Vibration Monitoring System for the RACF Data Center at BNL

Costin Caramarcu[1], Christopher Hollowell[1], William Strecker-Kellogg[1], Tony Wong[1], Alexandr Zaytsev[1*]
[1]RHIC & ATLAS Computing Facility (RACF), Brookhaven National Laboratory (BNL), Upton, NY, USA

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Vibration Monitoring Technology

Measuring acceleration for industrial & research application is a remarkably rich field of technology that addresses multiple different sub-cases, such as measuring:

- Vibration (oscillatory motion with zero mean shift),
- Shock (transient events highly localized in time),
- Motion (coordinate acceleration measurements for inertial navigation applications & measuring distance variation between objects)
- Seismic events (coordinate acceleration measurements with the emphasis on low and ultra-low frequencies).

When it comes specifically to the proper acceleration measurements for vibration monitoring systems, devices of the following types are available:

- piezoelectric accelerometers (of charge-mode & voltage-mode subtypes),
- piezoresistive accelerometers (best suited for shock measurement applications, high activation threshold),
- variable capacitance accelerometers (often implemented as micro electro-mechanical systems (MEMS), delivering high sensitivity for a broad frequency range starting from 0 Hz – so called "DC response" capability).

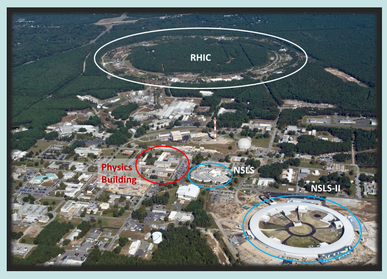
Most of the accelerometer systems designed specifically for the IT applications are represented by simple threshold or inclination detectors used primarily for monitoring the conditions during the IT equipment transportation.

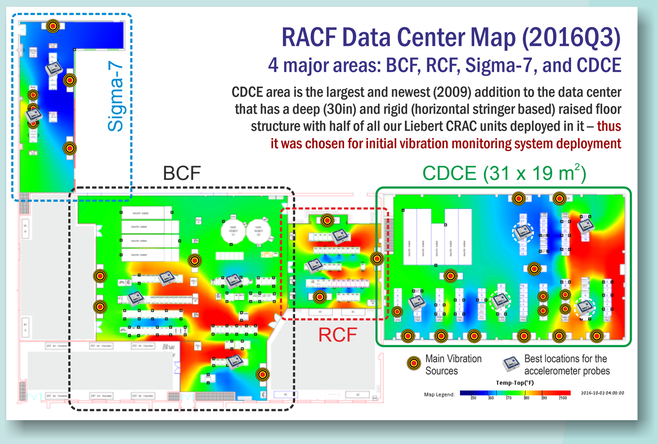
Another class of permanently deployed accelerometers for IT applications is designed purely for access monitoring and security purposes

Both of these classes of devices are not suitable for constant low amplitude vibration monitoring, and switching to a full research grade equipment isn't always an option due to prohibitive costs. Finding commercially available accelerometer devices with better price/performance balance is a challenging task.

After doing a research on what's available on the market, we selected Lansmont 3D MEMS accelerometers for our setup.

RHIC & ATLAS Computing Facility (RACF)





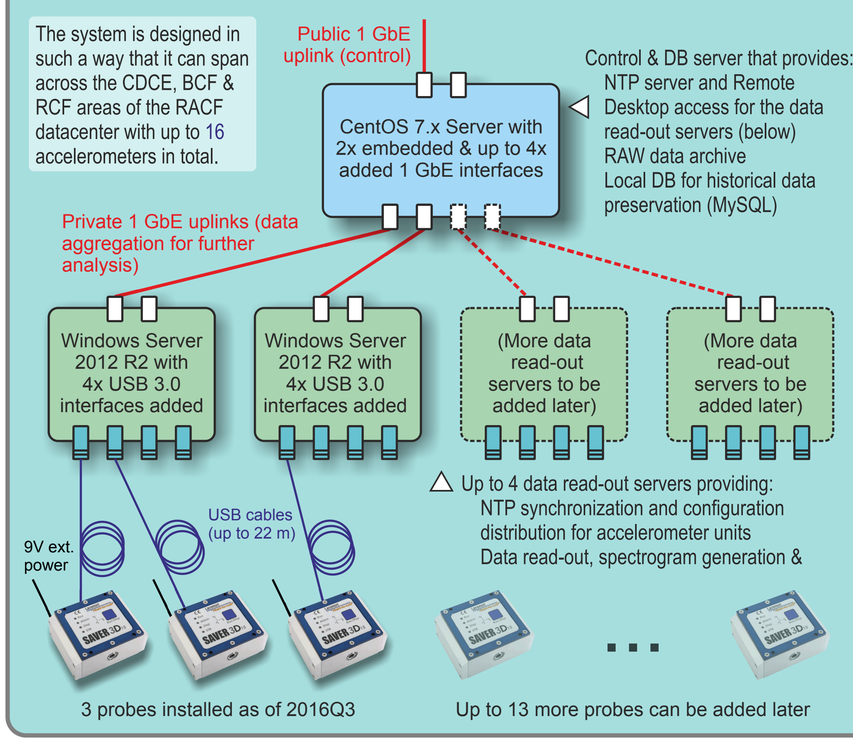
RACF was established in mid-1990s and currently hosts a variety of computing farms, clusters and storage systems for STAR and PHENIX detectors at RHIC, ATLAS detector at the LHC (Tier-1 site), and many other smaller collaborations and workgroups:

