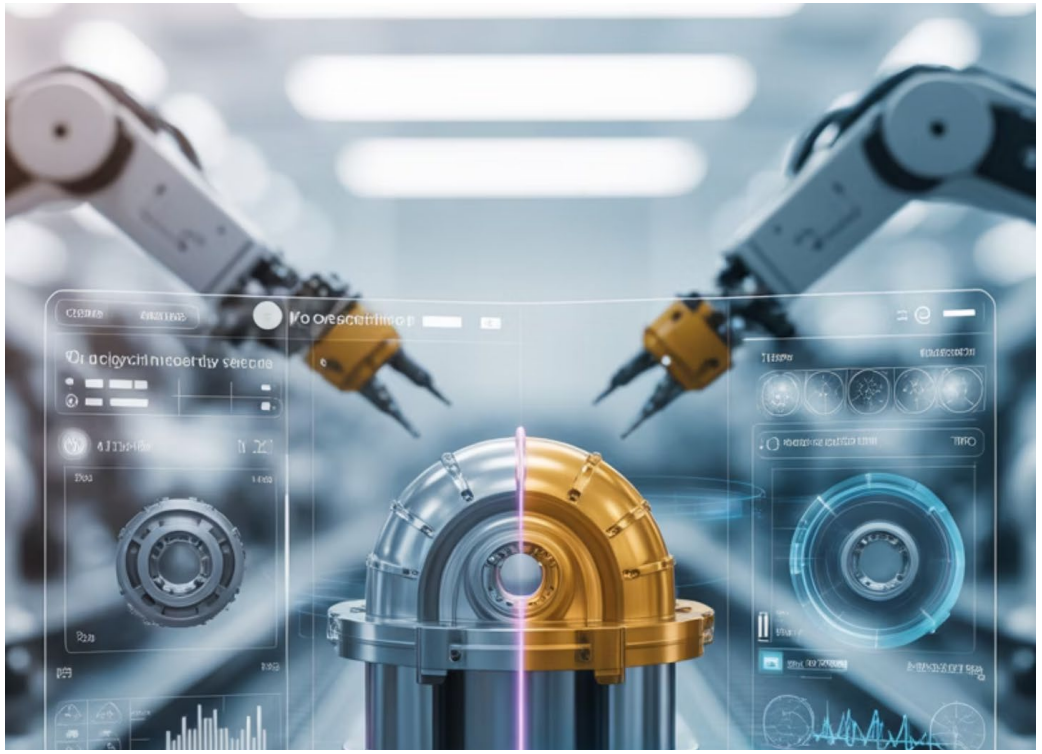
Quantum Spectral Holo-Sense: A Futuristic NDE Revolution



Anushrut Jignasu | **Aditya Balu** | **Adarsh Krishnamurthy**

“If you think you understand quantum mechanics, then you don’t.”
– Richard Feynman

(Don’t worry! We don’t either!! ☺)

Agenda

The Vision

Quantum Sensing

Advanced Spectral Correlation Engines

Bio-Inspired Monitoring

Augmented Reality

Summary

Q&A

The Vision

Materials as "Living Systems"

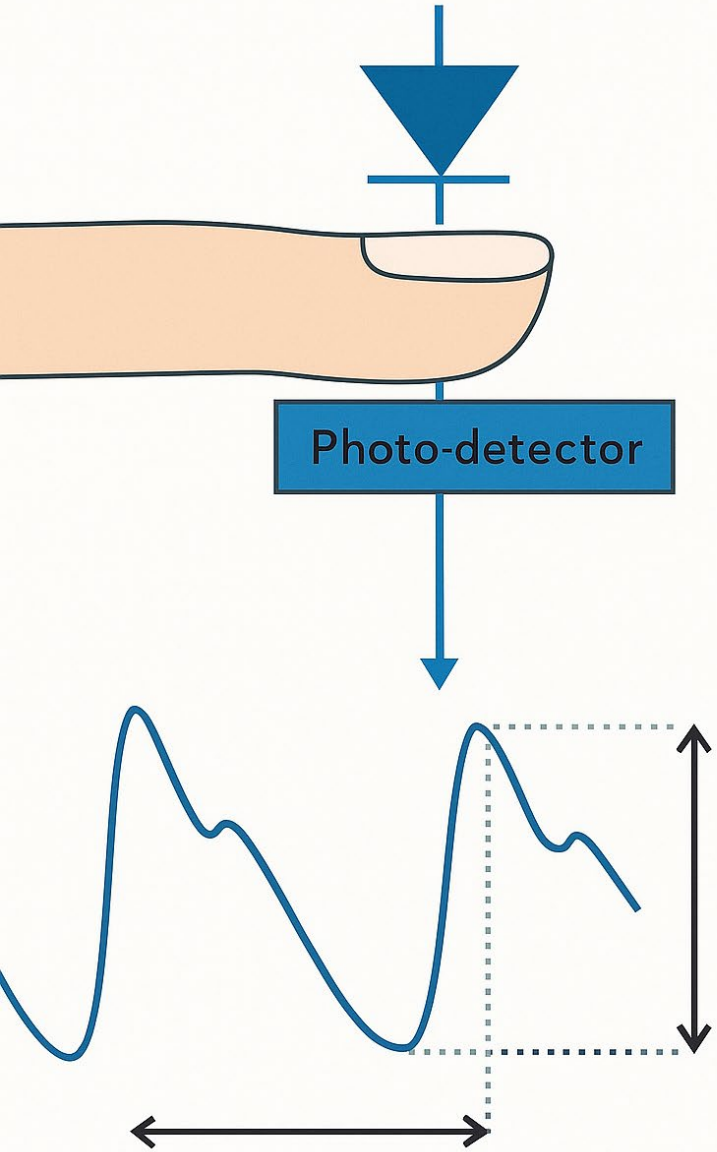
- Each material has unique characteristics or "pulses"

