July 3rd, 2009

The Storage Networking Industry Association (SNIA) has provided the following response to the EPA ENERGY STAR Enterprise Storage Draft Specification Framework ("draft framework") issued June 4th, 2009.

The SNIA is a not–for–profit global organization, made up of some 400 member companies spanning virtually the entire storage industry. The SNIA's mission is to lead the storage industry worldwide in developing and promoting standards, technologies, and educational services to empower organizations in the management of information. To this end, the SNIA is uniquely committed to delivering standards, education, and services that will propel open storage networking solutions into the broader market. For additional information, visit the SNIA web site at www.snia.org.

The SNIA responses represent the technical work and viewpoints of the Green Storage Initiative (GSI) http://www.snia.org/forums/green and the Green Storage Technical Working Group (TWG) http://www.snia.org/tech_activities/work/twgs/ . Collectively, the TWG and GSI represent over 30 companies. The website for the GSI lists company names which are a subset of this group. Collectively, the SNIA is a voice for the $50B-60B year storage and information management industry.

The SNIA responses include a commentary per each major section of the draft framework. Additionally, appendices have been added that separate lengthy sections intended for information transfer from specific commentary. This document includes:

- Overview Section
- Building Block # 1
- Building Block # 1 Questions
- Building Block # 2
- Building Block # 2 Questions
- Building Block # 3
- Building Block # 3 Questions
- Building Block # 4
- Building Block # 4 Questions
- Appendix #1 Terms and Definitions for Building Block # 1
- Appendix #2 SNIA Storage Product Taxonomy
- Appendix #3 Representative SNIA Taxonomy Online Storage Configurations

For follow-up, there are many individuals involved in the SNIA and the SNIA recommends these primary contacts, inclusively.

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General Comments

1. Framework and Specification Naming

The name and focus of the draft framework is for Enterprise Storage. The SNIA recommends renaming the draft framework and eventual specification to use the term Data Center Storage (or alternatively Networked Storage for the Data Center) instead of Enterprise Storage. We believe the suggested naming convention falls within the scope of the EPA focus and initiative for Data Center Efficiency and the EPA initiative encompasses information and communications technology (ICT). The suggested term should be searched and replaced throughout the specification and not just the title.

There is no exact industry definition for Enterprise Storage. The phrase is widely used, by vendors, media, analysts, and data center operations, to refer to storage deployed in a data center, in an extended data center cloud, or on a disaster recovery site or service. In addition to the place of deployment, there are a large number of optional products, features and complementary software solutions that are used in combination with the storage to efficiently store, manage, move, and protect a company's data and information. Many industry stakeholders may hold the view that Enterprise Storage is reflective of the data storage that would meet or exceed the needs of the top Global 500 commercial enterprises and governments or more narrowly to the USA, the Fortune 100 for performance and data protection, while physically residing in a data center.

The SNIA believes the intent of the EPA specification is to address storage in any data center to include any business and agency, with the exception of business run from an office or home environment, sometimes referenced as SOHO (small office, home office). Since the EPA Specification will be articulate in classifying storage technology and storage features, the recommendation to change the name from a marketing term to a broader, generic name will avoid further downstream confusion of marketing and classification terms and intent.

2. Taxonomy Adoption

The SNIA has defined a comprehensive taxonomy for the storage industry (http://www.snia.org/tech_activities/publicreview/GreenPower_v018.pdf, pp. 13-17). It uniquely identifies categories and classes of products to facilitate their evaluation, classification and comparison. Its adoption as a cornerstone of the draft framework and resulting specification would assure a clear understanding of market segmentation throughout the storage industry, would minimize confusion about the proper positioning and assessment of an ENERGY STAR candidate, and would simplify any segmentation of ENERGY STAR ratings necessary to address the breadth of available and emerging products.

3. Release Scoping

The SNIA recommends the scope of the first release of the framework and the resultant specification focus on a limited subset of the categories defined in the SNIA Taxonomy. See Block #2, Comment #1 for a more detailed recommendation.

4. Open Questions and Emerging Solutions

Much of the technology that is being deployed in the data center today has been developed or significantly enhanced relatively recently. Whether in underlying media (e.g., solid-state storage), deployment and topology (e.g., storage appliances) or software enhancement (e.g., deduplication), major sections of the storage industry are developing at a pace that can far outstrip that of standards development. The proscriptions defined in the ENERGY STAR specification for data center storage will need to be sensitive to the continual evolution of the storage industry in order to remain useful and appropriate.

In particular, the SNIA desires to ensure that the specification properly accounts for the impact of end-user configuration choices and product flexibility. A standard which drove product developers toward simpler products that failed to provide enhanced reliability, availability and serviceability (RAS) support, for example, might result in a net increase in power consumption; if the ENERGY STAR program rewarded simplistic systems at the expense of sophisticated systems, users might tend to purchase multiple simpler systems in lieu of a single more sophisticated system, to assure appropriate RAS functionality.

Building Block #1

Comment 1:

Clarification is needed for the statement found in section "a":

> "*Note that a product may not be qualified as ENERGY STAR under more than one specification – manufacturers must select the product category that best describes the product they wish to qualify*."

One way to interpret the statement is a product could not be tested under the ENERGY STAR specifications for both Enterprise Computer Servers and Data Center Storage.

An alternate way to interpret the statement is that a product must fit neatly into a Specifications taxonomy classification and not be tested in more than one class.

The SNIA believes the clarification of the statement should pertain to different EPA ENERGY STAR specifications and not within the Specification for Data Center Storage.

Comment 2:

The SNIA maintains and publishes a storage industry dictionary of terms, located at http:/www.snia.org/dictionary. The dictionary is updated twice a year. The draft framework should reference the SNIA dictionary and its definitions wherever possible. Suggestions for additional terms are welcome at http://www.snia.org/education/dictionary/submittal.

Appendix #1 lists revised definitions for existing terms and suggests additional terms for use in the draft framework.

Building Block #1 Questions for Discussion

1) *How are Active, Idle, Maximum, and Full Load states defined in the industry?*

The SNIA has created an initial definition for the Idle state for storage products (see Block #1, Question #2).

There are no industry-standard definitions for Active, Maximum, and Full Load. On-going discussions within the SNIA are summarized in the following paragraphs.

There is general agreement that a system is Active when it is handling user-initiated I/O requests that originate from a host computer system. Significant work remains to define the workload that should be executed while measuring a system's energy efficiency. For example, should the workload be geared towards synthetic patterns of I/O or towards typical applications; what percentage of a system's capabilities (e.g., throughput, IOPS, capacity) should be active during the measurement. Workloads would be different for each SNIA Taxonomy Class.

Maximum is best used when describing performance of a system in any one particular dimension. For example, the "maximum random read performance for system x is yyy I/Os per second." Or the "maximum sequential write performance for system x is zzz MB per second." Even here, the use of maximum must be qualified with other constraints such as "at an I/O Response Time of less than 80 ms." In general, a "maximum I/O per second (IOPS)" or a "maximum MB per second (MB/sec)" without a response time qualification is not all that meaningful, since long response times (e.g., > 2 seconds) cause applications to fail in the real world. Maximum also needs to be defined on a per Taxonomy category basis, since any given storage system is designed for specific functions.

There are two possible interpretations for the term "Full Load". The first applies when a storage product's response times has degraded (e.g., > 80 ms) for some I/Os, due to the quantity and breadth of I/O requests that it is processing. Because the system has reached a performance bottleneck in one or more of its resources, it can be described as "under full load". There are an infinite number of combinations of workloads that can drive a storage product to this state, since there are many components that could be stressed to the point of capacity, depending on the architecture and the configuration (e.g., I/O channels to the host, cache, I/O channels to the storage devices, the storage devices themselves). In general, the aggregate IOPS or MB/sec measurements at this Full Load would not be as high as measured at "Maximum" for a particular dimension of performance.

