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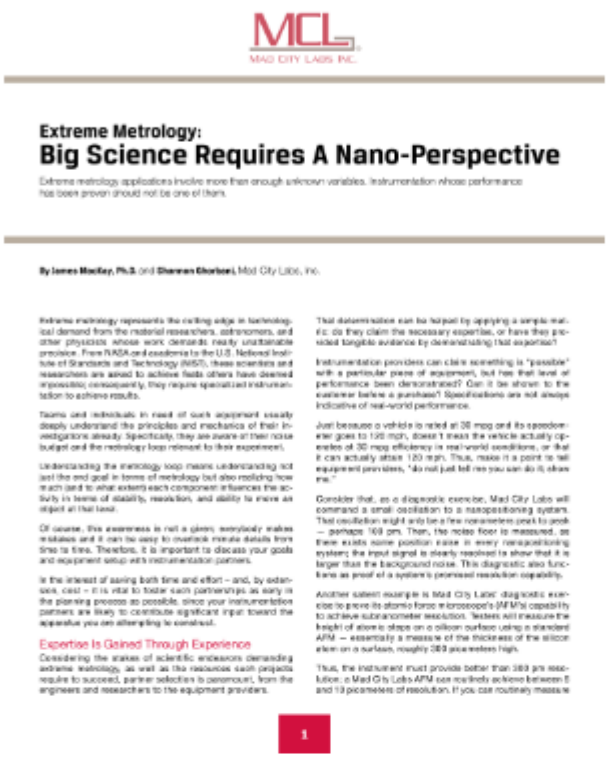
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Extreme Metrology:
Big Science Requires A Nano-Perspective

Extreme metrology applications involve more than enough unknown variables. Instrumentation whose performance has been proven should not be one of them.

By James MacKay, Ph.D. and Sharvan Kharbani, Mad City Labs, Inc.

Extreme metrology represents the cutting edge in technological demand from the material researchers, astronomers, and other physicists whose work demands nearly unattainable precision. From NASA and academia to the U.S. National Institute of Standards and Technology (NIST), these scientists and researchers are aimed to achieve feats others have deemed impossible; consequently, they require specialized instrumentation to achieve results.

Teams and individuals in need of such equipment usually deeply understand the principles and mechanics of their investigations already. Specifically, they are aware of their noise budget and the metrology loop relevant to their experiment.

Understanding the metrology loop means understanding not just the end goal in terms of metrology but also realizing how much (and to what extent) each component influences the activity in terms of stability, resolution, and ability to move an object at that level.

Of course, this awareness is not a given; everybody makes mistakes and it can be easy to overlook minute details from time to time. Therefore, it is important to discuss your goals and equipment setup with instrumentation partners.

In the interest of saving both time and effort – and, by extension, cost – it is vital to foster such partnerships as early in the planning process as possible, since your instrumentation partners are likely to contribute significant input toward the apparatus you are attempting to construct.

Expertise Is Gained Through Experience

Considering the stakes of scientific endeavors demanding extreme metrology, as well as the resources such projects require to succeed, partner selection is paramount, from the engineers and researchers to the equipment providers.

That determination can be helped by applying a simple metric: do they claim the necessary expertise, or have they provided tangible evidence by demonstrating that expertise?

Instrumentation providers can claim something is "possible" with a particular piece of equipment, but has that level of performance been demonstrated? Can it be shown to the customer before a purchase? Specifications are not always indicative of real-world performance.

Just because a vehicle is rated at 30 mpg and its speedometer goes to 120 mph, doesn't mean the vehicle actually operates at 30 mpg efficiency in real-world conditions, or that it can actually attain 120 mph. Thus, make it a point to tell equipment providers, "do not just tell me you can do it; show me."

Consider that, as a diagnostic exercise, Mad City Labs will command a small oscillation to a nanopositioning system. That oscillation might only be a few nanometers peak to peak — perhaps 100 pm. Then, the noise floor is measured, as there exists some position noise in every nanopositioning system; the input signal is clearly resolved to show that it is larger than the background noise. This diagnostic also functions as proof of a system's promised resolution capability.

Another salient example is Mad City Labs' diagnostic exercise to prove its atomic force microscope's (AFM's) capability to achieve subnanometer resolution. Testers will measure the height of atoms in steps on a silicon surface using a standard AFM — essentially a measure of the thickness of the silicon atom on a surface, roughly 383 picometers high.

Thus, the instrument must provide better than 383 pm resolution; a Mad City Labs AFM can routinely achieve between 5 and 10 picometers of resolution. If you can routinely measure

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