

# Validating Performance of NexentaStor Software Defined Storage Solution

## Nexenta Software Defined Storage All-Flash Performance

AFAs differ from traditional spinning disk arrays in behavior, performance and durability. For example, SSDs write and read in blocks and are limited in the number of writes that can be performed on a particular block. Sophisticated data reduction/On and array-wide wear leveling techniques can dramatically increase SSD durability, in some cases beyond the expected life of a spinning disk drive.

While the performance advantages of AFAs are well documented, much effort has gone into the design of modern AFAs to attack the price premium of flash over disk: sophisticated efficiency techniques promise, for a few workloads (such as full clone VDI), to bring the effective cost of disk arrays and AFAs within striking distance of each other. In addition to the AFA design, one of the potential big benefits of software defined storage (SDS) is a significant decrease in storage costs. But the total cost of storage ownership isn't just about commodity vs. proprietary hardware. It includes the value of all the software and integration and testing work done. To assist the prospective customer, Nexenta has commissioned Virtual Instruments to provide a profile of NexentaStor all-flash array performance.

Storage engineers and architects considering AFAs for their workloads must explore the behavior of these products, and as much as possible, assess them in the context of their expected workloads. With a robust validation process in place, storage engineers and architects can optimally select and configure AFA products for their workloads with potentially considerable impact on both the performance and the cost of their production solutions.

## Background & Objectives

Virtual Instruments was chartered with characterizing, benchmarking, and validating the performance of NexentaStor All-Flash arrays. The performance testing workload was representative of higher performance, low latency workloads with both random and sequential I/O profiles. By using Virtual Instrument's workload models, organizations can accurately simulate how well the underlying VDI storage infrastructure will perform based on a variety of real-world testing scenarios.

Virtual Instruments is a leading provider of pre-deployment testing based on production workloads utilizing the proven Load DynamiX Enterprise performance testing platform.

Nexenta is a global leader in Open Source-driven Software-Defined Storage (OpenSDS) with 6,000+ customers, 400+ partners, 42 patents, and more than 1,500 petabytes of storage under management. Nexenta uniquely integrates deep software-only "Open Source" collaboration with one of the largest and most vibrant Open Source communities (46,000 members) and a comprehensive vision around a commodity hardware-centric "Software-Defined Storage" innovation enabling ANY app, cloud platform and protocol

The objectives of the testing were to:

- Characterize and benchmark performance of the NexentaStor all-flash systems using a range of block sizes, access patterns, and mirrors.
- Provide the prospective customer a profile of expected performance characteristics with a range of application workload characteristics.

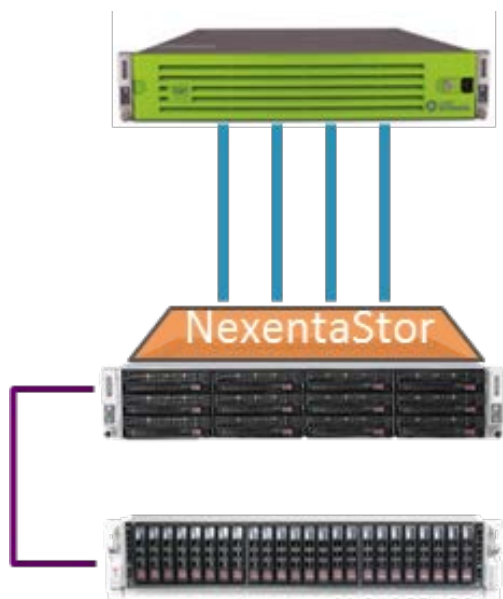
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## Executive Summary

The tests successfully characterized and validated the performance of the NexentaStor All-Flash Array for a range of I/O workload profiles. All latencies and throughputs are at expected levels for the IOPS, I/O sizes, and access patterns configured for this Software Defined Storage solution.