The second possible interpretation of Full Load is whatever workload is necessary to drive the storage system to its peak power consumption. The industry-preferred term for this condition is "peak power consumption."

Full Load also needs to be defined on a per Taxonomy category, since the storage system is designed for specific functions.

There are a handful of performance-oriented workloads that would apply to systems in the Online category of the SNIA Taxonomy. The SNIA recommends that scope of the first release of the framework and resultant specification be limited to the SNIA Taxonomy categories recommended in Block #2, Comment #1, to establish a baseline for these definitions while addressing a high volume/high energy consumption portion of the industry.

2) *What are the critical factors in determining if a Storage Product is idle? Are there other accepted terms for these states?*

The SNIA's Green Storage Power Measurement Technical Specification defines an idle system as follows:

> *Storage systems and components are said to be idle when they are configured, powered up, connected to host systems and capable of satisfying I/O requests from those systems, but no I/O requests are being submitted from the host systems.*

Additional discussion will be required to define and characterize the background or maintenance processing that may occur on a storage product independent of I/O requests submitted from host systems to which the products are connected. The SNIA's Green Storage Power Measurement Technical Specification makes the following distinction between different types of I/O requests:

> *All I/O requests […] shall be classified as either:*

- *Foreground I/O, an externally-initiated, application-level request for data transfer between [a host system] and the storage system being tested, or*
- *Background I/O, a system-initiated request for data transfer within the storage system being tested.*

Over the past 18 months, the SNIA has performed extensive testing and measurement of Online and Removable Media class systems for idle workloads. Collected data for Online systems show that a system in an idle state typically consumes between 80-85% of its maximum power draw. An Online system in an idle state may be performing various types of system and data integrity work (e.g., removing bad blocks, error checking). These system and device level workloads usually kick off when the system is idle so they do not compete for resources when a storage system is being asked to address user-initiated workloads.

There is no industry-standard definition of the types of background or maintenance activity on a storage product, or of the efficacy or impact of enabling or disabling some or all of that activity in the context of an energy measurement. More discussion and cross-industry agreement is needed to assure that these tasks are recognized as an important component of a data-center-class storage solution, and that systems which provide them are not at a disadvantage when measured on the single dimension of energy efficiency/consumption. Definition of background activity will also need to account for the different SNIA Taxonomy Classes, since an Online storage system is doing something in the idle state that is completely different from what is done by a Removable Media device.

3) *Are there other Operational States specific to Storage Products that will need to be defined in this specification? For example, how should EPA address data maintenance functions that may occur in the background while a product is in an idle state?*

There are three states the industry recognizes for storage systems, when it comes to data and work: data at rest (idle), data in flight (throughput) and data at work (I/Os per second). There are no industry accepted state names describing more or less activity in any of these areas except "idle" and "active".

The Specification may need to identify data resiliency features and take them into consideration during energy measurements for certain of the SNIA Taxonomy categories. Larger systems may have more noticeable energy consumption over smaller systems, e.g. Online-4 versus Online-2, since the more sophisticated data protection required in the higher categories (e.g., RAID, no SPOF) may require additional power to support additional controllers, more drives, etc. Further, more sophisticated systems may employ data protection and integrity checks that rely on background I/O, and incur additional power cost to provide additional assurance of data integrity and availability.

The storage industry has a long history of testing systems configurations built to match customer specific performance and data protection requirements. We recognize that no two customer application environments are identical for performance considerations and data protection/data restoration service level objectives. Given the configurability of storage systems to deliver on these two dimensions, deployed configurations need to balance these competing demands. A configuration that pursued one dimension with complete abandonment of the other would not satisfy a data center customer. There is concern that a naïve pursuit of energy reduction/energy ratings can be harmful to performance and data protection, especially when procurement mandates in certain industry sectors may be dictated by the energy ratings alone.

4) *Are there other definitions required to identify certain types of Storage Products or components?*

The SNIA Taxonomy provides a comprehensive start for products in the marketplace today. Please see Block #2, Comment #1 for a more complete discussion of the SNIA taxonomy. More considerations may be needed within the Taxonomy classes for selections of components such as drive types, based on speed and technology.

5) *Are there any other sources that the EPA should review for variations of, or additions to, this list of definitions?*

6) *The draft framework should reference the SNIA dictionary and its definitions wherever possible. Suggestions for additional terms are welcome at http://www.snia.org/education/dictionary/submittalAre the power supply definitions for Computer Servers also appropriate for Storage Products? If not, how do these PSUs differ?*

More work is needed with the Power supply definitions to address redundancy, swap-ability, and battery backup. Please see the answers provided in Block #3, comments #5 and #6 for a more detailed discussion of this issue.

7) *How prevalent are DC powered Storage Products? Do any Storage Products use power supplies directly integrated into the main system (i.e. not separable from the main system), or are PSUs always stand-alone (external) hardware?*

DC powered storage can be typical when deployed in Telecom applications, though this is a small segment of the total data storage market.

Storage systems designed for the Online-1 category, SOHO, are more likely to have integrated power-supplies or external/stand-alone supplies.

Building Block #2

Comment 1:

The SNIA has developed a taxonomy to help segment the storage products into different categories. Please reference the SNIA's Green Storage Power Measurement Technical Specification and a subset of the Taxonomy in Appendix #2.

Within each category there are classifications which delineate attributes of similar products for comparison purposes. These classifications could also be viewed as a method to look at market segmentation, although there is not a direct correlation between the classifications in each category and market segments as defined by IDC and other consultants. However, the SNIA has worked with IDC to analyze market sizing specific for deployed disk drives and their energy consumption that align with the SNIA Taxonomy categories.

Within a taxonomy category, a specific model or release of a product will support different feature sets, whether focused on capacity, reliability, functionality or another differentiator. Feature and functionality differences within a category are addressed with attributes. Each taxonomy category defines a set of attributes that are common to all products within the category. There are six (6) storage categories currently defined:

- Online Storage
- Near Online Storage
- Removable Media Libraries
- Virtual Media Libraries
- Infrastructure Appliances
- Infrastructure Interconnect Elements

To meet the EPA's intention in developing a Version 1.0 Specification that covers as much of the data center storage market as reasonable, consideration should be given to each category over time.

The SNIA recommends that the first release of the Specification (v. 1.0) focus on SNIA Taxonomy categories Online-2, Online-3, Removable-2 and Removable-3. Consideration should also be given to inclusion of Online-4 in v.1.0, but with caution since the scale and additional complexity associated with Online-4 products may prove to be problematic in the definition and implementation of the initial release. The SNIA recommends v1.1 or v2.0 of the Specification then include Online-4 (if v. 1.0 does not), plus Virtual Media Libraries, near On-Line, and Appliances. The SNIA recommends not including Online-1 in any Data Center Storage Specification, since it targets small office and home use, not the data center. The SNIA also recommends not including Online-5, since it is a relatively small niche (both in terms of the number of vendors and total market size), when compared to the recommended taxonomy categories.

While the SNIA does not know the EPA timetable for a Data Center Networking specification, it recommends the Infrastructure Interconnect Elements category be covered by that specification.

Comment 2:

With the suggested reduction in scope for the v1.0 Specification, sizeable market impact can be made while establishing the critical baselines for operational states, metrics, and methods for future versions of the specification. The SNIA believes that the complexity in active measurements, considerations for RAS (reliability, availability, and serviceability) features, and component selection (such as drive type) will be a sizeable amount of industry work. The SNIA recognizes that different active workloads will be required for each taxonomy category. The SNIA also recognizes that Online 4 will be more complex than the other recommended taxonomy categories, since its storage products are often comprised of several systems to provide additional RAS features; multi-system configurations add complexity to defining power supply efficiencies, defining configurations to test; and defining workloads and test harnesses.

