Cloud Vendor Benchmark 2015

Price-Performance Comparison Among 15 Top IaaS Providers

Part 2.5: 2XLarge VMs Linux

May 2015

Part 2.5: 2XLarge VMs Linux

CloudSpectator.com

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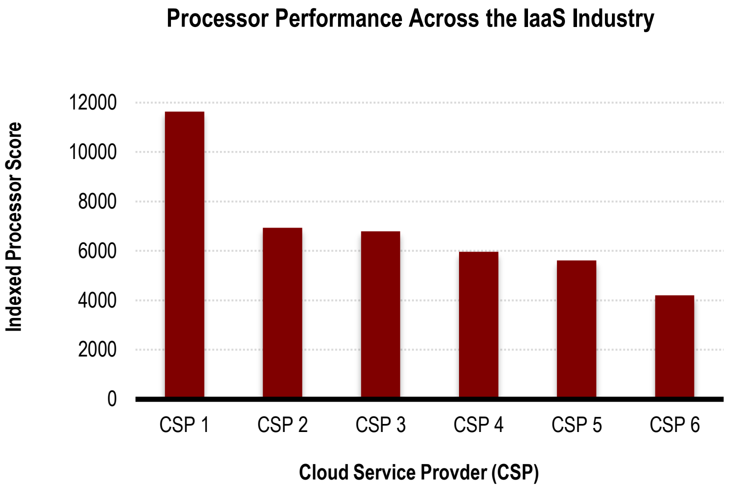
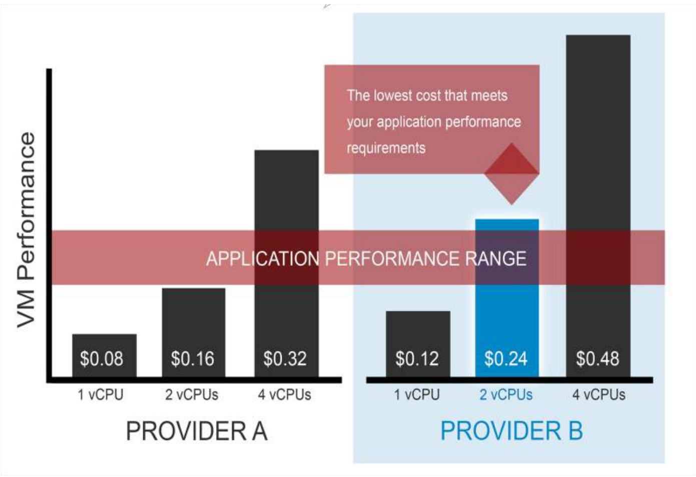
PREFACE

Performance and pricing are both key considerations in the public cloud industry, together having a substantial impact on annual operating costs. Cloud users may need fewer resources on better performing services, which can lower costs depending upon the price-performance ratio. Since many users only consider price and not price-performance, these users may be paying more because they require additional resources to achieve a desired level of performance. While some providers try to differentiate their offerings by cutting prices, others try to differentiate by focusing on improved performance. Recent examples of performance improvement include Rackspace's Performance Servers, Microsoft Azure's D-Series, and most recently, Amazon EC2's C4 family. This report examines the performance and the price-performance of the virtual machines included in the *Cloud Vendor Benchmark 2015 Part 1: Pricing Report*.

Why Does Performance Matter?

Differences in performance outputs of VMs across IaaS providers can greatly impact quality of service as well as annual operating costs. The graph on the right illustrates an example of the average processor performance from a sample of six Cloud Service Providers (CSPs) as studied by Cloud Spectator. CSP 1 has a processor performance three times as high as CSP 6 (names removed), which gives CSP 1 a notable advantage in many processor-intensive workloads. CSPs 2-5 exhibit a closer resemblance in processor performance, but do not offer nearly as much processing power as CSP 1 does.





The performance differences, as a result, will be further reflected in the operating costs of a cloud deployment. The graph on the left depicts a scenario where a 2 vCPU machine of provider B can meet the performance requirement of a certain application while a 2 vCPU machine of provider A cannot. Despite its higher unit price, clients can in fact save cost by deploying Provider B's 2 vCPU machine to run that application instead of a 4 vCPU machine on provider A, which is the lowest priced configuration that meets the application performance requirement for that specific provider. Therefore, understanding the price-performance output of different providers is critical since it allows clients to find the most cost-effective virtual machines that fit their application requirements and saves them money.

About the Cloud Vendor Benchmark 2015 Part 2: Performance and Price-Performance Report

The *Cloud Vendor Benchmark 2015 Part 1: Pricing* report compares pricing across vendors in the IaaS industry. The document did not assume performance differences across providers; for example, 1 vCPU on Amazon Web Services was considered equivalent to 1 vCPU on Rackspace Cloud. Comparisons were standardized by sets of minimum system requirements defined as Small, Medium, Large, Extra Large, and 2x Large (see

Appendix: VM Sizing for VM configuration information). For detailed information, please refer to the Part 1 report or contact Cloud Spectator at contact@cloudspectator.com.

Part 2 takes the pricing data and server sizes from Part 1 and incorporates CPU and memory performance testing. CPU and memory tests were conducted continuously over a 24-hour period across all of the VMs and providers examined in Part 1. Over the test period, more than 1.1 million data points were collected for the Linux OS (Ubuntu 14.04). By applying the results of the performance testing with the pricing and VM setups in Part 1, this report examines the value of the VMs with respect to performance, price-performance, and performance stability.

THIS REPORT ANALYZES ONLY THE 2XLARGE VM SETUP EXAMINED IN PART 1. EXACT VM SIZES USED CAN BE FOUND IN THE APPENDIX UNDER VM SIZES. RELATIVE PERFORMANCE RANKINGS WILL NOT BE THE SAME ACROSS DIFFERENT VM SIZES. FOR PERFORMANCE STUDIES ON ADDITIONAL VM SIZES, PLEASE VISIT CLOUD VENDOR BENCHMARK 2015 REPORTS.

Performance data was collected from CPU and memory tests. The CPU test includes 23 CPU-intensive tests categorized between integer and floating point tasks. The memory test includes 4 memory-intensive tasks measuring bandwidth. The aggregated CPU & memory test score includes a total of 27 tasks. All 27 tasks were run using the Geekbench 3 Test Suite. Performance results were categorized and analyzed in low, median and high scores. Price-performance was examined using hourly, monthly, annual and 3-year pricing. *The Cloud Vendor Benchmark 2015 Part 2: Performance and Price-Performance* is the largest public-facing performance and price-performance report on the IaaS industry.

Part 2 is divided into 10 separate reports with regard to different VM sizes and operating systems. **This report only examines the 2xlarge machines running Linux.** All data in this report is accurate as of April 1, 2015.

The IaaS Providers

Amazon EC2	DigitalOcean	Google Cloud	Internap	ProfitBricks
CenturyLink Cloud	Dimension Data*	HP Helion	Joyent*	Rackspace Cloud
CloudSigma	GoGrid	IBM SoftLayer	Microsoft Azure	Verizon Cloud*

**These providers do not have cloud offerings that fulfill the 2xlarge minimum requirement, and therefore were not included in the comparisons*

VM Pricing

Provider	Instance	vCPU	RAM	Storage (GB)	Hourly ($)	Monthly ($)	Annual ($)	3-Year ($)
AWS	r3.4xlarge	16	122	1 x 320 SSD	1.400	1022.00	6507	12906
CenturyLink	customized	16	32	-	0.640	467.20	5606	16819
CloudSigma	customized	16	32	50 SSD	-*	368.06	3975	9938
DigitalOcean	highvol3	16	48	480 SSD	0.714	480.00	5760	17280
Dimension Data	-	-	-	-	-	-	-	-
GoGrid	High RAM 4XL	16	64	40	1.640	897.90	7183	21550
Google	n1-standard-16	16	60	-	1.008	515.38	6185	18554
HP Helion	Standard 8XL	16	120	1770	3.240	2365.20	28382	85147
IBM SoftLayer	customized	16	32	25	0.756	520.80	6250	18749
Internap	B-16	16	60	320 SSD	1.280	934.40	11213	33638
Joyent	-	-	-	-	-	-	-	-
Microsoft Azure	D14	16	112	800 SSD	1.387	1012.51	12150	36450
ProfitBricks	customized	16	32	-	0.458	334.05	4009	12026
Rackspace	Compute1-60	32	60	-	1.580	1153.40	13841	41522
Verizon	-	-	-	-	-	-	-	-

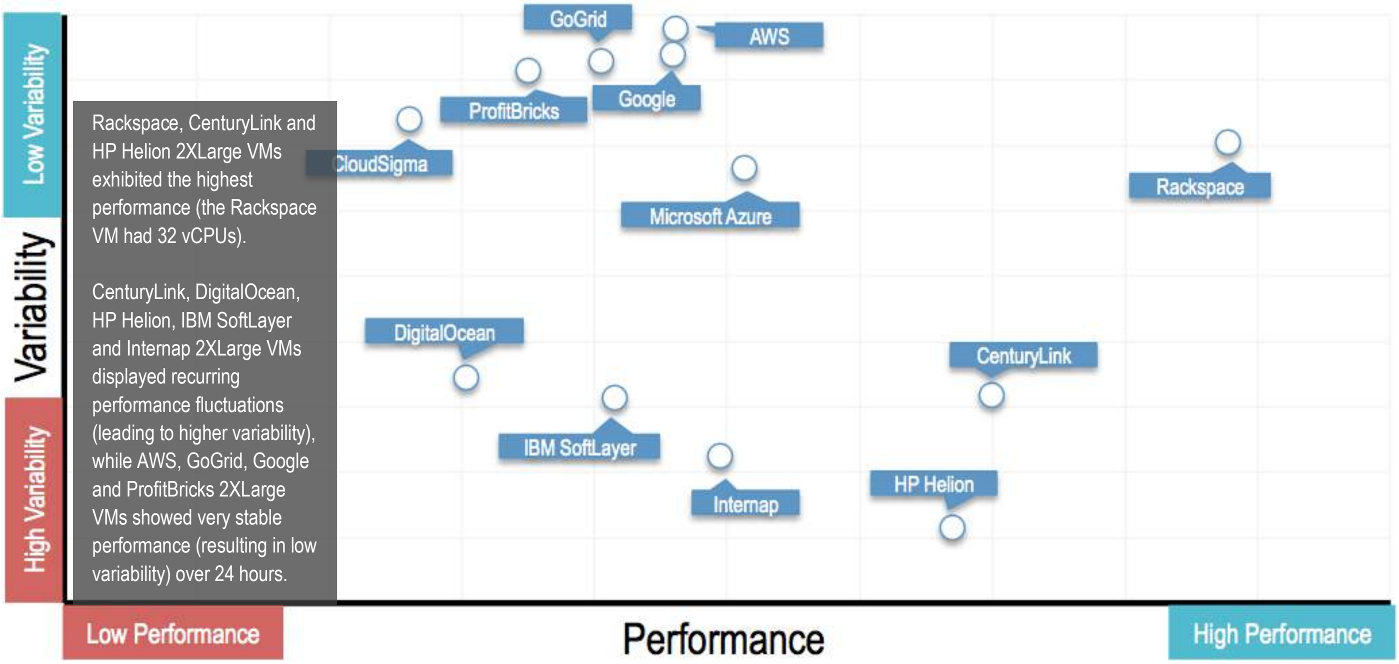
Prices in red are prices discounted from the hourly pricing.

**CloudSigma uses an algorithm to calculate its hourly pricing – burst pricing, which can be equal to or greater than monthly pricing. The price changes cannot be predicted ahead of time, and therefore CloudSigma's hourly pricing, along with its hourly price-performance values is not included in this report.*

EXECUTIVE SUMMARY

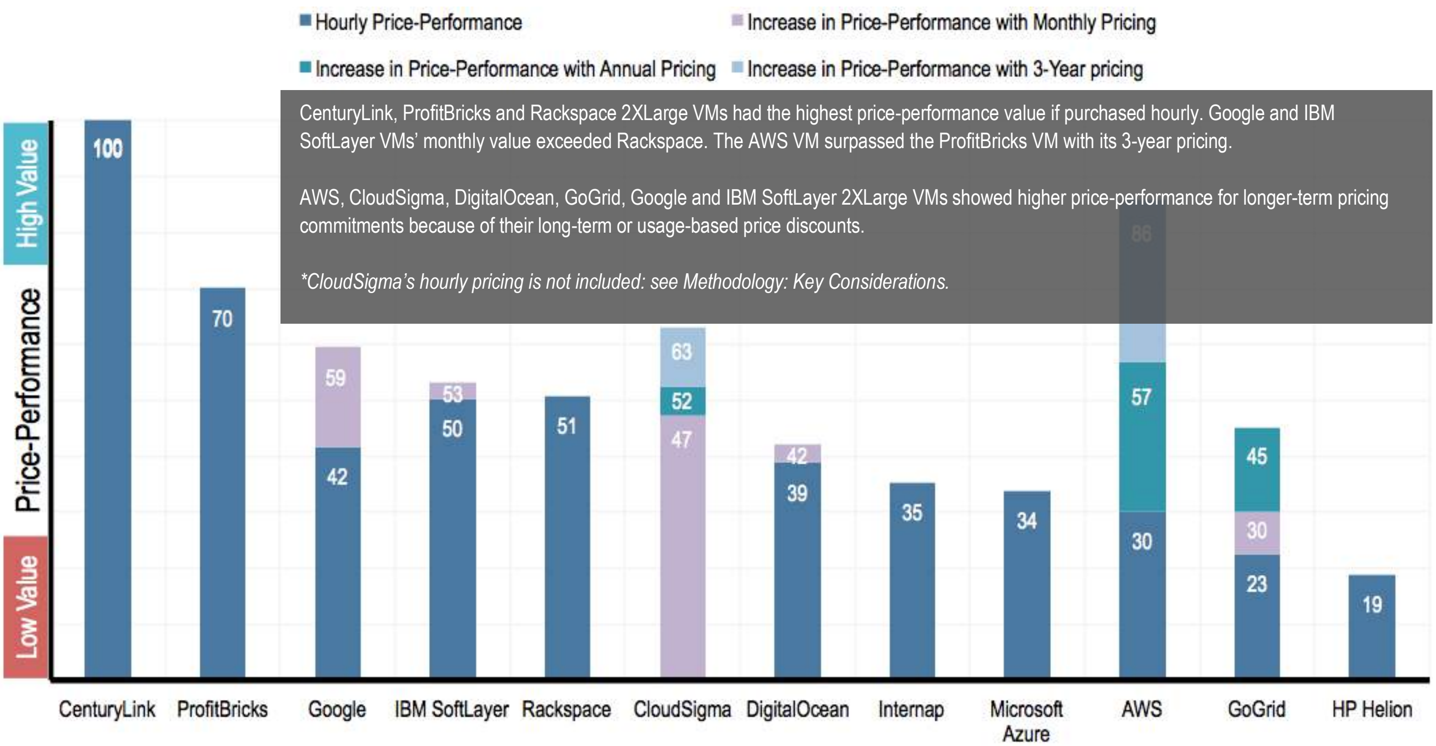
Key Performance Findings

The following graph shows the relationship between the included VMs' performance and variability. The performance is represented by median aggregated CPU & memory scores, and the variability is the degree of score variation during the 24-hour repeated testing.



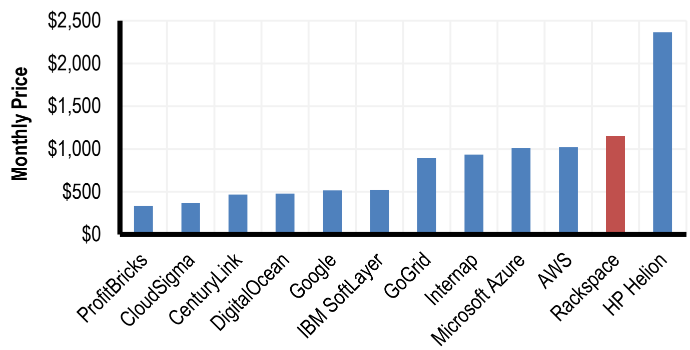
Key Price-Performance Findings

The following graph shows the CloudSpecs Scores™ of all included VMs representing their price-performance values, i.e., performance per unit of price. The scores were calculated using median aggregated CPU & memory performance scores. The providers are ranked by monthly CloudSpecs Scores™.

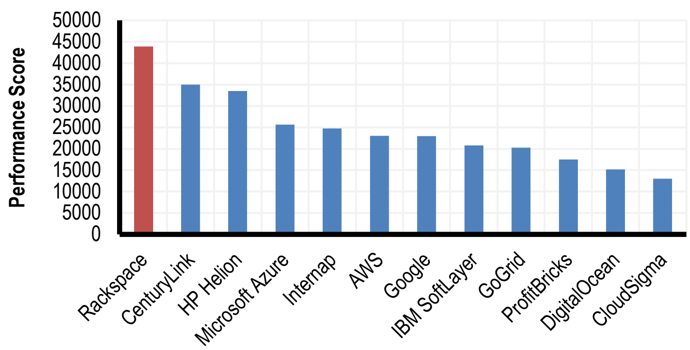


Key Takeaway

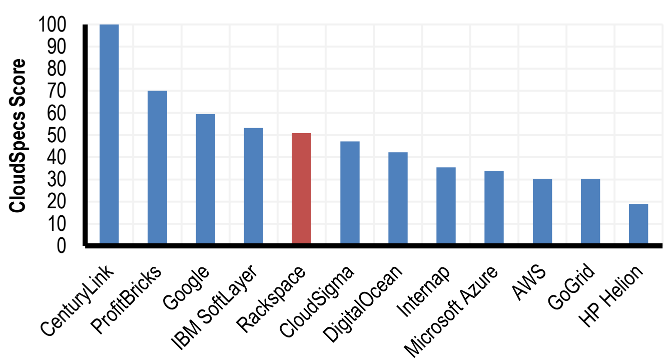
Monthly Pricing Ranking (Low to High) – 2XLarge VMs



Median Performance Ranking (High to Low) – 2XLarge VMs



Monthly Median Price-Performance Ranking (High to Low) – 2XLarge VMs



The three graphs on the left, which display rankings based on price, performance, and price-performance demonstrate the difference that may occur when comparing the same set of provider VMs using different criteria. Using Rackspace's 2XLarge VM as an example, while Rackspace ranks 11th in the monthly pricing comparison, its median performance output ranks first among the 12 providers, and its price-performance calculated using the data supporting the first two graphs ranks 5th. Selecting the right criteria when comparing across the cloud industry is essential in helping users optimize their decision-making process and outcome.

The graphs from the previous page illustrate the differences among the providers in both performance and variability. The differences between VMs can be significant when both performance and variability are taken into account, even though the provider VMs' configurations were relatively controlled.

Understanding both the performance and the severity of performance variation is critical to successfully operating certain applications in the cloud. Just as low-performing virtual machines may not satisfy application performance requirements, high-performing but unstable machines may have diminished performance output periodically, which may fail to sustain the application's ability to run at full capacity. Thorough considerations should be applied to examine performance level and performance variability when users are selecting cloud environments in order to optimize their application operations and IT spend.

Price-performance analysis is critical for choosing the best-fit providers for specific use cases in order to avoid unnecessary IT overspending. Businesses looking for the most economical cloud infrastructure should examine the price and performance output of a target environment together to understand the performance per unit cost value they can expect.

METHODOLOGY

Price

Each provider's pricing information was gathered based on 5 separately sized server configurations. All data on the proceeding pages refer to the specific sizes listed in Table 1.1:

Table 1.1

SERVER	CPU CORES	RAM IN GB
Small	1	2
Medium	2	4
Large	4	8
XLarge	8	16
2XLarge*	**16**	**32**

**Only the 2XLarge size is used in this report.*

The above configuration sizes listed are treated as minimum requirements. Any provider server tested in this report must meet or exceed those requirements. The provider server with the lowest price that meets or exceeds the minimum requirements listed above is used. Local storage is not factored into the requirements.

The values within the *Cloud Vendor Benchmark 2015* reports only apply to the listed configurations that are serving as minimum requirements. Different target configurations will yield different results, i.e. the most expensive VMs with the listed configurations in this report may be the least expensive on other target configurations.

Monthly figures are calculated using 730 hours unless discounts apply.

Scaling resources in a Tiered Package structure would require the user(s) to select the next available tier that would fulfill the configuration's requirements. This may mean more resources than necessary.

The application(s) that would hypothetically run on the server configurations listed in Table 1.1 are not assumed to be optimized for cross-server performance; thus, scaling resources in a Tiered Package structure would require the user(s) to select the next available tier that would fulfill the configuration requirements. This may mean more resources than necessary. For example, the 2XLarge Server configuration of 16 vCPU cores and 32GB RAM would require a purchase of HP Helion's closest tiered package (CPU & RAM) that fulfills the requirements, which provides 16 vCPU cores, 120GB RAM, and 1770GB local storage.

Pricing is measured exclusively by the specification of cores and RAM. However, it is valid that vCPU performance, RAM performance, and even overall server performance can alter costs based on each user's application's specific needs.

Performance

CPU and memory performance information was collected and explored using the Geekbench 3 testing suite on Linux Ubuntu 14.04 systems from VMs of the same configurations that were used in the *Cloud Vendor Benchmark 2015 Part 1: Pricing* report. Note that some providers' VMs have more resources (CPU or memory) than others. No storage or network performance is included.

A total of 27 separate tasks were conducted for integer, floating point and memory functions: 13 tasks for integer calculations, 10 tasks for floating point calculations, and 4 tasks for memory function. Python scripts were used, and all providers offered Python 2.7. Screen was used to continue the Python scripts upon terminating an SSH session. All VMs were accessed via SSH; SSH Keys were used when available. An overall weighted performance score for each VM was calculated by aggregating performance results of all 27 tasks. Both single task performance comparisons and aggregated performance comparisons are presented in this report. For specific Geekbench testing, score calculation and score aggregation information, please visit the Geekbench official website: http://www.primatelabs.com/geekbench/.

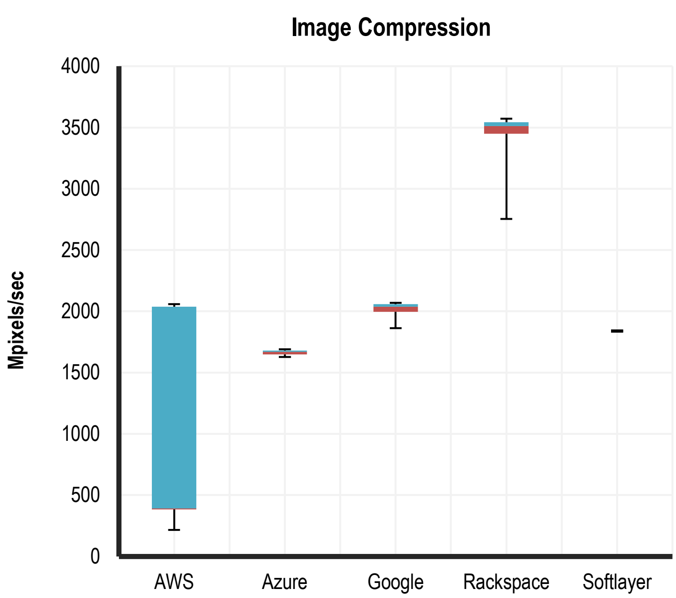
Tests and descriptions related to this report are described in the Table 1.2:

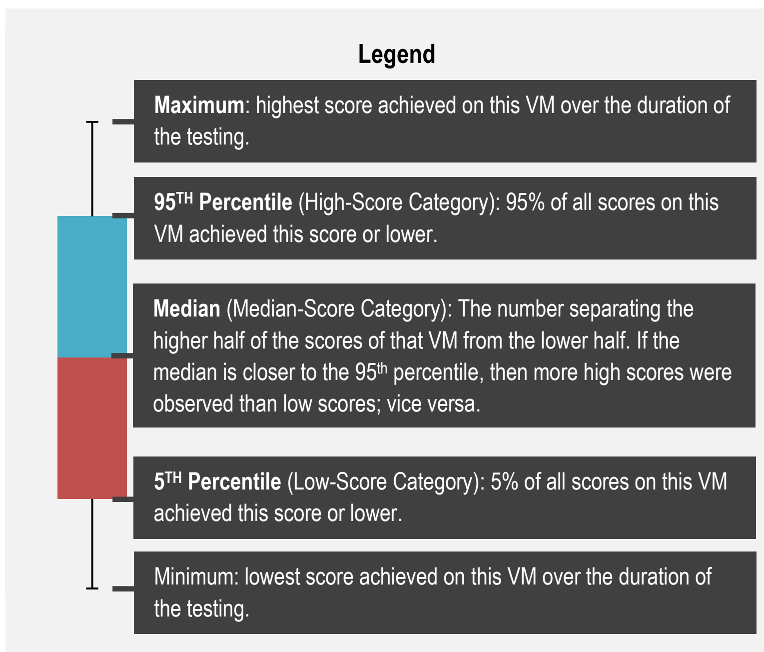
Table 1.2 Performance Tests and Descriptions

TEST	TOOL	TASK	DESCRIPTION
Integer	Geekbench 3	AES, Twofish, SHA1, SHA2, BZip2 Compression, BZip2 Decompression, JPEG Compression, JPEG Decompression, PNG Compression, PNG Decompression, Sobel, Lua, Dijkstra	Integer and Floating Point tasks together represent vCPU performance. The performance of all applications is highly dependent on the vCPU since the vCPU is responsible for the processing and orchestration of all applications.
Floating Point	Geekbench 3	Black Scholes, Mandelbrot, Sharpen Filter, Blur Filter, SGEMM, DGEMM, SFFT, DFFT, N-Body, Ray Trace	
Memory	Geekbench 3	STREAM Copy, STREAM Scale, STREAM Add, STREAM Triad	While memory performance is not considered one of the key bottlenecks in performance for many common applications, a subset of applications—particularly HPC and in-memory databases—is highly dependent on large sustained memory bandwidth.