## Test Setup and Array Under Test



- Dedicated Load DynamiX Enterprise Appliance, connected via 4x 10GbE to NexentaStor heads
- SMC hardware for All-Flash
  - 256GB of DRAM
  - 24x SSDs, 400GB HGST 1600MM
- 8x NFSv3 shares with 2.4TB working set
  - Each share with 15x files of 20GB each
  - Mimic 120x VM images
- All testing done with lz4 inline compression enabled, on non-compressible dataset (worst case scenario)
- Workload set to 95% Data & 5% Metadata
- Each test run for 10 mins to get sustained numbers

## Test Results Summaries

12x Mirrors, All-Flash, Random I/Os

| 12xMirrors - 32KB Record Size - async=4 Random I/Os |                         |                     |                     |                  |                  |                   |
|---|-------------------------|---------------------|---------------------|------------------|------------------|-------------------|
| IO Size   | Access Pattern - Read % | Avg Total BW (MB/s) | Avg Total Ops / Sec | Avg Latency (ms) | NFS Read Ops/sec | NFS Write Ops/sec |
| N/A   | N/A                     | 2,205               | 35,133              | 0.4              | -                | 35,133            |
| 4KB   | 100                     | 1,405               | 353,539             | 1.0              | 335,867          | -                 |
| 8KB   | 100                     | 2,735               | 355,941             | 1.0              | 338,159          | -                 |
| 16KB  | 100                     | 3,830               | 253,534             | 1.5              | 240,883          | -                 |
| 32KB  | 100                     | 3,778               | 126,145             | 2.8              | 119,855          | -                 |
| 64KB  | 100                     | 3,921               | 65,731              | 5.9              | 62,461           | -                 |
| 128KB   | 100                     | 3,926               | 32,972              | 11.7             | 31,337           | -                 |
| 4KB   | 75                      | 1,275               | 320,384             | 1.0              | 228,225          | 76,153            |
| 8KB   | 75                      | 2,165               | 281,597             | 1.1              | 200,603          | 66,938            |
| 16KB  | 75                      | 2,536               | 167,809             | 1.7              | 119,531          | 39,898            |
| 32KB  | 75                      | 2,657               | 88,705              | 3.3              | 63,180           | 21,108            |
| 64KB  | 75                      | 2,696               | 45,192              | 6.8              | 32,156           | 10,795            |
| 128KB   | 75                      | 2,742               | 23,024              | 13.4             | 16,359           | 5,532             |
| 4KB   | 50                      | 1,138               | 285,676             | 1.1              | 135,680          | 135,735           |
| 8KB   | 50                      | 1,307               | 169,821             | 1.5              | 80,673           | 80,670            |
| 16KB  | 50                      | 1,376               | 91,005              | 2.7              | 43,224           | 43,251            |
| 32KB  | 50                      | 1,491               | 49,762              | 5.4              | 23,632           | 23,658            |
| 64KB  | 50                      | 1,507               | 25,244              | 11.8             | 11,979           | 12,019            |
| 128KB   | 50                      | 1,571               | 13,188              | 23.6             | 6,251            | 6,293             |
| 4KB   | 25                      | 930                 | 233,128             | 1.1              | 55,431           | 166,056           |
| 8KB   | 25                      | 974                 | 126,406             | 1.9              | 30,073           | 90,038            |
| 16KB  | 25                      | 1,014               | 67,026              | 3.7              | 15,965           | 47,730            |
| 32KB  | 25                      | 1,075               | 35,860              | 7.7              | 8,565            | 25,518            |
| 64KB  | 25                      | 1,066               | 17,857              | 18.6             | 4,273            | 12,710            |
| 128KB   | 25                      | 1,117               | 9,364               | 36.0             | 2,265            | 6,647             |
| 4KB   | 0                       | 856                 | 214,334             | 1.3              | -                | 203,636           |
| 8KB   | 0                       | 858                 | 111,285             | 2.4              | -                | 105,732           |
| 16KB  | 0                       | 833                 | 55,051              | 5.0              | -                | 52,314            |
| 32KB  | 0                       | 825                 | 27,529              | 11.4             | -                | 26,163            |
| 64KB  | 0                       | 833                 | 13,946              | 26.7             | -                | 13,259            |
| 128KB   | 0                       | 900                 | 7,547               | 50.6             | -                | 7,179             |

- All Flash
- 24x SSDs, 12x Mirrors
- 12 SSDs usable capacity
- 100% overhead
- Random I/Os
- High performance, low latency use cases
- Random I/Os, 95% Data, 2.4TB working set
- async=4
- Max perf with 100% Read as we would expect
- Numbers to keep in mind
  - About 320k 4KB IOPS at 75:25
  - About 90k 32KB IOPS at 75:25
  - Max BW of 4GB/s with 128KB 100% Read