The following cited storage product types are covered by the following SNIA Taxonomy categories:

1. Online: DAS, NAS, SAN
2. Removable Media: Tape, Optical
3. Online and Near online: Hard Disk, Solid State
4. Virtual Media Library: Hard Disk, Solid State, Hybrid Media

Building Block #2 Questions for Discussion:

1) *What are some additional means of segmenting the storage market?*

The market can be segmented using the SNIA taxonomy or an analyst's segmentation. Well known analyst firms doing product segmentation are IDC and Gartner. The SNIA did review the analyst segmentations for starting points, but found a high likelihood of single product fitting into more than one segment or segmentation bands. The SNIA recognized the EPA's desire to have a given vendor product in only one EPA testable market segment, and developed the SNIA Taxonomy accordingly.

The SNIA does not recommend looking at vendor terminology such as high-end, mid-range, low-end, Enterprise Storage, etc, since there are no common, industry-wide definitions for these terms, nor any apples-to-apples criteria to support product placement into these segments.

Additional segmentation is sometimes drawn in terms of communications protocol (e.g., NFS, CIFS). While this distinction is important in application development and deployment decisions, these have limited impact on the energy consumption of the underlying product and will likely not be a meaningful differentiator for this framework.

2) *Are there any upcoming technologies or product types in development which are not included on the list provided in section (b) and should be considered for inclusion in ENERGY STAR?*

Beyond the list in section B, there are no new products or technologies on the horizon. There are new technologies still in the R&D lab that show promise, but have not advanced far enough to be commercially viable in the 2009-2012 timeframe.

3) *What portion of the enterprise storage market has the greatest need for an ENERGY STAR label to help customers identify the most efficient products? In what market segments can EPA expect to garner the most energy savings?*

The SNIA is basing its recommendations on IDC market sizing data, and sees potential savings in Online, Near online, Virtual Media and Removable Media categories. The SNIA taxonomy categories recommended in Block #2, Comment #1 is the best starting point to make an impact and establish a solid foundation for including the balance of the SNIA taxonomy in later revisions of the specification.

Building Block #3

Comment 1:

The SNIA understands the parameters being stated for the OEM and VAR. Within the storage industry it is more common for Storage Systems to be ordered with all the components from the OEM. A VAR or another Manufacturer private-labeling the storage solution would then expend most of their effort on configuring the solution, but not adding additional hardware to the solution. In the case of a Manufacturer private-labeling a solution from an OEM, the industry would expect that Manufacturer to obtain the ENERGY STAR label/rating under their own name for market brand recognition purposes.

Comment 2:

Over the past 18 months, the SNIA has been examining Green Storage and solutions. The SNIA has published a working draft (the SNIA Green Storage Power Measurement Technical Specification, see http://www.snia.org/green), which defines a storage taxonomy and a technique to measure the power consumption of idle storage systems. Most of the work has been focused on Online, Virtual Media Library, and Removable Media Library systems taxonomy categories.

While in the Idle state, a storage system is performing device and data integrity and maintenance work. This is quite different from a Computer Server, whose Idle state is defined by an absence of useful activity. Since many of these maintenance activities cannot be turned off by an end-user, the SNIA believes the EPA Specification will need to recognize a series of maintenance features and functions and factor them into ENERGY STAR ratings and procedures. The SNIA would not advocate having the EPA specification allow these essential features become an option. That would put data integrity and restoration at high risk, and is counter to best practice in the data center. Note that data integrity is achievable by many means on highly configurable storage arrays – all of which require some degree of power-consuming activity. Storage arrays that do not deliver a high level of reliability and integrity as integral to the system can be configured with high degrees of redundancy to compensate to some degree (e.g., less efficient RAID, extra snapshots, clones, mirrors, etc). Reliability and integrity of data are core reasons for purchasing RAID arrays in the first place (bad or lost data is not of any use), so if a storage architect purchases a system that uses less energy at the expense of less reliability, they will very likely configure greater redundancy into that array and thereby use even more energy rather than less. The worst case would involve two completely redundant storage arrays for a single customer need. Therefore, what's important to take away here is that maintaining reliability and integrity of data is never free and must somehow be accounted for in evaluating Storage Products for energy efficiency.

The SNIA is in the process of expanding its specification to include the idle measurement techniques in all taxonomy categories/classifications. Improvement to the idle metric may also be needed to account for the work a storage system performs to insure reliability, availability and serviceability (RAS) features within tested configurations.

These features represent a significant enhancement to storage products, and can require significant additional work by (or additional components in) the storage product, with a resultant increase in power consumption. The SNIA is working to define a framework that would properly balance the additional value provided by RAS functions with the additional power and complexity they require, so that fair comparison can be made between a broad range of systems.

The SNIA is also currently working on an active test procedure and metric. There are several aspects of the active storage to be rationalized. Such aspects include but are not limited to; differences between taxonomy categories and classifications, protection level adders in power consumption, size and make of drives, and usable versus raw capacity. Workloads may have to be defined for each type of taxonomy category and/or classification to assure that they provide a robust assessment of a storage products utilization and efficiency. The different types of storage systems may each require different types of workloads generators.

In summary, the storage industry is working on a three dimensional problem - assessing performance, RAS, and energy efficiency. Often, it is easy to configure or design a given storage system for two of the three elements, while degrading the third; the challenge to the storage industry is to embrace all three in an ENERGY STAR Specification with no one element being degraded in value.

Comment 3:

One of the cited objectives of the ENERGY STAR specification is to identify and reward storage solutions that seamlessly integrate software and hardware efficiency strategies that provide verifiable benefits without user intervention. This raises a few concerns.

First, data center class storage systems provide a high degree of configurability, and assume that a given installation will be carefully tailored to meet a mix of performance, reliability and efficiency requirements. Customers for such systems may not benefit from or tolerate “automatic” configuration and tuning. For example, home users are generally tolerant of 10-second hard drive spin up times. This allows the ENERGY STAR specification for home computers to mandate hard drive spin-down management configured by default. If it took 5 minutes to spin up a hard drive, however, users would not likely be tolerant of this, and the specification's intent would be quickly nullified.

Secondly, the ENERGY STAR specification should provide a means to assess energy consumption of a given storage product while accounting for common reliability, availability or performance requirements. Default configurations for energy efficiency measurement should not compromise other configuration considerations. This may also need to account for the use of additional components or products which, while not a required part of a given storage product, can provide substantial energy savings (e.g., deduplication).

Finally, this is another area for which the differing uses and demands of specific taxonomy categories will need to be accounted.

Comment 4:

The need to find ways to be more energy efficient when a system is not at peak load or active is desired by the EPA and the SNIA's members. It is not possible to have a deployed storage system that is optimally tuned for each and every workload. Measurement of any system's efficiency under any load is difficult at best. Storage systems have a variety of components that offer optimization for different workloads. For example, cache algorithms may be tuned for specific workloads, cache storage components distributed differently in a system, split caches may be reconfigured to be optimized for a particular workload. Optimizations for any one workload do not reflect a general increase in efficiency of that storage system in comparison to others. They merely reflect an increase in efficiency for that one workload. Favoring a system that is not flexible, or which has been specially tuned for the workload used when measuring ENERGY STAR ratings, may create an arbitrary advantage to one vendor which is not consistent with overall behavior of their system in all its possible real world deployments. Similarly, it is common for end-users to buy systems configured with growth in mind. At initial deployment a system may appear over configured, but in six or nine months, it could be maxed out with no upside space or bandwidth. The SNIA recognizes that storage systems being tested for ENERGY STAR will most likely be configured to the workload, but this can lead also to misconceptions in the marketplace of the tested rating versus a deployed configuration.