The Geekbench test suite was installed and run on the same machine continuously for 24 hours in order to capture performance variation. Each round of testing generated one set of data points for every task mentioned above. As a result, 1,121,796 Linux OS data points were collected to examine the value provided across vendors in the market with respect to performance and performance stability.

The virtual machines' performance information was depicted using the minimum, 5th percentile, median, 95th percentile, and maximum scores retrieved from all data points collected for each of the tasks mentioned above during the 24 hours. 5th percentile, median and 95th percentile scores corresponded to low, median and high scores. 5th percentile and 95th percentile scores were used instead of minimum and maximum scores in order to exclude potential outliers. The information was then integrated into percentile graphs and value tables, which were designed to visualize performance variation captured while testing over time. An example of the performance percentile graph along with a corresponding value table is displayed below:





	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	215	384	392	2038	2058	533	28.9%
Azure	1628	1649	1669	1679	1690	10	0.5%
Google	1864	1997	2038	2058	2068	18	1.0%
Rackspace	2755	3451	3512	3543	3574	49	2.7%
Softlayer	1833	1843	1843	1843	1843	1	0.1%

Variability was calculated by taking the percentage of each machine's standard deviation values (Stdev.) from the median of the Medians (median scores) of all VMs. The calculation formula is:

*Variability = [Stdev.] / [median{Median}] * 100%*

Machines with variability scores higher than 5% were considered fluctuating, and their standard deviation (Stdev.) and variability scores (Variability) will be highlighted in red.

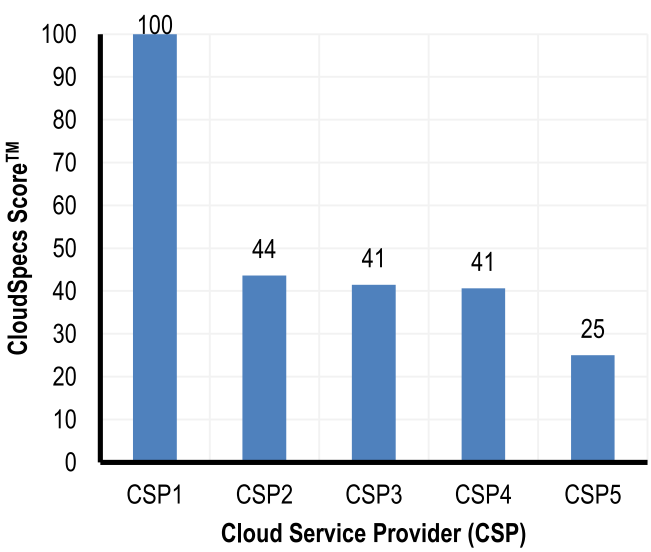
The variability score is designed to reflect the relative fluctuation of a machine in relationship with other VMs included in the same comparison. Therefore, the same variability value of different performance tasks can mean different fluctuation magnitudes. Standard deviation values (Stdev.), alternatively, can be used to compare the fluctuation sizes universally across different VMs and different tasks.

Price-Performance

Cloud Spectator's price-performance calculation, the CloudSpecs Score™, provides information on how much performance the user receives for each unit of cost. The CloudSpecs Score™ is an indexed, comparable score ranging from 0-100 indicative of value based on a combination of cost and performance. The calculation of the CloudSpecs Score™ is:

price-performance_value = [VM performance score] / [VM cost]
best_VM_value = max{price-performance_values}
*CloudSpecs ScoreTM = 100*price-performance_value / best_VM_value*

In this report, Cloud Spectator uses the aggregated performance scores as the [VM performance score] to calculate each machine's CloudSpecs Score™.



The graph on the left is an example of how Cloud Spectator's price-performance analysis is visualized. The closer the score is to 100, the higher price-performance value it indicates. The score 100 represents the best-value VM among all in the comparison. The value is scaled; e.g., the VM from Cloud Service Provider 1 (CSP1) with a score of 100 gives 4x the value of the VM from CSP5 with a score of 25.

The CloudSpecs Scores™ of any VM can change depending on the participants in the comparison. For example, if the highest score in a comparison changes, the price-performance value represented by score 100 will change accordingly, and so will the other CloudSpecs Score™ values.

If you have questions regarding Cloud Spectator's price-performance calculation, please contact us at contact@cloudspectator.com.

Data in this report is accurate as of April 1st, 2015. The report will continue to be accurate for an undetermined duration.

Key Considerations

Listed below are both general and provider-specific notes on how price, performance and price-performance values were calculated and what assumptions were made. The assumptions made for this report may differ from specific use cases, and thus, impact the relevancy of the results.

- This report examines price and performance only. Certain providers may include certain features or services (e.g. 24x7 support) in their price. Features and services comparisons are not included in this report.
- Price figures reflect those of US data centers only, and eastern US data centers were used when there are price differences among US data centers.
- For monthly, annual and 3-year pricing, virtual servers are assumed to be running at 100% utilization of each month.
- There are assumed to be 730 hours in each month.
- Only base virtual machine prices are included. No add-ons that would affect pricing were considered.
- Virtual machine sizes meet or exceed the requirements listed above. The virtual machines with the lowest price that meet or exceed the minimum requirements are used. **Therefore, in this report, 32 vCPU machines were used on Rackspace and 16vCPU machines were used on the remaining providers in order to meet the criteria for selecting 2XLarge VMs according to the listed minimum requirements.** Dimension Data, Joyent and Verizon were not included in the comparison because they don't offer VMs that meet the minimum requirement for 2xlarge machines.
- CloudSigma uses an algorithm to calculate its hourly pricing – burst pricing, which can be equal to or greater than monthly pricing. At the time Cloud Spectator checked, vCPU burst pricing was roughly 2x the cost of monthly pricing per hour, the RAM price was roughly 3x the cost of monthly pricing per hour, and the storage price was roughly 2x the cost of monthly pricing per hour. The price changes cannot be predicted ahead of time, and therefore CloudSigma's hourly pricing, along with its hourly price-performance values are not included in this report.
- The performance tests were administrated using a Python script written in Python 2.7, which ensured the continuous testing cycles over 24 hours.
- The VMs were deployed using Ubuntu 14.04 64-bit OS images. Using different images may yield different testing results from this report.
- Different provider VMs were based on different physical hardware. The influence of hardware on VM performance was not explored in this report.
- Some providers use more than one type of processor to host their VMs. Since Cloud Spectator only tested one random machine on each provider, the effect of this variable was not explored in this report.
- The CloudSpecs Scores™ cannot be compared against each other numerically over different graphs.

For any further questions or concerns regarding Cloud Spectator's *Cloud Vendor Benchmark 2015 Part 2.5: Performance and Price Performance (2XLarge VM, Linux)*, please contact Cloud Spectator at (+1) 617 300 0711 or email us at contact@cloudspectator.com.

PERFORMANCE COMPARISON

Aggregated CPU & Memory Performance Analysis

Table 2.1 shows the Minimum, 5th percentile, median, 95th percentile, and maximum value of the aggregated CPU & memory performance scores for each VM. For test information, please refer to the Methodology: Performance section; for aggregation information, please see Appendix: Score Aggregation.

Table 2.1: Aggregated CPU & Memory Performance Scores – 2XLarge VMs

	AWS	CenturyLink	CloudSigma	DigitalOcean	GoGrid	Google	HP Helion	IBM SoftLayer	Internap	Microsoft Azure	ProfitBricks	Rackspace
Min.	21468	23982	10180	10483	19121	19508	20073	19650	20282	18564	16684	40325
5th Per.	22815	26985	11149	11830	19564	22459	24806	20065	22194	24632	17103	42685
Median	**23058**	**34972**	**12997**	**15150**	**20244**	**22948**	**33485**	**20758**	**24736**	**25655**	**17509**	**43848**
95th Per.	23175	36457	13385	20223	20688	23296	35452	29446	32271	26572	18329	46161
Max.	23296	36808	13565	22097	21040	23473	36588	31650	35322	26850	18766	47702

Cloud Spectator ranks the VMs by their performance at the 95th percentile and 5th percentile (See *Figure 2.1 and Figure 2.2*), which are referenced as the High-Score Category and the Low-Score Category respectively. Rackspace, CenturyLink and HP Helion VMs display consistent high rankings in both the High-Score Category and the Low-Score Category, while the rankings of IBM SoftLayer and Internap VMs experience considerable changes.

Figure 2.1: CPU & Memory Performance Rank by 95th Percentile (High-Score Category) – 2XLarge VMs

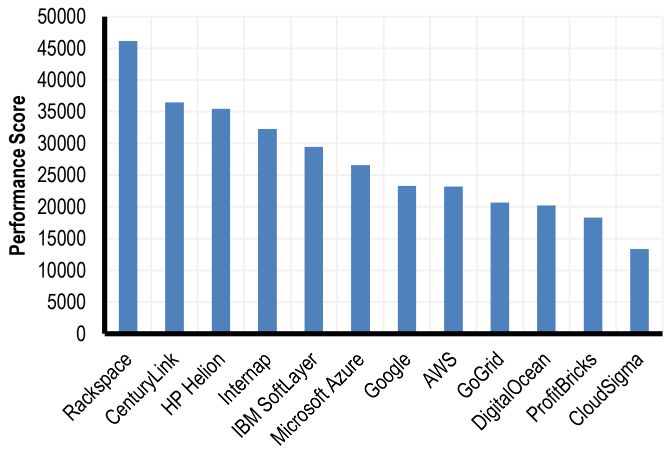
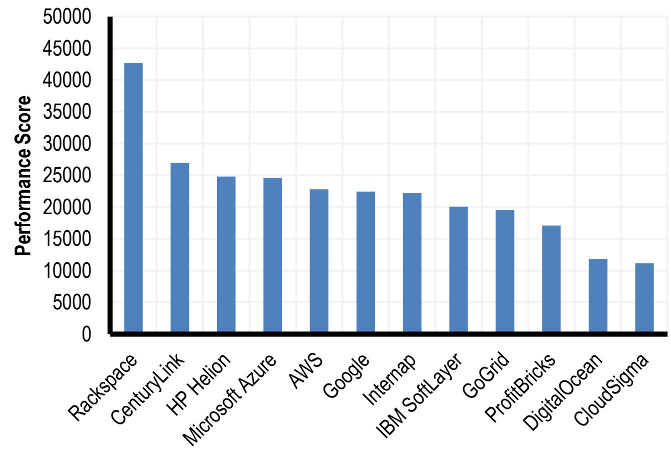


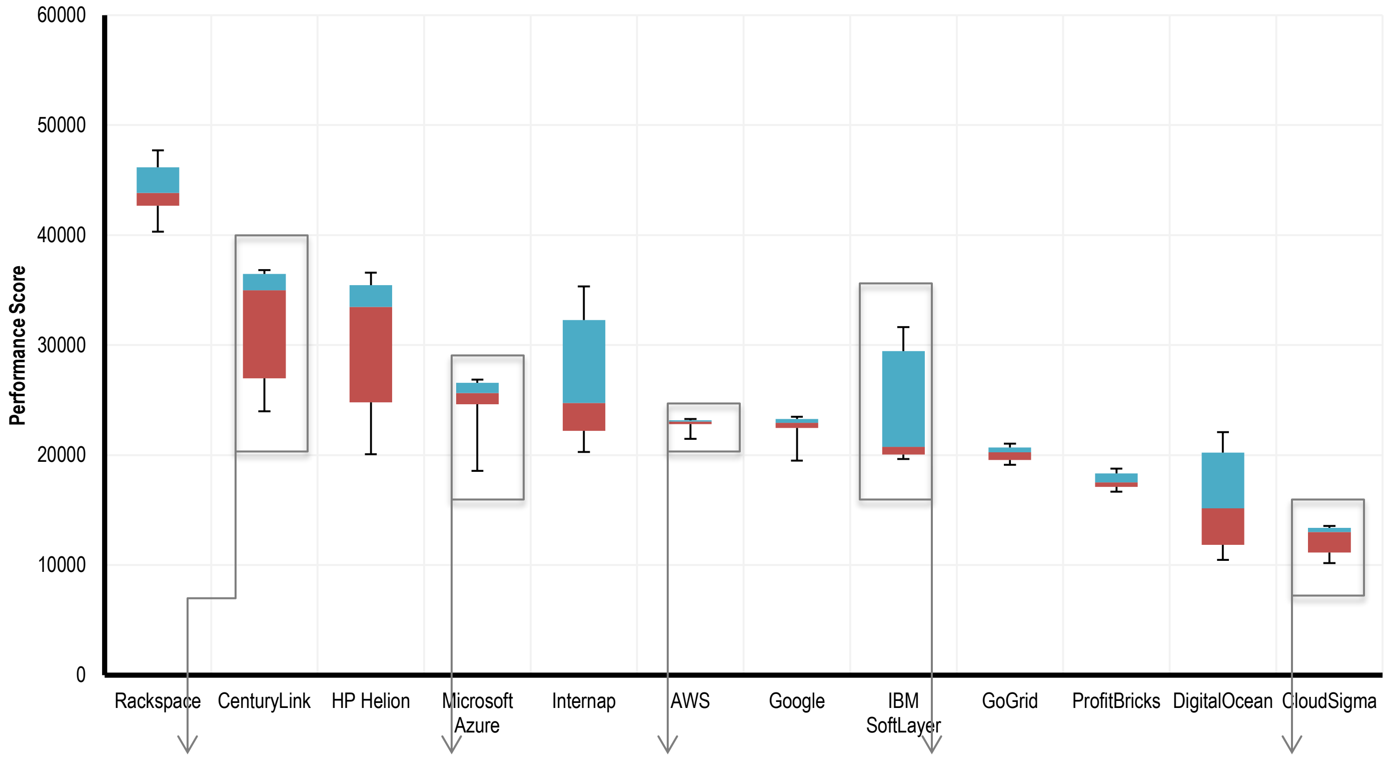
Figure 2.2: CPU & Memory Performance Rank by 5th Percentile (Low-Score Category) – 2XLarge VMs



The changes in performance rankings were due to the performance variations detected during the 24-hour testing period. In order to visualize the performance variations, Cloud Spectator introduces a percentile graph (*See Figure 2.3*). Figure 2.3 ranks the VMs by their median performance while incorporating the minimum, 5th percentile, median, 95th percentile, and maximum scores. For legend and instructions on reading the percentile graph, please refer to the Methodology: Performance section.

The graph indicates that Internap, IBM SoftLayer and DigitalOcean VMs had wide ranges of performance levels that covered the performance ranges of their neighboring providers, which caused their performance rankings to shift when comparing across the Low- and the High-Score Categories. CenturyLink and HP Helion VMs showed high variability but the performance variation did not affect their rankings. The percentile graph displays the importance of testing over time to capture a performance range instead of using single point-in-time performance data points to determine a virtual machine's comparative performance level in the market.

Figure 2.3: CPU & Memory Performance Percentile Graph – 2XLarge VMs – Ranked by Median



CenturyLink's performance graph shows a median line closer to the 95th percentile line than to the 5th percentile line, and the three lines are considerably distant from each other. This shows a **negative fluctuation**, and the fluctuation is relatively large in this comparison.

Microsoft Azure's performance graph displays a median line equally diving between the 95th percentile line and the 5th percentile line. The minimum line stretches downwards significantly. This indicates a **neutral fluctuation** with one or more extremely low scores.

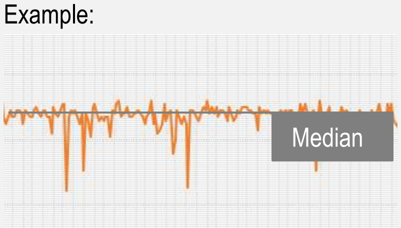
AWS has its 95th percentile line, median line and 5th percentile line closely compact together, and neither the minimum nor the maximum line stretches outward significantly. This indicates a highly stable performance pattern where **very little fluctuation** was detected.

IBM SoftLayer's performance graph shows a median line closer to the 55th percentile line than the 95th percentile line, and the three lines are considerably distant from each other. This indicates a **positive fluctuation**, and the fluctuation is relatively large in this comparison.

CloudSigma has its median line closer to the 95th percentile line than to the 5th percentile line, and neither the minimum nor the maximum line stretches outward significantly. This indicates a **negative fluctuation**, and no significant outlier on either high end or low end is

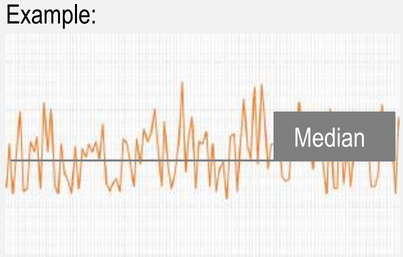
Negative Fluctuation:
One type of fluctuation where the scores below median have a larger magnitude.

Example:



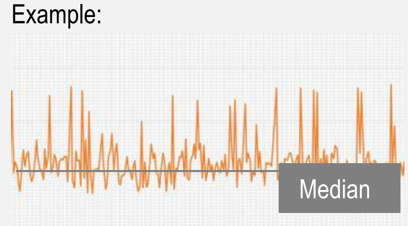
Neutral Fluctuation:
One type of fluctuation where the scores spread evenly above and below median.

Example:



Positive Fluctuation:
One type of fluctuation where the scores above median have a larger magnitude.

Example:



In order to perceive each VM's overall performance fluctuation numerically, Cloud Spectator calculated each VM's aggregated performance variability score by averaging the performance variability scores of the 27 individual tasks (see *Table 2.2*). The variability scores indicate that CenturyLink, DigitalOcean, HP Helion, IBM SoftLayer and Internap VMs had high CPU & memory performance fluctuations, as shown by their relatively large range of performance scores in *Figure 2.3*. For performance variability score calculation information, see Methodology: Performance.

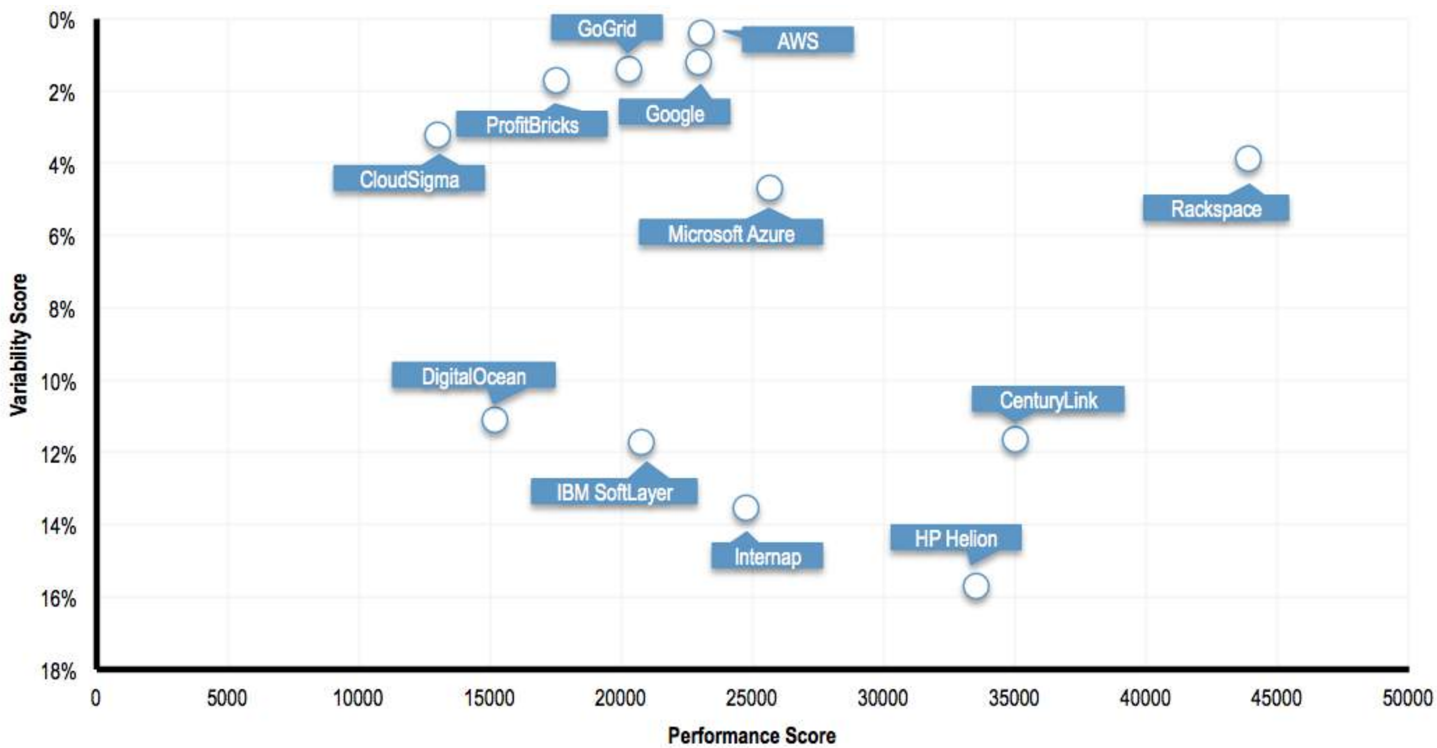
Table 2.2: Aggregated CPU & Memory Performance Variability – 2XLarge VMs

	AWS	CenturyLink	CloudSigma	DigitalOcean	GoGrid	Google	HP Helion	IBM SoftLayer	Internap	Microsoft Azure	ProfitBricks	Rackspace
Variability	0.4%	11.6%	3.2%	11.1%	1.4%	1.2%	15.7%	11.7%	13.5%	4.7%	1.7%	3.9%

It is worth noting that since the performance variability scores of different tasks vary within the same VM, an average variability score can only be seen as a rough indication of a provider VM's overall fluctuation. For specific variability information for individual tasks, see Appendix: Individual Tasks.

Figure 2.4 is a matrix incorporating both the performance scores and the variability scores of every VM. The x-axis shows the median CPU & memory performance scores, with higher performance on the right and lower performance on the left. The y-axis shows the CPU & memory performance variability, with the more stable VMs above the less stable VMs. In the top right corner are providers with both high performance and high stability. Most VMs have a performance score between 15000 and 30000 with variability lower than 12%.

Figure 2.4: CPU & Memory Performance-Variability Matrix – 2XLarge VMs



Aggregated CPU Performance Analysis

Cloud Spectator aggregated the scores of all CPU integer and CPU floating point tasks to form the CPU performance scores. Table 2.3 shows the minimum, 5th percentile, median, 95th percentile, and maximum CPU performance scores as well as CPU performance variability scores, which were calculated by averaging the variability scores of all CPU tasks. For test information, please refer to the Methodology: Performance section; for aggregation information, please see Appendix: Score Aggregation; for performance variability score calculation information, see Methodology: Performance.