Real-Time Detection

- Expose hidden flaws during manufacturing

Holographic Visualization

- Convey defects to engineers using Augmented Reality (AR)



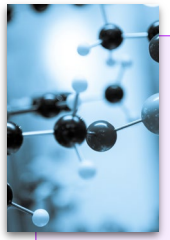
Material Pulse Concept

Inspired by photoplethysmography (PPG) used in medical monitoring

System tracks the "material pulse" - subtle variations in how materials respond to different probes during manufacturing processes

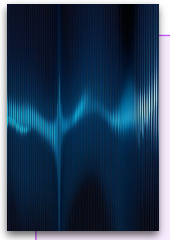
Treats each component as a dynamic system with its own unique "heartbeat" of responses that indicate its health and integrity

Detecting Material “Pulse”



Quantum-Enhanced Sensing

Detection capabilities beyond classical physics limitations through quantum mechanical properties

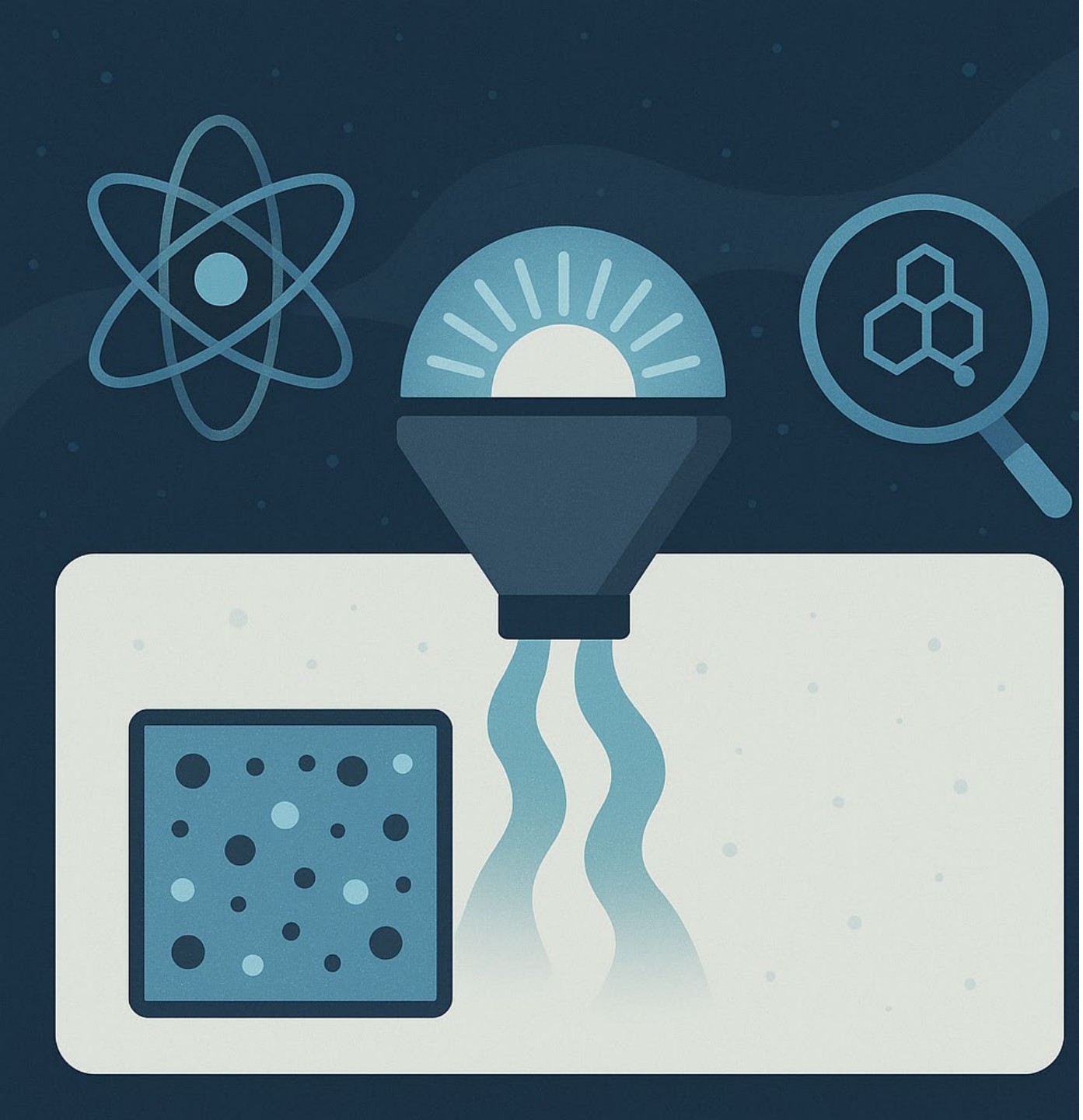


Advanced Spectral Correlation

Multi-spectral analysis powered by sophisticated machine learning algorithms

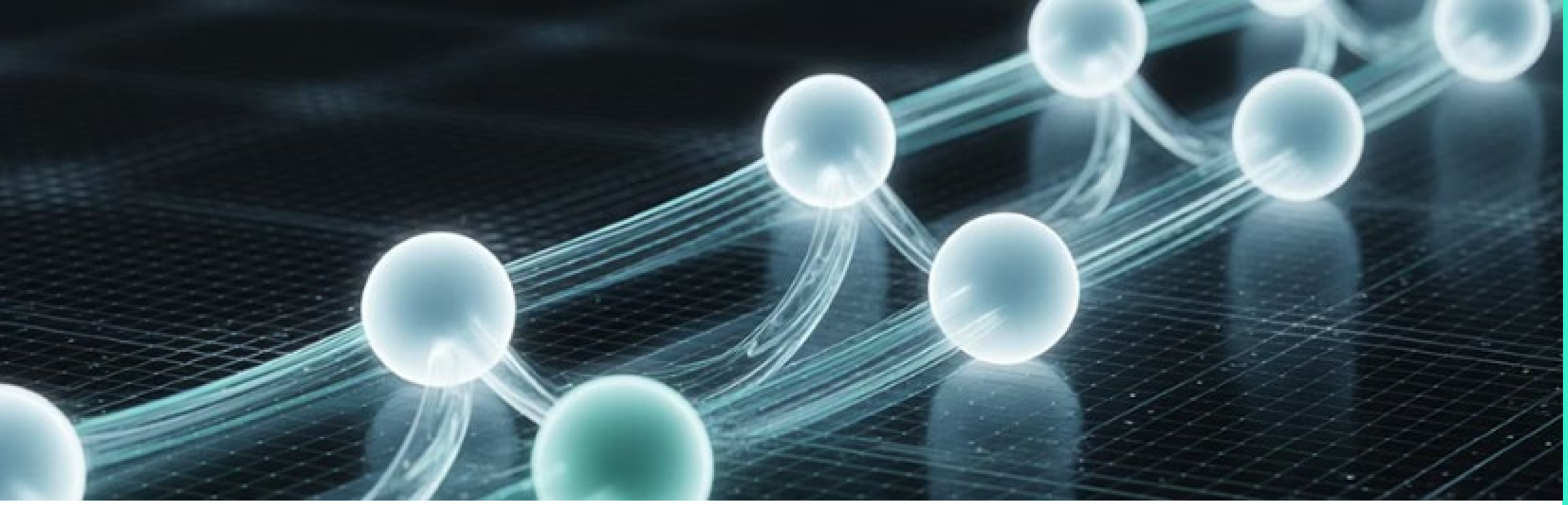
Bio-Inspired Monitoring

Material health evaluation principles derived from biological systems monitoring



Quantum-Enhanced Material Sensing

- Quantum sensing technologies are specifically hardened for operation in semi-controlled manufacturing environments
- Possible Technologies
  - Nitrogen-Vacancy Center Magnetometry
  - Single-Photon Detection Arrays