Significant tuning, refinement and reconfiguration of a product are done at a customer site and in response to evolving workload and business demands. Much of this work cannot be accurately anticipated beforehand, other than through the creation of a broad and flexible feature set that cannot be properly assessed through narrow or simplistic testing. Using a naïve solution to address the complex issue of the tuning, configuration and refinement of a storage product could be detrimental to markets, vendors and customers without providing an assured reduction in energy consumption.

Comment 5:

Data center storage systems are almost always powered with redundant PSUs. Most configurations are 1 + 1 or n + n redundant with the outputs of each PSU sharing the load at approximately 50%-50%. The PSU is, in most cases, a power-cooling module (the fan in the PSU FRU is used to provide cooling for the enclosure). It will be very difficult to instrument a system to allow measurement of the output loading of both PSUs without interfering with the system cooling; instruments will block air flow or force he enclosure to not be enclosed correctly. Relying on built-in monitors within the PSU will not give the accuracy required. Bench testing will provide the most accurate data for storage PSU efficiency measurements.

Comment 6:

Storage systems use both Single-Output and Multi-Output power supplies. These power supplies are almost always used in redundant power configurations (1 + 1 or n + n) with output load current sharing. The fans in the power supply are used to cool the system in most applications. It is our recommendation that the Fan Power be excluded in ALL power supply efficiency measurements, for both Single-Output and Multi-Output power supplies.

As the storage system is operated in a data center, and all power supplies are connected to the same data center power system, the input test conditions should be the same for Single-Output and Multi-Output power supplies. For consistency with the Server Specification, it is recommended that that condition be 230 Volts, 50Hz or 60 Hz. It is recommended that the EPRI specification be modified to reflect the above recommendation for Storage Power Supplies. See also block #3, comment #7.

Building Block 3: Questions for Discussion

1) *Which operational modes (e.g., Idle, Active, Full Load, Maximum) should EPA address in the specification? In which mode(s) might the highest energy savings be achieved?*

The SNIA believes Idle and some form or active measurement are two areas to start. The SNIA has already published a technical specification (the SNIA Green Storage Power Measurement Technical Specification, http://www.snia.org/green), and is working to define an extension to the standard that addresses active power consumption.

From some of the SNIA data collected for Online storage systems, an idle system consumes as much as 80 to 85% of the power draw of an active storage system. The storage industry generally accepts that a backup or archive system spends 60 to 80% of the time in the idle state.

There is no standard industry use of the terms Maximum and Full Load. See Block #1, Question #1, for our recommendations in this area.

2) *For various types or classes of Storage Products, what is the typical breakdown of energy consumption across operational states? E.g. an xx TB Storage Product typically consumes between xx and xx watts, and over the course of a year, xx % of the power is consumed in Idle state and xx% in Active state*

The answer to this question is too dependent on the data center and its applications for a single answer to be possible. The same storage system can be used in video streaming, large database applications, or backup and archive. Each of these instances would have a different idle or active state percentage. The amount of power consumed for a TB of storage will depend on the drive type placed in the storage system and is a continually moving target.

3) *Are there any additional power consumption or efficiency test procedures that should be considered for reference in the ENERGY STAR specification?*

The SNIA is working on an active metric. There are performance benchmarks in the industry from other associations; however there is no common agreement in the industry on whether these are reflective of the typical daily workload environment for any given end-user. The SNIA also recognizes different workloads may be required for different taxonomy categories. For example, a performance workload would not apply to a Near online storage system.

4) *Are there industry standard methods of measuring or specifying the useful work capacity or performance of a Storage Product? What other benchmarks might EPA consider for Storage Products?*

See #3. We recognize SPC and SPEC as having related tests.

5) *It has been noted that the SPECsfs2008 benchmark might be an appropriate workload for NAS devices and is currently used by many NAS vendors. Is the benchmark suitable for more than NAS?*

The SPECsfs2008 benchmark is valid for filesystem tests only. It would not be appropriate for Block based storage systems, backup tests, or archiving.

6) *Are the power supply test procedures, test methods and levels from the Computer Server specification applicable to Storage? Is there data available that support these levels? What modifications might have to be made to address any of the unique characteristics of storage power supplies?*

Refer to Comments #5 and # 6 above

7) *What are the typical loading ranges for Enterprise Storage power supplies? What are the typical redundancy configurations of these systems?*

Data center storage power systems are almost always 1 + 1 or n + n redundant configurations with the output of each power supply shared with another power supply at approximately 50-50 ratio. That means that no power supply under normal operating conditions will be operating at greater than 50% of its rated power load. In most cases it will be operating at <50% of rated load. Typical operating range will be 20% to 45%. For this reason, we recommend dropping any efficiency requirements for utilization ratios above 50%, so that power supply vendors can concentrate design efforts on the load range that is actually used.

8) *Would a specification for net power loss or efficiency over the load range be appropriate for Enterprise Storage?*

See Block #3, Comment #5.

9) *Does the VAR sales channel play an important role in the Enterprise Storage market? Would the above requirements make clear how to qualify storage products through third-party sales channels?*

The VAR channel is important for the configuration, delivery, and support of systems in the SMB market. Most OEMs configure and deploy to the Fortune 500. Most VARs are not responsible for substantive change to product composition or design, focusing instead on configuration and tuning for a specific customer. The SNIA believes the specification will be understandable to the VAR channel. There may be some specific issues in niche markets (e.g., Telco or military), but they are beyond the scope of the currently proposed specification.

Building Block #4

Questions for Discussion

1) *What, if any, characteristics of the above requirements may not be appropriate for Storage Equipment? What data reporting capabilities do typical Storage Equipment currently posses? Are there industry trends towards the inclusion of these reporting capabilities?*

Systems today provide management and measurement interfaces using either SNMP, SMI-S, or XML.

Most storage products today can report basic asset, capacity utilization and configuration information. However, energy consumption, system performance, and temperature reporting is neither common nor complete. The available reporting does not provide the data, format and units as defined by the suggested forms in the EPA specification Computer Server program. Some of the measurement accuracies need further investigation, given the complexity of storage systems, (e.g. multiple inlets, multiple power supplies, and multiple cabinets). Whatever the utilization metric might be, the metric may not match the customer environment. Once the proposed specification has defined Storage system metrics, they will need to be harmonized with the Server specification.

Expanding the reporting capabilities of a shipping product, if required, is likely to take as much as 18 to 24 months, if anything has to be done at the circuit board level or driven back into a vendor's supply chain.

There are some system and component challenges that need to be resolved as it relates to overall system reporting. For example, today's systems do not have the ability to report input power to every power supply within the system. Is every power supply required to be independently measured or is a system-wide aggregate or average result sufficient?

Some vendors product configurations include off the shelf equipment manufactured by companies that are not storage system providers (i.e. data switches, UPS, etc.) If the Specification is to focus on total input power for the Storage System, this value would need to be calculated and communicated by a PDU. If the PDU is not supplied by the Storage System vendor, then the vendor can recommend PDUs to the data center, but it would be up to the data center to procure and install the appropriate PDU to meet this reporting requirement.

2) *What additional information specific to Enterprise Storage might be required for the Power and Performance Data Sheet?*

A more detailed disclosure of the configuration should be required, including RAS features present and configured, types of components in the system such as drive size/speed/type, speed of the FC or network, along with anything that would correlate or affect energy consumption, and any new metrics that are defined in this V1.0 Specification.

