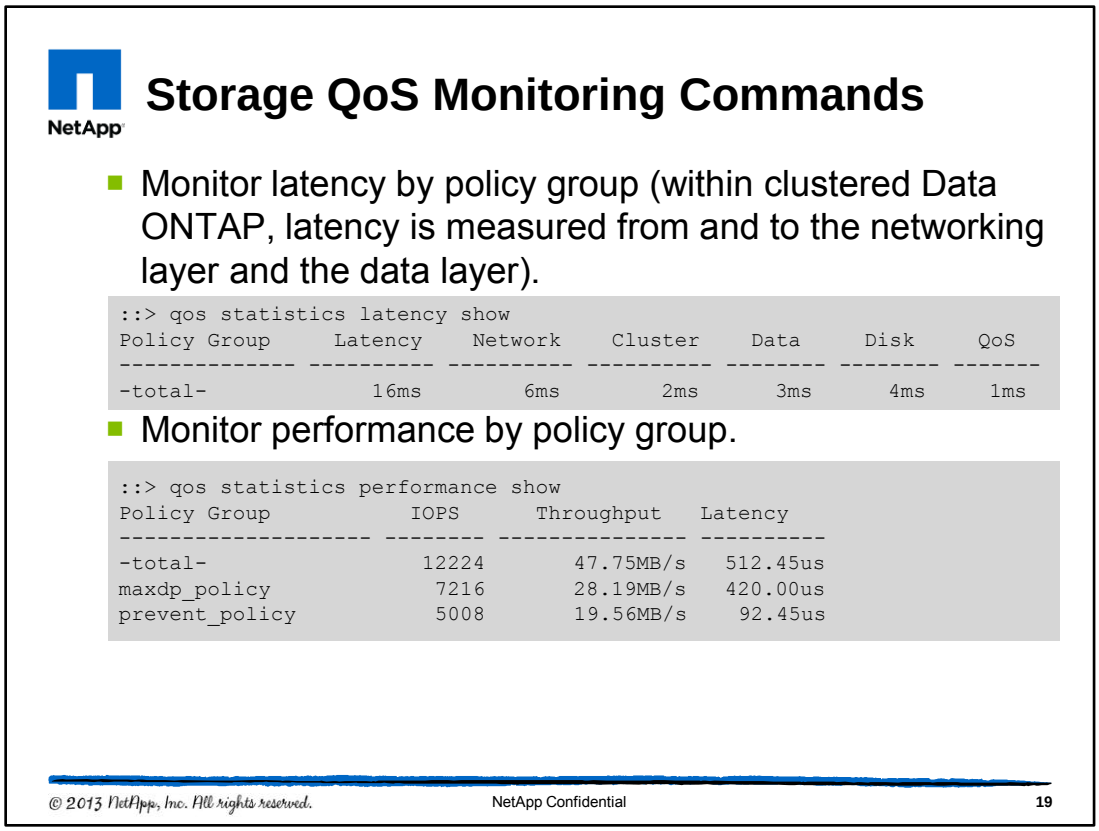
- Create a policy group with a throughput limit that is associated with a service level for the tenant.

```
::> qos policy-group create tenant5_gold_policy -vserver tenant5
    -max-throughput 40000iops
```

- Create the SVM for tenant5 and assign it to the new policy group.

```
::> vserver create -vserver tenant5
    -qos-policy-group tenant5_gold_policy
```


TENANT ISOLATION WORKLOAD THROTTLING



STORAGE QOS MONITORING COMMANDS

Storage QoS limits I/O to and from the cluster. The rate of I/O that the cluster experiences can differ from the rate of I/O that an application experiences. For example, reads from the application can go to the file system buffer cache and not to the cluster. Due to this behavior, you should monitor performance from the cluster and not from a host-side tool.

Storage QoS Design Considerations

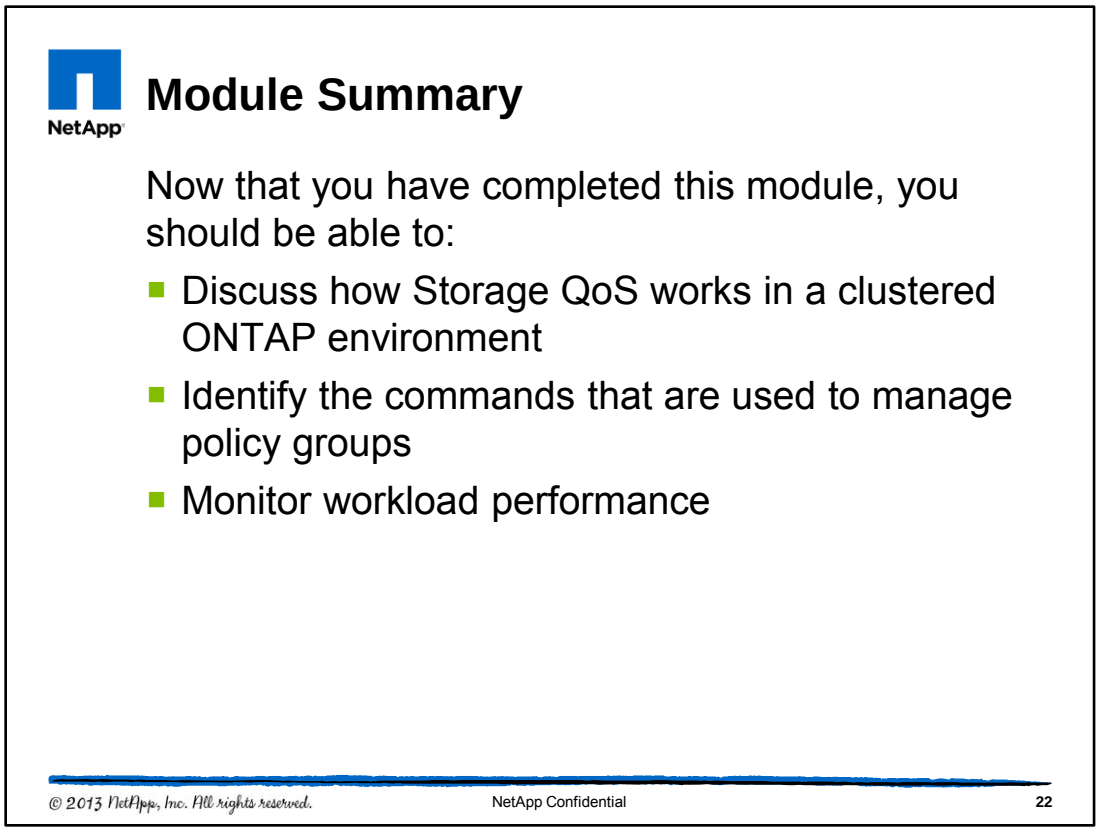
- All protocols are supported.
- All client I/O (both disk and metadata) are counted toward IOPS limit, regardless of I/O block size.
- Transactional workloads should use IOPS limits.
- Large block I/O workloads should use MBps limits.
- AutoSupport and archival data reporting is supported.