Table 2.3: Aggregated CPU Performance and Variability Scores – 2XLarge VMs

	AWS	CenturyLink	CloudSigma	DigitalOcean	GoGrid	Google	HP Helion	IBM SoftLayer	Internap	Microsoft Azure	ProfitBricks	Rackspace
Min.	25753	28328	12300	11291	23125	23463	23274	23710	23863	22027	20226	47686
5th Per.	27429	31974	13496	12875	23673	27111	28983	24224	26102	29515	20746	50585
Median	**27721**	**41904**	**15784**	**16897**	**24518**	**27699**	**39338**	**25082**	**28865**	**30619**	**21243**	**51990**
95th Per.	27859	43733	16227	23036	25058	28103	41421	35922	37963	31409	22250	54834
Max.	28001	44143	16417	25261	25488	28307	42652	38674	41663	31546	22700	56729
Variability	0.5%	13.4%	3.5%	11.8%	1.6%	1.2%	14.9%	13.7%	12.8%	3.4%	1.7%	4.4%

The CPU performance and variability scores are similar to the CPU & memory scores, given that the CPU & memory scores consisted mainly of CPU scores. The CPU & memory performance scores and CPU performance scores are not comparable numerically, i.e., a score of 2000 in CPU & memory performance is not the same as a score of 2000 in CPU performance, because of the difference in calculation process. CenturyLink, DigitalOcean, HP Helion, IBM SoftLayer and Internap VMs exhibited high CPU performance fluctuation. The performance ranking with variability patterns is shown in *Figure 2.5*.

Figure 2.5: CPU Performance Percentile Graph – 2XLarge VMs – Ranked by Median

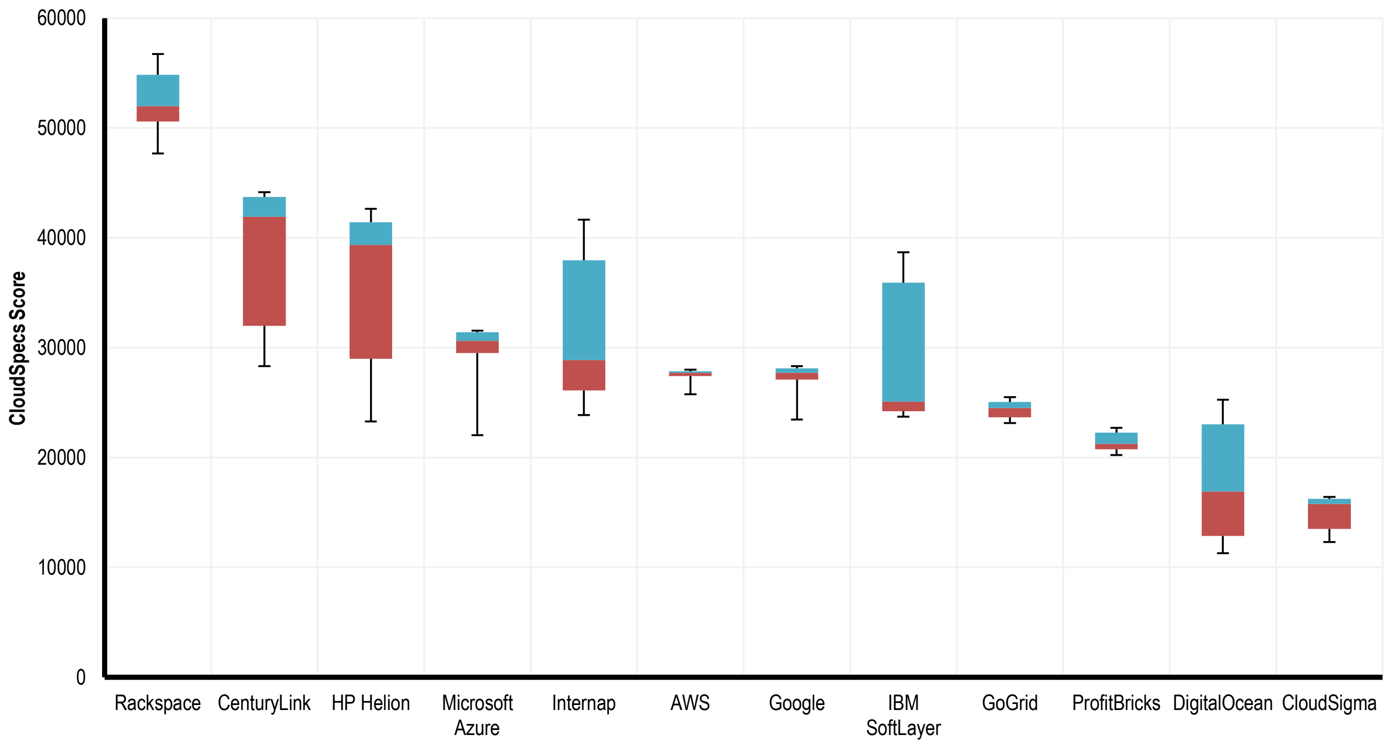
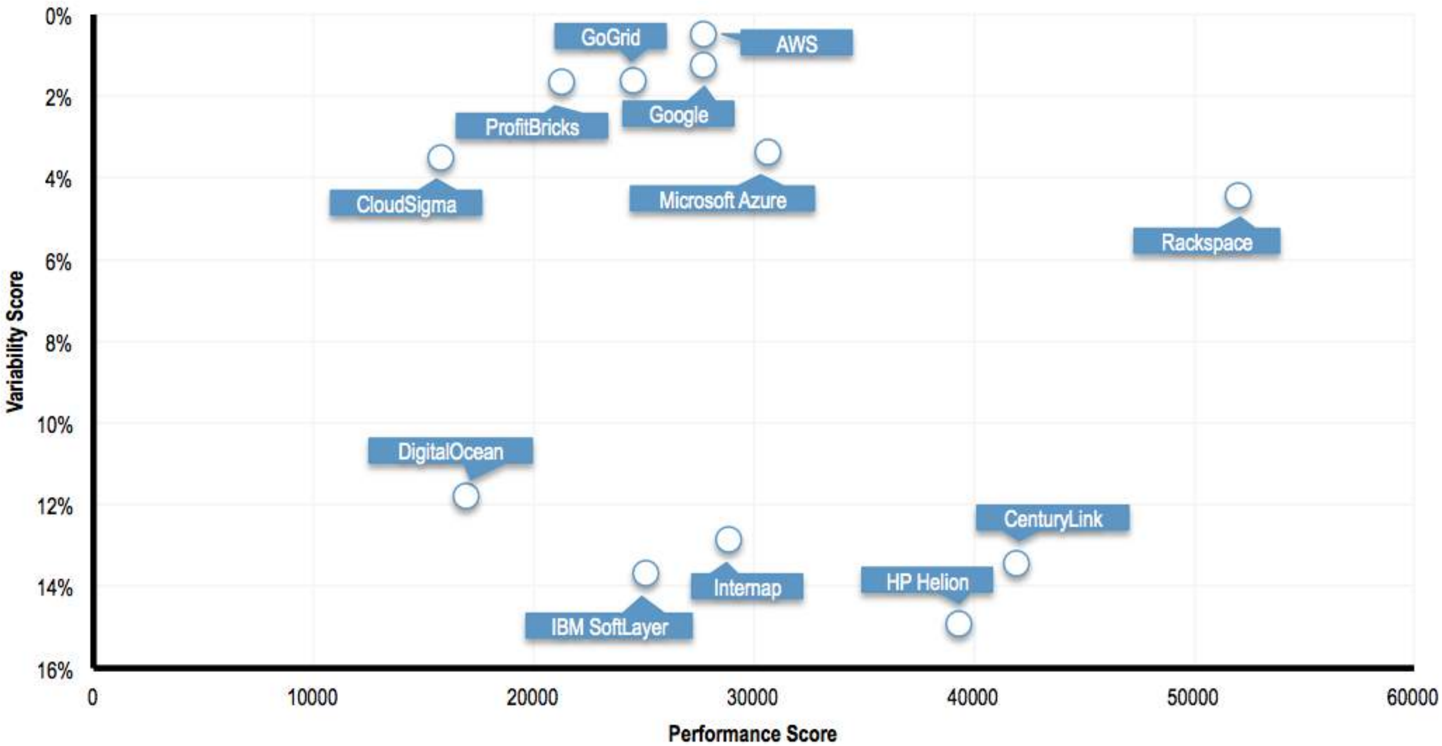


Figure 2.5 shows that Rackspace, CenturyLink and HP Helion are the top three providers for 2XLarge VM CPU performance. It is important to keep in mind that the VM from Rackspace was a 32 vCPU machine, while 16 vCPU machines were used on the remaining providers based on Cloud Spectator's selection criteria consistent with that of the *Cloud Vendor Benchmark 2015 Part 1: Pricing* report. For detailed information, see Preface: Configurations and Pricing.

CenturyLink, DigitalOcean, HP Helion, IBM SoftLayer and Internap VMs displayed high CPU performance variability, while AWS, GoGrid, Google and ProfitBricks VMs showed high stability with their variability scores being equal to or lower than 2.0%. Since the performance variability scores of different tasks vary within the same VM, an average variability score can only be seen as a rough indication of a provider VM's overall fluctuation. For specific variability information for individual tasks, see Appendix: Individual Tasks.

The CPU performance-variability matrix is shown in *Figure 2.6*. The x-axis shows the median CPU performance scores, with higher performance on the right and lower performance on the left. The y-axis shows the CPU performance variability, with the more stable VMs above the less stable VMs. In the top right corner are providers with both high performance and high stability. Most VMs have a performance score between 20000 and 40000 with variability lower than 12%.

Figure 2.6: CPU Performance-Variability Matrix – 2XLarge VMs



Aggregated Memory Performance Analysis

Cloud Spectator aggregated the scores of all memory tasks to form the memory performance scores. *Table 2.4* shows the minimum, 5th percentile, median, 95th percentile, and maximum memory performance scores as well as memory performance variability scores, which were calculated by averaging variability scores of all memory tasks. For test information, please refer to the Methodology: Performance section; for aggregation information, please see Appendix: Score Aggregation; for performance variability score calculation information, see Methodology: Performance.

Table 2.4: Aggregated Memory Performance and Variability Scores – 2XLarge VMs

	AWS	CenturyLink	CloudSigma	DigitalOcean	GoGrid	Google	HP Helion	IBM SoftLayer	Internap	Microsoft Azure	ProfitBricks	Rackspace
Min.	4330	6598	1702	7251	3105	3690	7265	3410	5959	4715	2517	10882
5th Per.	4359	7029	1761	7652	3127	3851	8100	3428	6566	5099	2530	11084
Median	**4406**	**7241**	**1851**	**8162**	**3151**	**3941**	**10069**	**3464**	**8222**	**5801**	**2575**	**11277**
95th Per.	4439	7353	2019	8971	3210	4068	11579	3541	9503	7222	2645	11466
Max.	4474	7468	2156	9440	3249	4138	12331	3554	9957	8063	3031	11594
Variability	0.0%	1.4%	1.4%	7.2%	0.1%	0.9%	20.2%	0.6%	17.4%	12.0%	1.9%	0.7%

Similar to what was mentioned in the CPU performance section, the CPU & memory performance scores and memory performance scores are not comparable numerically, i.e., a score of 2000 in CPU & memory performance is not the same as a score of 2000 in memory performance, because of the difference in calculation process. HP Helion, Internap and Microsoft Azure VMs exhibited high memory performance fluctuation. The performance ranking with variability patterns is shown in *Figure 2.7*.

Figure 2.7: Memory Performance Percentile Graph – 2XLarge VMs – Ranked by Median

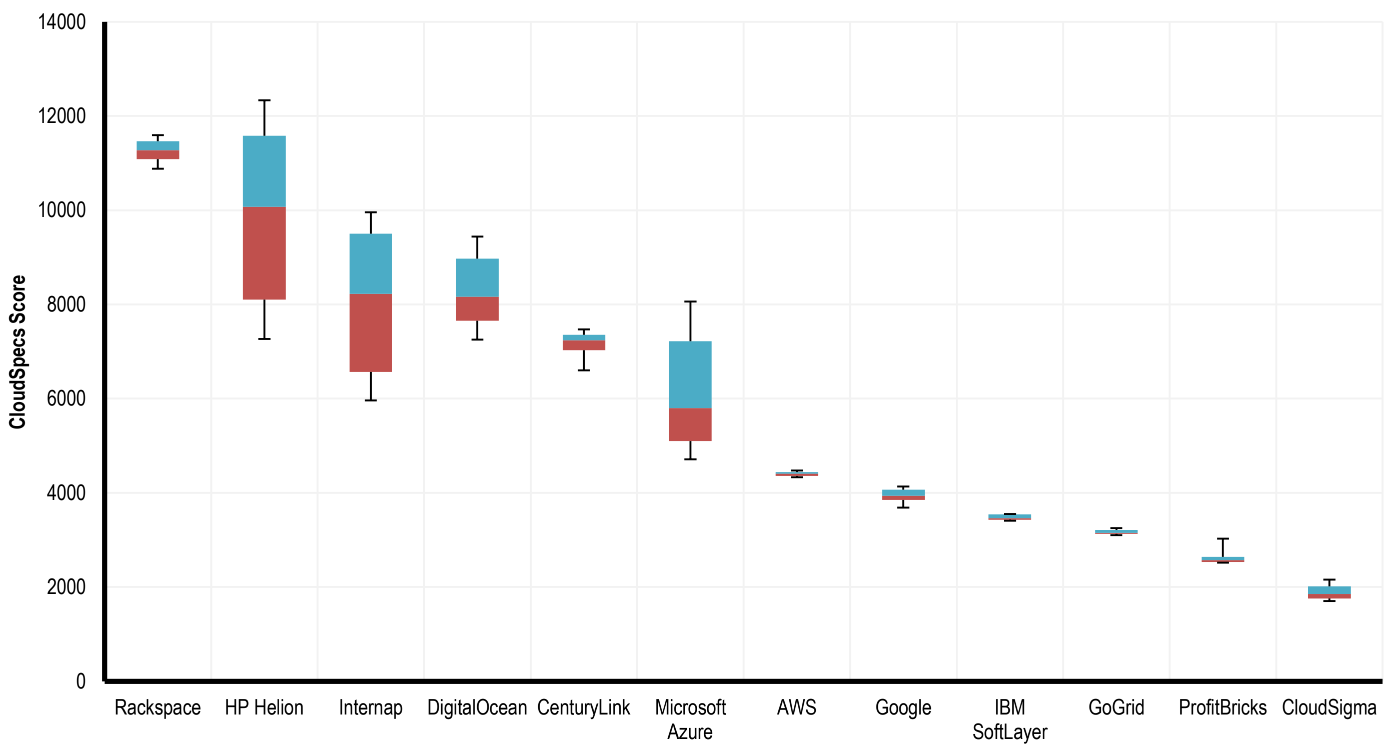
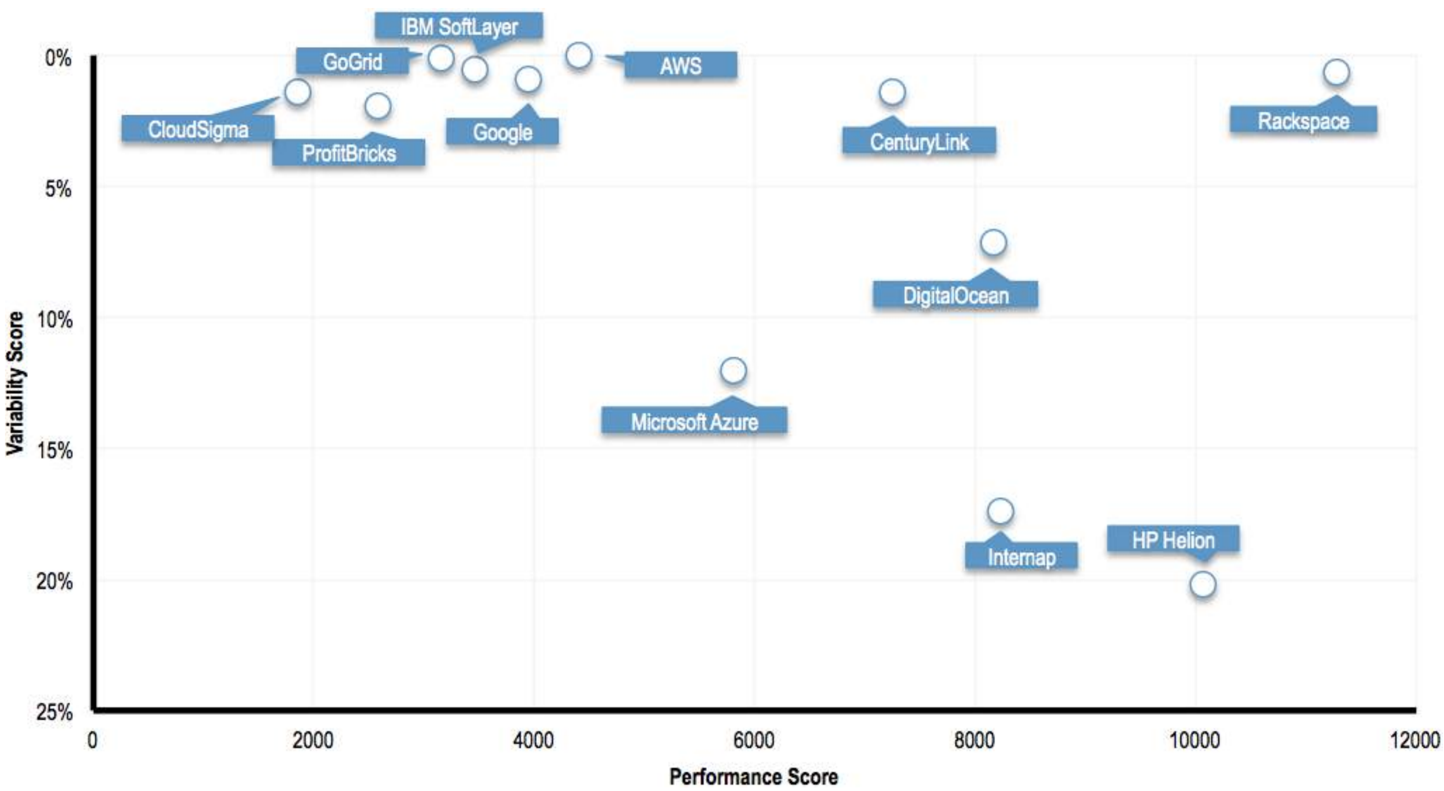


Figure 2.7 shows that Rackspace, HP Helion and Internap are the top three providers for 2XLarge VM memory performance. HP Helion, Internap and Microsoft Azure VMs displayed high memory performance variability, while AWS, GoGrid, Google, IBM SoftLayer and Rackspace VMs showed high stability with their variability scores being equal to or lower than 1.0%. Since the performance variability scores of different tasks vary within the same VM, an average variability score can only be seen as a rough indication of a VM's overall fluctuation. For specific variability information for individual tasks, see Appendix: Individual Tasks.

The memory performance-variability matrix is shown in *Figure 2.8*. The x-axis shows the median memory performance scores, with higher performance on the right and lower performance on the left. The y-axis shows the memory performance variability, with the more stable VMs above the less stable VMs. In the top right corner are providers with both high performance and high stability. Most VMs have a performance score between 3000 and 9000 with variability lower than 12%.

Figure 2.8: Memory Performance-Variability Matrix – 2XLarge VMs



Individual Task Performance Analysis

Cloud Spectator conducted analysis for each task tested in this report to show the performance rankings and performance fluctuation for all provider VMs tested. Percentile graphs and tables can be found in Appendix: Individual Tasks. In general, the AES, SHA1, SHA2, JPEG Decompression, PNG Decompression, Sobel, Lua, SGEMM, SFFT, DFFT, N Body and Ray Trace tasks yielded larger overall variability within the VMs, while smaller fluctuations were observed for the rest of the tasks. The VM rankings are relatively stable across tasks within the same categories (i.e. integer, floating point or memory), while some changes in rankings can be observed across the categories.

On an individual level, Rackspace, CenturyLink and HP Helion VMs had the highest performance rankings across all providers for the majority of tasks. Rackspace's VM displayed the highest performance output for all 27 tasks, and CenturyLink's VM ranked second in 20 out of the 27 tests.

CenturyLink, DigitalOcean, HP Helion IBM SoftLayer and Internap VMs displayed recurring fluctuations in all tasks included in the testing. A summary of their performance fluctuation in terms of variability scores is provided in Table 2.5:

Table 2.5: High Variability VM Summary – 2XLarge VMs

	High Variability Score*	Low Variability Score*	Average Variability Score	Variability Pattern
CenturyLink	19.0%	1.3%	11.6%	Mostly negative fluctuations
DigitalOcean	13.7%	6.2%	11.1%	Mostly positive fluctuations
HP Helion	24.8%	9.7%	15.7%	Mostly negative and neutral fluctuations
IBM SoftLayer	22.4%	0.7%	11.7%	Mostly positive fluctuations
Internap	20.2%	6.5%	13.5%	Mostly positive and neutral fluctuations

**High/low variability scores were obtained by eliminating the max/min scores and selecting the second highest/lowest scores of each VM. This procedure ensures a more realistic score range, which shows general trends without being skewed by extreme scores.*

The CenturyLink VM showed an average variability of 11.6%, with 90% of the variability scores ranging between 1.3% and 19.0%, mostly negative fluctuations; the DigitalOcean VM showed an average variability of 11.1%, with 90% of the variability scores ranging between 6.2% and 13.7%, mostly positive fluctuations; the HP Helion VM showed an average variability of 15.7%, with 90% of the variability scores ranging between 9.7% and 24.8%, mostly negative and neutral fluctuations; the IBM SoftLayer VM showed an average variability of 11.7%, with 90% of the variability scores ranging between 0.7% and 22.4%, mostly positive fluctuations; and the Internap VM showed an average variability of 13.5% with 90% of the variability scores ranging between 6.5% and 20.2%, mostly positive and neutral fluctuations. All variability scores can be viewed in the performance analysis tables. These recurring fluctuations across tasks explain their aggregated performance variation, which resulted in the aggregated performance ranking changes between the low scores and high scores. For variability calculation information, see Methodology: Performance.

AWS, GoGrid, Google and ProfitBricks VMs showed little fluctuation in all tasks included in the testing. A summary of their performance fluctuation is provided in Table 2.6:

Table 2.6: Low Variability VM Summary – 2XLarge VMs

	High Variability Score (95%)	Low Variability Score (5%)	Average Variability Score	Variability Pattern
AWS	1.3%	0.0%	0.4%	-
GoGrid	3.2%	0.0%	1.4%	-
Google	2.1%	0.8%	1.2%	-
ProfitBricks	5.9%	0.4%	1.7%	-

The AWS VM showed an average variability of 0.4%, with 90% of the variability scores ranging between 0.0% and 1.3%; the GoGrid VM showed an average variability of 1.4%, with 90% of the variability scores ranging between 0.0% and 3.2%; the Google VM showed an average variability of 1.2%, with 90% of the variability scores ranging from 0.8% and 2.1%; and the ProfitBricks VM showed an average variability of 1.7%, with 90% of the variability scores ranging from 0.4% and 5.9%. No variability patterns are attributed to VMs with variability scores less than 5% All variability scores can be viewed in the performance analysis tables. The small degree of variability of these VMs indicates stable aggregate performance outputs during the 24-hour testing. For variability calculation information, see Methodology: Performance.