3) *How is utilization defined for Storage Equipment? What utilization information would be helpful to managers for procuring the proper equipment and integrating those systems into their data centers?*

Utilization, like storage capacity, is in the eye of the beholder. Generally, it is a measure of resource consumption, but that presumes a common understanding of the underlying resource and its initial, total capacity. In storage, that total changes as the initial raw capacity is refined and enhanced (through the addition of data protection, increased bandwidth, or virtualization, for example). The manufacturer, storage administrator and end-user all have a different sense of what constitutes “available capacity” and “used capacity” each has a different sense of Utilization. To help clarify the situation, the SNIA Dictionary Review Board is working on definitions for "raw", "formatted", "usable", "available" and "nominal" forms of capacity.

This definition may also change for different taxonomy categories or installation types. For storage systems deployed in high performance environments, utilization may be a percent of the available bandwidth, the number of ports, and or the amount of cache; whatever measure focuses on the resource that is either most scarce or most important in assessing the overall performance perception of the system.

End-users typically size their workload and storage needs, and then procure a system with additional capacity that they will grow into over 3-12 months. Some end-users have characterized their workloads and setup vendor comparison benchmarks with planned configurations to select the best price/performance solution. A clear explanation of the use of storage capacity (utilization) throughout the layers of storage abstraction present in a data center product (e.g., raw, formatted, protected) would provide additional guidance to this sizing process.

4) *Are there any industry accepted communication protocols available for measuring utilization, temperature, etc?*

Within the storage industry there are no communication protocols available specifically for measuring utilization and temperature. Most systems can be communicated with today either by SNMP, SMI-S, or XML for basic asset information (including utilization and temperature, if the system keeps statistics on those) and limited configuration commands.

Appendix # 1 Storage Industry Terms and Definitions

This appendix includes terms which the SNIA feels should be added to the draft framework (labeled “new”), suggested changes to the current definitions (labeled “revised”), as well as terms for which the SNIA has yet to finalize its recommended definition.

Storage Hardware:

blade chassis: Not an industry standard term. Further discussion required.

blade storage: Not an industry standard term. Further discussion required.

blade system: A computer or storage system composed of a chassis that provides power, cooling and other common infrastructure, and one or more removable server or storage units, usually called blades. Blade systems are designed as a scalable solution to efficiently package and operate multiple processing or storage units in a single enclosure, and are designed for technicians to be able to easily add or replace hot-swappable boards in the field. [The SNIA Dictionary, 2009 fall edition]

I/O adapter: An adapter that converts between the timing and protocol requirements of a system's memory bus and those of an I/O bus or network. In the context of storage subsystems, I/O adapters are contrasted with embedded storage controllers, that not only adapt between buses, but also perform transformations such as device fan-out, data caching, and RAID. Host bus adapters (HBAs) and Ethernet NICs are types of I/O adapters. [The SNIA Dictionary, 2009 fall edition]

I/O device: Synonym for I/O adapter. [The SNIA Dictionary, 2009 fall edition]

[Note for EPA draft definition]: The I/O device does not generate the workload; it carries the workload. Example of a workload generator is a host computer. Additionally, an I/O device should not to be confused with initiators and targets (terms originated from SCSI I/O technology) of I/O. An example of a device generated workload would be the periodic scan for bad blocks.

storage appliance: Not an industry standard term. Further discussion required.

storage blade: Not an industry standard term. Further discussion required

storage controller: A device for handling storage requests that includes a processor or sequencer programmed to autonomously process a substantial portion of I/O requests directed to storage devices. [revised 2009 SNIA definition]. Aggregating RAID controllers and filers are examples of storage controllers. [The SNIA Dictionary, 2009 fall edition]

storage device: A collective term for devices containing and providing I/O to storage media. E.g., disk drives, tape drives, JBOD (just a bunch of disks) disk enclosures, and any other mechanisms capable of non-volatile data storage. This definition is specifically intended to exclude aggregating storage elements such as RAID array subsystems, robotic tape libraries, filers, and file servers. [The SNIA Dictionary]

storage -media: The material in a storage device on which data is recorded. Storage media includes electrical (e.g. solid state), magnetic (hard disk, tape), and optical media. [The SNIA Dictionary, 2009 fall edition]

storage product family: Not an industry standard term. Further discussion required.

storage product: Not an industry standard term. Further discussion required

Storage Characteristics:

[Note; the SNIA recommends expanding the capacity definitions, and replacing the direct and network connect definitions with DAS and networked attached storage.]

raw capacity: A SNIA definition under development

available capacity: A SNIA definition under development

formatted capacity: A SNIA definition under development

consumable capacity: A SNIA definition under development

usable capacity: A SNIA definition under development

nominal capacity: A SNIA definition under development

Storage capacity units of measure: Capacities in base-10.

A kilobyte (KB) is equal to 1,000 (10^3) bytes.

A megabyte (MB) is equal to 1,000,000 (10^6) bytes.

A gigabyte (GB) is equal to 1,000,000,000 (10^9) bytes.

A terabyte (TB) is equal to 1,000,000,000,000 (10^{12}) bytes.

A petabyte (PB) is equal to 1,000,000,000,000,000 (10^{15}) bytes

RAS: An acronym for Reliability, Availability and Serviceability [The SNIA Dictionary]

network-connected: Storage designed to be connected to a host via a network protocol (e.g., TCP/IP, InfiniBand, FibreChannel, etc).

Direct Attached Storage (DAS): One or more dedicated storage devices connected to one or more servers. [The SNIA Dictionary, 2009 fall edition]

Network Attached Storage (NAS):

1. A term used to refer to storage elements that connect to a network and provide file access services to computer systems. These elements generally consist of an engine that implements the file services, and one or more devices, on which data is stored.
2. A class of systems that provide file services to host computers using file access protocols such as NFS or CIFS. See storage area network. [The SNIA Dictionary]

Storage Area Network (SAN)

1. A network whose primary purpose is the transfer of data between computer systems and storage elements and among storage elements. A SAN consists of a

communication infrastructure, which provides physical connections, and a management layer, which organizes the connections, storage elements, and computer systems so that data transfer is secure and robust. The term SAN is usually (but not necessarily) identified with block I/O services rather than file access services.

2. A storage system consisting of storage elements, storage devices, computer systems, and/or appliances, plus all control software, communicating over a network. [The SNIA Dictionary]

Storage Terminology – Correlates to the SNIA Taxonomy and Configurations:

Count Key Data (CKD): A disk data organization model in which the disk is assumed to consist of a fixed number of tracks, each having a maximum data capacity. The CKD architecture derives its name from the record format, which consists of a field containing the number of bytes of data and a record address, an optional key field by which particular records can be easily recognized, and the data itself. [The SNIA Dictionary]

Fixed Block Architecture (FBA): A model of disks in which storage space is organized as linear, dense address spaces of blocks of a fixed size. Fixed block architecture is the disk model on which SCSI is predicated. [The SNIA Dictionary]

maximum configuration: **(new)** Specifies the lower bound on the maximum number of storage devices in the PRODUCT, either as part of original configuration or through field upgrades.

Maximum Time To Data (MaxTTD): (new) The maximum time before an entire data object is accessible within the constraints imposed by its storage media. For random-access media, a data object is accessible when any byte may be accessed. For sequential-access media, a data object is accessible when the requested object has begun streaming from a previously inactive drive.

non-disruptive serviceability: (new) Support for continued availability of data during all FRU service operations, including break/fix, code patches, software/firmware upgrades, configuration changes, data migrations, and system expansion. Service operations may result in performance impacts to data availability, but shall not result in a loss of access.

sequential writes: An I/O load consisting of consecutively issued write requests to adjacently located data. Sequential I/O is characteristic of data transfer intensive applications. [The SNIA Dictionary]

Single Point of Failure (SPOF): One component or path in a system, the failure of which would make the system inoperable. [The SNIA Dictionary]

storage protection: (new) A combination of RAID, NVRAM and sparing that assures that all I/O operations will be preserved in the event of power loss or storage device failure.