12x Mirrors, All-Flash, Sequential I/Os

| 12xMirrors - 32KB Record Size - async=4 Seq I/Os |                         |                     |                     |                  |                  |                   |
|--|-------------------------|---------------------|---------------------|------------------|------------------|-------------------|
| IO Size  | Access Pattern - Read % | Avg Total BW (MB/s) | Avg Total Ops / Sec | Avg Latency (ms) | NFS Read Ops/sec | NFS Write Ops/sec |
| 4KB  | 0                       | 858                 | 214,997             | 1.4              | -                | 204,257           |
| 8KB  | 0                       | 869                 | 112,863             | 2.8              | -                | 107,234           |
| 16KB   | 0                       | 898                 | 59,347              | 5.3              | -                | 56,395            |
| 32KB   | 0                       | 926                 | 30,889              | 10.8             | -                | 29,361            |
| 64KB   | 0                       | 915                 | 15,333              | 24.3             | -                | 14,577            |
| 128KB  | 0                       | 971                 | 8,146               | 46.9             | -                | 7,750             |
| 4KB  | 50                      | 1,075               | 269,899             | 1.2              | 128,209          | 128,215           |
| 8KB  | 50                      | 1,311               | 170,396             | 1.7              | 80,924           | 80,983            |
| 16KB   | 50                      | 1,444               | 95,558              | 2.7              | 45,376           | 45,429            |
| 32KB   | 50                      | 1,611               | 53,778              | 5.2              | 25,523           | 25,581            |
| 64KB   | 50                      | 1,599               | 26,801              | 11.2             | 12,717           | 12,759            |
| 128KB  | 50                      | 1,683               | 14,123              | 21.7             | 6,690            | 6,743             |
| 4KB  | 75                      | 1,199               | 301,494             | 1.1              | 214,755          | 71,687            |
| 8KB  | 75                      | 1,775               | 230,949             | 1.4              | 164,487          | 54,928            |
| 16KB   | 75                      | 2,046               | 135,419             | 2.1              | 96,439           | 32,233            |
| 32KB   | 75                      | 2,569               | 85,753              | 3.3              | 61,044           | 20,440            |
| 64KB   | 75                      | 2,558               | 42,864              | 6.9              | 30,505           | 10,237            |
| 128KB  | 75                      | 2,681               | 22,513              | 13.2             | 15,981           | 5,423             |
| 4KB  | 100                     | 1,346               | 338,847             | 1.1              | 321,923          | -                 |
| 8KB  | 100                     | 2,198               | 286,116             | 1.3              | 271,833          | -                 |
| 16KB   | 100                     | 2,668               | 176,632             | 2.0              | 167,815          | -                 |
| 32KB   | 100                     | 3,689               | 123,151             | 2.9              | 117,012          | -                 |
| 64KB   | 100                     | 3,950               | 66,222              | 5.8              | 62,924           | -                 |
| 128KB  | 100                     | 3,982               | 33,452              | 11.4             | 31,789           | -                 |

- All Flash
  - 24x SSDs, 12x Mirrors
  - 12 SSDs usable capacity
  - 100% overhead
  - Sequential I/Os
1. High performance, low latency use cases
  2. Seq I/Os, 95% Data, 2.4TB working set