STORAGE QOS DESIGN CONSIDERATIONS

Additional Design Considerations

- Throughput limits can be exceeded, based on an error margin.
- Storage QoS performance overhead is less than 2% per node.
- Storage QoS is always on.
- Policy groups must be re-created on data-protection target storage.
- Infinite volumes and V-Series are not supported.

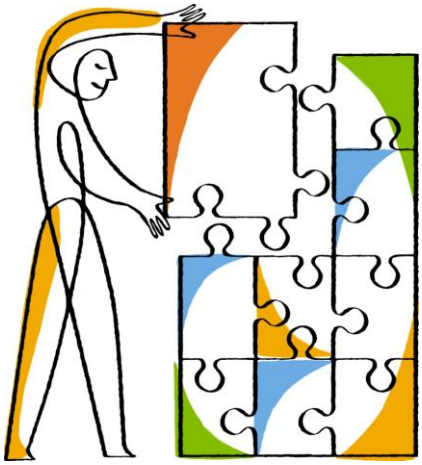
ADDITIONAL DESIGN CONSIDERATIONS



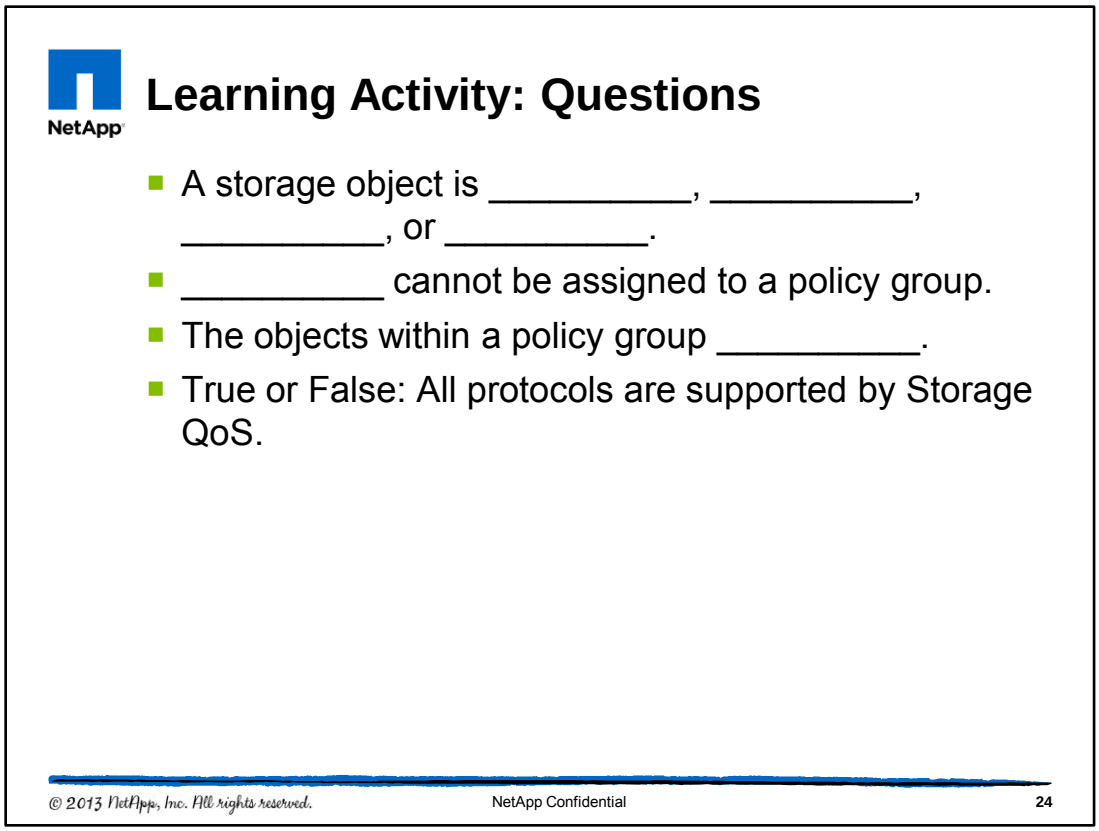
MODULE SUMMARY

Learning Activity Questions

Module 6: Storage QoS



LEARNING ACTIVITY QUESTIONS

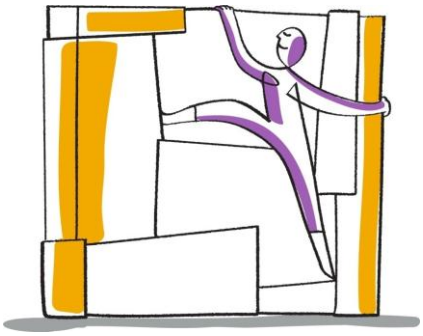


LEARNING ACTIVITY: QUESTIONS

Exercise

Module 6: Storage QoS

Time Estimate: 60 Minutes

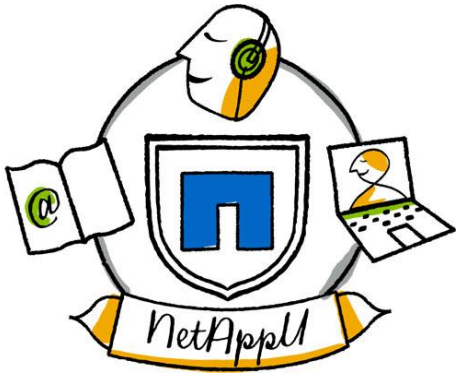


EXERCISE

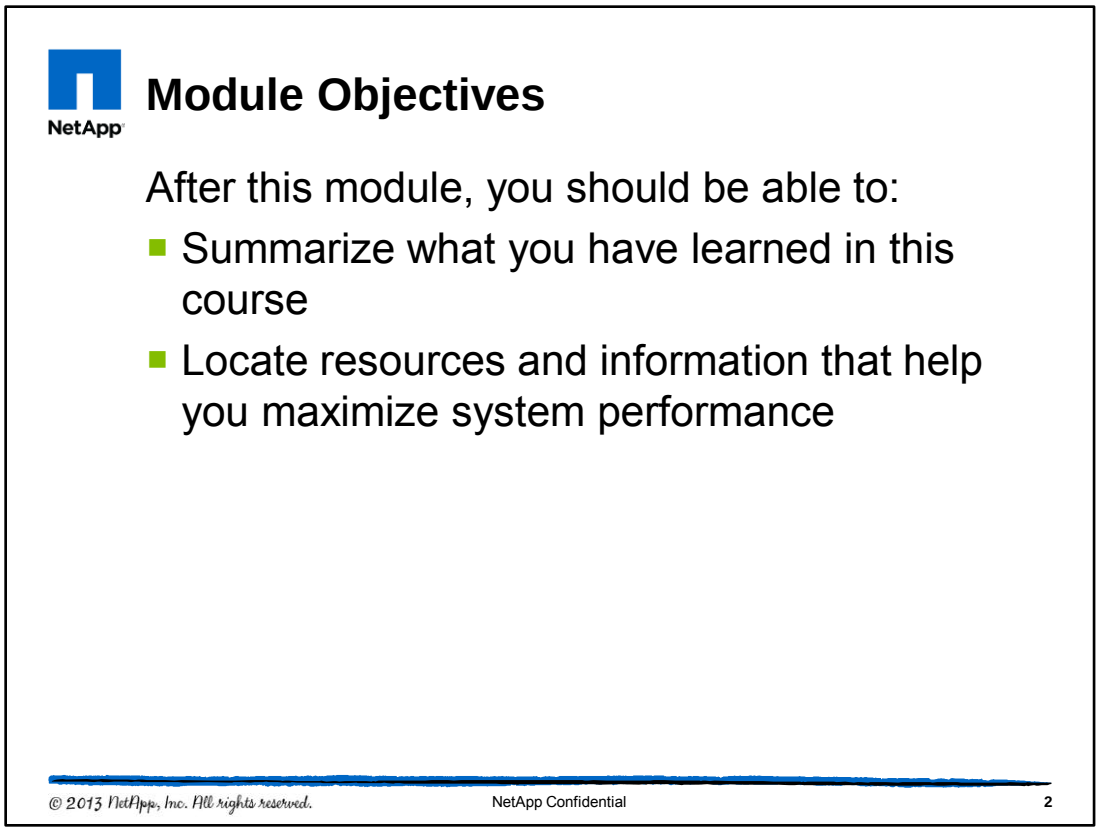
Please refer to your exercise guide.

