

## Plenary Talk 5



### Hybrid Measurements for Complex Systems: One of the Next Frontiers in Metrology

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#### Abstract:

The increasing complexity of systems being measured, combined with advances in data science and computing power are fundamentally reshaping the landscape of metrology. Historically isolated metrology disciplines are increasingly intertwined, giving rise to hybrid metrology methods. These methods transcend traditional correlative approaches by combining datasets from multiple measurement modalities to create “virtual” measurands where the direct correlation between input measurements is not always well understood but can provide critical, reproducible indicators of complex system performance or quality. This shift is especially prominent in advanced materials, biotechnology, and environmental sciences, where single-parameter assessments are insufficient, and correlated parameter relationships can be leveraged for more efficient and informative characterization.

However, hybrid metrology presents significant challenges. The primary source of uncertainty often shifts from SI traceability to method-defined measurands, requiring robust, globally reproducible measurement protocols and sophisticated data analytics. Additionally, the rising complexity and number of measurements necessitate novel solutions to minimize costs, reduce measurement times, and simplify expert-dependent processes. Smart sampling techniques, such as compressive sensing offer promising results by strategically reducing data acquisition without compromising information integrity, which can lead to enhanced signal-to-noise ratios with significantly decreased measurement durations.

Addressing these challenges necessitates close collaboration among the metrology community, industry, and academia. This presentation explores recent progress at the National Physical Laboratory (NPL) in developing hybrid metrology and compressive sensing techniques, highlighting current challenges, and future opportunities for advancing measurement science through the symbiotic integration of metrology, data science, and advanced computing power.