GOOGLE'S RANDOM VIBRATION TESTING METHODOLOGY, OPEN TEST DATA

Part 3.1: 3D DISPLACEMENT DATA OF A MACHINE DURING RACK LEVEL VIBRATION TESTING
REVISION A

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3D Displacement Data of Lenovo ThinkSystem SR650 V2 During Rack Level Transportation Vibration

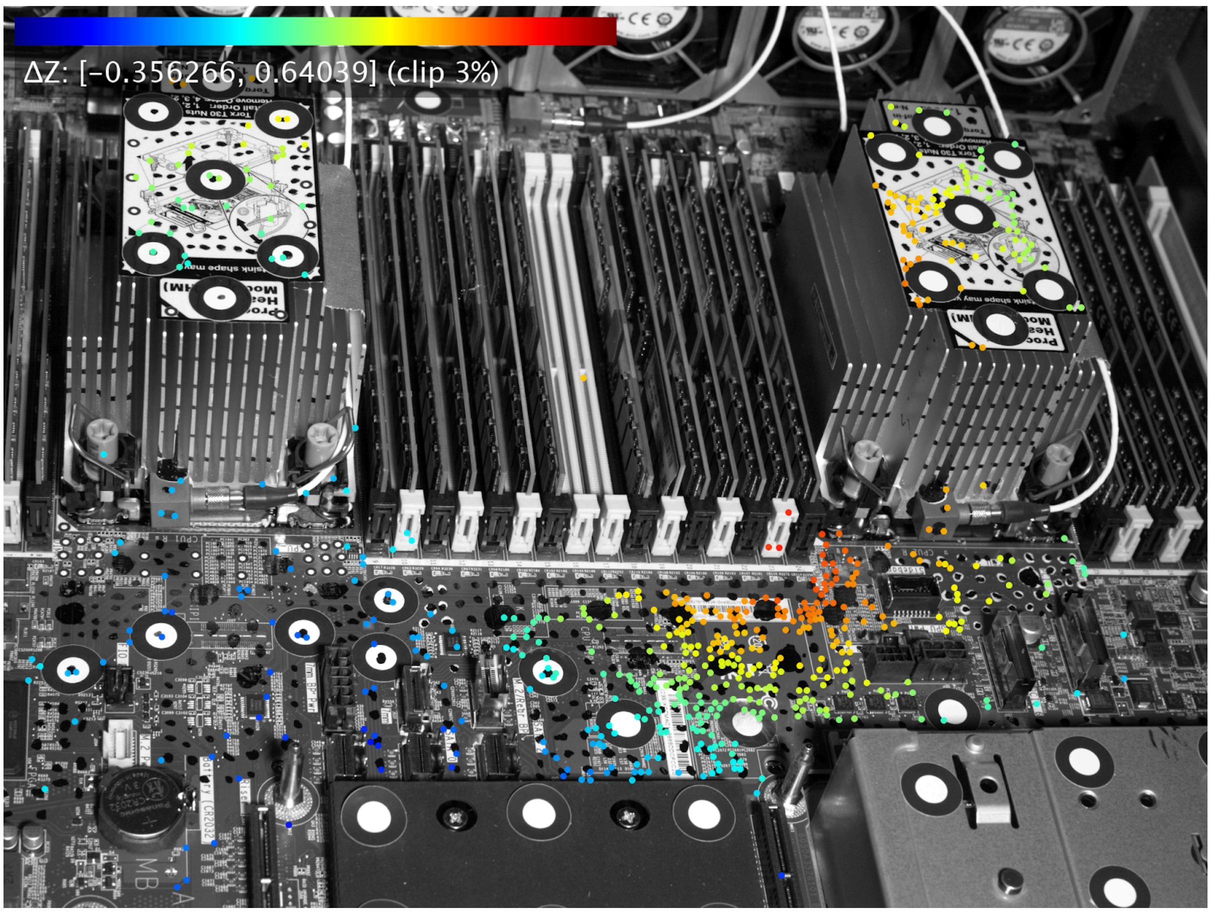


Figure 1.

3D Displacement Data Sharing Track

Since the first paper, we spent a lot of time describing various measurements and testing capabilities used during Google's vibration testing of data center hardware. We went over acceleration, strain, pressure, and 3D displacement measurements, and how they can be used to analyze a machine's dynamic behavior in different scenarios.