Module 7

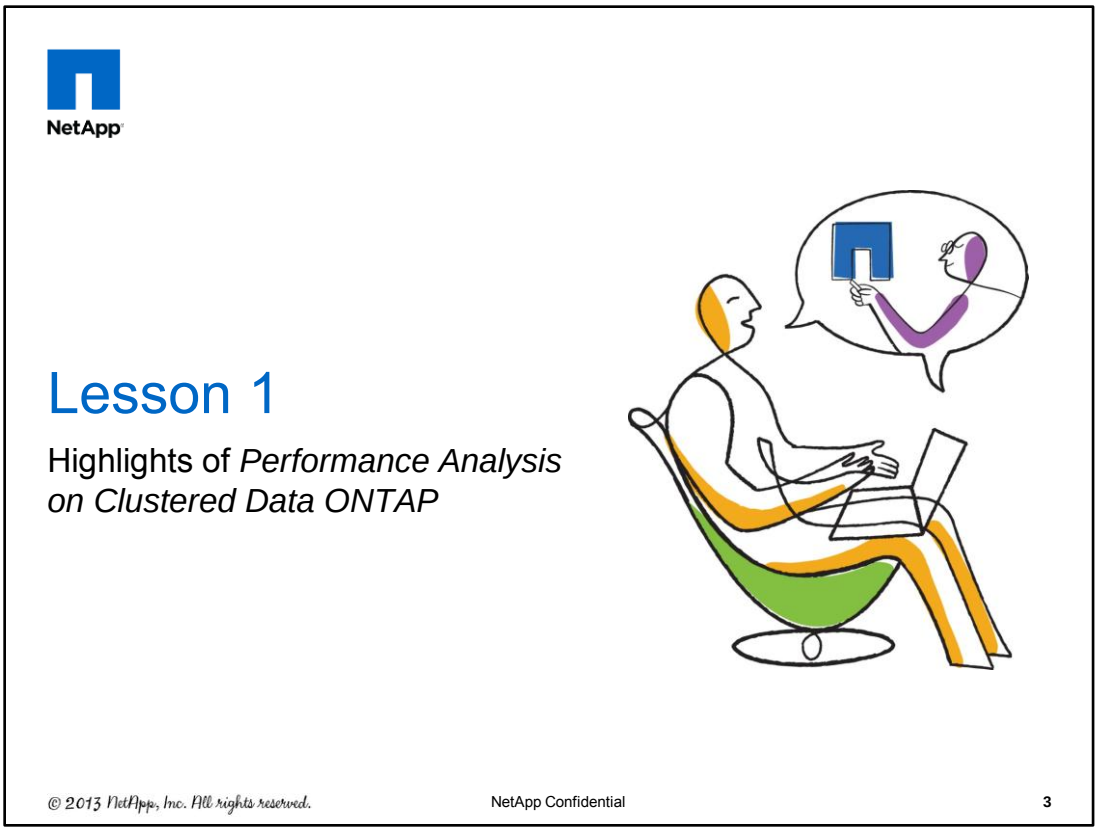
Summary



MODULE 7: SUMMARY

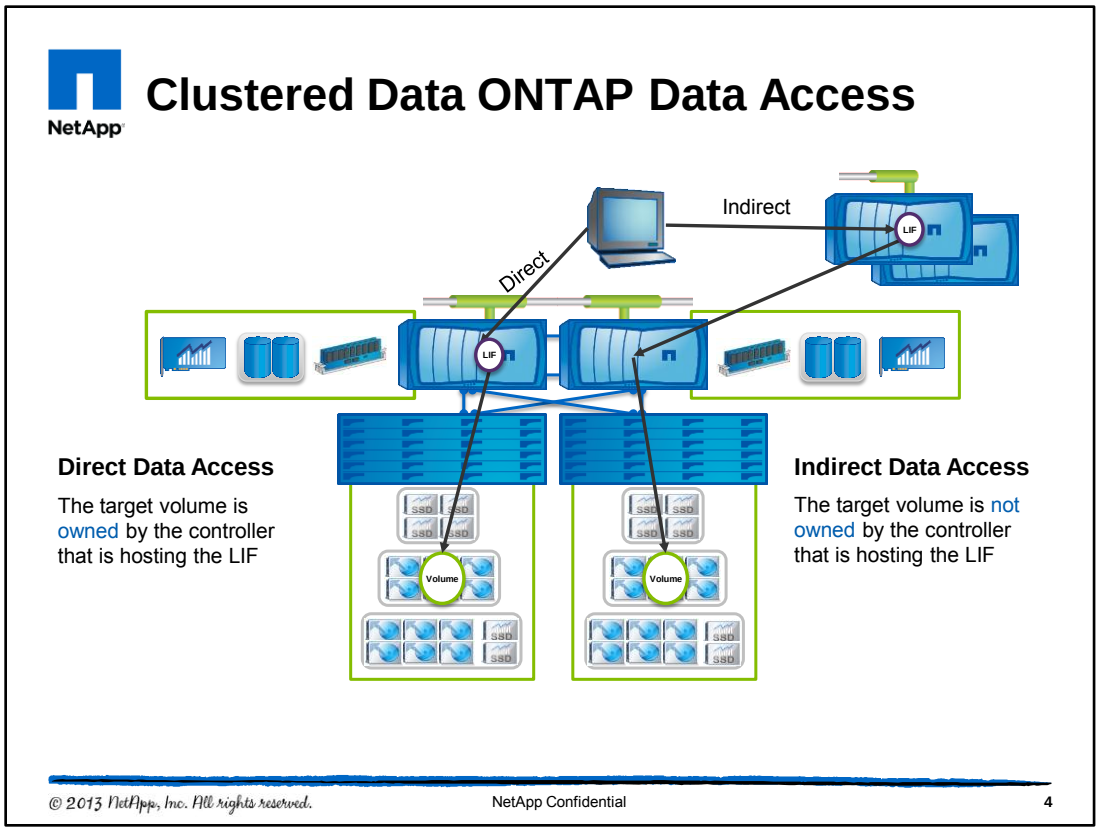


MODULE OBJECTIVES



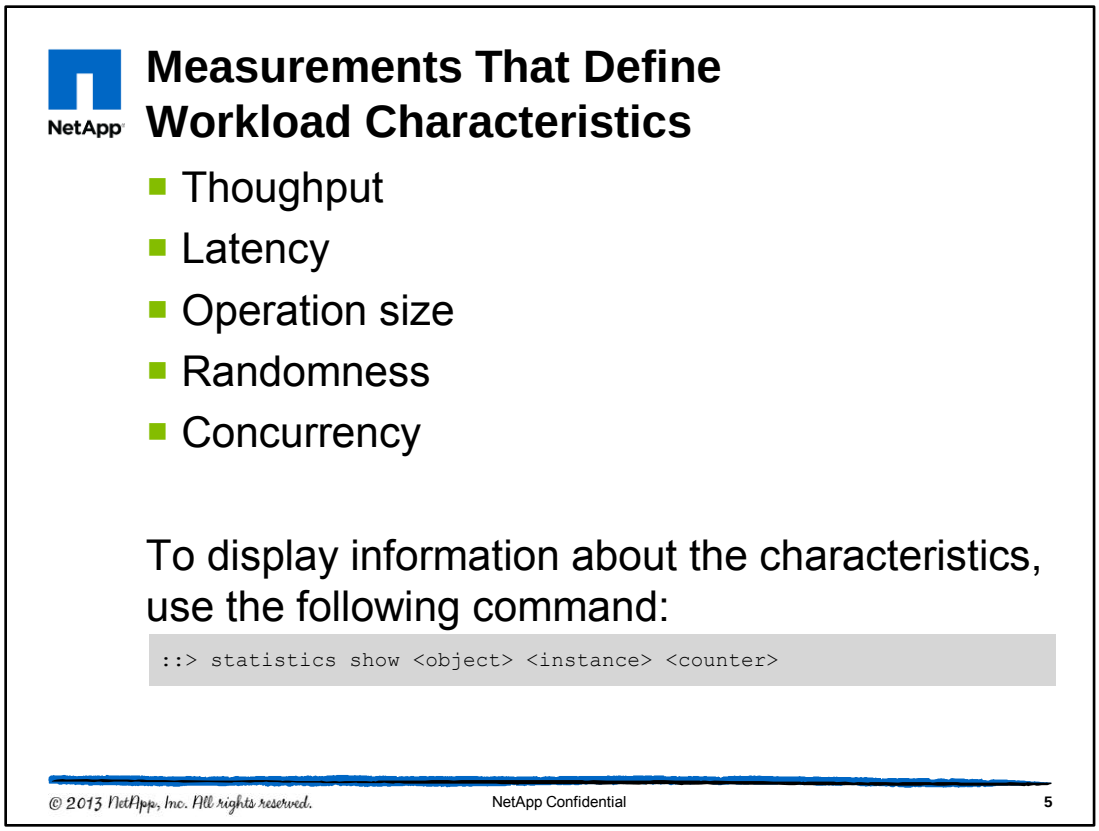
LESSON 1: HIGHLIGHTS OF PERFORMANCE ANALYSIS ON CLUSTERED DATA ONTAP

This lesson reviews the key topics covered in this course.



CLUSTERED DATA ONTAP DATA ACCESS

Both clustered Data ONTAP and Data ONTAP operating in 7-Mode support direct data access; however, only clustered Data ONTAP supports indirect data access.