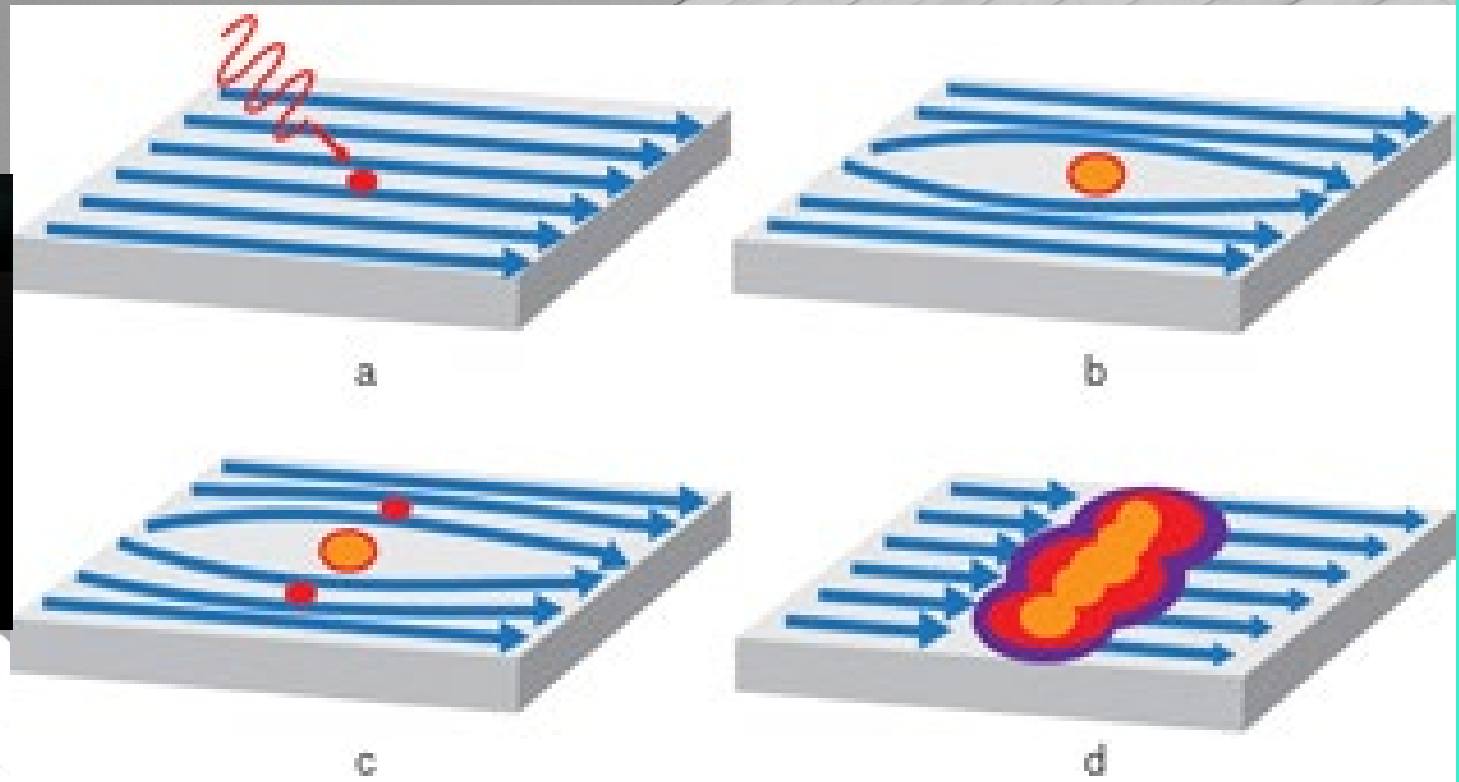


Nitrogen-Vacancy Center Magnetometry

- Tiny defects in diamond that act as ultra-sensitive magnetic field sensors at the nanoscale
- Detect material stress, strain, and microstructural changes
- Read quantum spin states by shining laser light on NV centers
- Remains coherent at room temperature

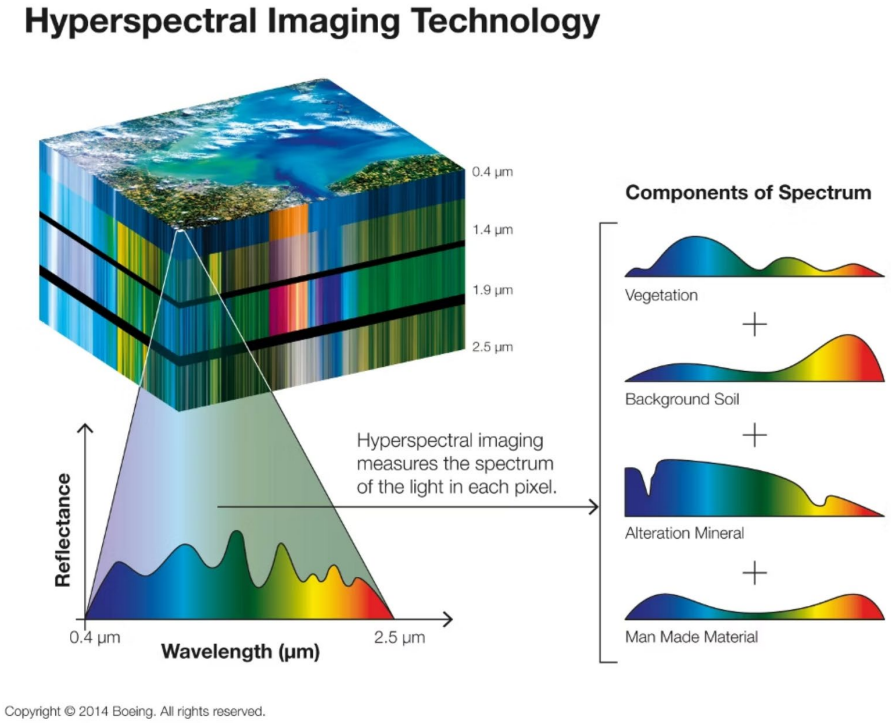
China's new quantum radar tracked a stealth drone at 350 km — without sending out a single signal