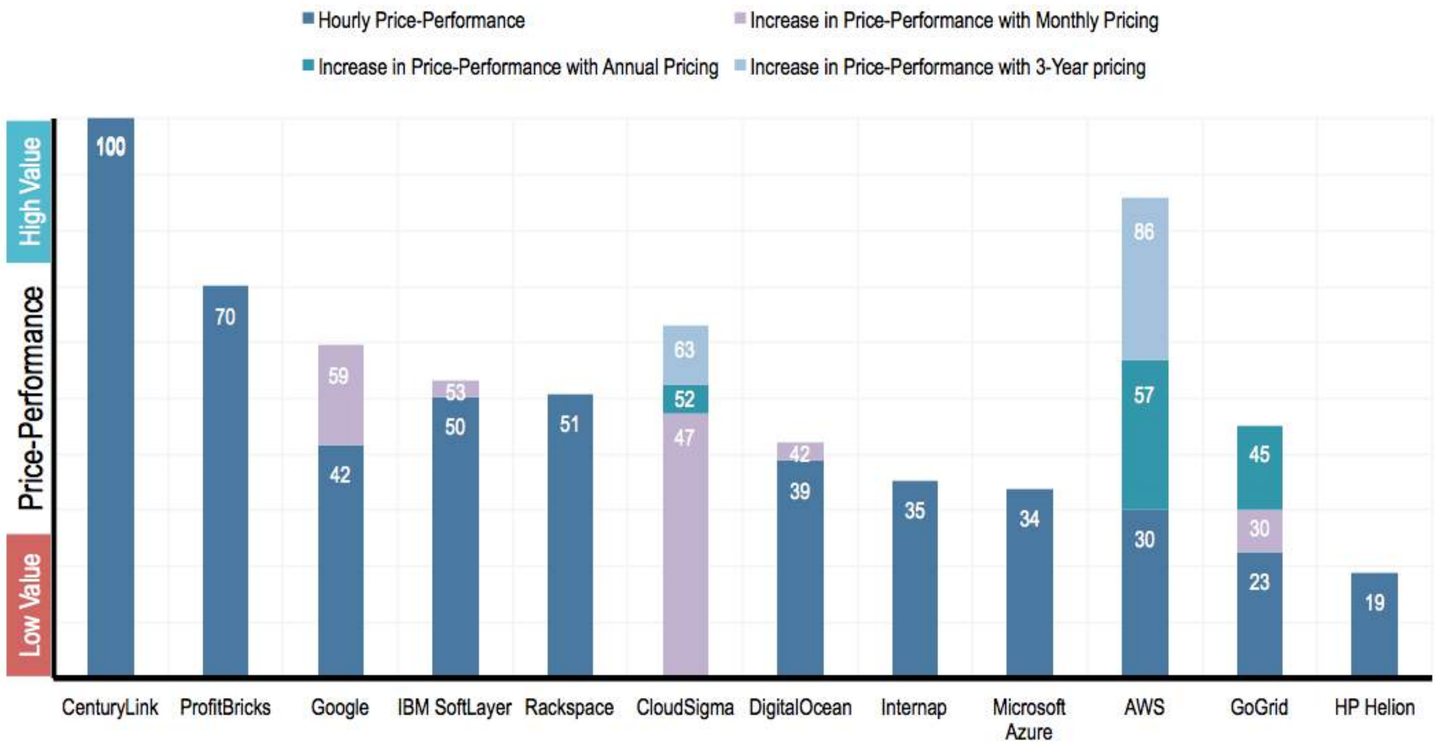
CenturyLink, Google, HP Helion and Microsoft Azure VMs exhibited performance outliers on the lower end for many of the tasks tested. This implies that some extremely low, but infrequent scores were detected over the course of the 24-hour continuous testing.

PRICE-PERFORMANCE COMPARISON

Price-performance value is illustrated by Cloud Spectator's index – the CloudSpecs Score™. The CloudSpecs Score™ is calculated by combining performance scores with hourly, monthly, annual and 3-year pricing. In this study, the aggregated CPU & memory score was used to represent performance. For details on the CloudSpecs Score™ calculation, see Methodology: Price-Performance; for VM performance information, see Performance Comparison; for VM pricing information, see Preface: VM Configurations and Pricing.

Figure 3.1 shows the price-performance comparison of VMs with hourly, monthly, annual and 3-year pricing using the median aggregated CPU & memory performance scores. The CloudSpecs Score™ in *Figure 3.1* was calculated using the equivalent hourly pricing of all pricing commitment durations, and referenced the highest price-performance score of all price-performance values as 100. The VM ranking is based on the monthly CloudSpecs Score™; monthly, annual and 3-year CloudSpecs Score™ increases are added on top of the hourly scores.[1]

Figure 3.1: Median CPU & Memory Aggregated Price-Performance of All Pricing Models – 2XLarge VMs – Ranked in Monthly Values



**CloudSigma's hourly price-performance is not calculated because its burst hourly pricing is not a set value. See Methodology: Key Considerations for more details.*

For the median-score performance results, the CenturyLink VM had the highest price-performance values. ProfitBricks, IBM SoftLayer and Rackspace VMs exhibited high price-performance value for hourly and monthly pricing, and AWS, Google and CloudSigma VMs exhibited high price-performance values when discounts applied. AWS, CloudSigma, DigitalOcean, GoGrid, Google and IBM SoftLayer VMs all showed increased price-performance with long-term discounted pricing. AWS, CloudSigma, GoGrid and Google VMs' long-term price-performance resulted in ranking increases.

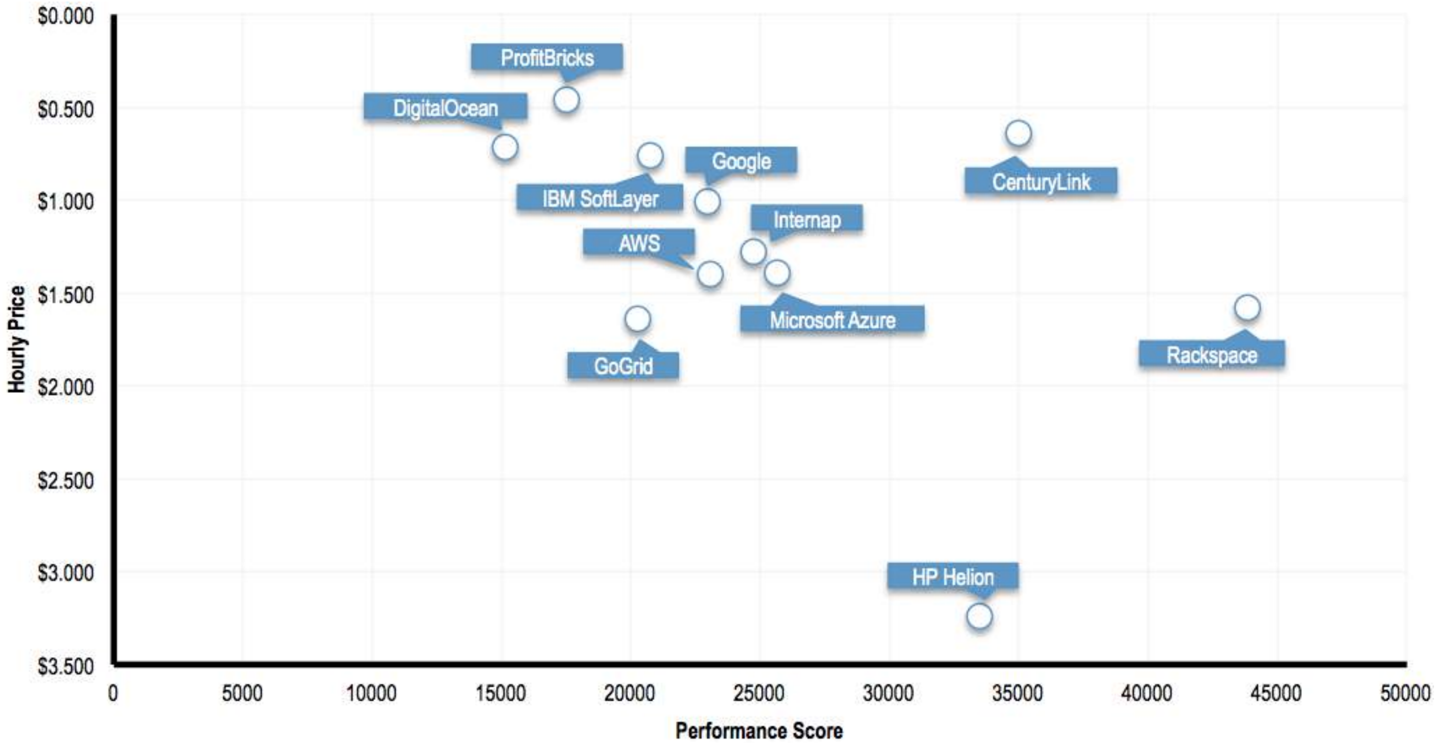
The graphs on the next few pages show the relationship between price and performance for hourly, monthly, annual and 3-year pricing individually, using median performance data, and display the CloudSpecs Score™ price-performance comparison for each pricing model using low scores, median scores and high scores (correspondingly 5th percentile, median and 95th percentile performance values) separately. In each graph, the CloudSpecs Score™ was calculated using the highest price-performance value within the given commitment timeframe (hourly, monthly, annual or 3-year). The CloudSpecs Scores™ of different graphs are not comparable to each other.

[1] In this case, the longer-term pricing models always produce CloudSpecs Scores™ equivalent to larger or than the shorter-term pricing models, because longer-term prices are always equal to or less than shorter-term prices.

Price-Performance with Hourly Pricing

Figure 3.2 presents hourly VM prices and their performance values. The x-axis represents the median CPU & memory performance scores, with lower scores on the left and higher scores on the right. The y-axis represents the hourly cost of the VMs, with lower prices on the top and higher prices on the bottom.

Figure 3.2: Price-Performance Matrix with Hourly Pricing – 2XLarge VMs



**CloudSigma's hourly price-performance is not calculated because its burst hourly pricing is not a set value. See Methodology: Key Considerations for more details.*

Figure 3.3 – 3.5 are price-performance rankings using the CloudSpecs Score™ calculation. The VMs are ranked from high to low by CloudSpecs Score™ calculated using low, median and high CPU & memory performance scores and hourly prices.

Figure 3.3: Low-Score Category Price-Performance – 2XLarge VMs (Hourly)

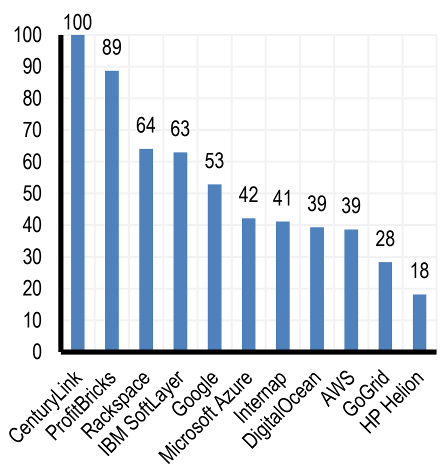


Figure 3.4: Median-Score Category Price-Performance – 2XLarge VMs (Hourly)

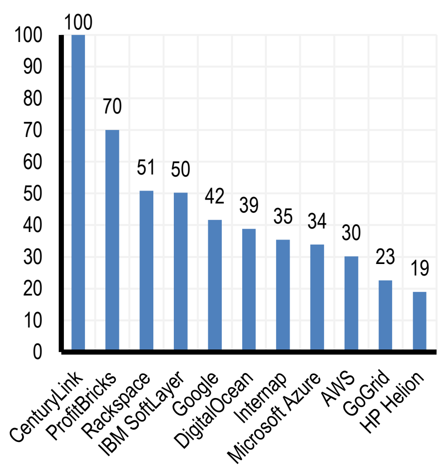
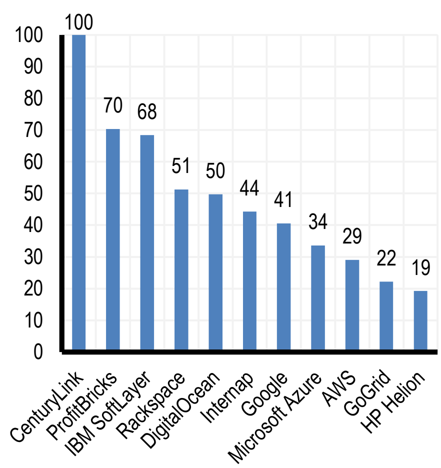


Figure 3.5: High-Score Category Price-Performance – 2XLarge VMs (Hourly)



**CloudSigma's hourly price-performance is not calculated because its burst hourly pricing is not a set value. See Methodology: Key Considerations for more details.*

Price-Performance with Monthly Pricing

Figure 3.6 presents monthly VM prices and their performance values. The x-axis represents the median CPU & memory performance scores, with lower scores on the left and higher scores on the right. The y-axis represents the monthly cost of the VMs, with lower prices on the top and higher prices on the bottom.

Figure 3.6: Price-Performance Matrix with Monthly Pricing – 2XLarge VMs

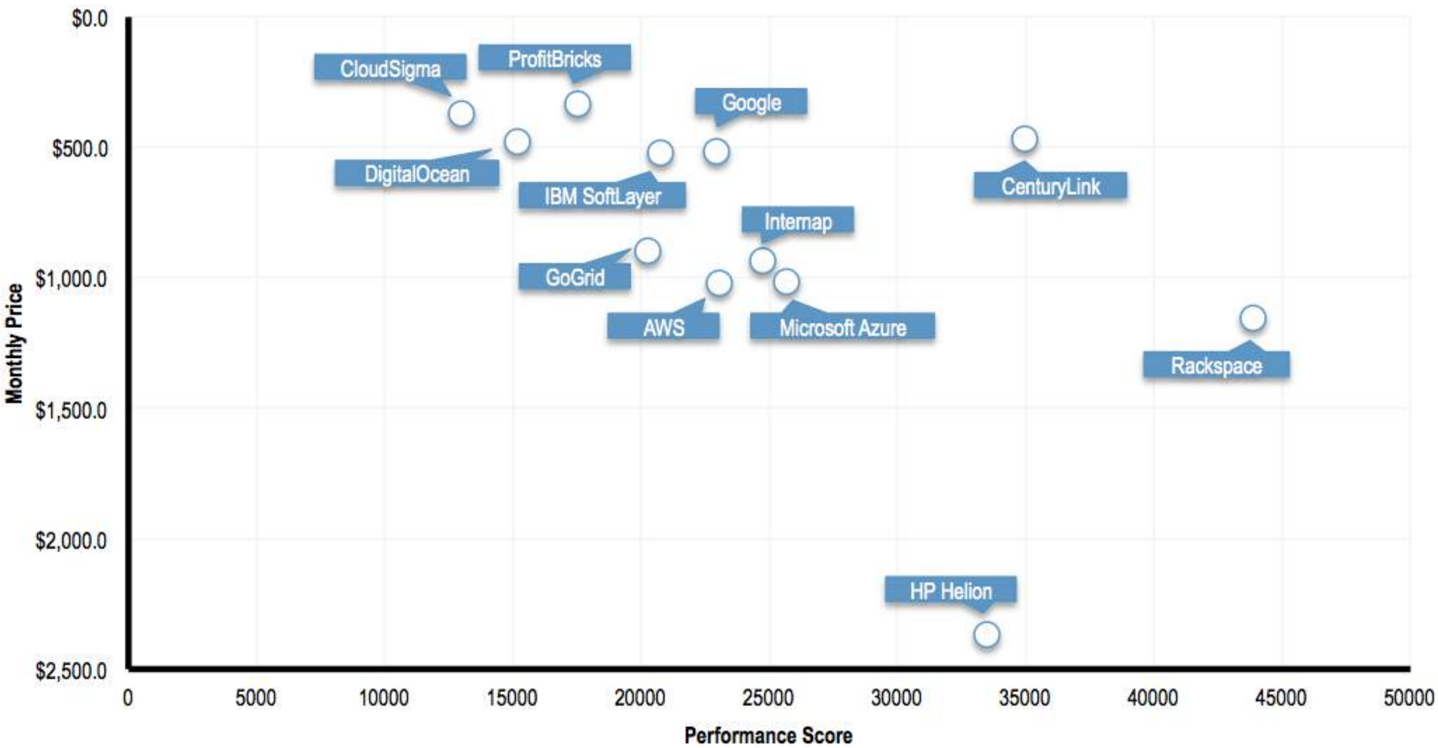


Figure 3.7 – 3.9 are price-performance rankings using the CloudSpecs Score™ calculation. The VMs are ranked from high to low by CloudSpecs Score™ calculated using low, median and high CPU & memory performance scores and monthly prices.

Figure 3.7: Low-Score Category Price-Performance – 2XLarge VMs (Monthly)

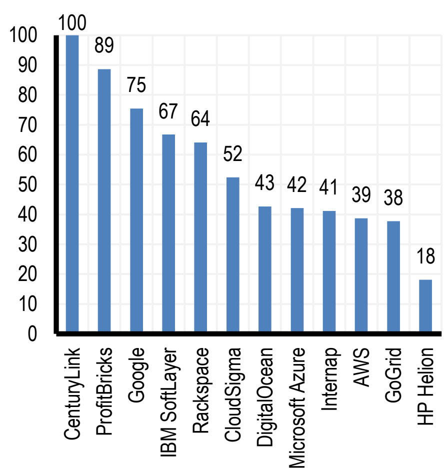


Figure 3.8: Median-Score Category Price-Performance – 2XLarge VMs (Monthly)

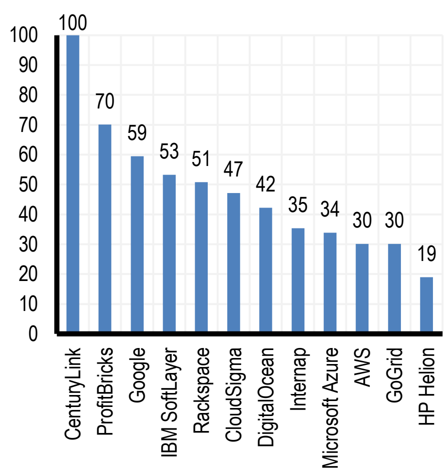
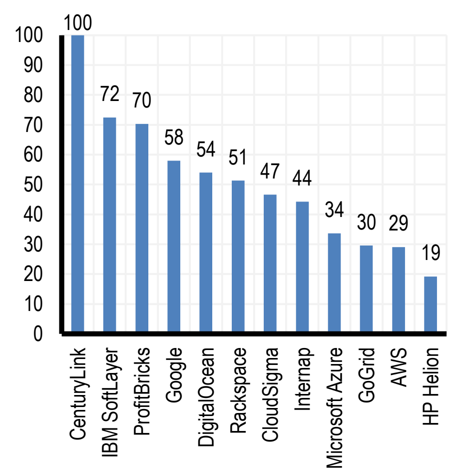


Figure 3.9: High-Score Category Price-Performance – 2XLarge VMs (Monthly)



Price-Performance with Annual Pricing

Figure 3.10 presents annual VM prices and their performance values. The x-axis represents the median CPU & memory performance scores, with lower scores on the left and higher scores on the right. The y-axis represents the annual cost of the VMs, with lower prices on the top and higher prices on the bottom.

Figure 3.10: Price-Performance Matrix with Annual Pricing – 2XLarge VMs

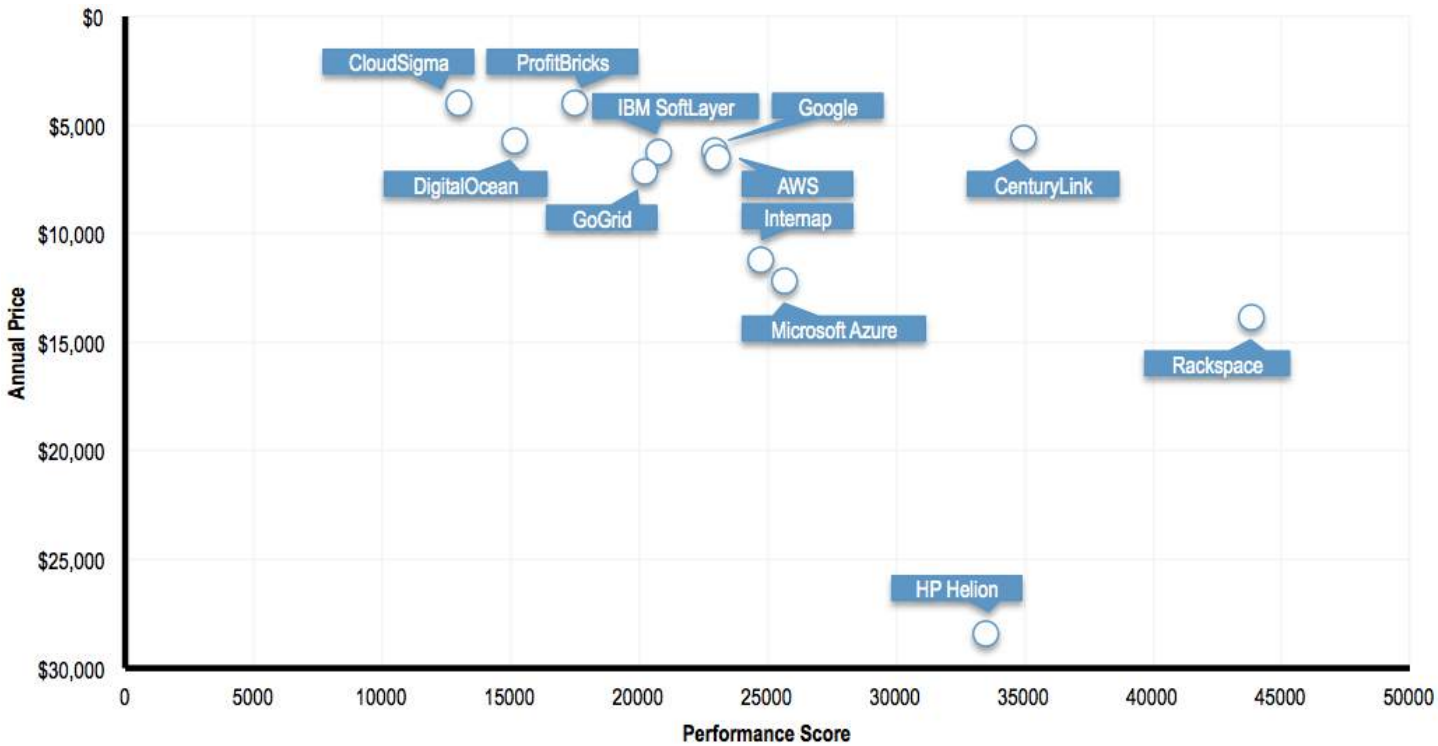


Figure 3.11 – 3.13 are price-performance rankings using the CloudSpecs Score™ calculation. The VMs are ranked from high to low by CloudSpecs Score™ calculated using low, median and high CPU & memory performance scores and annual prices.

Figure 3.11: Low-Score Category Price-Performance – 2XLarge VMs (Annual)

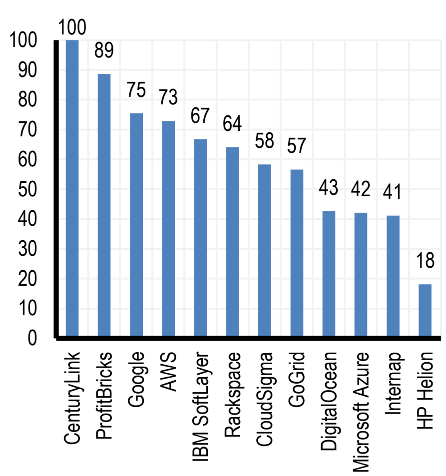


Figure 3.12: Median-Score Category Price-Performance – 2XLarge VMs (Annual)

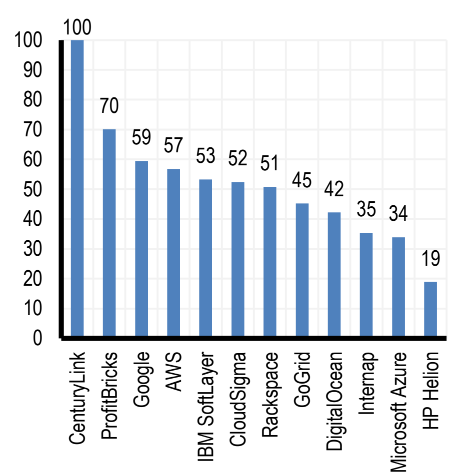
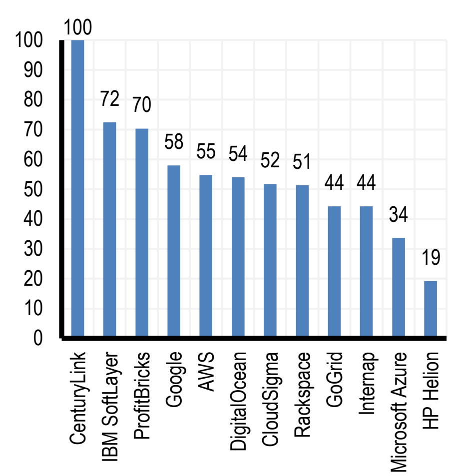


Figure 3.13: High-Score Category Price-Performance – 2XLarge VMs (Annual)



Price-Performance with 3-Year Pricing

Figure 3.14 presents 3-year VM prices and their performance values. The x-axis represents the median CPU & memory performance scores, with lower scores on the left and higher scores on the right. The y-axis represents the 3-year cost of the VMs, with lower prices on the top and higher prices on the bottom.