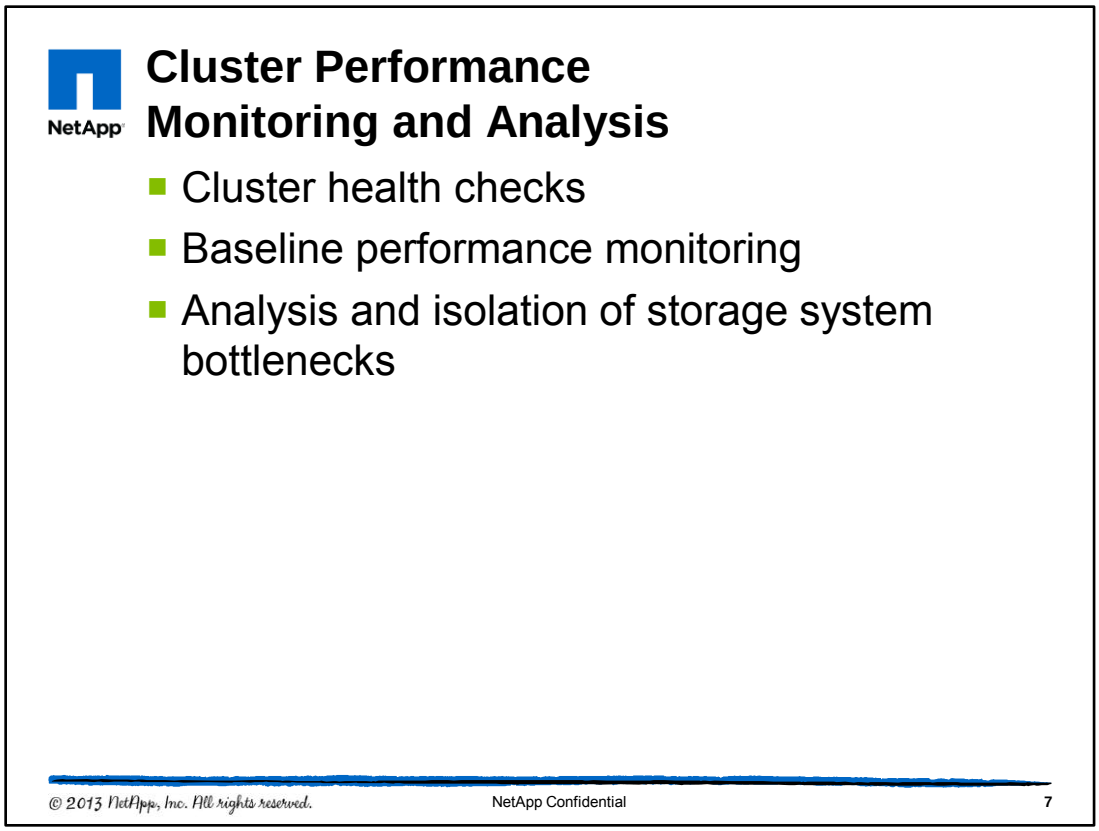
MEASUREMENTS THAT DEFINE WORKLOAD CHARACTERISTICS

Data About Workload Characteristics

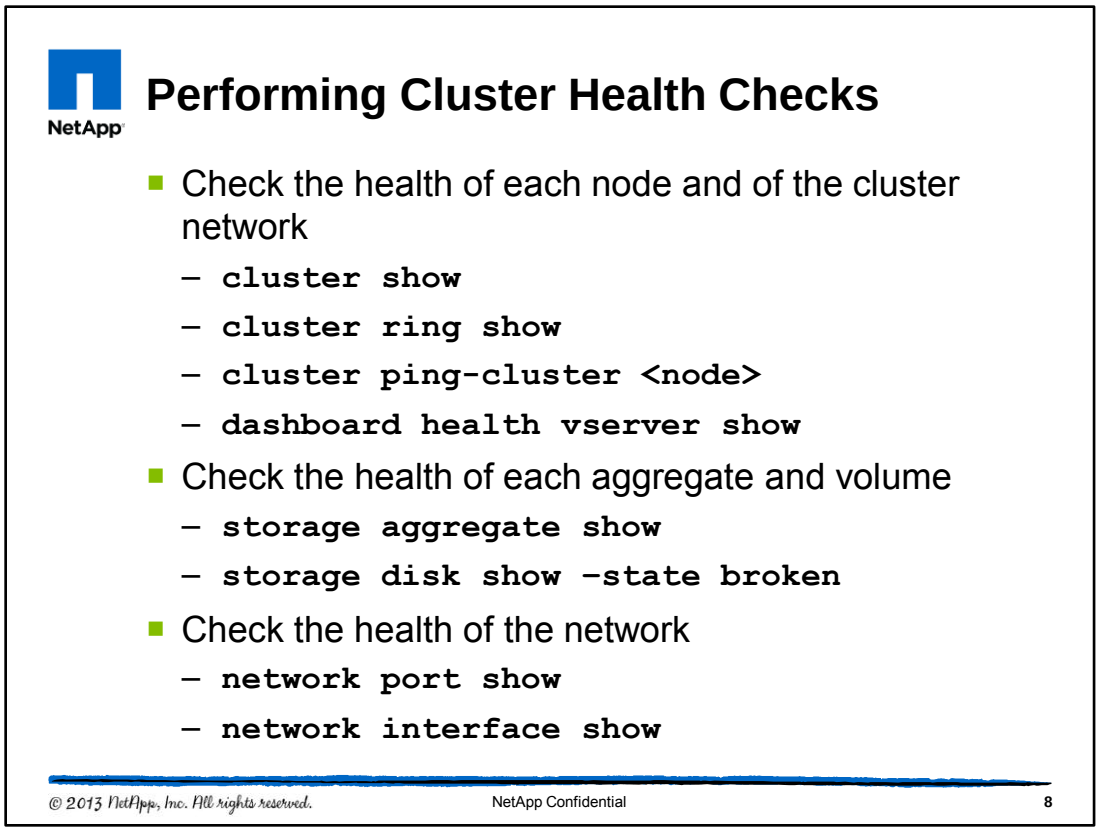
You can use information about workload characteristics in various ways:

- Is critical for a storage-system sizing exercise
- Can help you determine what technologies you should use to improve storage system performance
  - Small-block, random operations can benefit significantly from the use of Flash Cache or Flash Pool.
  - Caching technologies or pure SSD aggregates can greatly reduce operation latency.