FRU: Field-replaceable Unit, A unit, or component of a system that is designed to be replaced “in the field;” i.e., without returning the system to a factory or repair depot. Field replaceable units may either be customer-replaceable, or their replacement may require trained service personnel. [The SNIA Dictionary]

PDU: (new) Power Distribution Unit. A well-constructed power strip suitable for data center use. Two basic varieties distinguished by the type of input power are common: single-phase and three-phase. The output power (i.e. the power to the load device) is always single-phase, however. In the case of a three-phase PDU, each of the three phases appears individually on every third receptacle. PDUs can be dumb -- meaning that they have no instrumentation and are not manageable, or they can be metered -- meaning that they are equipped with a display that shows current load on each phase, or they can be switched -- meaning that some or all of their receptacles can be individually switched on or off remotely.

SCSI: (new) Small Computer System Interface. A collection of ANSI standards and proposed standards that define I/O buses primarily intended for connecting storage subsystems or devices to hosts through host bus adapters. Originally intended primarily for use with small (desktop and desk-side workstation) computers, SCSI has been extended to serve most computing needs, and is arguably the most widely implemented I/O bus in use today

UPS: Uninterruptible Power Supply. A source of electrical power that is not affected by outages in a building’s external power source. UPSs may generate their own power using generators, or they may consist of large banks of batteries. UPSs are typically installed to prevent service outages due to external power grid failure in computer applications deemed by their owners to be “mission critical.” [The SNIA Dictionary]

Other Data Center Hardware

The SNIA recommends adding in a qualifier for both Computer Server and Blade Server: they are intended to run general purpose OSes with end-user applications.

Power Supplies

Power Supply Unit (PSU): Synonym for power supply. [The SNIA Dictionary] Note: if the ENERGY STAR Specification requires the PSU to be a FRU, then the definition should elaborate more about this.

power supply: A component which converts an AC or DC voltage input to one or more DC voltage outputs for the purpose of powering a system or subsystem. Power supplies may be redundant and hot swappable. [The SNIA Dictionary, 2009 fall edition]

AC-DC definition: could include in its description that it supports single phase and three phase power. This elaboration will correlate to the tables for single phase and three phase power efficiency ratios.

DC-DC definition: should include in its description the capability of converting from higher voltages to lower voltages inside of a system, e.g. tape library example going from 48V to a lower voltage.

redundant power supplies: Two or more power supplies that are in active/active configuration, equally sharing the total load required. If a power supply fails, the remaining power supplies can handle the full load.

Operational States

idle: Not an industry standard term. Further discussion required. See Block #1, Question #1 for more detail.

active: Not an industry standard term. Further discussion required. See Block #1, Question #1 for more detail

maximum: Not an industry standard term. Further discussion required. See Block #1, Question #1 for more detail

Appendix #2 The SNIA Recommended Storage Product Taxonomy

(Note: the following material is taken from the SNIA's Green Storage Power Measurement Technical Specification. It is available free-of-charge at http://www.snia.org/green)

Taxonomy categories define broad market segments that can be used to group products that share common functionality or performance requirements, and within which meaningful product comparison can be undertaken. This specification defines six broad taxonomy categories:

- Online, Products in this profile may provide any combination of block, file or object interfaces.
- Near-Online, Products in this profile employ MAID or FCAS architectures.
- Removable-Media Library, Products that rely on automated or manual media loaders (e.g., tape or optical libraries).
- Virtual Media Library, Products that rely on optical or disk-based storage media to provide a Virtual Tape Library
- Infrastructure Appliance, Products in this category rely on a closed environment to typically support a single-purpose, dedicated storage-oriented service or application (e.g., virtualization, de-duplication, NAS gateways). No end-user accessible data is stored in the appliance. Devices in this category are part of the data path from a host to a storage device, and are responding to I/O requests in real time. Storage appliances that are outside the data path (e.g., backup servers) are not addressed by this category
- Infrastructure Interconnect Elements, Products and components for managed inter-connect elements within a storage area network (e.g., switches, extenders)

Within a taxonomy category, a specific model or release of a product will support different feature sets, whether focused on capacity, reliability, functionality or another differentiator. Feature and functionality differences within a category are addressed with attributes. Each taxonomy category defines a set of attributes that are common to all products within the category.

Table 1 Online Taxonomy Classifications

Attribute	Category					
	Online	**Near online**	**Removable Media Library**	**Virtual Media Library**	**Appliance**	**Interconnect**
Access Pattern	Random	Random	Sequential write	Sequential write		
MaxTTD (t)	t < 80 ms	t > 80 ms	t > 80 ms t < 5 min	t < 80 ms	t < 80 ms	t < 80 ms
User accessible data	Required	Required	Required	Required	Prohibited	Prohibited

Table 2 Online Taxonomy Classifications

Attribute	Classification				
	Online 1	Online 2	Online 3	Online 4	Online 5
Access Pattern	Random	Random	Random	Random	Random
Connectivity	Not specified	Connected to single or multiple hosts, but not shared	Network-connected	Network-connected	Network-connected
Storage Protection	Optional	Optional	Required	Required	Required
FBA/CKD Support	Optional	Optional	Optional	Optional	Required
Maximum Configuration	4	> 4	> 20	> 100	> 1000
MaxTTD (t)	t < 80 ms	t < 80 ms	t < 80 ms	t < 80 ms	t < 80 ms
No SPOF	Optional	Optional	Optional	Required	Required
Integrated PDU and UPS	Optional	Optional	Optional	Optional	Required
Rackmount	No	Yes	Yes	Yes	Yes
Non-Disruptive Serviceability	Optional	Optional	Optional	Optional	Required
User-Accessible Data	Required	Required	Required	Required	Required

Table 3 Removable-Media Library Taxonomy Classifications

Attribute	Classification				
	Removable 1	**Removable 2**	**Removable 3**	**Removable 4**	**Removable 5**
Access Pattern	Sequential write	Sequential write	Sequential write	Sequential write	Sequential write
MaxTTD (t)	t > 80 ms t < 5 m	t > 80 ms t < 5 m	t > 80 ms t < 5 m	t > 80 ms t < 5 m	t > 80 ms t < 5 m
No SPOF	Optional	Optional	Optional	Optional	Required
Robotics	Prohibited	Required	Required	Required	Required
Maximum Drive Count	Not specified	≤ 4	≥ 5	≥ 25	≥ 12
User-accessible Data	Required	Required	Required	Required	Required

Refer to the SNIA's Green Storage Power Measurement Technical Specification for more details on the other taxonomy categories.