Figure 3.14: Price-Performance Matrix with 3-Year Pricing – 2XLarge VMs

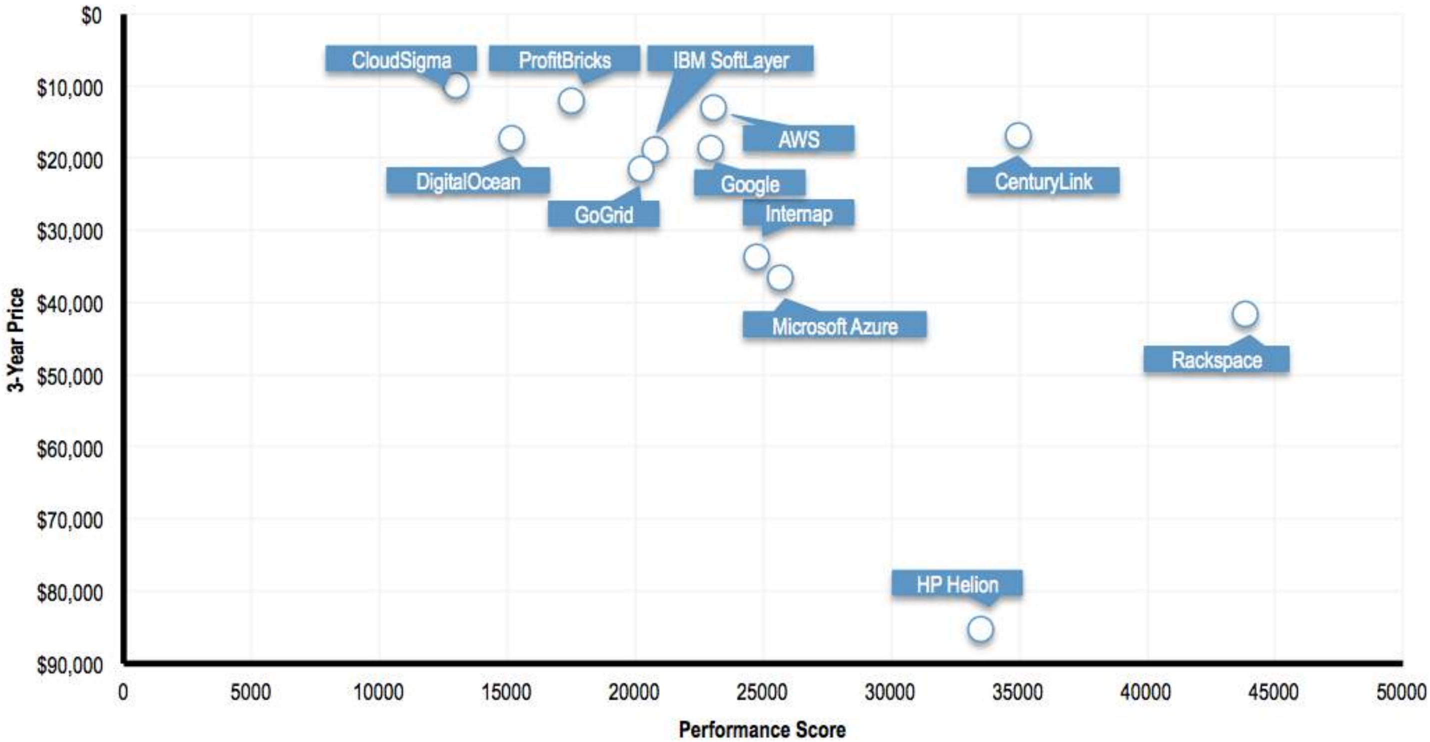


Figure 3.15 – 3.17 are price-performance rankings using the CloudSpecs Score™ calculation. The VMs are ranked from high to low by CloudSpecs Score™ calculated using low, median and high CPU & memory performance scores and 3-year prices.

Figure 3.15: Low-Score Category Price-Performance – 2XLarge VMs (3-Year)

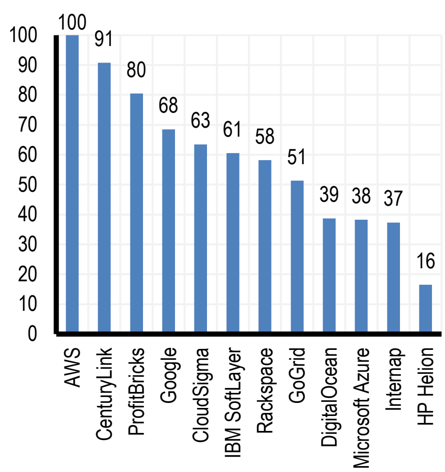


Figure 3.16: Median-Score Category Price-Performance – 2XLarge VMs (3-Year)

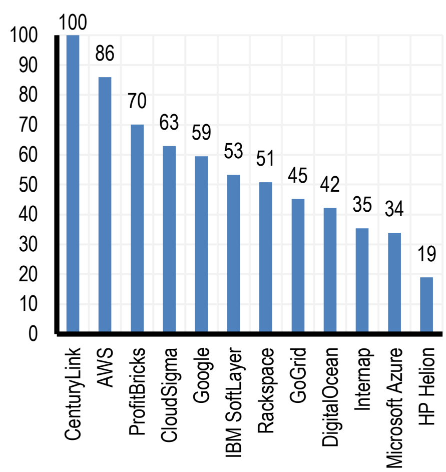
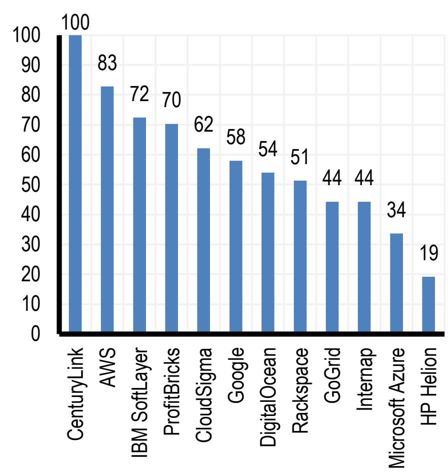


Figure 3.17: High-Score Category Price-Performance – 2XLarge VMs (3-Year)

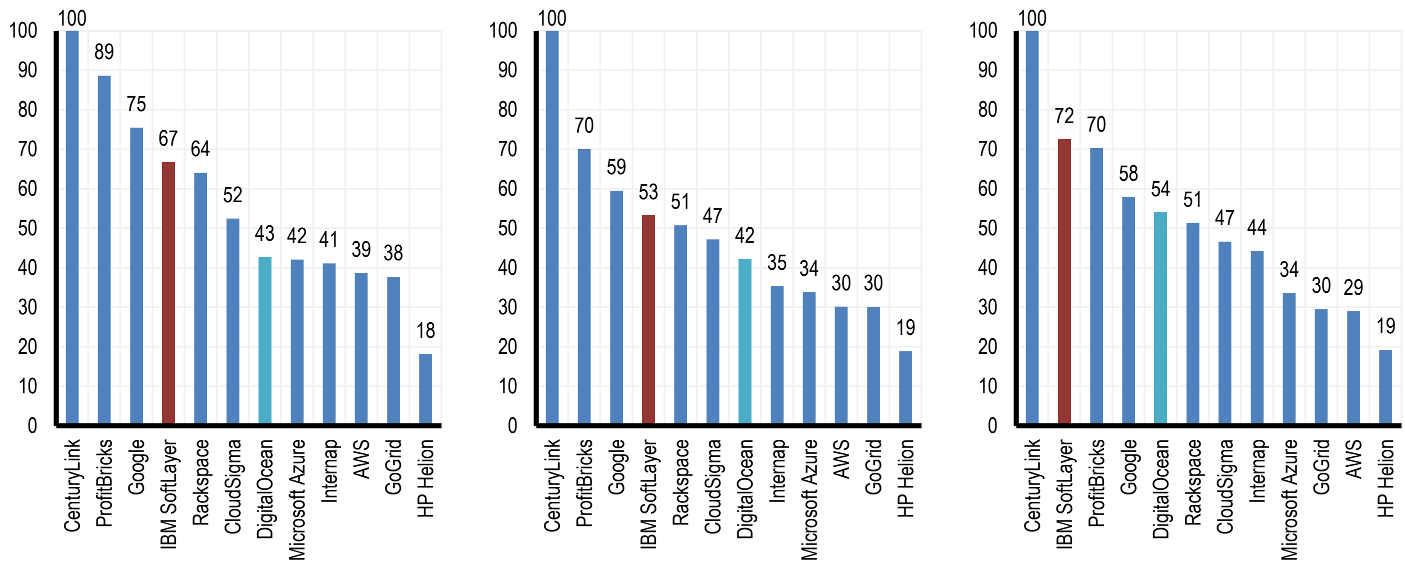


Overall, CenturyLink, ProfitBricks and IBM SoftLayer VMs had the highest rankings in low, median and high CloudSpecs scores of all pricing intervals. The CenturyLink VM had the highest price-performance value for all but the 3-year low-score comparison, and ProfitBricks and IBM SoftLayer VMs ranked next to the CenturyLink VM for hourly, monthly and annual prices. For the 3-year price-performance comparisons, the AWS VM ranked the first and the second with its 3-year discount pricing.

Changes in rankings can be seen when switching among the Low-, Median- and High-Score Categories, indicating large price-performance value ranges of some VMs during the testing period.

Figure 3.18: Comparing Price-Performance with Monthly Pricing – 2XLarge VMs

Low-Score Category **Median-Score Category** **High-Score Category**



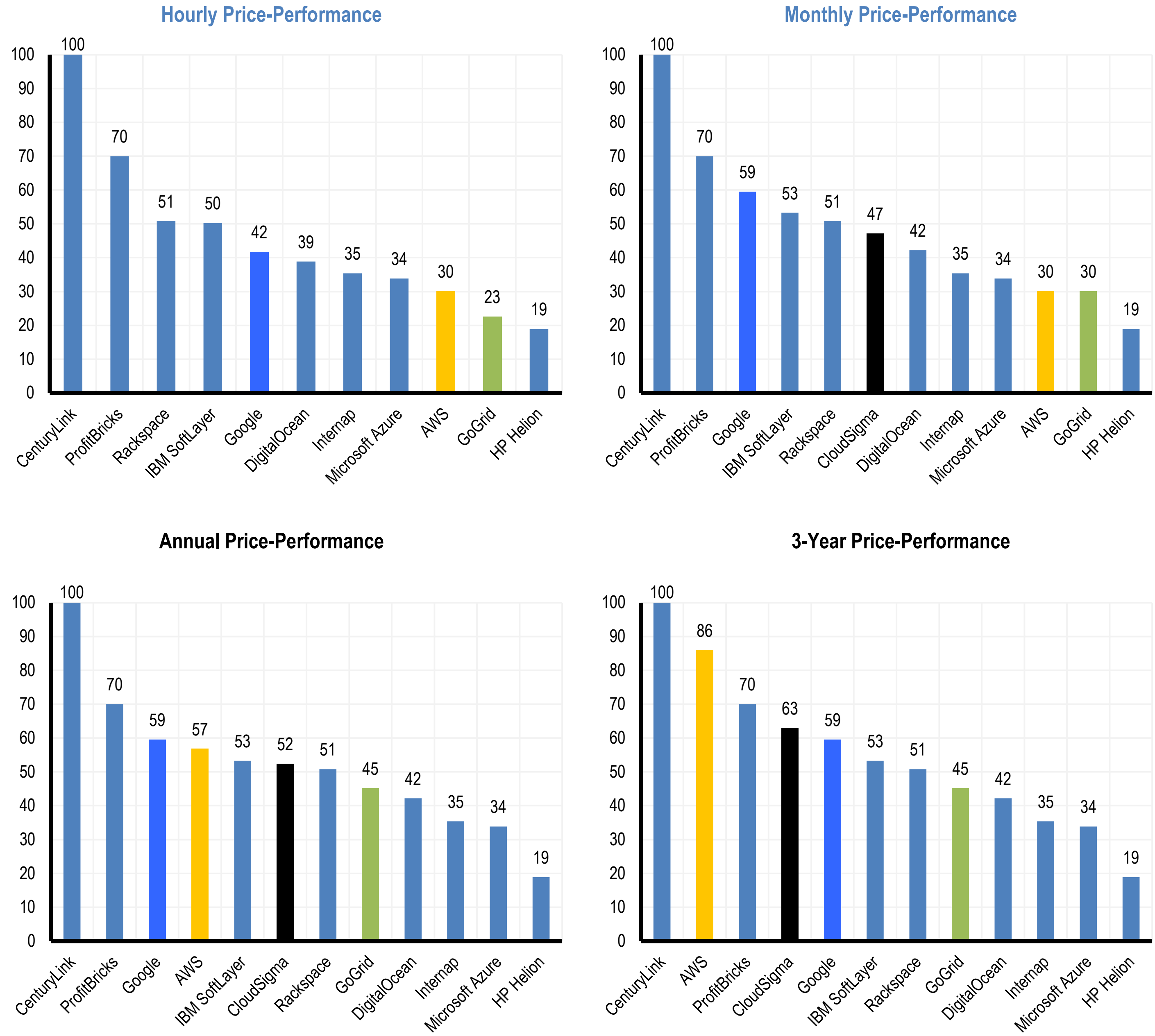
As illustrated above using the monthly examples, the DigitalOcean and IBM SoftLayer VMs' price-performance ranking was higher in the High-Score Category than the Low- and Median-Score Categories.

The price-performance value ranges reflected by the three categories are consistent with their performance variations, which are shown in the section titled Performance Comparison.

When viewing the graphs across pages, and as shown in *Figure 3.1*, commitment duration has an impact on price-performance ranking changes as well. In general, AWS, CloudSigma, GoGrid and Google VMs' price-performance rankings increase as the pricing structure changes to longer-term prices, because they all offer discounts that increase with longer time commitments (i.e., AWS offers a 47% discount on its annual pricing and a 65% discount on its 3-year pricing[2]; CloudSigma offers a 10% discount on its annual pricing and a 25% discount on its 3-year pricing; GoGrid offers a 25% discount on its monthly pricing and a 50% discount on its annual pricing; Google discounts pricing for persistent full usage). The trend is illustrated below using median performance as an example:

[2] This AWS discount information only applies to the r3.4xlarge instance at their Virginia data center assuming full payment upfront. Any changes in conditions may change the discount information for both annual and 3-year pricing.

Figure 3.19: Price-Performance with Median Scores – 2XLarge VMs



AWS, CloudSigma, GoGrid and Google VMs' price-performance rankings increase as the pricing structure changes to longer-term prices, because they all offer discounts that increase with longer time commitments.

GENERAL OBSERVATIONS

As cloud adoption increases and more cloud users compare services, considering performance alongside price will help them lower their annual operating costs and achieve greater value. Deploying VMs with outstanding price-performance not only ensures value, but also enables optimized resource allocation and prevents IT overspending. In this report, Cloud Spectator tested the 2XLarge size VMs of 15 top providers in the industry and examined their performance and price-performance values against each other.

The results carry two key messages:

1. Both performance levels and performance variability can vary greatly among provider VMs of similar configurations.

The performance data in this report illustrates the discrepancies among VMs in both performance and variability, and shows that the differences between VMs can be significant when both performance and variability are measured, even if the provider VMs are selected with controlled configurations.

Understanding both the performance level and the severity of performance variation is critical to successfully operating certain applications in the cloud. Just as low performing machines may not satisfy application performance requirements, high performing but unstable machines may have diminished performance output periodically, which may fail to support the application's ability to run at full capacity. Thorough considerations should be applied to examine performance levels and performance variability when users are selecting cloud environments in order to optimize their application operations.

2. Comparing cloud provider VMs based on price, performance and price-performance yields different results.

When comparing the same set of provider VMs using price, performance and price-performance, the results may be quite different. Using Rackspace's 2XLarge VM as an example, while the VM ranks 11h in the monthly pricing comparison, its median performance output ranks first among the 12 providers, and its price-performance calculated using the data supporting the first two graphs ranks 5th. In this case, selecting the right criteria when comparing across the cloud industry is essential in helping users optimize their decision-making process and outcome.

Price-performance analysis is critical for choosing the best-fit VMs for specific use cases in order to avoid unnecessary IT overspending. Businesses looking for the most economical cloud infrastructure should examine the price and performance output of a targeted VM together to understand the performance per unit cost they can expect.

As the cloud industry continues to become more competitive, it is important to make data-driven decisions with sufficient and accurate information. If you have questions about comparing cloud provider VMs, please call or email Cloud Spectator at +1 617-300-0711 or contact@cloudspectator.com.

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- **Cloud Vendor Benchmark 2015 Part 2.5: Performance and Price-Performance (2XLarge VMs, Linux)**
- Cloud Vendor Benchmark 2015 Part 2.6: Performance and Price-Performance (Small VMs, Windows)
- Cloud Vendor Benchmark 2015 Part 2.7: Performance and Price-Performance (Medium VMs, Windows)
- Cloud Vendor Benchmark 2015 Part 2.8: Performance and Price-Performance (Large VMs, Windows)
- Cloud Vendor Benchmark 2015 Part 2.9: Performance and Price-Performance (XLarge VMs, Windows)
- Cloud Vendor Benchmark 2015 Part 2.10: Performance and Price-Performance (2XLarge VMs, Windows)

For more reports produced by Cloud Spectator, visit http://www.cloudspectator.com/reports.

APPENDIX

VM Sizing

The table below outlines the specific VMs used for each pricing and price-performance comparison. VMs outside the scope of the 2XLarge VM report are also included in the tables. For price-performance comparisons for Small, Medium, Large and XLarge VMs, see Cloud Vendor Benchmark 2015 Reports.

VM Size	Provider	Instance	vCPU	RAM	STORAGE (GB)
Small	AWS	t2.small	1	2	EBS only
	CenturyLink	customized	1	2	-
	CloudSigma	customized	1	2	50 SSD
	DigitalOcean	standard2	2	2	40 SSD
	Dimension Data	customized	1	2	-
	GoGrid	Standard Medium	2	2	100
	Google	n1-standard-1	1	3.75	-
	HP Helion	Standard Small	2	2	10
	IBM SoftLayer	customized	1	2	25
	Internap	B-1	1	4	20 SSD
	Internap (Windows)	A-2	2	2	40 SSD
	Joyent	standard3	1	3.75	123
	Joyent (Windows)	standard4	2	7.5	738
	Microsoft Azure	D1	1	3.5	50 SSD
	Microsoft Azure (Windows)	A2 Basic	2	3.5	60
	ProfitBricks	customized	1	2	-
	Rackspace	General1-2	2	2	40 SSD
	Verizon	3.5	1	3.5	-
Medium	AWS	t2.medium	2	4	EBS only
	CenturyLink	customized	2	4	-
	CloudSigma	customized	2	4	50 SSD
	DigitalOcean	standard4	2	4	60 SSD
	Dimension Data	customized	2	4	-
	GoGrid	Standard Large	4	4	200
	Google	n1-standard-2	2	7.5	-
	HP Helion	Standard Medium	2	4	50
	IBM SoftLayer	customized	2	4	25
	Internap	B-2	2	8	40 SSD
	Joyent	standard4	2	7.5	738
	Microsoft Azure	D2	2	7	100 SSD
	Microsoft Azure (Windows)	A3 Basic	4	7	120

	ProfitBricks	customized	2	4	-
	Rackspace	General1-4	4	4	80 SSD
	Verizon	4	2	4	-
Large	AWS	m3.xlarge	4	15	2 x 40 SSD
	CenturyLink	customized	4	8	-
	CloudSigma	customized	4	8	50 SSD
	DigitalOcean	standard5	4	8	80 SSD
	Dimension Data	customized	4	8	-
	GoGrid	Standard X-Large	8	8	400
	Google	n1-standard-4	4	15	-
	HP Helion	Standard Large	4	8	130
	IBM SoftLayer	customized	4	8	25
	Internap	B-4	4	15	80 SSD
	Joyent	Standard5	4	15	1467
	Microsoft Azure	D3	4	14	200 SSD
	Microsoft Azure (Windows)	A4 Basic	8	14	240
	ProfitBricks	customized	4	8	-
	Rackspace	General1-8	8	8	160 SSD
	Verizon	7	4	8	-
XLarge	AWS	m3.2xlarge	8	30	2 x 80 SSD
	CenturyLink	customized	8	16	-
	CloudSigma	customized	8	16	50 SSD
	DigitalOcean	highvol1	8	16	160 SSD
	Dimension Data	customized	8	16	-
	GoGrid	Standard XX-Large	16	16	800
	Google	n1-standard-8	8	30	-
	HP Helion	Standard 2XL	8	30	470
	IBM SoftLayer	customized	8	16	25
	Internap	B-8	8	30	160 SSD
	Joyent	High Storage1	8	32	7680
	Microsoft Azure	D4	8	28	400 SSD
	Microsoft Azure (Windows)	A7	8	56	605
	ProfitBricks	customized	8	16	-
	Rackspace	Compute1-30	16	30	-
	Verizon	11	8	16	-
2XLarge	AWS	r3.4xlarge	16	122	1 x 320 SSD
	CenturyLink	customized	16	32	-
	CloudSigma	customized	16	32	50 SSD
	DigitalOcean	highvol3	16	48	480 SSD
	Dimension Data	-	-	-	-
	GoGrid	High RAM 4XL	16	64	40

Google	n1-standard-16	16	60	-
HP Helion	Standard 8XL	16	120	1770
IBM SoftLayer	customized	16	32	25
Internap	B-16	16	60	320 SSD
Joyent	-	-	-	-
Microsoft Azure	D14	16	112	800 SSD
ProfitBricks	customized	16	32	-
Rackspace	Compute1-60	32	60	-
Verizon	-	-	-	-

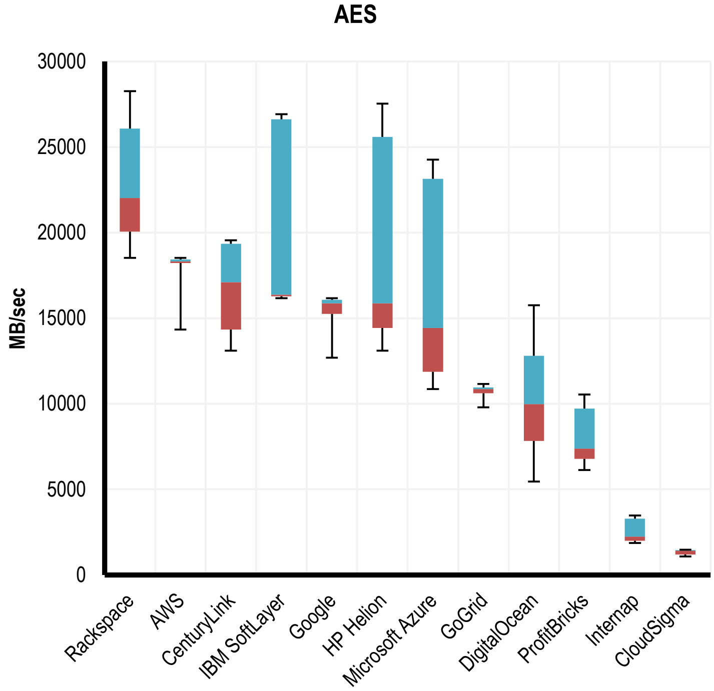
VM Processor Information

Provider	OS	Python Version	Processor (small)
AWS	Ubuntu 14.04	2.7	Intel Xeon CPU E5-2670 v2
CenturyLink	Ubuntu 14.04	2.7	Intel Xeon CPU E502650 v2
CloudSigma	Ubuntu 14.04	2.7	AMD Opteron Processor 6380
DigitalOcean	Ubuntu 14.04	2.7	Intel Xeon CPU E5-2630L v2
Dimension Data	Ubuntu 14.04	2.7	Intel Xeon CPU E5-4650
GoGrid	Ubuntu 14.04	2.7	Intel Xeon X5650
Google	Ubuntu 14.04	2.7	Intel Xeon CPU
HP Helion	Ubuntu 14.04	2.7	Intel Core 2 Duo T7700
IBM SoftLayer	Ubuntu 14.04	2.7	Intel Xeon CPU E5-2650 v2
Internap	Ubuntu 14.04	2.7	Common KVM processor
Joyent	Ubuntu 14.04	2.7	Intel Xeon E5645
Microsoft Azure	Ubuntu 14.04	2.7	AMD Opteron Processor 4171 HE
ProfitBricks	Ubuntu 14.04	2.7	AMD Opteron 62xx (Gen 4 Class Opteron)
Rackspace	Ubuntu 14.04	2.7	Intel Xeon CPU E5-2670 v2
Verizon	Ubuntu 14.04	2.7	Intel Xeon CPU E31265L

Individual Tasks

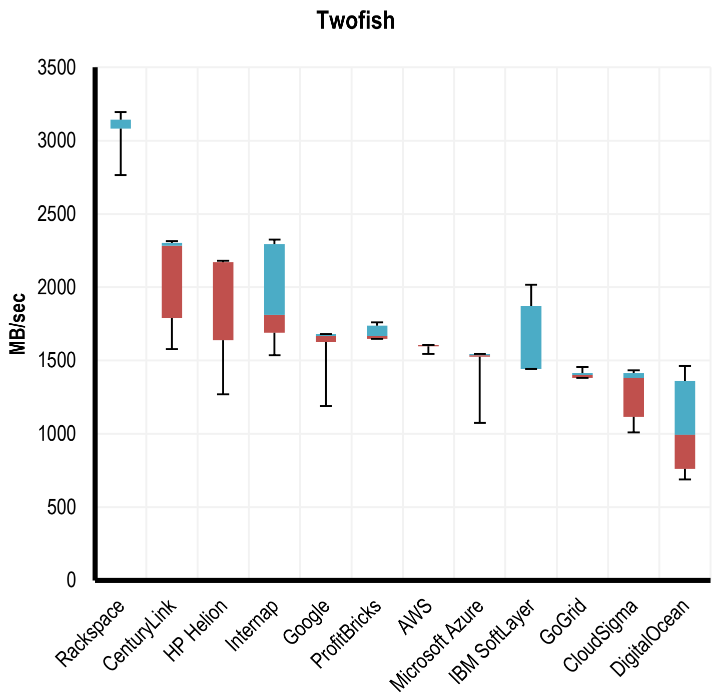
The following tables and graphs describe the performance ranking through each individual task. The rankings are from high to low based on median.