DATA ABOUT WORKLOAD CHARACTERISTICS



CLUSTER PERFORMANCE MONITORING AND ANALYSIS

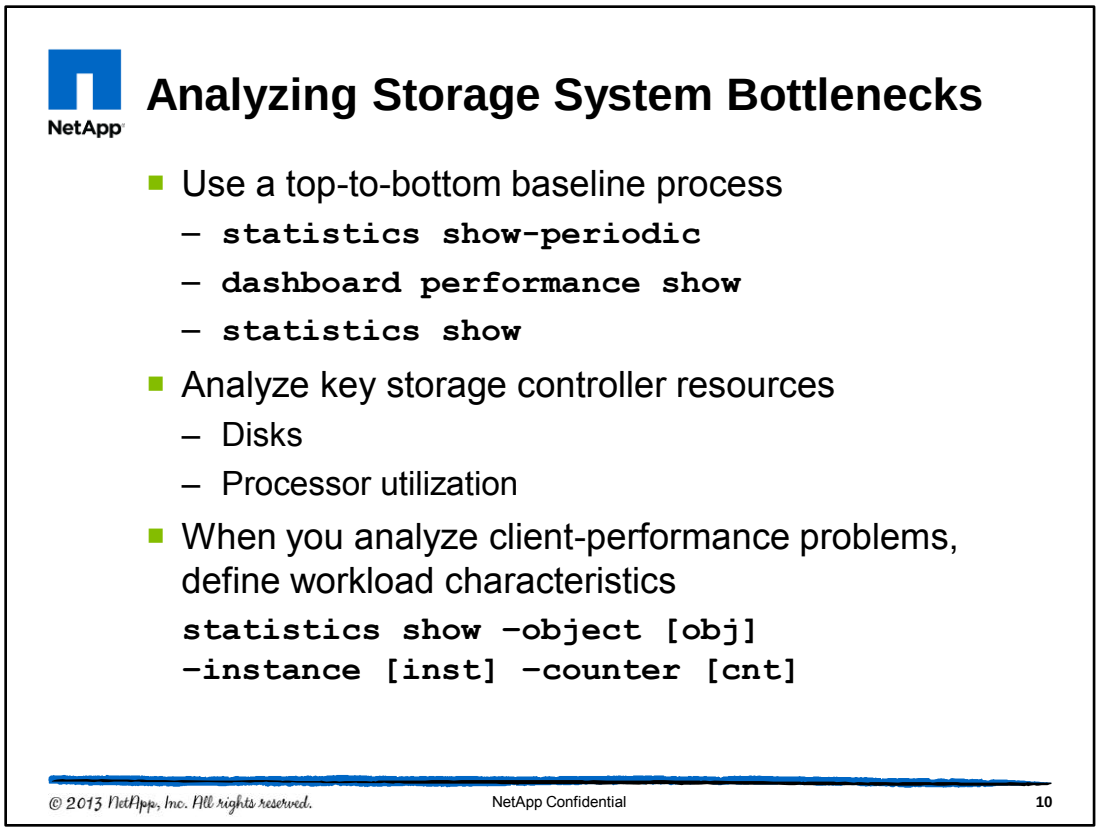


PERFORMING CLUSTER HEALTH CHECKS

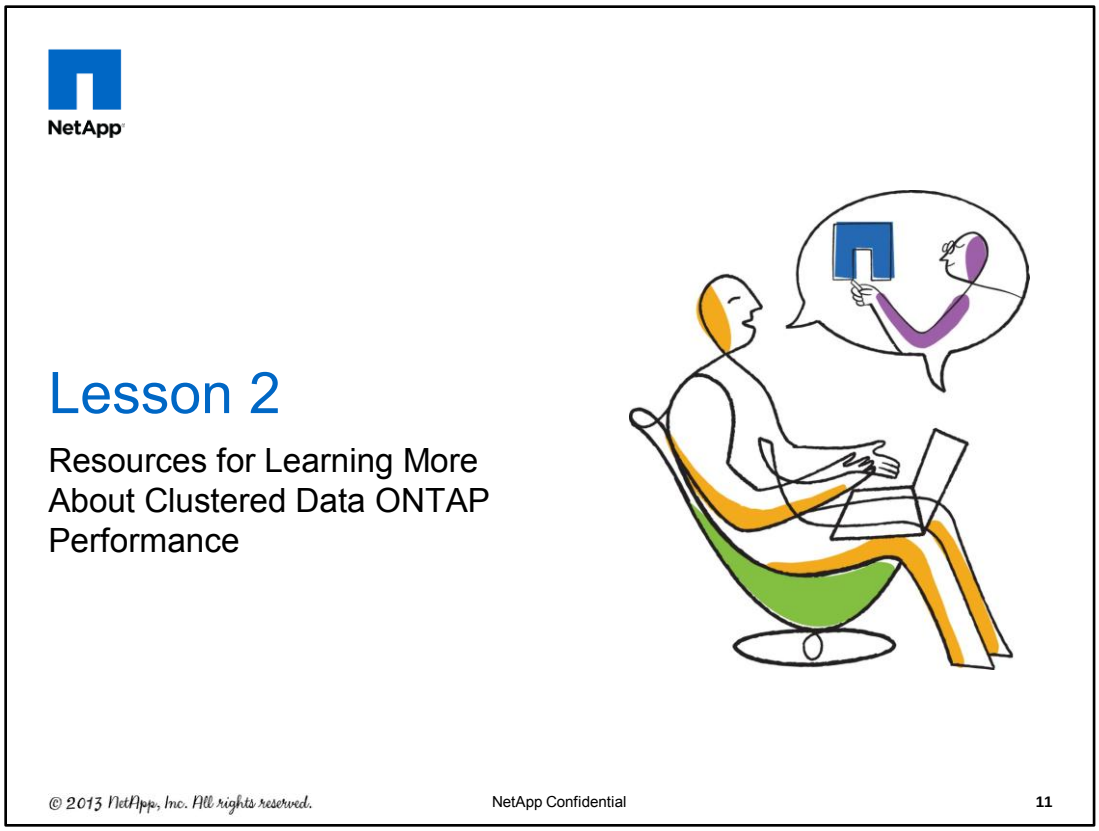
Monitoring Performance

- Work from top (cluster) to bottom (node)
  - **`statistics show-periodic`**
    - Operates by cluster, node, or object
    - Is similar to **`sysstat`** in Data ONTAP 7-Mode
  - **`dashboard performance show`**
    - Is very powerful
    - Provides useful summary Information
- Narrow the search to values and objects that you want to monitor
  - **`statistics show`**

MONITORING PERFORMANCE



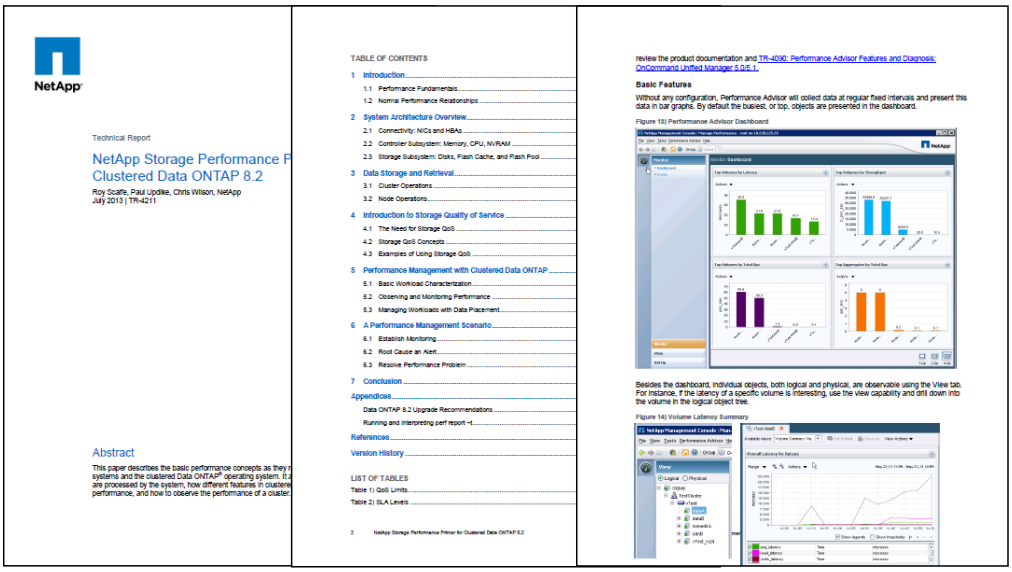
ANALYZING STORAGE SYSTEM BOTTLENECKS



LESSON 2: RESOURCES FOR LEARNING MORE ABOUT CLUSTERED DATA ONTAP PERFORMANCE

This lesson discusses where to find additional clustered Data ONTAP performance information.

NetApp Storage Performance Primer for Clustered Data ONTAP (TR-4211)