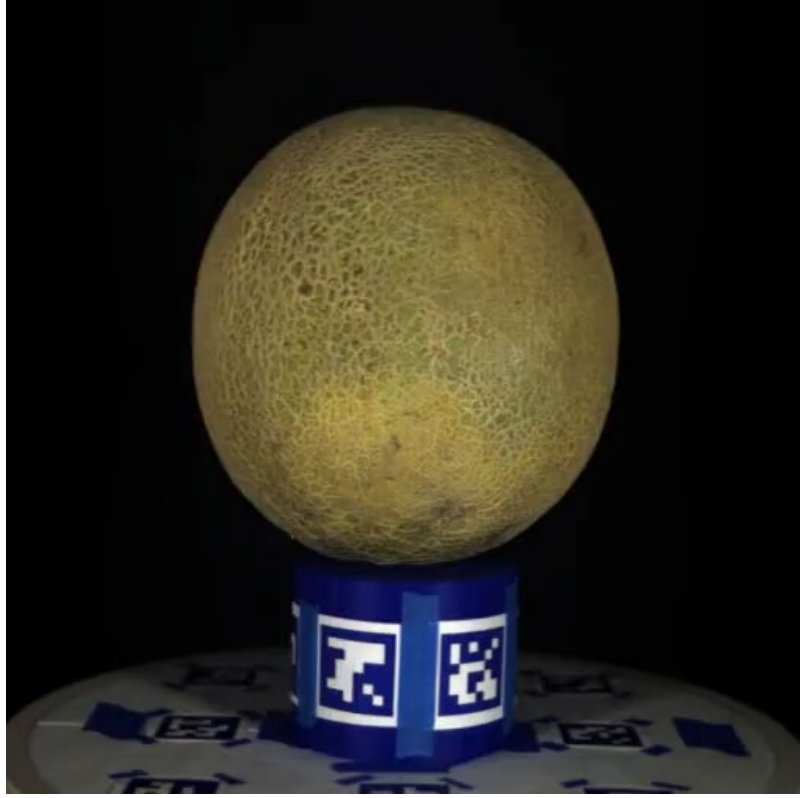
Eu Corner / Science And Nature Page

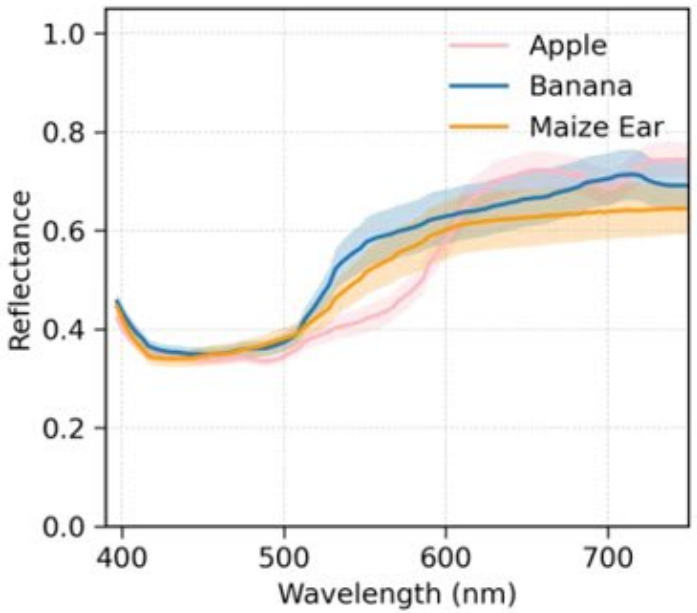


Single-Photon Detection Arrays

- Quantum Probe Generation
  - Entangled photon pairs are created, with one photon sent to interact with the material while its entangled partner is preserved as a reference.
- Single-photon avalanche diode (SPAD) arrays record individual photons with 10-30 picosecond timing resolution
- Captures the faintest signals from deep within materials







Spectral Correlation Engines

- Hyperspectral Data Fusion
  - Ultraviolet, visible light, near-infrared, and terahertz frequencies
  - Already used in agricultural applications
  - Hyperspectral Neural-Radiance Fields (NeRFs)
- Provides a more complete picture of material properties than any single-spectrum method

Differential Spectroscopy

Pulse oximetry's comparison of light absorption at different wavelengths

Employ multi-wavelength comparative analysis to isolate specific material characteristics.

Filter out background noise

The Quantum Inspection Advantage

1nm

Resolution

Quantum sensors achieve nanometer-scale resolution, seeing what conventional methods miss.

100x

Sensitivity

Detects defects 100 times smaller than traditional methods.