- 1400 m² of combined area (raised floor used everywhere)
- 400 racks and 20 Liebert CRAC units on the floor
- 1.5 MW of combined power consumption
- 1 MW battery UPS plus 1.3 MW diesel generator
- 50k HT CPU cores in RHIC & ATLAS Linux farms
- 60k tapes in robotic tape silos, 70 PB in HPSS storage system
- 38 PB of distributed storage (dCache/XRootD)
- 6 PB in five GPFS storage clusters
- 3 PB in two Ceph storage clusters

20k HDDs in total

Monitoring System Design

Lansmont Equipment Adaptation to the Datacenter Environment



Lansmont Shock & Vibration Measurement Units

Table taken from the "SAVER Product Matrix Sheet" document available at http://www.lansmont.com

	SAVER™ 3D15	SAVER™ 3X90	SAVER™ 9X30
Lansmont Field-to-Lab®	Ideal for low-frequency dynamics, which may occur in aerospace, amusement park rides, rail impacts, crash recording, brake testing, and others.	Characterizing complete dynamic and environmental conditions (temperature and humidity) as they exist in longer-term transport conditions.	Same as 3X90 with external dynamic channel connections and the ability to seamlessly link all data to GPS location, all in one data file.
Size	3.7 x 2.9 x 1.7 in. (95 x 74 x 43 mm)	3.7 x 2.9 x 1.7 in. (95 x 74 x 43 mm)	5.0 x 4.9 x 1.7 in. (127 x 124 x 43 mm)
Weight	16.7 oz. (473 g)	16.7 oz. (473 g)	35.0 oz. (1 kg)
Triggering	threshold and timer	threshold and timer	threshold and timer
Memory	128 MB	128 MB	128 MB
Programmable Sampling	50-5,000 samples per second	50-5,000 samples per second	50-10,000 sample per second
Programmable Filtering	10, 20, 25, 50, 100, 200, 250, 500 Hz	10, 20, 25, 50, 100, 200, 250, 500 Hz.	10, 20, 25, 50, 100, 200, 250, 500 Hz. external channels: 1,000, 2,000, 2,500 Hz.
Continuous Record Time	15 days	90 days	30 days
Accelerometer Type	triax MEMS	triax piezoelectric	triax piezoelectric
Accelerometer Range	50 g	200 g	200 g
3dB Frequency Response	DC to filter maximum	0.4 Hz. to filter maximum	0.4 Hz. to filter maximum
Data: Shock	✓	✓	✓
Data: Vibration	✓	✓	✓
Data: Temperature	✓	✓	✓
Data: Humidity	✓	✓	✓
Data: Atmospheric Pressure			✓
Data: GPS Location	able to import external data	able to import external data	optionally embedded in 9X-GPS
External Acceleration Channels			6 programmable

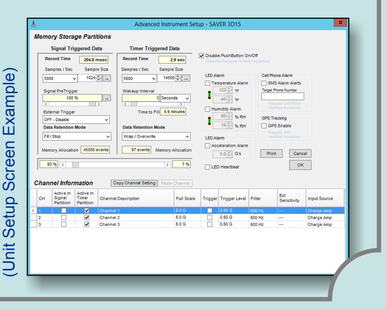
SAVER 3D15 model is the high sensitivity tri-axial MEMS "DC response" accelerometer best suited for monitoring low amplitude (~0.1 g RMS) vibration in a broad frequency range up to 500 Hz (DC filter maximum; maximum recordable frequency is 2.5 kHz). It also provides the optimal feature set (per unit of price) for permanent deployment in a datacenter environment:

- no GPS data needed,
- MEMS technology delivers the best low amplitude sensitivity,
- no need for analogue signal cable routing across the floor (only the USB cables for data read-out and unit control).