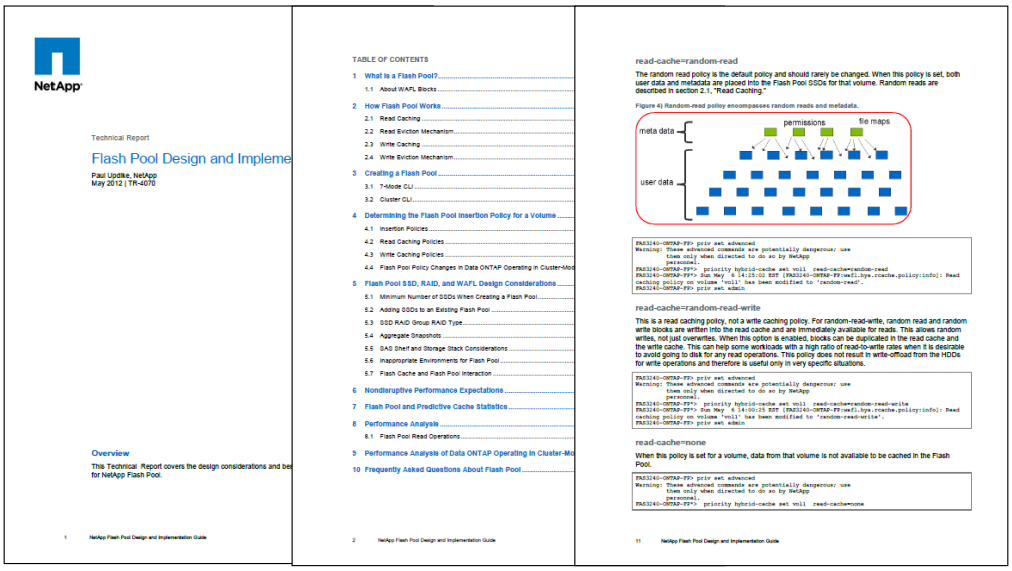


NETAPP STORAGE PERFORMANCE PRIMER FOR CLUSTERED DATA ONTAP (TR-4211)

This primer addresses the following topics:

- System architecture
- Direct versus indirect access
- Storage QoS
- Performance Advisor
- Cluster operations
- Protocols

Flash Pool Design and Implementation (TR-4070)



FLASH POOL DESIGN AND IMPLEMENTATION (TR-4070)

This technical report addresses the following topics and answers frequently asked questions.

- What a flash pool is
- How the Flash Pool feature works
- How to create a flash pool
- How to analyze performance

Additional Training
OnCommand Insight

For in-depth hands-on training on OnCommand Insight, visit the NetApp Learning Center and enroll in NetApp OnCommand Insight Operations and Best Practices

- Instructor-led training (ILT)
- Three days


NETAPP UNIVERSITY

NetApp OnCommand Insight Operation and Best Practices

COURSE DESCRIPTION

Learn how OnCommand Insight software manage and improve an organization's IT infrastructure and service management processes. This hands-on course explains the features and functions of the Insight suite of products and how they work together as a solution. You learn how Insight helps you use service policies to manage storage, plan for change, and use resources and capacity more effectively. You complete extensive exercises in which you use best practices and operational procedures to manage Insight. You also review and use data warehouse performance reporting features.

DELIVERY TYPE

Instructor-led training (ILT)

DURATION

Three days

AUDIENCE

Customers, Professional Services employees, and Professional Services partners

TRAINING UNITS

36

PREREQUISITES

Learner should complete the Getting Started series videos:

- OnCommand Insight Installation
- OnCommand Insight Configuration

OBJECTIVES

By the end of this course, you should be able to:

- Describe the four OnCommand Insight products and how they interact with each other
- Describe the three phases of OnCommand deployment
- Describe inventory, paths, policies, thresholds, violations, and vulnerabilities
- Use Insight to manage multiprotocol storage systems (FC, iSCSI, NFS, and CIFS)
- Address violations and troubleshoot performance issues
- Configure business entities, applications, and annotations, and use them for business-level reporting
- Define the data marts and data models that are in a data warehouse and describe how data is loaded into them
- Create standard and custom Insight reports

PRICING AND CANCELLATION POLICY

For pricing and cancellation information, see the NetApp University LearningCenter.

NOTE: If you are registering for this course with an Authorized Learning Partner, review the partner's pricing and cancellation policy.

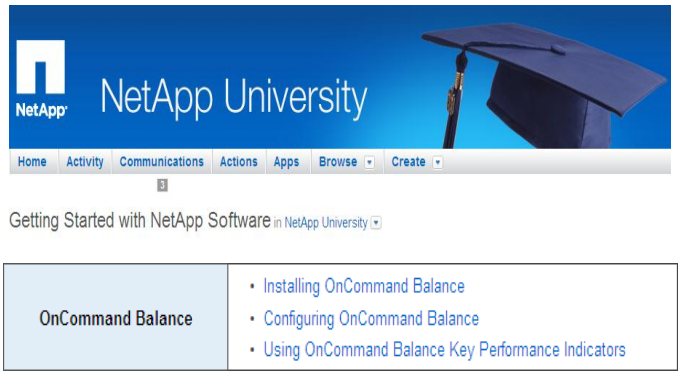
NetApp
www.netapp.com

ADDITIONAL TRAINING: ONCOMMAND INSIGHT

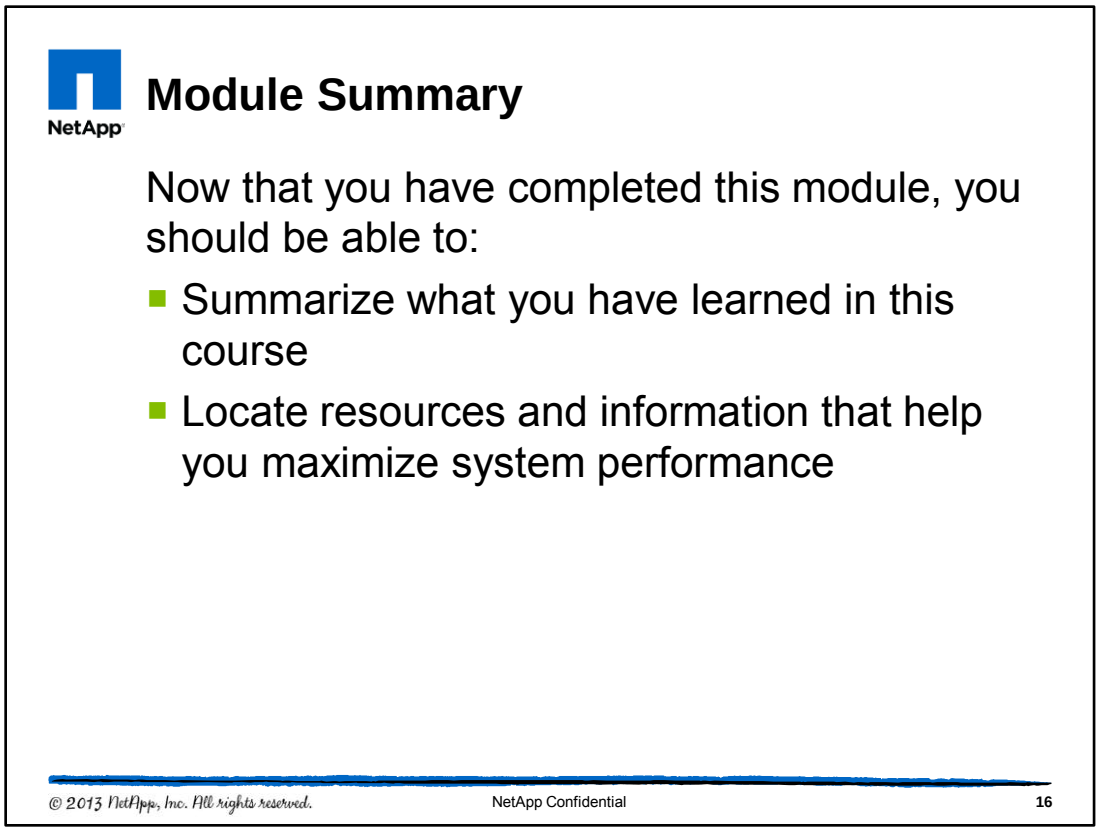
Additional Training
OnCommand Balance

For in-depth training on OnCommand Balance, visit the NetApp Learning Center and enroll in the NetApp OnCommand Balance Getting Started Series.