CPU Integer – AES: The AES workload encrypts a generated text string using the advanced encryption standard (AES). AES is used in security tools such as SSL, IPsec, and GPG. Geekbench uses the AES-NI instructions when they are available. When the AES-NI instructions are not available, Geekbench uses its own software AES implementation.



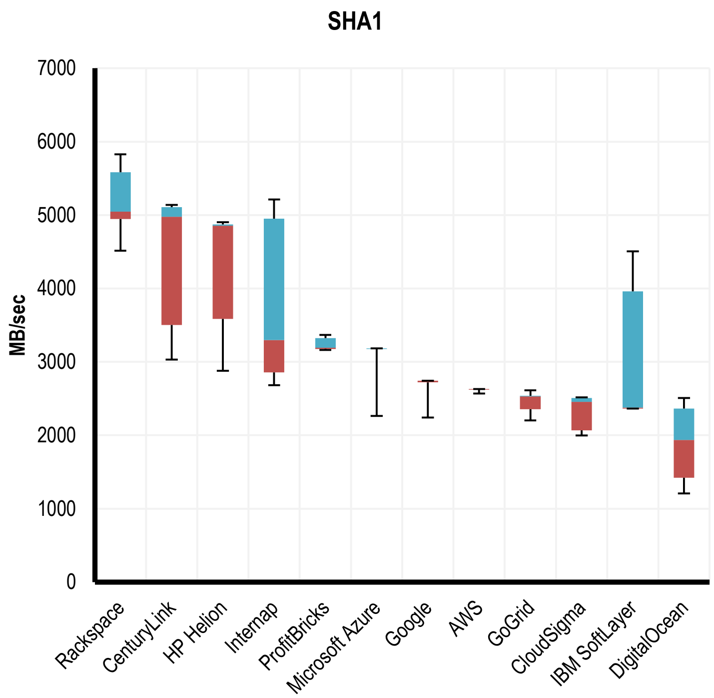
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	14336	18227	18330	18432	18534	173	1.1%
CenturyLink	13107	14336	17101	19354	19558	1942	12.8%
CloudSigma	1075	1188	1423	1464	1475	102	0.7%
DigitalOcean	5458	7842	9984	12800	15770	1507	9.9%
GoGrid	9789	10619	10854	10957	11162	173	1.1%
Google	12698	15258	15872	16077	16179	323	2.1%
HP Helion	13107	14438	15872	25600	27546	3751	24.8%
IBM SoftLayer	16179	16282	16384	26624	26931	3484	23.0%
Internap	1864	1997	2243	3287	3471	333	2.2%
Microsoft Azure	10854	11878	14438	23142	24269	3999	26.4%
ProfitBricks	6134	6786	7383	9719	10547	888	5.9%
Rackspace	18534	20070	22016	26081	28262	1661	11.0%

CPU Integer – Twofish: The Twofish workload also encrypts a text string, but it uses the Twofish algorithm. Twofish is from the family of encryption algorithms known as "Feistel ciphers." It is included in the OpenPGP standard.



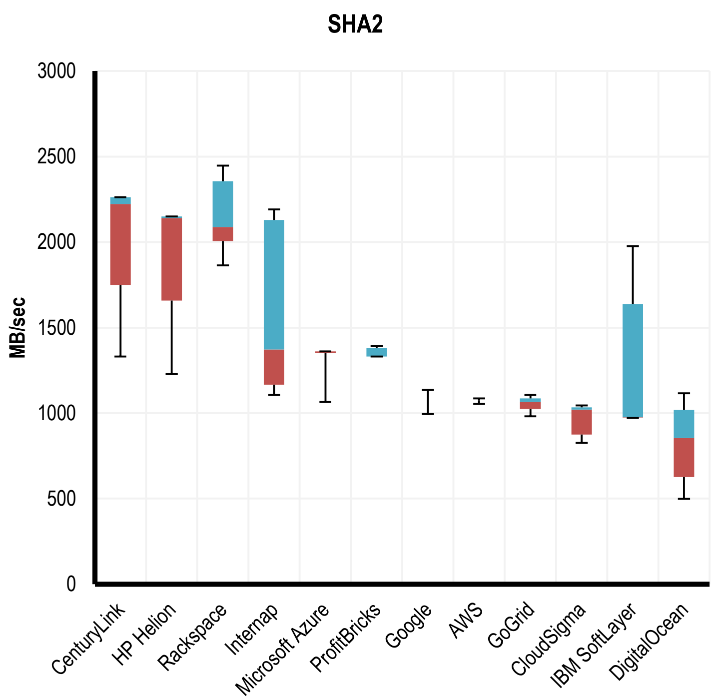
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	1546	1597	1608	1608	1608	4	0.2%
CenturyLink	1577	1790	2284	2304	2314	148	9.0%
CloudSigma	1011	1116	1382	1413	1434	111	6.8%
DigitalOcean	690	762	994	1362	1464	207	12.6%
GoGrid	1382	1382	1403	1413	1454	14	0.9%
Google	1188	1628	1669	1679	1679	25	1.5%
HP Helion	1270	1639	2171	2171	2181	183	11.2%
IBM SoftLayer	1444	1444	1444	1874	2017	143	8.7%
Internap	1536	1690	1812	2294	2324	168	10.3%
Microsoft Azure	1075	1526	1536	1546	1546	29	1.8%
ProfitBricks	1649	1650	1669	1739	1761	25	1.5%
Rackspace	2765	3082	3082	3144	3195	29	1.8%

CPU Integer – SHA1: SHA1 is a cryptographic hash algorithm: given a binary input it generates a "hash" or "digest" of the input. SHA1 is designed so that the hash may be computed quickly, but it is difficult to find a string that generates a given hash. SHA1 may be used, for example, to encrypt passwords by storing the hash instead of the password text. The SHA1 workload uses a text string as input.



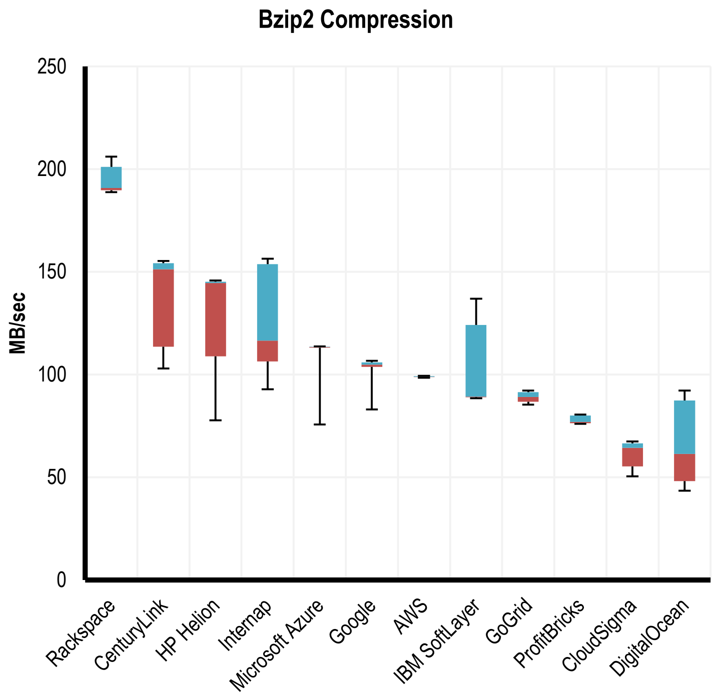
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	2570	2621	2632	2632	2632	3	0.1%
CenturyLink	3031	3502	4977	5110	5140	503	17.0%
CloudSigma	1997	2068	2458	2509	2519	162	5.5%
DigitalOcean	1208	1423	1935	2365	2509	298	10.1%
GoGrid	2202	2355	2529	2540	2611	63	2.1%
Google	2243	2724	2744	2744	2744	24	0.8%
HP Helion	2877	3585	4854	4874	4905	399	13.5%
IBM SoftLayer	2365	2365	2376	3961	4506	527	17.8%
Internap	2683	2857	3297	4954	5212	538	18.2%
Microsoft Azure	2263	3174	3174	3185	3185	44	1.5%
ProfitBricks	3164	3174	3195	3324	3369	47	1.6%
Rackspace	4516	4946	5048	5584	5827	200	6.8%

CPU Integer – SHA2: SHA2 solves the same problem as SHA1, but is more secure: SHA1 has a known vulnerability to "collision attacks." Although these attacks are still impractical and SHA1 is still widely used, it is being gradually replaced by SHA2.



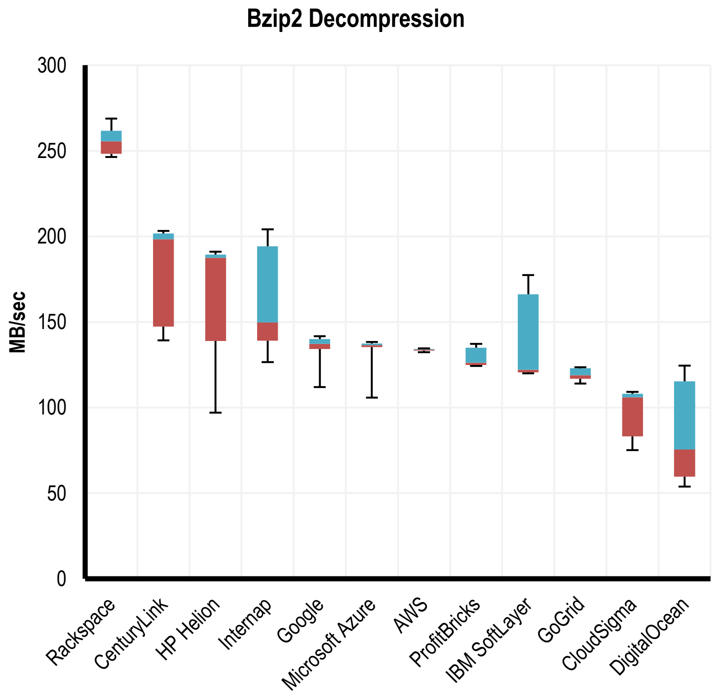
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	1055	1075	1075	1075	1085	1	0.1%
CenturyLink	1331	1750	2222	2263	2263	167	13.5%
CloudSigma	827	875	1020	1034	1044	62	5.0%
DigitalOcean	499	627	855	1018	1116	118	9.6%
GoGrid	981	1024	1065	1085	1106	20	1.6%
Google	994	1137	1137	1137	1137	5	0.4%
HP Helion	1229	1659	2140	2150	2150	150	12.2%
IBM SoftLayer	973	974	977	1638	1976	233	18.9%
Internap	1106	1167	1372	2130	2191	258	20.9%
Microsoft Azure	1065	1352	1362	1362	1362	13	1.1%
ProfitBricks	1331	1331	1331	1381	1393	16	1.3%
Rackspace	1864	2007	2089	2355	2447	98	7.9%

CPU Integer – Bzip2 Compression: BZip2 is a compression algorithm. The BZip2 workloads compress and decompress an ebook formatted using HTML. Geekbench 3 uses bzlib version 1.0.6 in the BZip2 workloads.



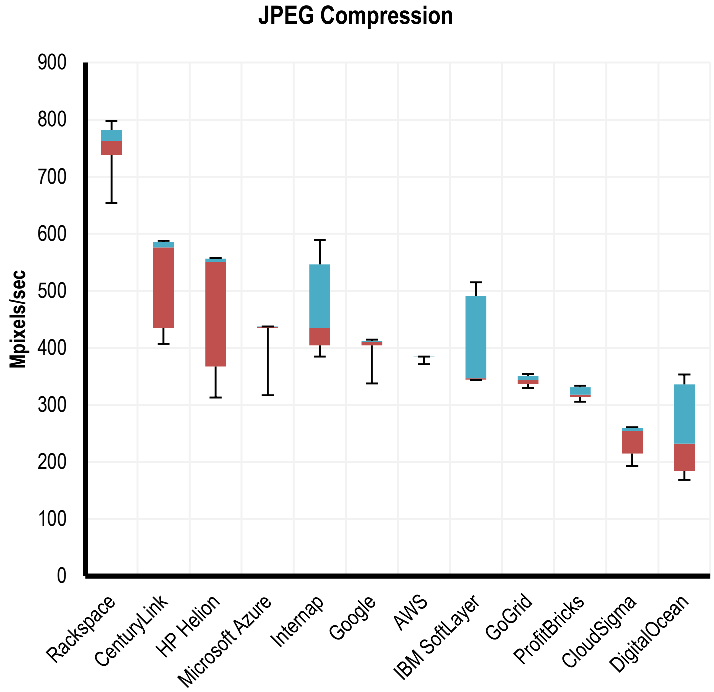
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	98.4	98.8	99.0	99.2	99.4	0.0	0.0%
CenturyLink	103.0	113.6	151.3	154.2	155.4	11.6	11.4%
CloudSigma	50.5	55.3	64.4	66.5	67.4	3.7	3.6%
DigitalOcean	43.4	48.2	61.4	87.5	92.2	13.0	12.8%
GoGrid	85.3	86.7	89.1	91.4	92.3	0.9	0.9%
Google	83.1	103.7	104.9	105.9	106.7	1.0	1.0%
HP Helion	77.8	108.9	144.6	145.2	145.8	11.2	11.0%
IBM SoftLayer	88.5	88.9	89.2	124.2	136.9	11.3	11.1%
Internap	92.9	106.4	116.6	153.7	156.4	11.9	11.7%
Microsoft Azure	75.7	113.1	113.4	113.6	113.7	2.3	2.2%
ProfitBricks	76.1	76.3	77.0	80.1	80.5	0.8	0.8%
Rackspace	188.8	189.8	190.8	201.1	206.1	1.9	1.9%

CPU Integer – Bzip2 Decompression: BZip2 is a compression algorithm. The BZip2 workloads compress and decompress an ebook formatted using HTML. Geekbench 3 uses bzlib version 1.0.6 in the BZip2 workloads.



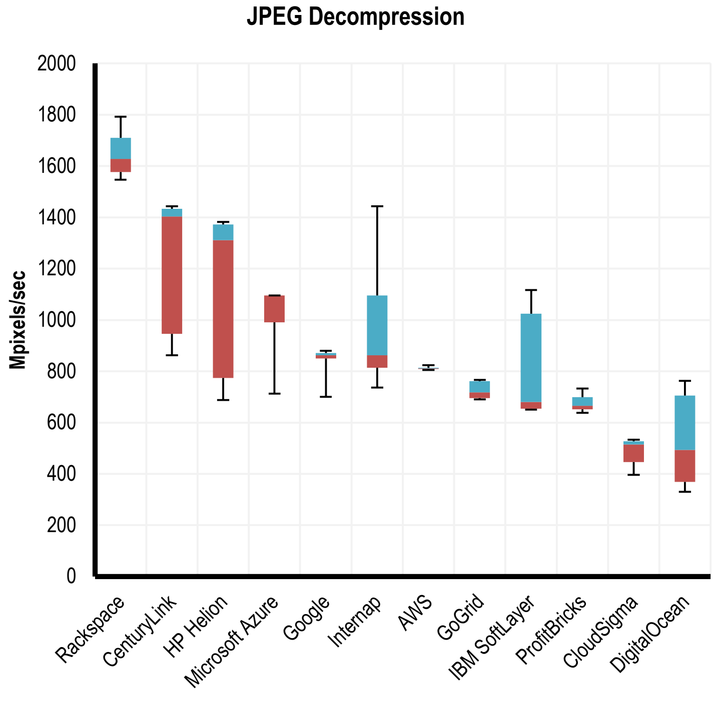
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	132.4	133.2	133.8	134.2	134.6	0.0	0.0%
CenturyLink	139.2	147.2	198.4	201.8	203.2	17.0	12.6%
CloudSigma	75.1	83.2	106.0	108.0	109.1	8.1	6.0%
DigitalOcean	53.8	59.6	75.5	115.4	124.5	17.0	12.6%
GoGrid	114.0	116.8	118.9	123.0	123.6	1.2	0.9%
Google	112.0	134.2	137.2	140.1	141.7	1.4	1.0%
HP Helion	97.0	138.9	187.5	189.3	191.1	14.6	10.8%
IBM SoftLayer	120.1	120.5	122.0	166.2	177.4	12.8	9.5%
Internap	126.5	139.1	149.8	194.2	204.1	13.8	10.2%
Microsoft Azure	105.8	135.4	136.5	137.5	138.4	1.4	1.0%
ProfitBricks	124.3	124.8	126.1	135.0	137.3	2.5	1.9%
Rackspace	246.4	248.4	255.7	261.8	268.9	2.6	1.9%

CPU Integer – JPEG Compression: The JPEG workloads compress and decompress one digital image using lossy JPEG format. The workloads use libjpeg version 6b.



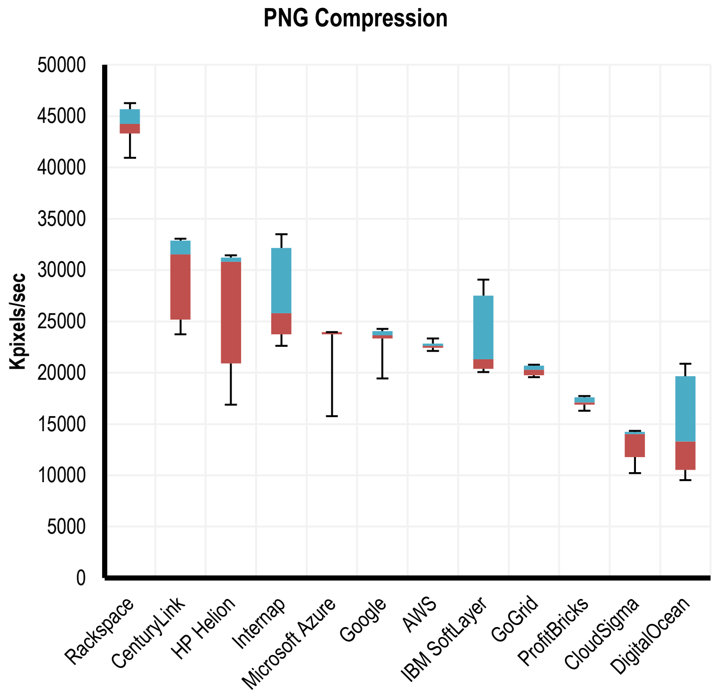
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	371.5	383.8	384.0	384.2	384.7	0.0	0.0%
CenturyLink	407.3	434.9	576.2	585.3	587.7	44.2	11.1%
CloudSigma	192.9	215.0	254.5	259.1	260.9	12.4	3.1%
DigitalOcean	168.6	183.8	232.3	335.7	353.2	52.1	13.1%
GoGrid	329.8	336.6	344.0	351.2	354.4	3.4	0.9%
Google	337.7	404.4	410.6	412.5	414.3	3.0	0.8%
HP Helion	312.9	367.5	550.2	556.2	557.3	65.8	16.6%
IBM SoftLayer	343.9	344.2	346.6	491.4	515.1	45.2	11.4%
Internap	384.5	404.3	435.5	546.6	589.1	79.9	20.1%
Microsoft Azure	316.8	435.1	436.8	437.2	437.4	4.4	1.1%
ProfitBricks	305.9	313.9	317.8	331.0	333.8	3.2	0.8%
Rackspace	654.2	738.3	762.0	781.7	797.4	15.2	3.8%

CPU Integer – JPEG Decompression: The JPEG workloads compress and decompress one digital image using lossy JPEG format. The workloads use libjpeg version 6b.



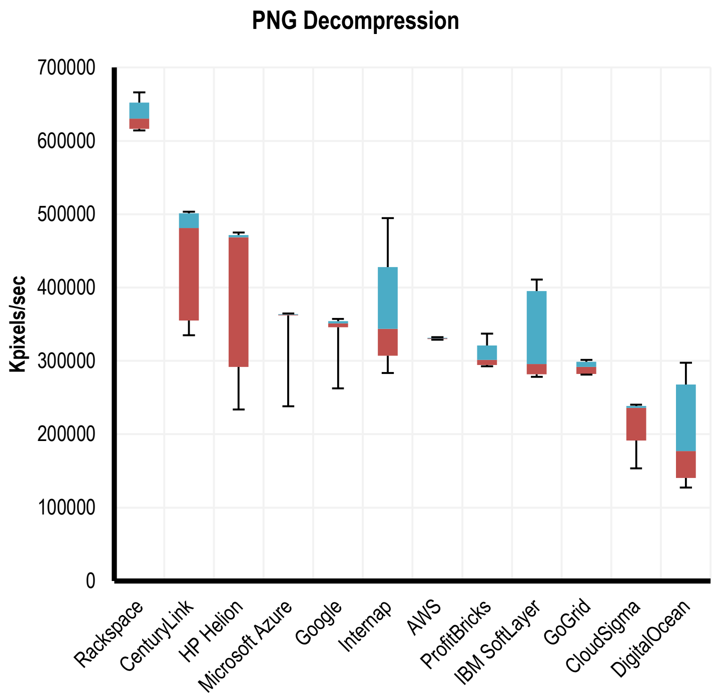
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	806	809	811	814	824	1	0.1%
CenturyLink	862	947	1403	1434	1444	149	17.8%
CloudSigma	396	446	515	528	534	24	2.9%
DigitalOcean	331	369	493	705	763	101	12.1%
GoGrid	690	695	718	762	767	21	2.5%
Google	700	851	863	872	880	8	1.0%
HP Helion	688	774	1311	1372	1382	223	26.7%
IBM SoftLayer	651	654	680	1024	1116	114	13.6%
Internap	736	814	862	1096	1444	110	13.1%
Microsoft Azure	713	991	1096	1096	1096	40	4.8%
ProfitBricks	638	652	666	699	732	18	2.2%
Rackspace	1546	1577	1628	1710	1792	38	4.5%

CPU Integer – PNG Compression: The PNG workloads also compress and decompress a digital image, but they do so using the PNG format. The workloads use libpng 1.6.2.