0

Speed Penalty

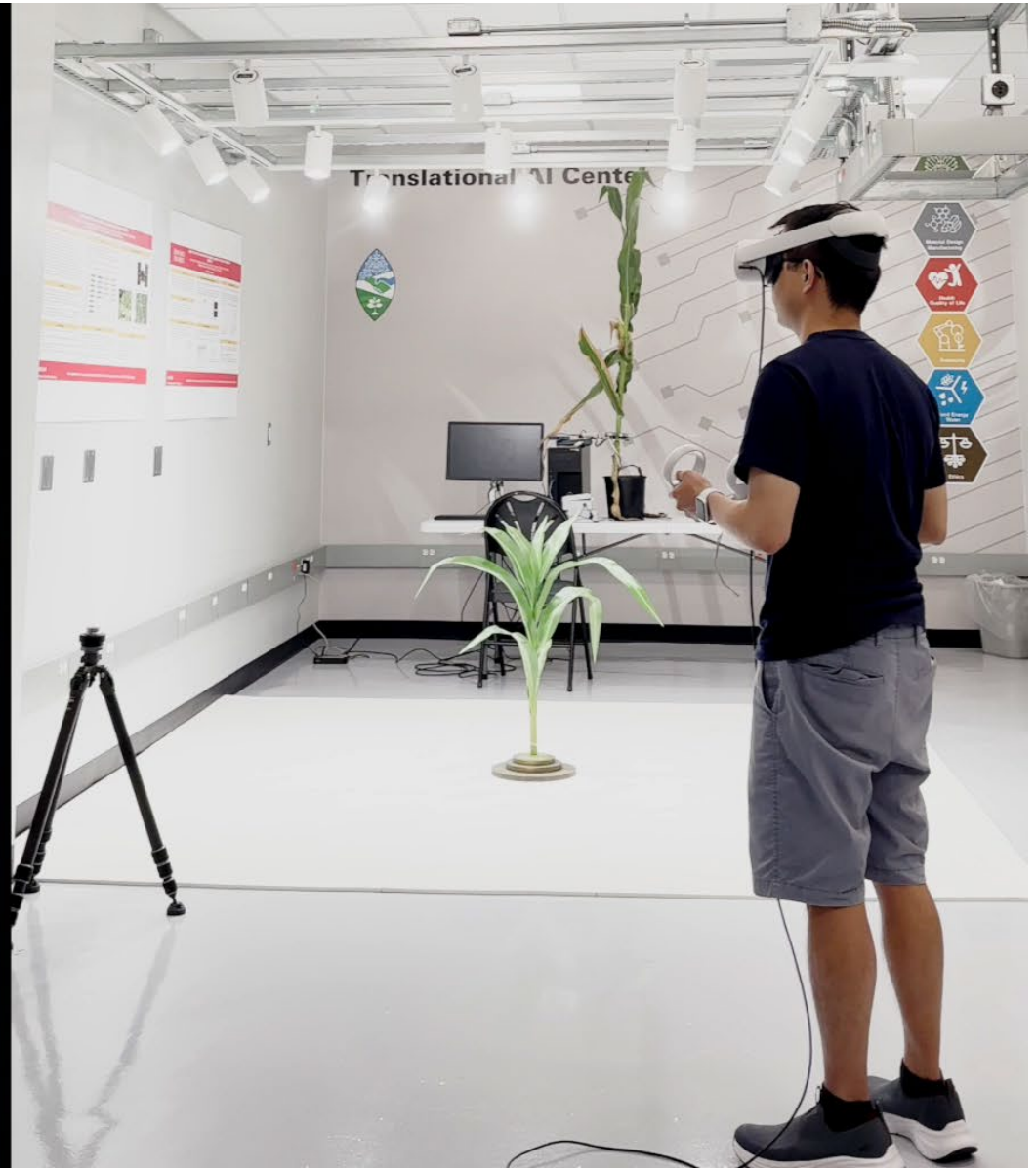
Real-time inspection with no production slowdown.

Augmented Reality

Consume spectral NDE results

Enables In-situ monitoring

Virtual/Augmented Reality



Virtual/Augmented Reality

Holographic Augmented Reality Interface

QSHS delivers complex material analysis directly to engineers through holographic augmented reality interface. This intuitive visualization system transforms abstract quantum data into actionable insights.

Spatially-Registered Data Overlay

Material analysis data is precisely mapped to physical components in real space, allowing engineers to see exactly where potential issues are located