Appendix #3: Representative Configurations

SNIA Education

SNIA Taxonomy - Online Storage

Diagrams Online #2,#3,#4

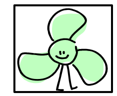
Range of Online Configurations

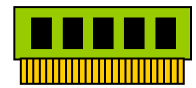
with RAS Energy Challenges

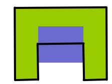
Legend for Acronyms and Symbols

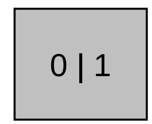
Education SNIA

- FBA/CKD: **F**ixed **B**lock **A**rchitecture / **C**ount **K**ey **D**ata
- JBOD : **J**ust a **B**unch **o**f **D**isks
- Max TTD: **M**aximum **T**ime **t**o **D**ata (access)
- PDU: **P**ower **D**istribution **U**nit
- RAS: **R**eliability, **A**vailability, **S**erviceability
- SPOF: **S**ingle **P**oint **o**f **F**ailure
- UPS: **U**ninterruptible **P**ower **S**upply

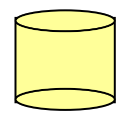

Fan

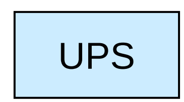

Memory module


Port



Power supply


Rotating disk media



UPS

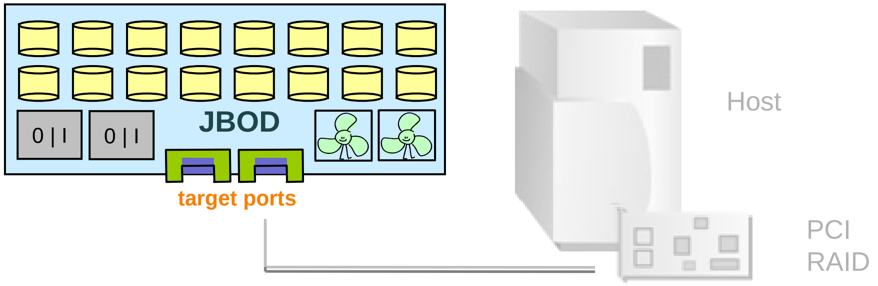
Online Storage Classes and Attributes

Attribute	Classification				
	Online #1	**Online #2**	**Online #3**	**Online #4**	Online #5
Access Pattern	Random	Random	Random	Random	Random
Connectivity	Not specified	Connected to single or multiple hosts, but not shared	Network-connected	Network-connected	Network-connected
Storage Protection	Optional	Optional	Required	Required	Required
FBA/CKD Support	Optional	Optional	Optional	Optional	Required
Maximum Configuration [1]	4	> 4	> 20	> 100	> 1000
MaxTTD (t)	t < 80 ms	t < 80 ms	t < 80 ms	t < 80 ms	t < 80 ms
No SPOF	Optional	Optional	Optional	Required	Required
Integrated PDU and UPS	Optional	Optional	Optional	Optional	Required
Rackmount	No	Yes	Yes	Yes	Yes
Non-Disruptive Serviceability	Optional	Optional	Optional	Optional	Required
User-Accessible Data	Required	Required	Required	Required	Required

(grey box) =Not recommended in scope for Tier 1 EPA ENERGYSTAR Specification

Typical Online #2 Storage Array: Small JBOD

Attribute	Online #2
Access Pattern	Random
Connectivity	Connected to single or multiple hosts, but not shared
Storage Protection	Optional
FBA/CKD Support	Optional
Maximum Configuration [1]	> 4
MaxTTD (t)	t < 80 ms
No SPOF	Optional
Integrated PDU and UPS	Optional
Rackmount	Yes
Non-Disruptive Serviceability	Optional
User-Accessible Data	Required



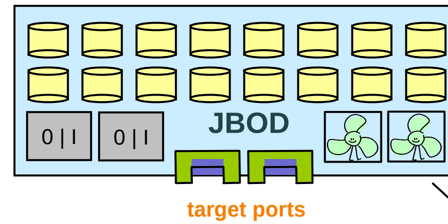
JBOD

* 1 or 2 power supplies
* 1 or 2 fans
* 1 or more ports
* single-port disks

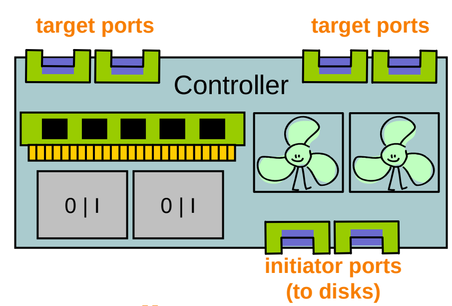
The host is the controller

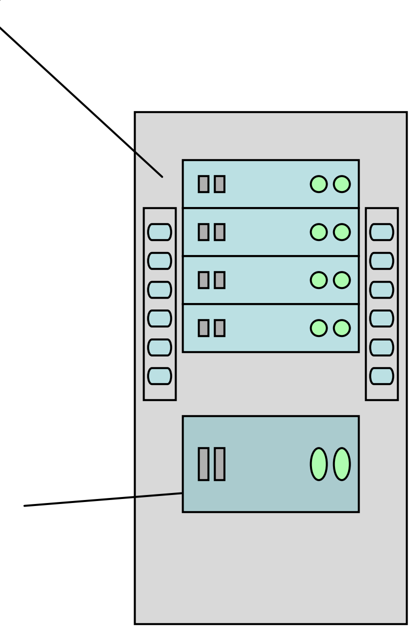
Typical Online #3 Storage Array:
Single controller with redundant power supplies and fans

Attribute	Online #3
Access Pattern	Random
Connectivity	Network-connected
Storage Protection	Required
FBA/CKD Support	Optional
Maximum Configuration [1]	> 20
MaxTTD (t)	t < 80 ms
No SPOF	Optional
Integrated PDU and UPS	Optional
Rackmount	Yes
Non-Disruptive Serviceability	Optional
User-Accessible Data	Required



JBODs ("disk shelves")
* 1 or 2 power supplies
* 1 or 2 (or more) fans
* 2 ports





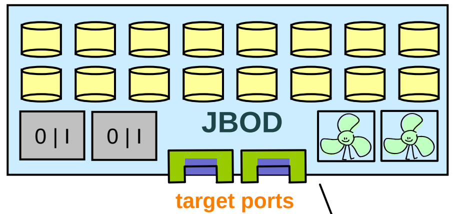
Controller
* 1 or 2 power supplies
* 1 or 2 (or more) fans
* 4+ ports

- 10+ power supplies
- 10+ fans
- 1 or 2 PDUs

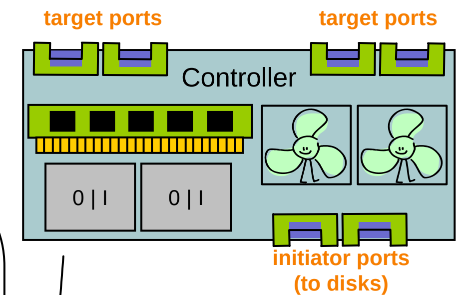
Typical Online #4 Storage Array:
High Availability configuration – redundant pair (“cluster”)

Education SNIA

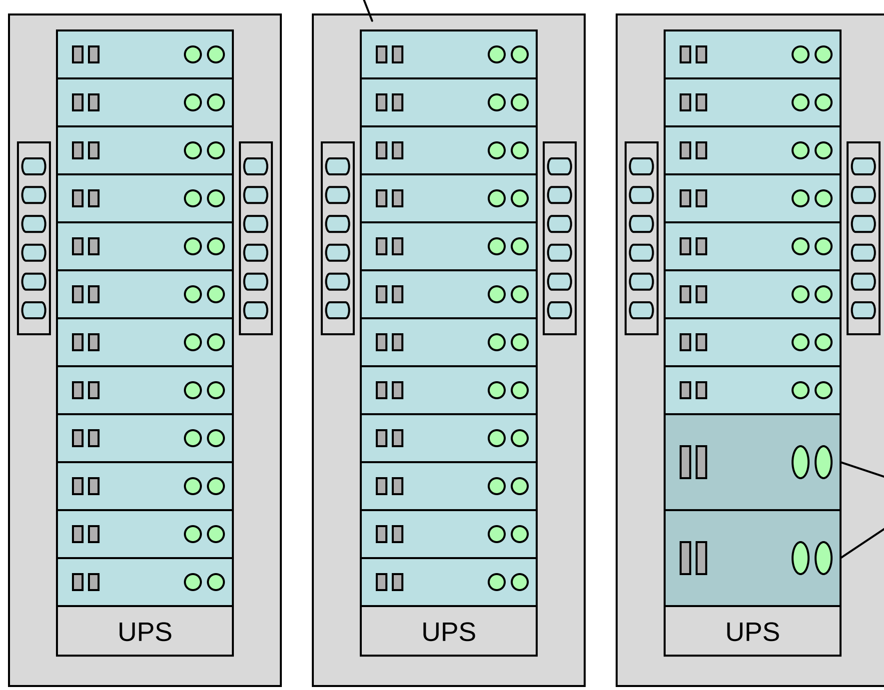
Attribute	Online #4
Access Pattern	Random
Connectivity	Network-connected
Storage Protection	Required
FBA/CKD Support	Optional
Maximum Configuration [1]	> 100
MaxTTD (t)	t < 80 ms
No SPOF	Required
Integrated PDU and UPS	Optional
Rackmount	Yes
Non-Disruptive Serviceability	Optional
User-Accessible Data	Required