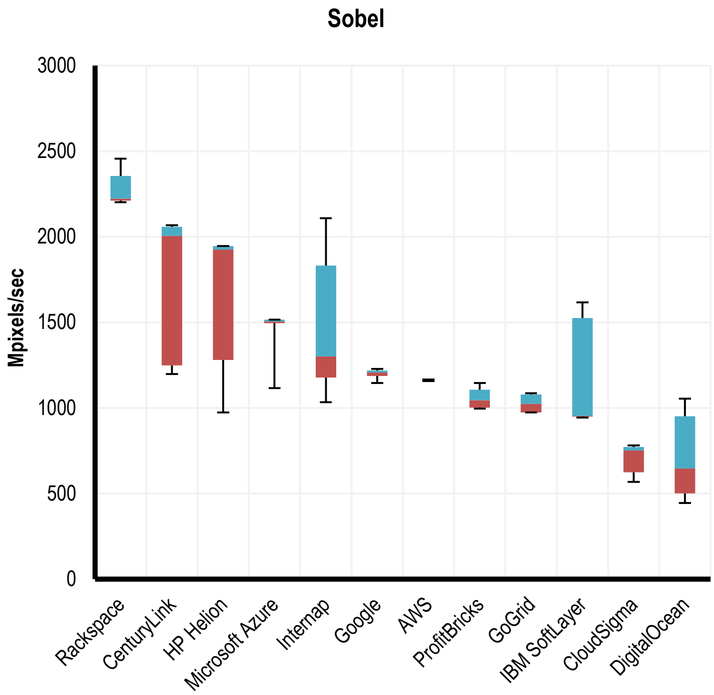
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	22118	22426	22630	22835	23347	120	0.5%
CenturyLink	23757	25190	31539	32870	33075	2744	11.9%
CloudSigma	10230	11776	14029	14234	14336	776	3.4%
DigitalOcean	9533	10527	13312	19661	20890	3162	13.7%
GoGrid	19558	19763	20275	20685	20787	249	1.1%
Google	19456	23347	23654	24064	24269	273	1.2%
HP Helion	16896	20895	30822	31232	31437	3540	15.3%
IBM SoftLayer	20070	20378	21299	27505	29082	2178	9.4%
Internap	22630	23757	25805	32154	33485	2215	9.6%
Microsoft Azure	15770	23757	23962	23962	23962	380	1.6%
ProfitBricks	16282	16896	17101	17603	17715	262	1.1%
Rackspace	40960	43315	44237	45670	46285	753	3.3%

CPU Integer – PNG Decompression: The PNG workloads also compress and decompress a digital image, but they do so using the PNG format. The workloads use libpng 1.6.2.



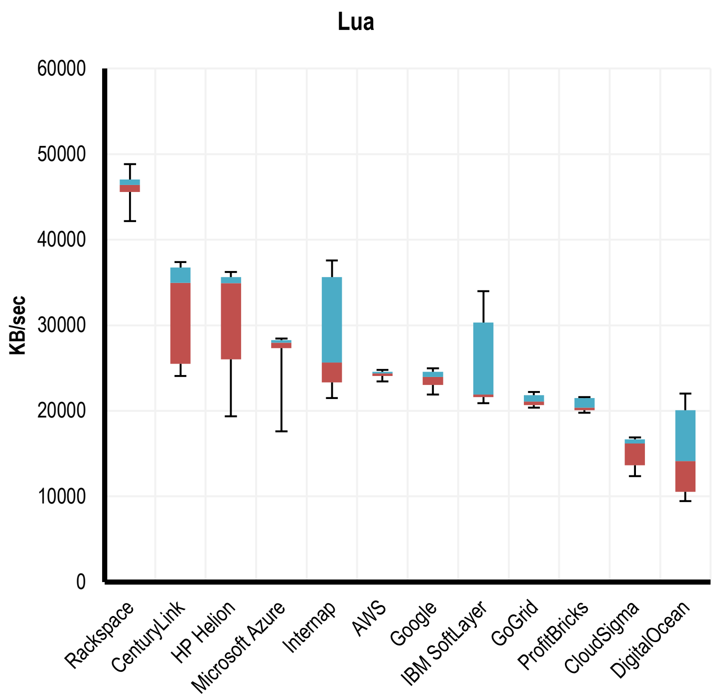
	Min	5th Per.	Median	95th Per.	Max	Stdev.	Variability
AWS	328806	329626	330445	331469	332493	551	0.2%
CenturyLink	334848	355123	480973	501043	503603	54385	16.1%
CloudSigma	153702	191406	235827	238756	240538	16293	4.8%
DigitalOcean	127488	140308	176947	268001	297370	40181	11.9%
GoGrid	281190	282184	291942	298660	301568	5266	1.6%
Google	262656	345805	351334	354202	357069	4042	1.2%
HP Helion	233779	292035	468480	471654	474931	59473	17.6%
IBM SoftLayer	278118	281805	295834	395223	411136	37172	11.0%
Internap	283341	306995	343757	428140	494490	36248	10.8%
Microsoft Azure	237978	361882	363110	363725	364544	6857	2.0%
ProfitBricks	292557	294380	301261	321014	337203	9576	2.8%
Rackspace	614298	616346	630528	652396	666112	12628	3.7%

CPU Integer – Sobel: The "Sobel operator" is used in image processing for finding edges in images. The Sobel workload uses the same input image as the JPEG and PNG workloads.



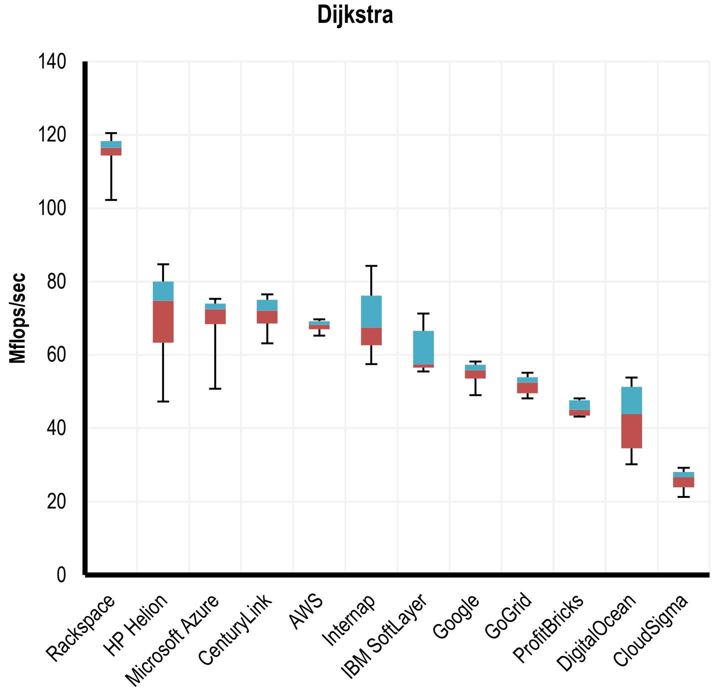
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	1157	1167	1167	1167	1167	0	0.0%
CenturyLink	1198	1249	2007	2058	2068	271	22.8%
CloudSigma	569	623	752	772	782	45	3.8%
DigitalOcean	446	502	646	951	1055	139	11.7%
GoGrid	975	975	1024	1078	1085	44	3.7%
Google	1147	1188	1208	1219	1229	10	0.8%
HP Helion	974	1280	1925	1946	1946	217	18.3%
IBM SoftLayer	944	950	954	1526	1618	179	15.1%
Internap	1034	1178	1300	1833	2109	192	16.2%
Microsoft Azure	1116	1495	1505	1516	1516	29	2.4%
ProfitBricks	997	1002	1044	1106	1147	31	2.6%
Rackspace	2202	2212	2222	2355	2458	45	3.8%

CPU Integer – Lua: Lua is lightweight scripting language. The Lua workload is similar to the code used to display Geekbench results in the Geekbench Browser.



	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	23450	24064	24371	24576	24781	169	0.7%
CenturyLink	24064	25498	34970	36762	37376	3571	14.8%
CloudSigma	12390	13660	16179	16691	16896	931	3.9%
DigitalOcean	9472	10547	14131	20070	22016	3076	12.7%
GoGrid	20378	20685	21094	21842	22221	388	1.6%
Google	21914	23040	23962	24576	24986	485	2.0%
HP Helion	19354	26010	34918	35635	36250	2965	12.3%
IBM SoftLayer	20890	21606	21914	30310	33997	2750	11.4%
Internap	21504	23347	25651	35635	37581	3326	13.8%
Microsoft Azure	17613	27341	27955	28262	28467	683	2.8%
ProfitBricks	19763	20070	20378	21494	21606	451	1.9%
Rackspace	42189	45568	46387	47037	48845	608	2.5%

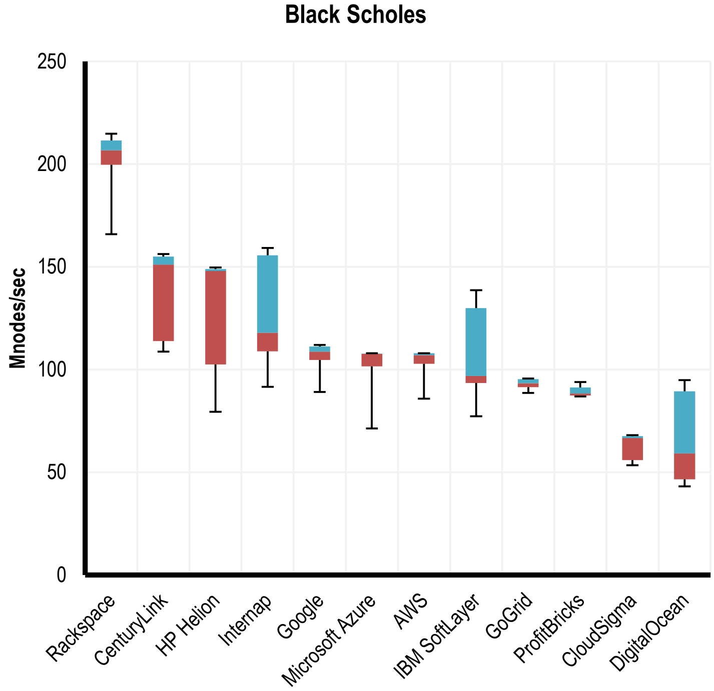
CPU Integer – Dijkstra: The Dijkstra workload computes driving directions between a sequence of destinations. Similar techniques are used by AIs to compute paths in games and by network routers to route computer network traffic.



	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	65.30	67.00	68.20	69.20	69.70	0.00	0.0%
CenturyLink	63.20	68.59	72.10	75.02	76.50	1.44	2.3%
CloudSigma	21.30	23.90	26.70	28.10	29.20	1.30	2.1%
DigitalOcean	30.20	34.58	43.90	51.30	53.80	5.16	8.3%
GoGrid	48.20	49.57	52.40	53.90	55.10	1.04	1.7%
Google	49.00	53.60	55.80	57.36	58.20	1.10	1.8%
HP Helion	47.30	63.32	74.80	80.00	84.70	4.38	7.0%
IBM SoftLayer	55.50	56.50	57.40	66.60	71.30	2.95	4.7%
Internap	57.50	62.67	67.40	76.20	84.30	4.08	6.5%
Microsoft Azure	50.80	68.40	72.40	74.00	75.30	2.13	3.4%
ProfitBricks	43.20	43.44	45.00	47.67	48.20	0.90	1.4%
Rackspace	102.30	114.40	116.50	118.30	120.50	1.16	1.9%

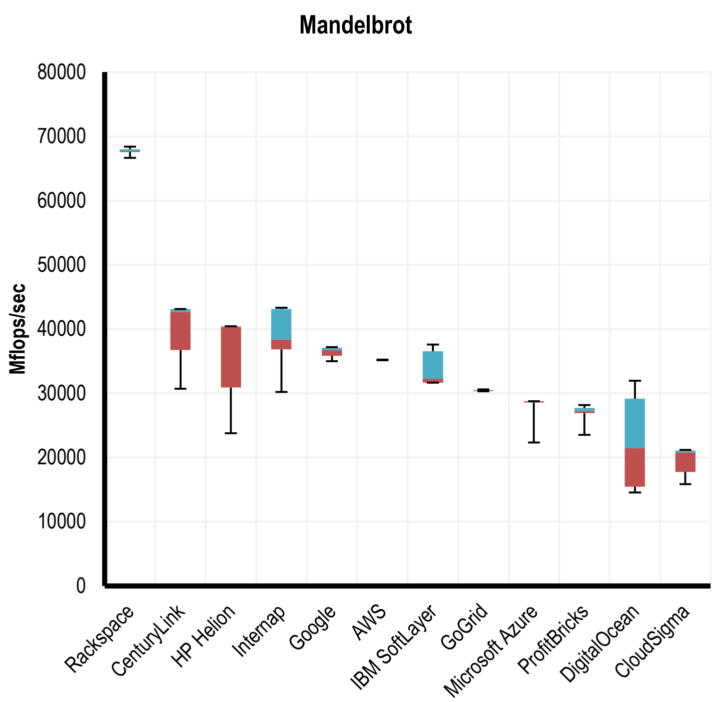
--- End of CPU Integer Results ---

CPU Floating Point – Black Scholes: The Black-Scholes equation is used to model option prices on financial markets. The Black-Scholes workload computes the Black-Scholes formula: a special case solution of the Black-Scholes equation for European call and put options.



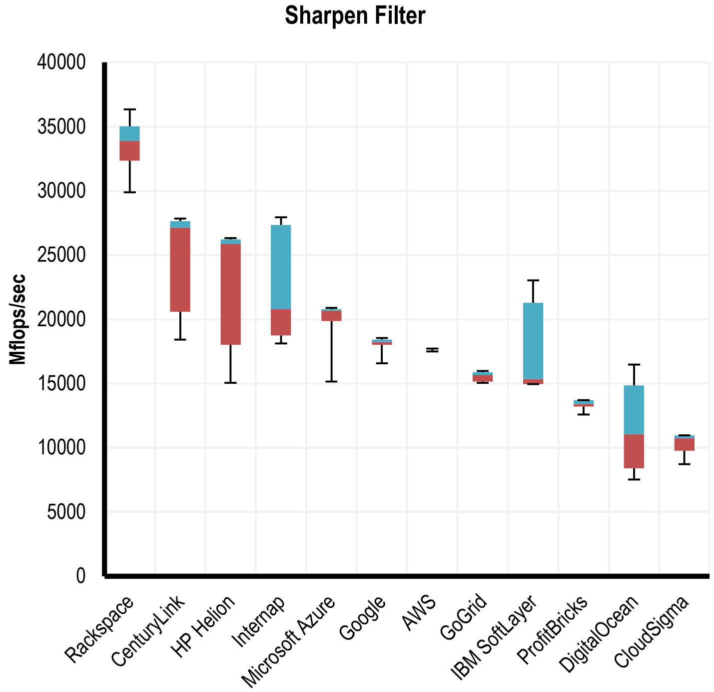
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	85.9	102.9	107.1	107.9	108.0	1.1	1.0%
CenturyLink	108.7	113.9	151.1	155.1	156.2	13.0	12.1%
CloudSigma	53.4	55.9	66.6	67.6	68.0	3.3	3.0%
DigitalOcean	43.1	46.6	59.2	89.4	94.9	14.1	13.1%
GoGrid	88.7	91.4	93.3	95.3	95.6	0.9	0.9%
Google	89.1	104.7	108.8	111.2	112.0	1.1	1.0%
HP Helion	79.5	102.5	148.0	149.0	149.8	14.1	13.1%
IBM SoftLayer	77.3	93.5	96.9	130.0	138.6	10.2	9.5%
Internap	91.6	108.9	118.0	155.7	159.3	12.1	11.3%
Microsoft Azure	71.4	101.5	107.6	107.7	107.9	2.1	2.0%
ProfitBricks	86.9	87.4	88.3	91.3	94.0	0.9	0.8%
Rackspace	166.0	199.8	206.8	211.5	214.8	2.1	1.9%

CPU Floating Point – Mandelbrot: The Mandelbrot set is a fractal. It is a useful floating point workload because it has a low memory bandwidth requirement.



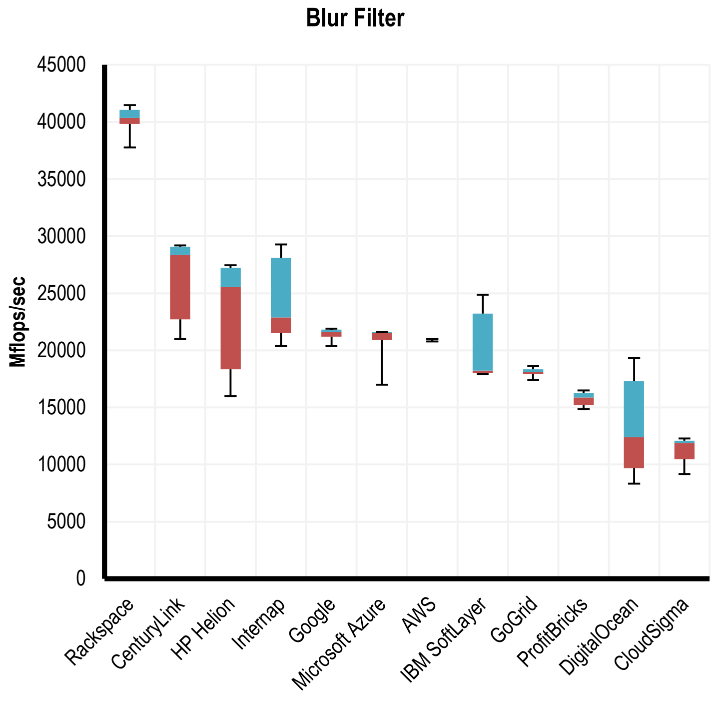
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	35123	35226	35226	35226	35226	13	0.0%
CenturyLink	30720	36762	42701	43110	43110	2217	6.6%
CloudSigma	15872	17756	20787	21094	21197	1021	3.0%
DigitalOcean	14541	15462	21504	29184	31949	4764	14.1%
GoGrid	30310	30310	30310	30515	30618	71	0.2%
Google	35021	35840	36762	37069	37171	423	1.3%
HP Helion	23757	30930	40346	40448	40448	3285	9.7%
IBM SoftLayer	31642	31642	32256	36557	37581	1579	4.7%
Internap	30208	36864	38400	43110	43315	2192	6.5%
Microsoft Azure	22323	28570	28774	28774	28774	369	1.1%
ProfitBricks	23552	26931	27238	27730	28160	611	1.8%
Rackspace	66662	67548	67686	67994	68403	155	0.5%

CPU Floating Point – Sharpen Filter: The sharpen image workload uses a standard image sharpening technique similar to those found in Photoshop or Gimp.



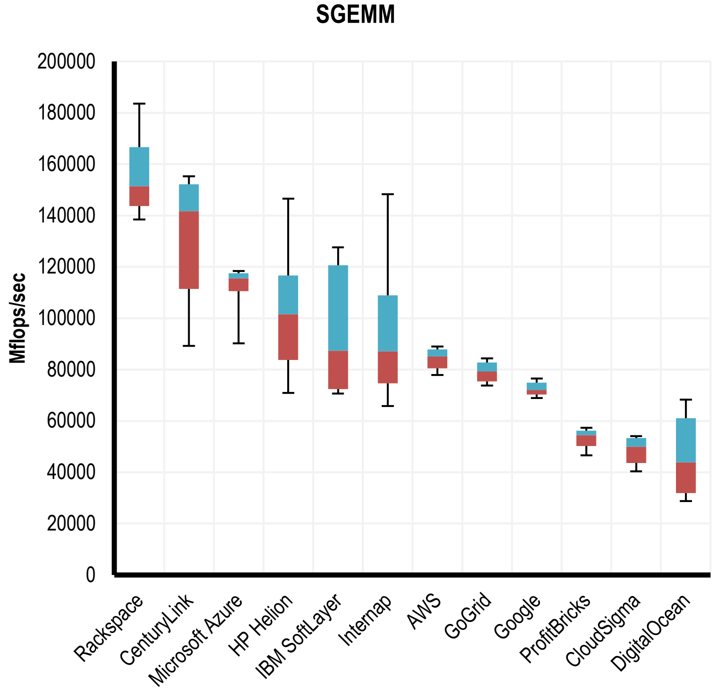
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	17510	17613	17613	17613	17715	11	0.1%
CenturyLink	18432	20582	27136	27648	27853	2114	11.8%
CloudSigma	8735	9767	10752	10957	10957	382	2.1%
DigitalOcean	7526	8405	11059	14848	16486	2227	12.4%
GoGrid	15053	15155	15667	15872	15974	274	1.5%
Google	16589	18022	18227	18432	18534	155	0.9%
HP Helion	15053	18022	25856	26214	26317	3084	17.2%
IBM SoftLayer	14950	14950	15360	21299	23040	2146	12.0%
Internap	18125	18739	20787	27341	27955	2374	13.2%
Microsoft Azure	15155	19866	20685	20787	20890	408	2.3%
ProfitBricks	12595	13210	13414	13701	13722	186	1.0%
Rackspace	29901	32358	33894	35021	36352	776	4.3%

CPU Floating Point – Blur Filter: Image blurring is also found in tools such as Photoshop. In Geekbench 3, the blur image workload is more computationally demanding than the sharpen workload.



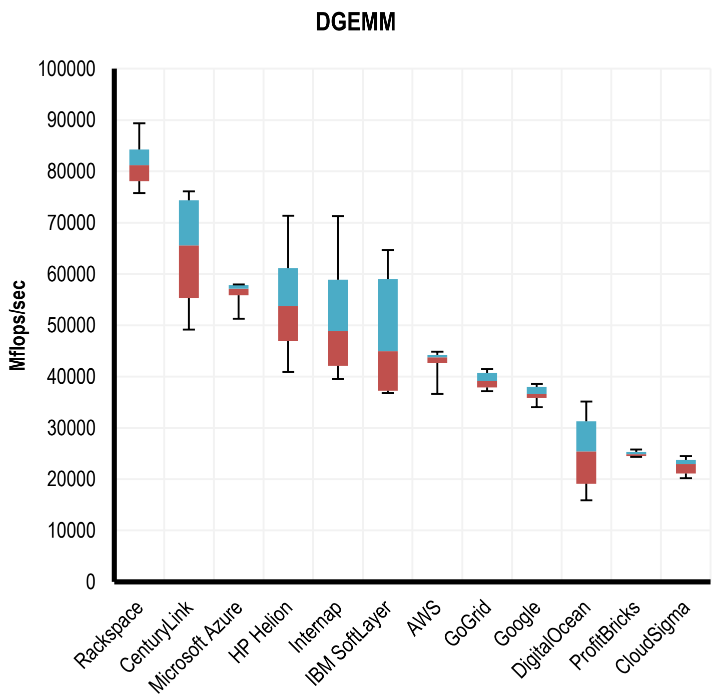
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	20787	20890	20890	20890	20992	8	0.0%
CenturyLink	20992	22717	28365	29082	29184	1945	9.2%
CloudSigma	9155	10445	11878	12083	12288	516	2.4%
DigitalOcean	8325	9685	12390	17306	19354	2725	12.9%
GoGrid	17408	17920	18125	18330	18637	168	0.8%
Google	20378	21197	21606	21811	21914	202	1.0%
HP Helion	15974	18330	25549	27238	27443	3350	15.8%
IBM SoftLayer	17920	18022	18227	23224	24883	1724	8.1%
Internap	20378	21504	22886	28093	29286	1708	8.1%
Microsoft Azure	16998	20910	21504	21606	21606	322	1.5%
ProfitBricks	14848	15186	15872	16271	16486	298	1.4%
Rackspace	37786	39834	40346	41062	41472	404	1.9%

CPU Floating Point – SGEMM: GEMM is "general matrix multiplication." Matrix multiplication is a fundamental mathematical operation. It is used in physical simulations, signal processing, graphics processing, and many other areas.



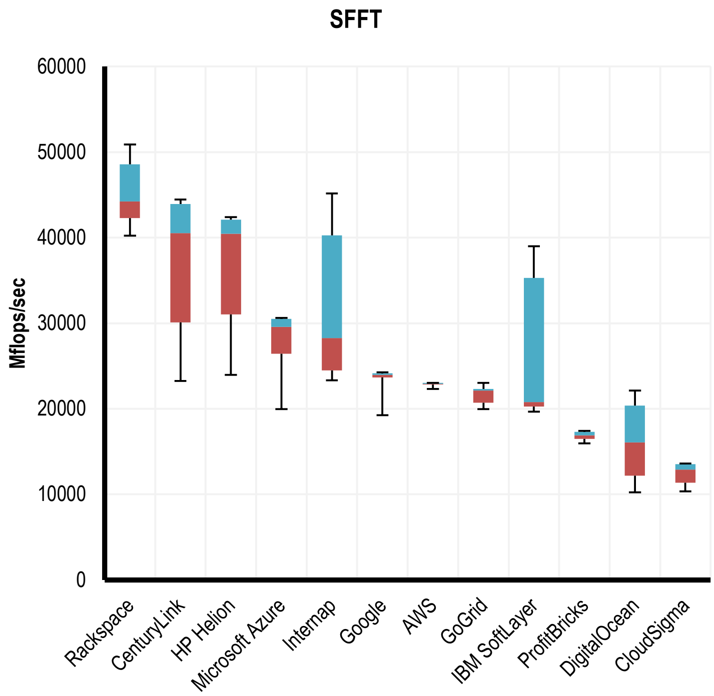
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	77926	80486	85094	87859	88986	2344	2.7%
CenturyLink	89293	111396	141773	152166	155341	12918	15.0%
CloudSigma	40346	43663	49971	53350	54067	2971	3.4%
DigitalOcean	28774	31928	43827	61030	68301	9321	10.8%
GoGrid	73728	75366	79258	82770	84378	2229	2.6%
Google	68915	70349	71987	74854	76493	1396	1.6%
HP Helion	70861	83763	101581	116634	146534	11575	13.4%
IBM SoftLayer	70656	72417	87347	120709	127590	15210	17.7%
Internap	65843	74614	87142	108989	148275	10504	12.2%
Microsoft Azure	90214	110510	115507	117555	118374	2590	3.0%
ProfitBricks	46592	50186	54477	56197	57344	2220	2.6%
Rackspace	138445	143667	151501	166641	183603	6925	8.0%

CPU Floating Point – DGEMM: GEMM is "general matrix multiplication." Matrix multiplication is a fundamental mathematical operation. It is used in physical simulations, signal processing, graphics processing, and many other areas.