We are at a point in the project where actual data will be more meaningful than methods and techniques. **Methodology describes the overall architecture in broad strokes. Details of equipment enable methods and capabilities, and need to be provided up front. But actual data ground everything to reality, and feed into specific products to help understand behavior, assess risks, and improve design if necessary.**

Moving forward, we will spend a lot of time looking at 3D displacement and deformation data because there is a huge vacuum of such data in the testing world, which describes a system's **"Macro Dynamic Behavior"** during shock and vibration. There are numerous publication of accelerometer and strain data of PCB and chips, but it is difficult to visualize a complex machine's dynamic behavior, particularly when installed inside a populated rack:

1. How do the whole board displaced and deformed during specific sine vibration, random vibration, and shock scenario?
2. How does the overall test sample behave inside the rack?
3. What unexpected behaviors are missed by the classical mass-spring system that everyone assumes?
4. What can we learn from 3D data that cannot easily be described with traditional acceleration, strain, and pressure measurements?

We will find out as we deep dive into the rack and server test sample used previously in "PART 1.2: SINE VIBRATION OF A MACHINE INSIDE A RACK".

Typical rack level shock and vibration test profiles at Google

Google's shock and vibration test profiles are straight forward, and should be familiar with most readers who work in this field:

Google's Typical Shock and Vibration Test Suite	
1.	Sine Sweep, 0.2G, 5Hz to 500Hz, 1 oct/min
2.	ASTM d4169-14 Truck Vibration, Assurance Level 2, 2 Hours
3.	ASTM d4169-14 Air Vibration, Assurance Level 2, 2 Hours
4.	ASTM d4169-14 Forklift Truck Handling Drop, Assurance Level 2, 4 corners, 4 edges, 1 flat bottom surface

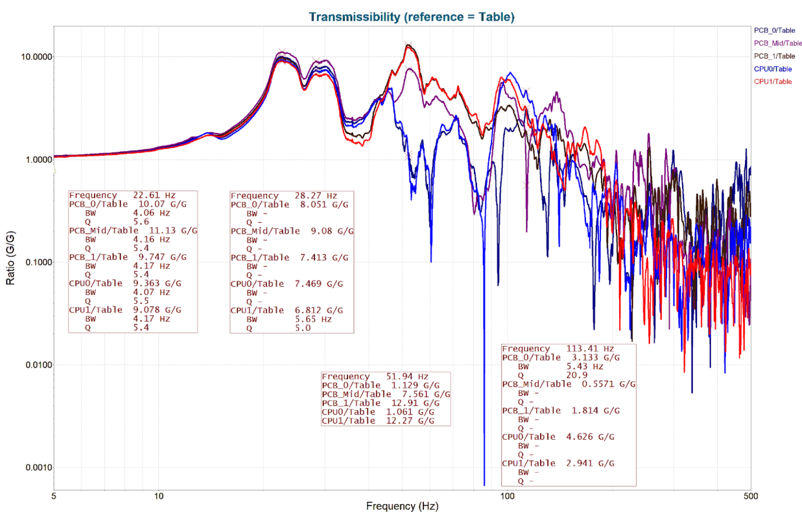
Sinesweep provide some basic information about the test sample's resonance frequency, **Truck and Air Vibration** stress any systems and components with design flaws missed during early phase of design (lack of sufficient constraints, insufficient fastener sizes, flimsy sheet metal parts), and the **6 inches Free Fall Shock Impact** at the end provide a level of stress most server racks will see during typical transportation and handling.

Historically, accelerometers are used at obvious locations during testing (heatsinks, middle of PCBA, critical components and interconnects, etc) and their values are shown in the final report, but it is difficult to understand what actually happened during testing. Racks and machines with complex structures are too complicated to explain with simple acceleration measurements. Let's look at what 3D displacement data can tell us that traditional accelerometers can't.

<u>3D displacement and deformation data during rack level vibration testing</u>

Recall the acceleration transmissibility plot shown in Part 1.2:

Lenovo SR650 V2 Rack Level Acceleration Transmissibility Profile, Rack Vibration



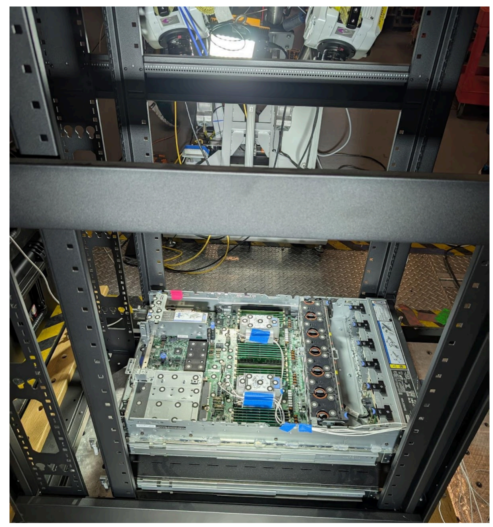


Figure 2.