JBODs (“disk shelves”)
Everything redundant or dual-pathed
* 2 power supplies
* 2 (or more) fans
* 2 network ports
* dual-port disks
* dual-path backplane



Controllers
If backplane = SPOF, must be redundant
Each has
* 2 power supplies
* 2 (or more) fans
* 4+ network ports



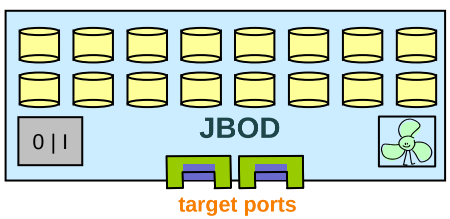
2 controllers (linked)

•72+ power supplies
•72+ fans
•6 or more PDUs

UPS is optional -depending on design

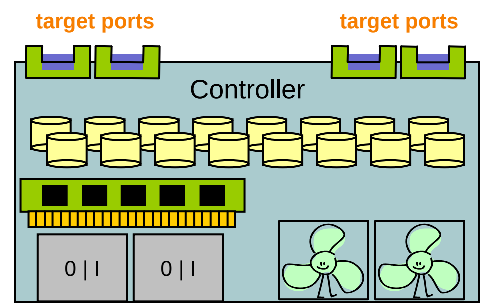
RAS energy challenges with Online #2 Storage Arrays

Minimal configuration Online #2 - no RAS features



JBOD
* 1 power supply
* 1 fan
* 1 or more ports
* single-port disks

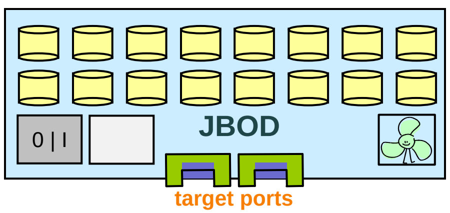
Robust configuration Online #2 - several RAS features - no need for dedicated host



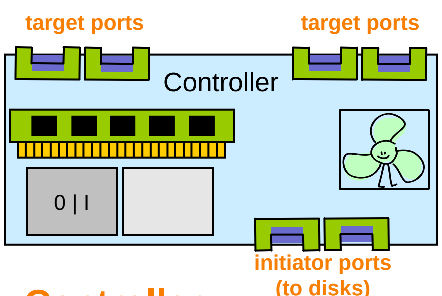
JBOD
* 2 power supplies
* 2 fans
* 2 or more ports
* possibly dual-port disks

RAS energy challenges with Online #3 Storage Arrays

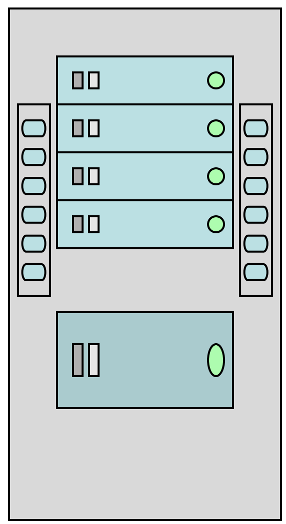
Minimal configuration Online #3 - fewer RAS features



JBODs (“disk shelves”)
* 1 power supply, extra slot for 2nd
* 1 fan



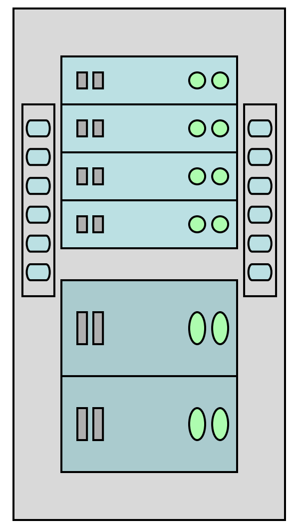
Controller
* 1 power supply, 1 fan



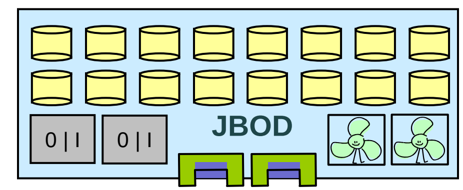
Larger, slower fans use less power

Non-redundant power supplies run at higher efficiency

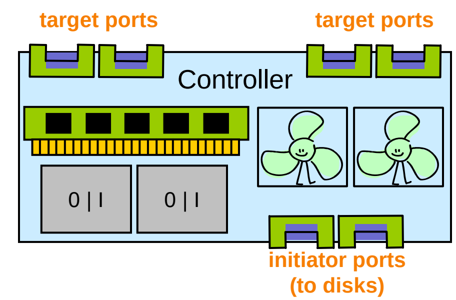
Robust configuration Online #3 - many RAS features



Redundant fans and power supplies



JBODs (“disk shelves”)
* 2 power supplies
* 2 (or more) fans



Controller
* 2 power supplies
* 2 or more fans

RAS energy challenges with #4 Online Storage Arrays

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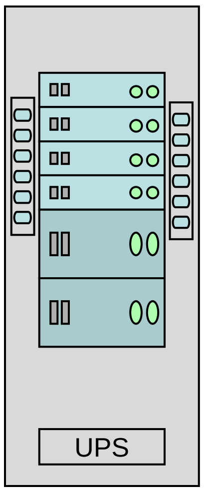
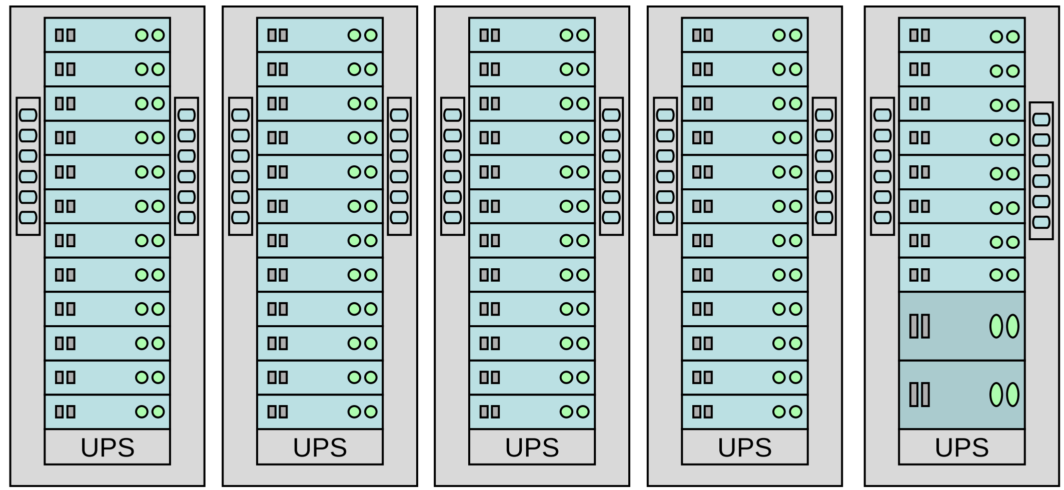
Minimal configuration -many RAS features



Less efficient

Large configuration - many RAS features



More efficient--energy cost of controllers is amortized against more storage devices