4xraidz2 (4+2), All Flash, Random I/O

| 4xraidz2(4+2) - 128KB Record Size - async=4 - Random I/Os |                         |                     |                     |                  |                  |                   |
|---|-------------------------|---------------------|---------------------|------------------|------------------|-------------------|
| IO Size   | Access Pattern - Read % | Avg Total BW (MB/s) | Avg Total Ops / Sec | Avg Latency (ms) | NFS Read Ops/sec | NFS Write Ops/sec |
| N/A   | N/A                     | 2,290               | 36,482              | 0.4              | -                | 36,482            |
| 4KB   | 100                     | 1,028               | 258,632             | 0.9              | 245,705          | -                 |
| 8KB   | 100                     | 1,135               | 147,652             | 1.9              | 140,286          | -                 |
| 16KB  | 100                     | 1,463               | 96,809              | 3.3              | 91,982           | -                 |
| 32KB  | 100                     | 2,283               | 76,222              | 4.6              | 72,418           | -                 |
| 64KB  | 100                     | 3,212               | 53,854              | 5.8              | 51,174           | -                 |
| 128KB   | 100                     | 4,412               | 37,060              | 9.8              | 35,220           | -                 |
| 4KB   | 75                      | 965                 | 242,532             | 0.9              | 172,778          | 57,642            |
| 8KB   | 75                      | 1,184               | 153,914             | 1.5              | 109,628          | 36,611            |
| 16KB  | 75                      | 1,353               | 89,530              | 3.7              | 63,753           | 21,315            |
| 32KB  | 75                      | 1,767               | 58,971              | 6.1              | 41,977           | 14,061            |
| 64KB  | 75                      | 2,509               | 42,044              | 7.7              | 29,918           | 10,043            |
| 128KB   | 75                      | 3,291               | 27,633              | 11.5             | 19,647           | 6,622             |
| 4KB   | 50                      | 979                 | 245,727             | 0.9              | 116,731          | 116,732           |
| 8KB   | 50                      | 1,157               | 150,283             | 1.4              | 71,379           | 71,402            |
| 16KB  | 50                      | 1,239               | 81,905              | 3.4              | 38,906           | 38,920            |
| 32KB  | 50                      | 1,400               | 46,724              | 5.3              | 22,190           | 22,216            |
| 64KB  | 50                      | 1,907               | 31,947              | 7.5              | 15,173           | 15,194            |
| 128KB   | 50                      | 2,292               | 19,240              | 12.2             | 9,138            | 9,156             |
| 4KB   | 25                      | 902                 | 225,990             | 0.9              | 53,717           | 160,992           |
| 8KB   | 25                      | 1,074               | 139,435             | 1.3              | 33,164           | 99,319            |
| 16KB  | 25                      | 1,156               | 76,432              | 2.8              | 18,200           | 54,431            |
| 32KB  | 25                      | 1,221               | 40,726              | 5.1              | 9,718            | 28,989            |
| 64KB  | 25                      | 1,614               | 27,041              | 7.8              | 6,463            | 19,241            |
| 128KB   | 25                      | 1,738               | 14,588              | 15.5             | 3,506            | 10,368            |
| 4KB   | 0                       | 1,005               | 251,515             | 1.0              | -                | 238,943           |
| 8KB   | 0                       | 1,291               | 167,424             | 1.3              | -                | 159,069           |
| 16KB  | 0                       | 1,301               | 85,956              | 2.6              | -                | 81,672            |
| 32KB  | 0                       | 1,207               | 40,270              | 5.4              | -                | 38,271            |
| 64KB  | 0                       | 1,385               | 23,206              | 9.7              | -                | 22,054            |
| 128KB   | 0                       | 1,356               | 11,378              | 21.8             | -                | 10,820            |

- All Flash
- 24x SSDs
- 4x raidz2 (4+2)
- 16 SSDs usable capacity
- 50% overhead
- Random I/Os
- High performance, low latency use cases
- Random I/Os, 95% Data, 2.4TB working set
- Numbers to keep in mind
  - About 240k 4KB IOPS at 75:25
  - About 60k 32KB IOPS at 75:25
  - Max BW of 4.4GB/s with 128KB 100% Read