The same rack and server was brought back for 3D displacement measurement. Every single test setup is slightly different. PCB samples fastened to aluminum fixtures, for example, are a lot more repeatable and generate much more consistent results. In this scenario, we weren't able to achieve the exact same resonance frequency as before. Resonance frequencies measured during the second round, 24Hz, 33Hz, 49Hz, 107Hz, are slightly different from frequencies during the first round, 22.61Hz, 28.27Hz, 51.94Hz, and 113.41Hz.

Sinesweep helps us to identify major resonance frequencies of the system, and understand what happens during random vibration when a whole range of frequencies are excited. But it is also very easy for accelerometer data to generate inconsistent results. 3D displacement measurements add an extra layer so that later, we can use them to decipher how a system behaves during ASTM random vibration profiles.

Integrating 3D Displacement Measurement into Traditional Vibration Testing Workflow

Figure 3.

Lenovo SR650 V2 High Speed Camera Video During Rack Level Test

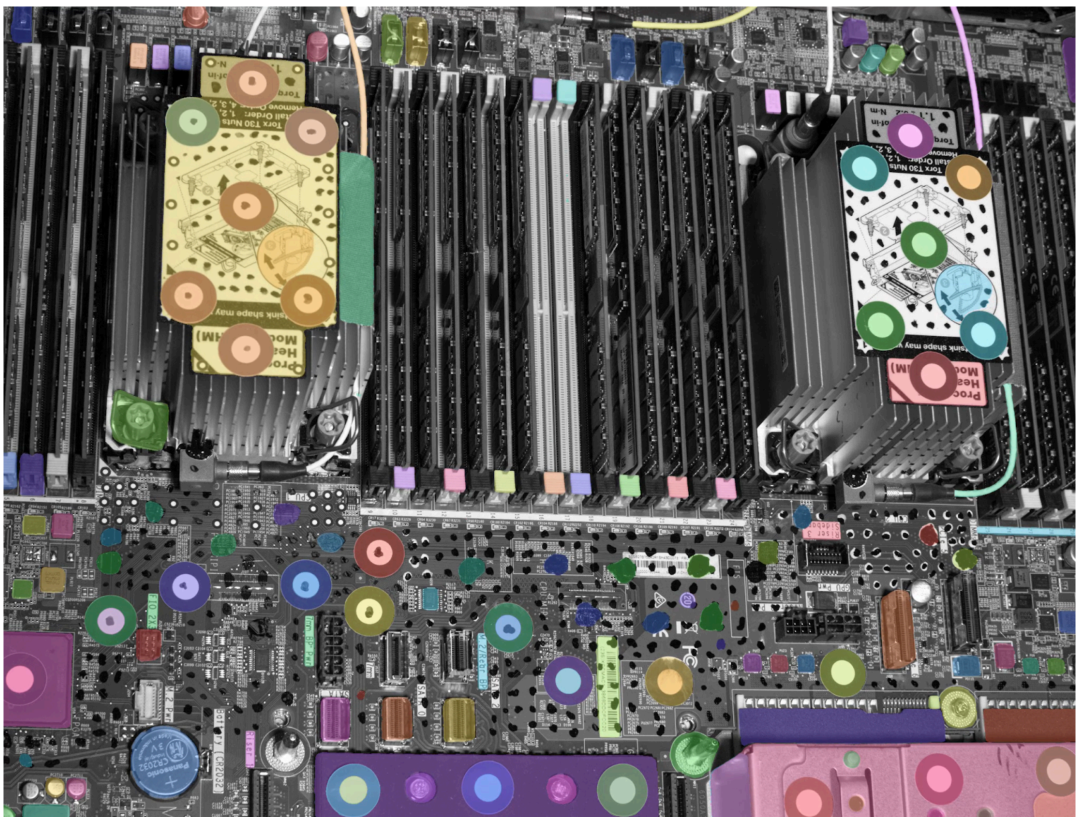


Figure 4.

Using open sourced vision based AI such as Meta's SAM2 (Segmentation Anything Model 2), objects and features can be easily identified so that specific data can be easily extracted during analysis, when specific information is needed. We will focus on the overall distribution and concentration of displacement at the moment, but there will be times when product designers and reliability engineers only require data of critical components such as heatsinks and specific areas of PCB.

The data captured are real time displacements (in mm) of critical points in three dimensions, ones identified by test operators or computer vision models. The 3D points are plotted over time, and a color mapping is applied (based on relative displacement in the vertical direction) to help understand shapes and distribution. Deformation only occurs when the PCB is moving relative to the shaker table's displacement. That's why the color mapping is based on relative displacement rather than absolute displacement.