External 9V DC power option is available for all units.

The software for unit control, data readout & analysis is freely available from Lansmont (Windows only).

Lansmont High Sensitivity Accelerometers



Initial System Deployment

The first deployment of the vibration monitoring system was performed in CDCE area of the RACF datacenter in 2016Q3. Currently the system includes:

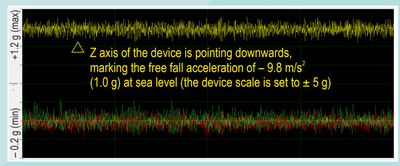
- Three Lansmont SAVER 3D15 units provided with both internal (battery) & external 9V DC power constantly plugged to the data aggregation servers with 2-22m USB cables,

Two rackmount Windows (Server 2012 R2) servers for reading out data from the probes & generating graphical plus CSV representations of the spectrograms every 5 min,

One rackmount Linux server (CentOS 7.x) for data aggregation for long-term preservation and time-frequency analysis using historical data.

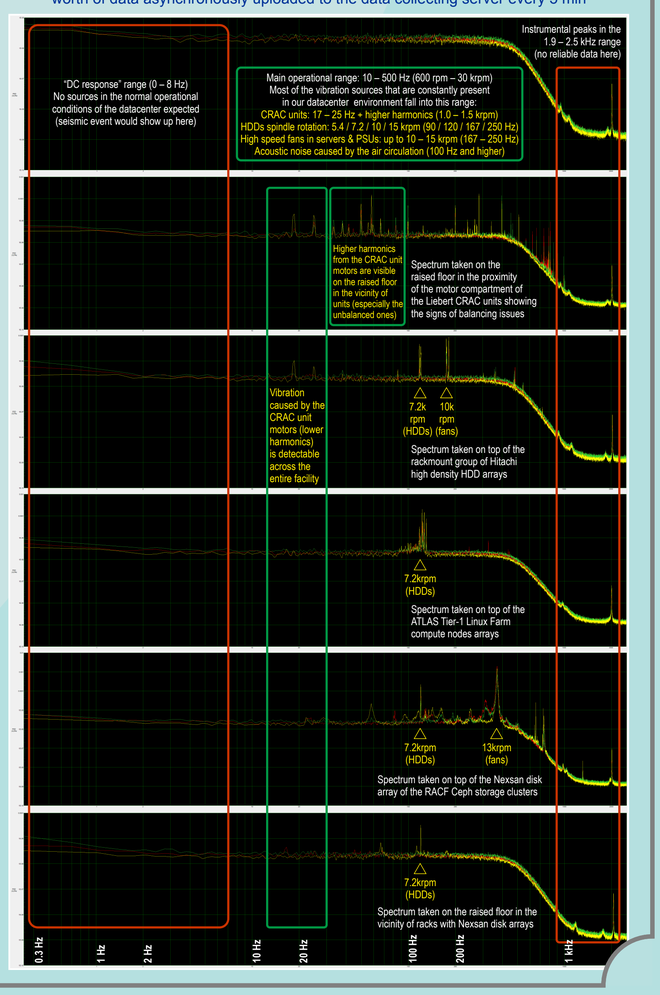
RAW Data Sample (Levelled Raised Floor)

2 sec worth of tri-axial data at 5 kHz sampling rate



Sample Spectrograms Generated with Lansmont SaverXware Software

Collected by blocks of 97x 2.9 sec data samples with 3 sec wake up timer period: 4.7 min worth of data asynchronously uploaded to the data collecting server every 5 min



Summary & Future Plans

Main results obtained:

Evaluation of Lansmont SAVER 3D15 units performed in 2016Q2 have shown that they are matching all the requirements for the production setup in the RACF datacenter.

The high sensitivity of the units makes it possible to observe all major sources of vibration even in a large server room with a small number of sensors (3-5) carefully distributed across the raised floor.

Initial deployment of the vibration monitoring system based on three Lansmont SAVER 3D15 accelerometer units is now complete for the largest single continuous area in the RACF datacenter (CDCE).

Future plans:

Finalise the software adaptation process for the full pipeline of data gathering and analysis.

Add time-frequency analysis capabilities.

Add more sensors to increase the spatial resolution of the system.

BROOKHAVEN NATIONAL LABORATORY

Designed by Alexandr S. Zaytsev (RACF, BNL), Oct 2016, E-mail: alezayt@bnl.gov