4xraidz1 (4+1), All Flash, Random I/O with only 20 SSDs

| 4xraidz1(4+1) - 128KB Record Size - async=4 - Random I/Os |                         |                     |                     |                  |                  |                   |
|---|-------------------------|---------------------|---------------------|------------------|------------------|-------------------|
| IO Size   | Access Pattern - Read % | Avg Total BW (MB/s) | Avg Total Ops / Sec | Avg Latency (ms) | NFS Read Ops/sec | NFS Write Ops/sec |
| N/A   | N/A                     | 2,328               | 37,085              | 0.4              | -                | 37,085            |
| 4KB   | 100                     | 1,040               | 261,820             | 0.8              | 248,737          | -                 |
| 8KB   | 100                     | 1,228               | 159,740             | 1.9              | 151,761          | -                 |
| 16KB  | 100                     | 1,693               | 112,033             | 2.9              | 106,452          | -                 |
| 32KB  | 100                     | 2,445               | 81,617              | 4.5              | 77,553           | -                 |
| 64KB  | 100                     | 3,402               | 57,024              | 6.0              | 54,187           | -                 |
| 128KB   | 100                     | 4,418               | 37,110              | 9.8              | 35,268           | -                 |
| 4KB   | 75                      | 992                 | 249,376             | 0.8              | 177,656          | 59,273            |
| 8KB   | 75                      | 1,202               | 156,278             | 1.8              | 111,311          | 37,175            |
| 16KB  | 75                      | 1,355               | 89,660              | 3.8              | 63,840           | 21,355            |
| 32KB  | 75                      | 1,819               | 60,703              | 5.9              | 43,216           | 14,471            |
| 64KB  | 75                      | 2,624               | 43,973              | 7.7              | 31,298           | 10,492            |
| 128KB   | 75                      | 3,408               | 28,613              | 11.4             | 20,339           | 6,862             |
| 4KB   | 50                      | 969                 | 243,237             | 0.9              | 115,555          | 115,536           |
| 8KB   | 50                      | 1,206               | 156,638             | 1.7              | 74,409           | 74,420            |
| 16KB  | 50                      | 1,322               | 87,437              | 3.7              | 41,527           | 41,557            |
| 32KB  | 50                      | 1,549               | 51,684              | 5.4              | 24,548           | 24,569            |
| 64KB  | 50                      | 2,066               | 34,615              | 7.3              | 16,436           | 16,465            |
| 128KB   | 50                      | 2,461               | 20,658              | 12.0             | 9,804            | 9,840             |
| 4KB   | 25                      | 968                 | 242,479             | 0.9              | 57,626           | 172,742           |
| 8KB   | 25                      | 1,177               | 152,753             | 1.3              | 36,326           | 108,809           |
| 16KB  | 25                      | 1,237               | 81,778              | 2.6              | 19,471           | 58,237            |
| 32KB  | 25                      | 1,325               | 44,186              | 4.8              | 10,549           | 31,445            |
| 64KB  | 25                      | 1,763               | 29,530              | 7.3              | 7,055            | 21,015            |
| 128KB   | 25                      | 1,892               | 15,878              | 14.6             | 3,815            | 11,286            |
| 4KB   | 0                       | 1,041               | 260,347             | 0.9              | -                | 247,348           |
| 8KB   | 0                       | 1,321               | 171,349             | 1.3              | -                | 162,792           |
| 16KB  | 0                       | 1,375               | 90,822              | 2.4              | -                | 86,300            |
| 32KB  | 0                       | 1,297               | 43,251              | 5.1              | -                | 41,101            |
| 64KB  | 0                       | 1,515               | 25,387              | 8.7              | -                | 24,128            |
| 128KB   | 0                       | 1,479               | 12,416              | 19.9             | -                | 11,805            |

- All Flash
- 20x SSDs
- 4x raidz1 (4+1)
- 16 SSDs usable capacity
- 25% overhead
- Random I/Os
- Only 20 SSDs
- High performance, low latency use cases
- Random I/Os, 95% Data, 2.4TB working set
- Max perf with 100% Read as we would expect
- Numbers to keep in mind
  - About 250k 4KB IOPS at 75:25
  - About 60k 32KB IOPS at 75:25
  - Max BW of 4.4GB/s with 128KB 100% Read