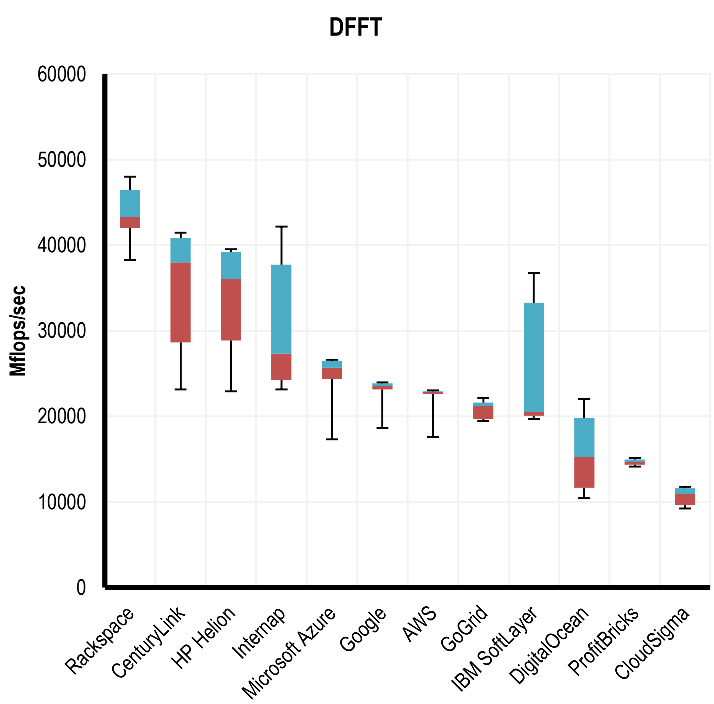
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	36659	42598	43725	44237	44851	570	1.3%
CenturyLink	49152	55337	65587	74358	76083	5595	12.6%
CloudSigma	20173	21094	22938	23757	24474	756	1.7%
DigitalOcean	15872	19149	25395	31293	35123	3668	8.3%
GoGrid	37171	37888	39219	40755	41472	947	2.1%
Google	33997	35840	36659	37990	38605	691	1.6%
HP Helion	40960	47002	53811	61128	71373	4360	9.8%
IBM SoftLayer	36762	37274	44954	59044	64717	7562	17.1%
Internap	39526	42153	48845	58916	71270	5090	11.5%
Microsoft Azure	51302	55808	57139	57856	57958	670	1.5%
ProfitBricks	24371	24474	24883	25283	25805	289	0.7%
Rackspace	75776	78095	81203	84275	89395	1914	4.3%

CPU Floating Point – SFFT: The fast Fourier transform (FFT) workloads simulate the frequency analysis used to compute the spectrum view in an audio processing application such as Pro Tools.



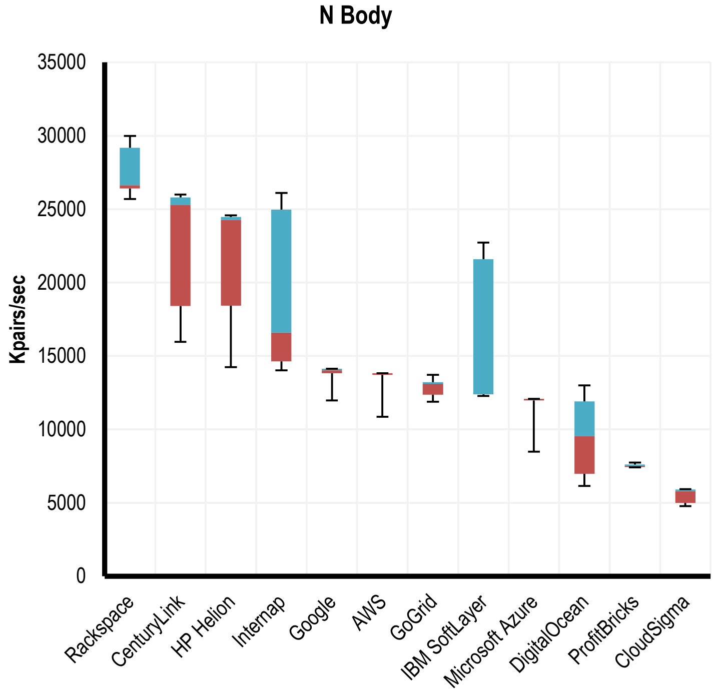
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	22323	22835	22938	23040	23040	72	0.3%
CenturyLink	23245	30090	40550	43930	44442	4293	18.3%
CloudSigma	10342	11366	12902	13517	13619	721	3.1%
DigitalOcean	10240	12186	16077	20378	22118	2674	11.4%
GoGrid	19968	20726	22118	22323	23040	531	2.3%
Google	19251	23654	23962	24166	24269	250	1.1%
HP Helion	23962	31027	40448	42086	42394	3878	16.5%
IBM SoftLayer	19661	20275	20787	35308	39014	5071	21.6%
Internap	23347	24474	28262	40279	45158	4380	18.7%
Microsoft Azure	19968	26419	29594	30515	30618	1389	5.9%
ProfitBricks	15974	16497	16896	17295	17408	270	1.2%
Rackspace	40243	42291	44237	48573	50893	2082	8.9%

CPU Floating Point – DFFT: The fast Fourier transform (FFT) workloads simulate the frequency analysis used to compute the spectrum view in an audio processing application such as Pro Tools.



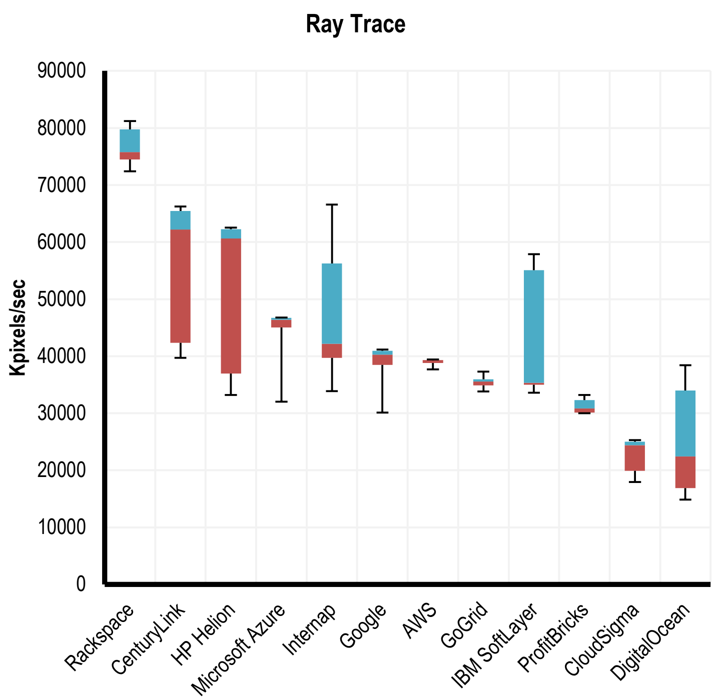
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	17613	22630	22835	22938	23040	211	0.9%
CenturyLink	23142	28657	37990	40858	41472	3658	15.8%
CloudSigma	9236	9595	10957	11571	11776	677	2.9%
DigitalOcean	10445	11674	15258	19763	22016	2672	11.5%
GoGrid	19456	19661	21197	21606	22118	746	3.2%
Google	18637	23142	23552	23859	23962	274	1.2%
HP Helion	22938	28882	36045	39219	39526	3039	13.1%
IBM SoftLayer	19661	20070	20480	33280	36762	4412	19.0%
Internap	23142	24233	27341	37719	42189	3918	16.9%
Microsoft Azure	17306	24371	25702	26522	26624	876	3.8%
ProfitBricks	14131	14346	14643	14940	15155	182	0.8%
Rackspace	38298	41984	43315	46490	48026	1436	6.2%

CPU Floating Point – N Body: This workload computes a physical simulation similar to that required for a physics game placed in outer space.



	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	10854	13722	**13824**	13824	13824	108	0.8%
CenturyLink	15974	18417	**25293**	25805	26010	2082	15.5%
CloudSigma	4772	4987	**5796**	5908	5939	353	2.6%
DigitalOcean	6144	6980	**9554**	11899	13005	1575	11.7%
GoGrid	11878	12360	**13107**	13210	13722	289	2.1%
Google	11981	13824	**14029**	14131	14131	123	0.9%
HP Helion	14234	18437	**24269**	24474	24576	1957	14.5%
IBM SoftLayer	12288	12390	**12390**	21586	22733	3011	22.4%
Internap	14029	14643	**16589**	24986	26112	2721	20.2%
Microsoft Azure	8479	11981	**12083**	12083	12083	172	1.3%
ProfitBricks	7414	7434	**7516**	7617	7731	62	0.5%
Rackspace	25702	26419	**26624**	29184	30003	940	7.0%

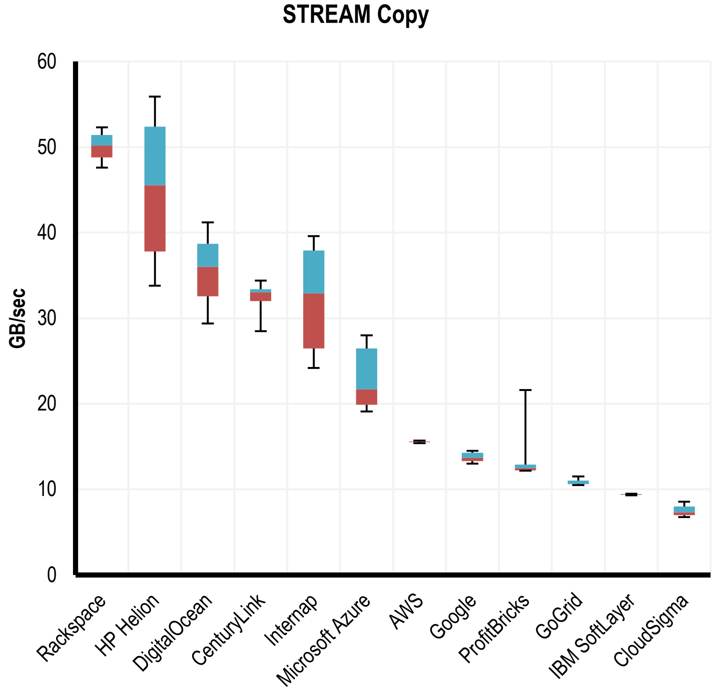
CPU Floating Points – Ray Trace: The ray trace workload renders a 3D scene from a geometric description.



	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	37683	38810	**39322**	39322	39424	230	0.6%
CenturyLink	39731	42363	**62208**	65434	66253	7551	19.0%
CloudSigma	17920	19907	**24371**	24986	25293	1896	4.8%
DigitalOcean	14848	16896	**22426**	33997	38400	5458	13.7%
GoGrid	33792	34857	**35533**	35942	37274	451	1.1%
Google	30106	38502	**40243**	40960	41165	930	2.3%
HP Helion	33178	36972	**60621**	62259	62566	9159	23.0%
IBM SoftLayer	33587	35021	**35328**	55091	57856	6680	16.8%
Internap	33894	39695	**42189**	56253	66560	5331	13.4%
Microsoft Azure	32051	45056	**46387**	46694	46797	1286	3.2%
ProfitBricks	30003	30116	**30822**	32307	33178	669	1.7%
Rackspace	72397	74511	**75776**	79770	81203	1763	4.4%

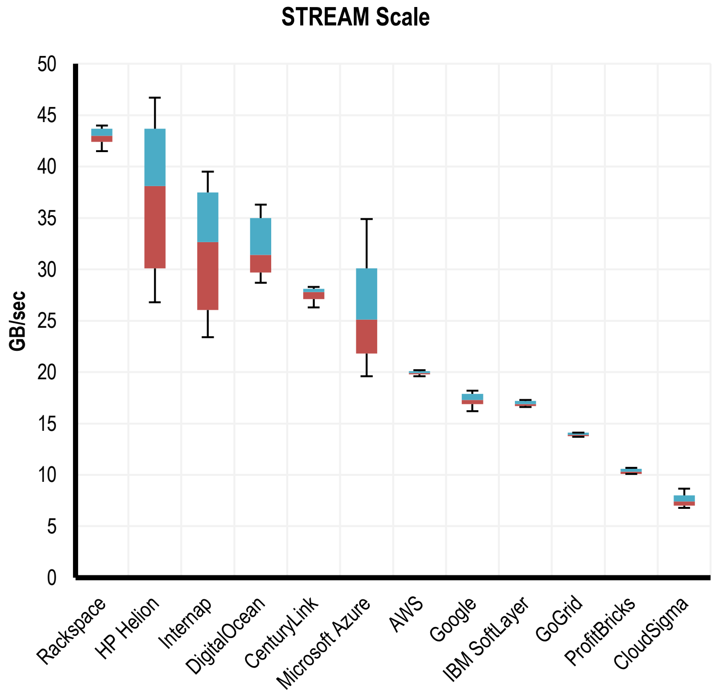
--- End of Floating Point Results ---

Memory – STREAM Copy: The stream copy workload tests how fast your computer can copy large amounts of data in memory. It executes a value-by-value copy of a large list of floating point numbers.



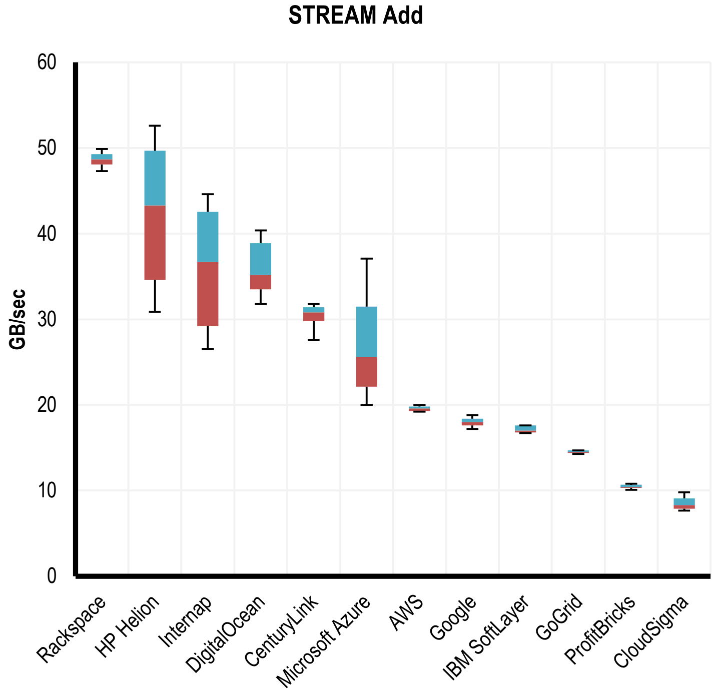
	Min	5th Per.	Median	95th Per.	Max	Stdev.	Variability
AWS	15.40	15.50	15.60	15.60	15.70	0.00	0.0%
CenturyLink	28.50	32.00	33.00	33.40	34.40	0.32	1.7%
CloudSigma	6.75	6.98	7.31	8.01	8.57	0.28	1.5%
DigitalOcean	29.40	32.58	36.00	38.70	41.20	1.75	9.4%
GoGrid	10.50	10.60	10.60	11.03	11.50	0.10	0.5%
Google	13.00	13.30	13.70	14.30	14.50	0.26	1.4%
HP Helion	33.80	37.81	45.55	52.40	55.90	4.05	21.7%
IBM SoftLayer	9.30	9.33	9.39	9.45	9.48	0.00	0.0%
Internap	24.20	26.47	32.90	37.90	39.60	3.52	18.9%
Microsoft Azure	19.10	19.90	21.70	26.46	28.00	1.76	9.4%
ProfitBricks	12.20	12.21	12.50	12.89	21.60	1.20	6.4%
Rackspace	47.60	48.80	50.20	51.40	52.30	0.50	2.7%

Memory – STREAM Scale: This workload is similar to stream copy, but each value is multiplied by a constant during the copy.



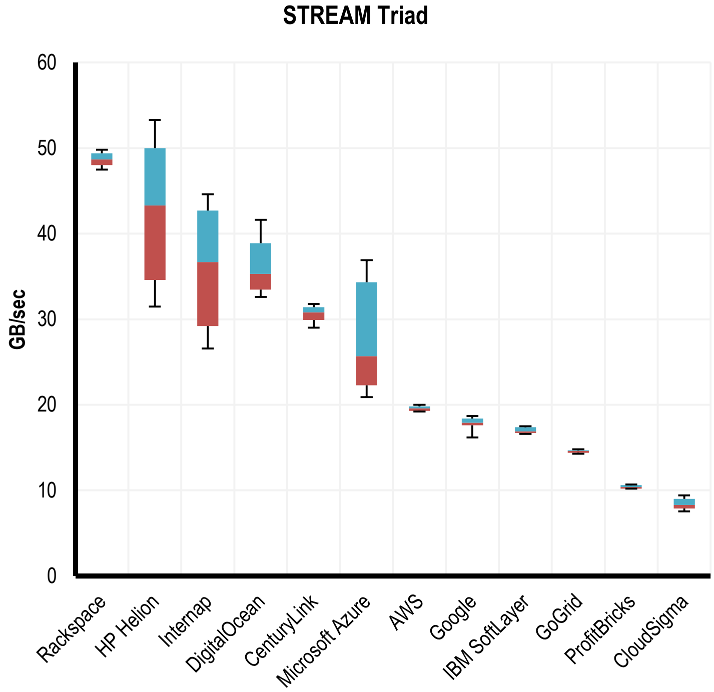
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	19.60	19.80	19.90	20.10	20.20	0.00	0.0%
CenturyLink	26.30	27.10	27.80	28.10	28.30	0.27	1.2%
CloudSigma	6.78	7.02	7.40	8.01	8.65	0.28	1.2%
DigitalOcean	28.70	29.70	31.40	35.00	36.30	1.55	6.9%
GoGrid	13.70	13.77	13.90	14.10	14.10	0.00	0.0%
Google	16.20	16.90	17.30	17.90	18.20	0.17	0.8%
HP Helion	26.80	30.11	38.10	43.70	46.70	4.07	18.1%
IBM SoftLayer	16.60	16.70	16.90	17.20	17.30	0.16	0.7%
Internap	23.40	26.07	32.65	37.50	39.50	3.52	15.6%
Microsoft Azure	19.60	21.80	25.10	30.10	34.90	2.50	11.1%
ProfitBricks	10.10	10.10	10.30	10.60	10.70	0.10	0.4%
Rackspace	41.50	42.40	43.00	43.70	44.00	0.00	0.0%

Memory – STREAM Add: The stream add workload reads two large lists of floating point numbers value-by-value, adds corresponding values, and stores the result in a third list.



	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	19.20	19.30	19.60	19.80	20.00	0.00	0.0%
CenturyLink	27.60	29.80	30.80	31.40	31.80	0.30	1.3%
CloudSigma	7.68	7.88	8.29	9.08	9.79	0.32	1.4%
DigitalOcean	31.80	33.50	35.20	38.90	40.40	1.40	6.2%
GoGrid	14.30	14.40	14.50	14.70	14.70	0.00	0.0%
Google	17.20	17.60	18.00	18.40	18.80	0.17	0.8%
HP Helion	30.90	34.61	43.30	49.70	52.60	4.62	20.4%
IBM SoftLayer	16.70	16.80	17.00	17.60	17.60	0.17	0.8%
Internap	26.50	29.20	36.70	42.54	44.60	3.96	17.5%
Microsoft Azure	20.00	22.12	25.60	31.50	37.10	2.86	12.7%
ProfitBricks	10.10	10.30	10.40	10.69	10.80	0.10	0.4%
Rackspace	47.30	48.10	48.70	49.30	49.90	0.00	0.0%

Memory – STREAM Triad: This workload combines stream add and stream scale. It reads two lists of floating point numbers value-by-value, multiplies one of the numbers by a constant, adds the result to the other number, and writes that result to a third list.



	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	19.20	19.30	19.60	19.80	20.00	0.00	0.0%
CenturyLink	29.00	29.90	30.80	31.40	31.80	0.30	1.3%
CloudSigma	7.56	7.87	8.28	9.03	9.42	0.32	1.4%
DigitalOcean	32.60	33.48	35.30	38.90	41.60	1.40	6.2%
GoGrid	14.30	14.40	14.60	14.70	14.80	0.00	0.0%
Google	16.20	17.60	17.90	18.40	18.70	0.17	0.8%
HP Helion	31.50	34.60	43.30	50.00	53.30	4.62	20.4%
IBM SoftLayer	16.60	16.70	16.90	17.40	17.50	0.17	0.8%
Internap	26.60	29.20	36.70	42.70	44.60	3.96	17.5%
Microsoft Azure	20.90	22.30	25.70	34.32	36.90	3.38	14.9%
ProfitBricks	10.20	10.21	10.40	10.60	10.70	0.10	0.4%
Rackspace	47.50	48.00	48.70	49.40	49.80	0.00	0.0%

--- End of Memory Results ---

Score Aggregation

The performance output of each individual task was converted into Geekbench performance scores using the conversion rates and formulas below. The below conversion rates are consistent with Geekbench's methodology. Information on how specific aggregate scores were calculated appears in the equations below the table.

Category	Task	Conversion Rate
Integer	AES (MB/sec)	1.14
	Twofish (MB/sec)	17.82
	SHA1 (MB/sec)	9.21
	SHA2 (MB/sec)	23.11
	BZip2 Compression (MB/sec)	246.02
	BZip2 Decompression (MB/sec)	184.51
	JPEG Compression (Mpixels/sec)	75.27
	JPEG Decompression (Mpixels/sec)	42.42
	PNG Compression (Kpixels/sec)	1.28
	PNG Decompression (Kpixels/sec)	0.09
	Sobel (Mpixels/sec)	28.82
	Lua (KB/sec)	1.09
	Dijkstra (Mflops/sec)	292.20
Floating Point	BlackScholes (Mnodes/sec)	235.64
	Mandelbrot (Mflops/sec)	1.02
	Sharpen Filter (Mflops/sec)	1.41
	Blur Filter (Mflops/sec)	1.10
	SGEMM (Mflops/sec)	0.37
	DGEMM (Mflops/sec)	0.71
	SFFT (Mflops/sec)	0.99
	DFFT (Mflops/sec)	1.15
	N-Body (Kpairs/sec)	2.76
	Ray Trace (Kpixels/sec)	0.87
Memory	STREAM Copy (GB/sec)	250.66
	STREAM Scale (GB/sec)	250.48
	STREAM Add (GB/sec)	221.14
	STREAM Triad (GB/sec)	227.55

*Task_Performance_Score = Test_Score * Conversion_Rate*

Integer_Performance_Score = Geometric mean {Integer_Task_Performance_Scores}

Floating_Point_Performance_Score = Geometric mean {Floating_Point_Task_Performance_Scores}

CPU_Performance_Score = Average {Integer_Performance_Score, Floating_Point_Performance_Score}

Memory_Performance_Score = Geometric mean {Memory_Test_Performance_Scores}

CPU_&_Memory_Performance_Score = (4 CPU_Performance_Score + Memory_Performance_Score)/5*

About Cloud Spectator

Cloud Spectator is a cloud analyst agency focused on cloud Infrastructure-as-a-Service (IaaS) performance. The company actively monitors several of the largest IaaS providers in the world, comparing VM performance (i.e., CPU, RAM, disk, internal network, and workloads) and pricing to achieve transparency in the cloud market. The company helps cloud providers understand their market position and helps business make intelligent decisions in selecting cloud providers and lowering total cost of ownership. The firm was founded in early 2011 and is located in Boston, MA.

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