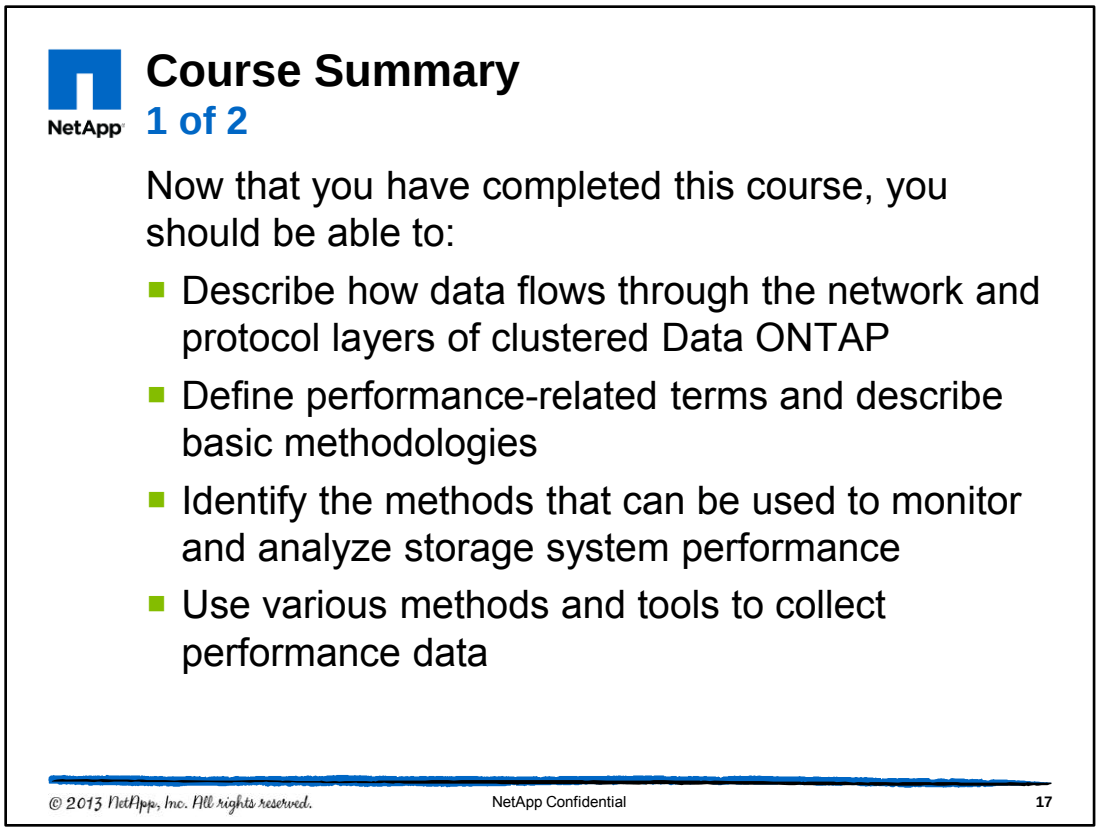
http://www.netapp.com/gettingstarted



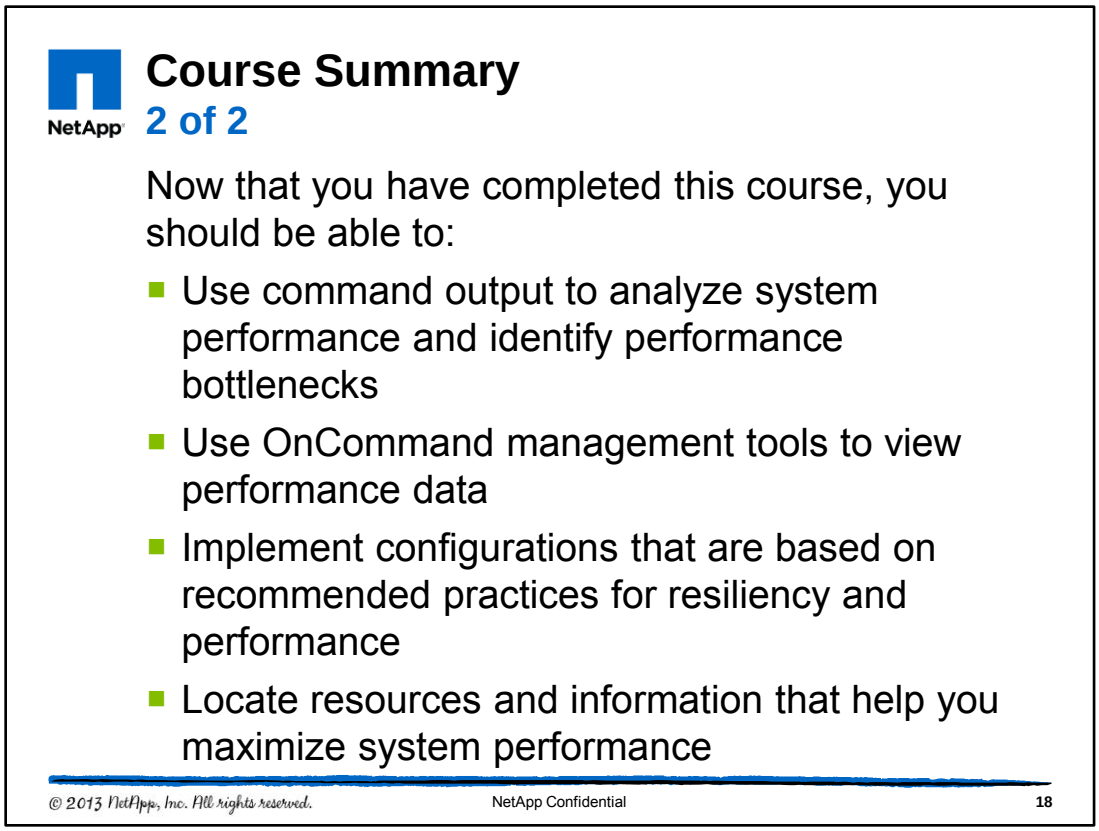
ADDITIONAL TRAINING: ONCOMMAND BALANCE



MODULE SUMMARY



COURSE SUMMARY: 1 OF 2



COURSE SUMMARY: 2 OF 2

THANK YOU