4xraidz1 (4+1), All Flash, Random I/O with only 20 SSDs and 100% Data

|         |                         | 4xraidz1(4+1) - 128KB Record Size - async=1 Random I/Os<br>100% Data |                     |                  |                  |                   |
|---------|-------------------------|--|---------------------|------------------|------------------|-------------------|
| IO Size | Access Pattern - Read % | Avg Total BW (MB/s)  | Avg Total Ops / Sec | Avg Latency (ms) | NFS Read Ops/sec | NFS Write Ops/sec |
| N/A     | N/A                     |  |                     |                  |                  |                   |
| 4KB     | 100                     | 1,070  | 257,896             | 0.4              | 257,636          | -                 |
| 8KB     | 100                     | 1,509  | 187,433             | 0.6              | 187,244          | -                 |
| 16KB    | 100                     | 1,929  | 121,645             | 0.9              | 121,521          | -                 |
| 32KB    | 100                     | 2,704  | 85,939              | 1.3              | 85,850           | -                 |
| 64KB    | 100                     | 3,683  | 58,752              | 1.8              | 58,691           | -                 |
| 128KB   | 100                     | 4,384  | 35,037              | 2.5              | 35,000           | -                 |
| 4KB     | 75                      | 1,063  | 255,438             | 0.4              | 191,338          | 63,843            |
| 8KB     | 75                      | 1,498  | 185,799             | 0.6              | 139,160          | 46,451            |
| 16KB    | 75                      | 1,860  | 117,250             | 1.0              | 87,806           | 29,326            |
| 32KB    | 75                      | 2,397  | 76,165              | 1.5              | 57,007           | 19,080            |
| 64KB    | 75                      | 2,742  | 43,741              | 2.5              | 32,692           | 11,004            |
| 128KB   | 75                      | 3,614  | 28,885              | 3.7              | 21,571           | 7,282             |
| 4KB     | 50                      | 1,049  | 251,673             | 0.5              | 125,728          | 125,692           |
| 8KB     | 50                      | 1,410  | 174,751             | 0.7              | 87,290           | 87,284            |
| 16KB    | 50                      | 1,639  | 103,233             | 1.1              | 51,575           | 51,553            |
| 32KB    | 50                      | 1,808  | 57,426              | 2.0              | 28,666           | 28,701            |
| 64KB    | 50                      | 1,979  | 31,564              | 3.5              | 15,726           | 15,804            |
| 128KB   | 50                      | 2,597  | 20,760              | 5.4              | 10,334           | 10,404            |
| 4KB     | 25                      | 1,030  | 246,513             | 0.5              | 61,607           | 184,658           |
| 8KB     | 25                      | 1,409  | 174,425             | 0.7              | 43,611           | 130,638           |
| 16KB    | 25                      | 1,444  | 90,945              | 1.2              | 22,768           | 68,084            |
| 32KB    | 25                      | 1,501  | 47,661              | 2.4              | 11,931           | 35,681            |
| 64KB    | 25                      | 1,640  | 26,161              | 4.3              | 6,550            | 19,583            |
| 128KB   | 25                      | 1,956  | 15,636              | 7.2              | 3,926            | 11,693            |
| 4KB     | 0                       | 1,019  | 243,419             | 0.5              | -                | 243,174           |
| 8KB     | 0                       | 1,666  | 206,031             | 0.6              | -                | 205,824           |
| 16KB    | 0                       | 1,660  | 104,467             | 1.2              | -                | 104,362           |
| 32KB    | 0                       | 1,384  | 43,946              | 2.9              | -                | 43,900            |
| 64KB    | 0                       | 1,304  | 20,788              | 6.1              | -                | 20,766            |
| 128KB   | 0                       | 1,524  | 12,184              | 10.3             | -                | 12,170            |

- All Flash
- 20x SSDs
- 4x raidz1 (4+1)
- 16 SSDs usable capacity
- 25% overhead
- Low Latency
- Only 20 SSDs
- High performance, low latency use cases
- Random I/Os, 100% Data, 2.4TB working set
- Latency measured with client side Queue Depth=1

## Conclusions

1. The tests successfully characterized and validated the performance of the NexentaStor All-Flash Array for a range of I/O workload profiles. All latencies and throughputs are at expected levels for the IOPS, I/O sizes, and access patterns configured.
2. With mirrored all-flash, performance for sequential I/Os is very similar to performance with random I/O. For example, for a workload with a 16KB I/O size, 50/50 R/W access, random latency was 2.7ms, sequential latency was also 2.7ms.
3. With RAID 4+2, latency differences between all Read and all Write were surprisingly small, especially when I/O sizes were below 64KB. As expected, significant differences in throughput and bandwidth showed up in workloads where R/W ratios differed a lot. For instance, at 100% Read and 128KB I/O size, bandwidth was 4.4GB/s, while at 100% Write, it was 1.4GB/s.
4. When RAID was changed to 4+1 and the number of SSDs was reduced to only 20, latencies and throughput stayed fairly similar when compared to the 4+2 system and 24 SSDs.
5. With a 4+1 system and client side queue depth = 1, there was a minor drop in total IOPS with 4KB I/O numbers, but the figures are still very good. Note the great latency figures in the in the 500 $\mu$ s to 700 $\mu$ s range for 4 and 8KB IOPS numbers.



Sales  
[Sales@virtualinstruments.com](mailto:Sales@virtualinstruments.com)  
1.888-522.2557

Website  
[virtualinstruments.com](http://virtualinstruments.com)