Multi-Dimensional Data Visualization

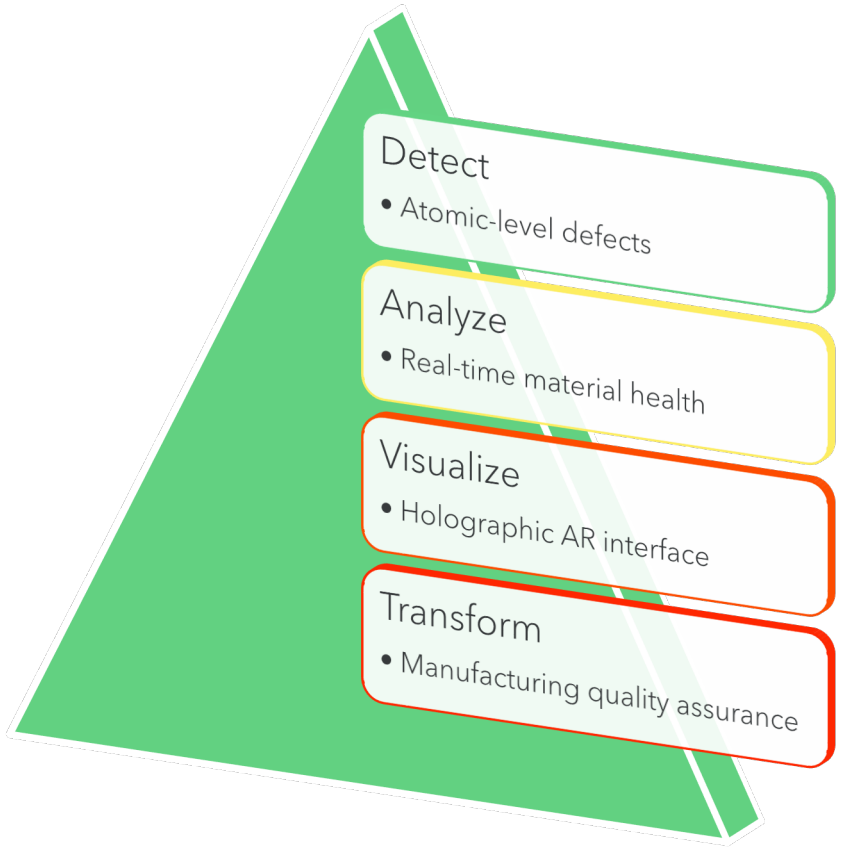
Complex datasets from multiple sensing modalities are presented through intuitive visual metaphors, using color, transparency, and animation to represent material properties

Interactive Analysis Tools

Interact with the holographic data using gesture controls to isolate specific parameters, zoom into areas of interest, or compare current readings with historical baselines

This interface bridges the gap between quantum-level material sensing and practical manufacturing decisions, directly accessible to production teams.

The Future of Manufacturing



Industry Applications and Possible Case Studies

Aerospace Component Manufacturing

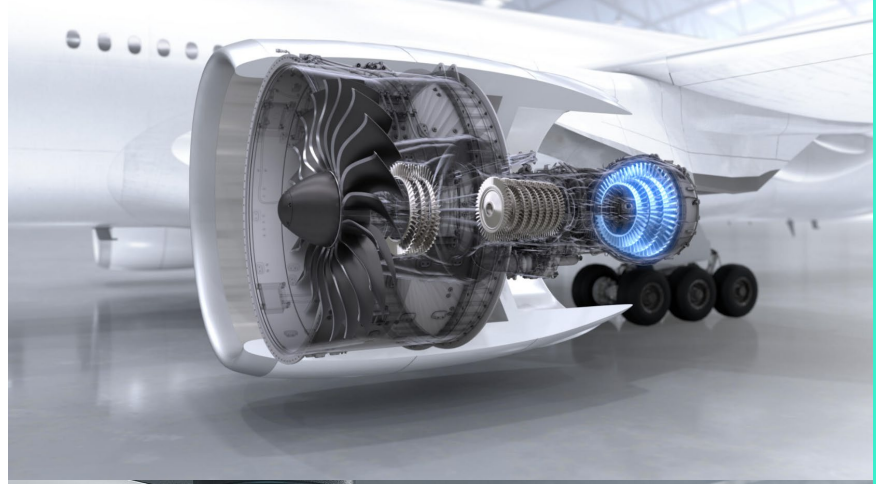
- Inspect turbine blades during production, for detecting **subsurface crystallographic anomalies** that conventional methods can miss.

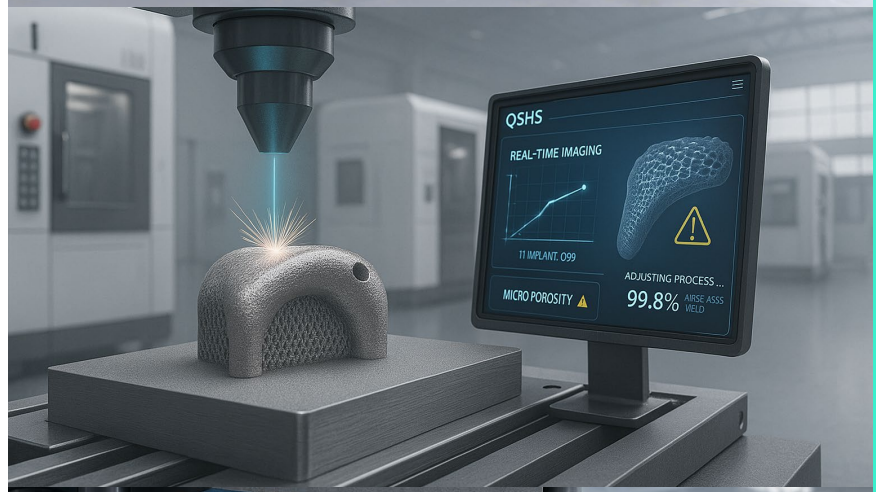
Medical Device Production

- Monitor material integrity during 3D printing of titanium implants, identifying micro-porosity issues in real-time and adjusting process parameters dynamically.

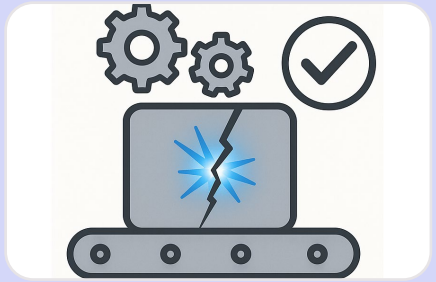
Automotive Structural Components

- Detect incipient fractures during forming operations for a high-strength steel stamping line, and preventing downstream assembly issues, saving in warranty costs.





Economic Impact for Manufacturers

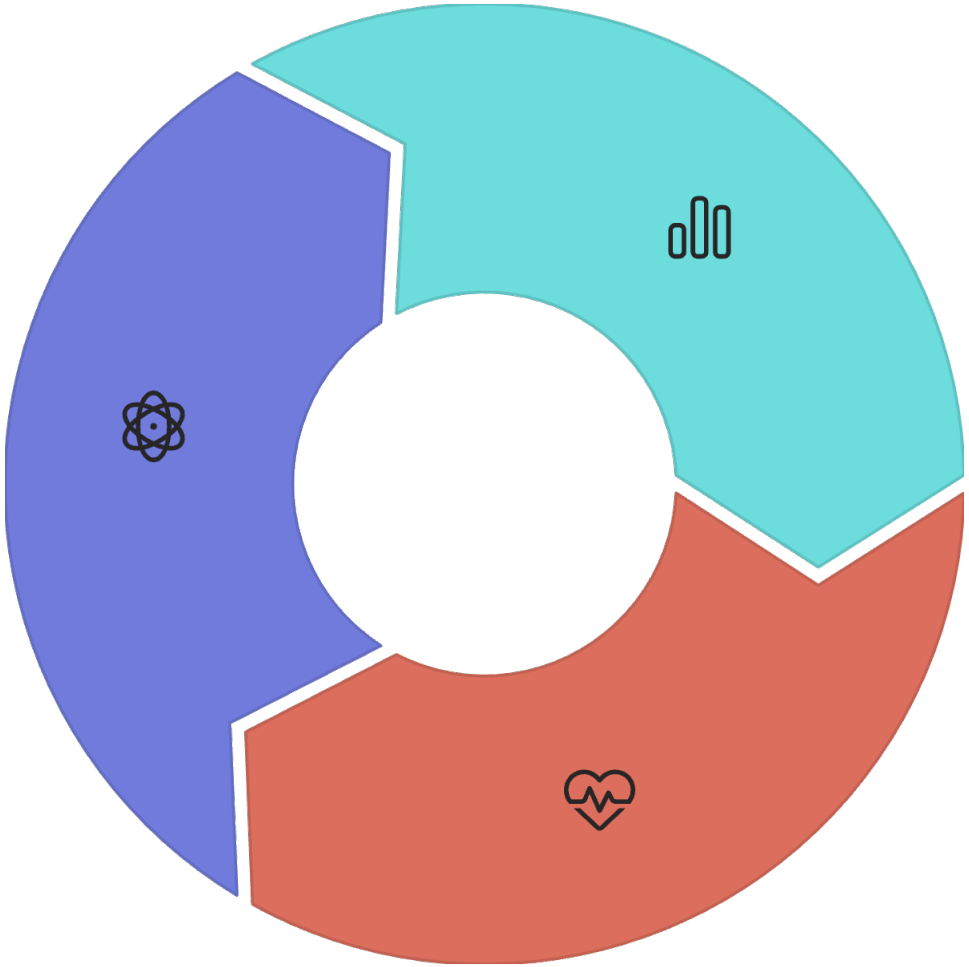


Defect Reduction: Reduction in field failures and warranty claims due to improved detection of previously invisible defects during production.

Scrap Reduction: Early detection of emerging defects allows for process corrections, reducing scrap rates.

ROI Multiplier: Average return on investment for QSHS implementation can be as high as 3x in the first year of operations.

QSHS - Summary



Quantum Sensing

See defects at atomic scales

Spectral Correlation

Intelligent material diagnostics

Bio-Inspired Monitoring

Read material vital signs

Dedication

Prof. David Dornfeld

Q&A

Acknowledgements:

NSF CMMI-I2347623 -
EAGER/Collaborative Research: An
LLM-Powered Framework for G-Code
Comprehension and Retrieval