



# Automating Science to Rapidly Discover Higher Performing Armor Ceramics for Readiness Today

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# A Solution to the Challenge We Face

Armor Development



Threat Development

Outpace developing threats by *accelerating* the finding of scientific discoveries that lead to better armor.

Modernize our approach to science





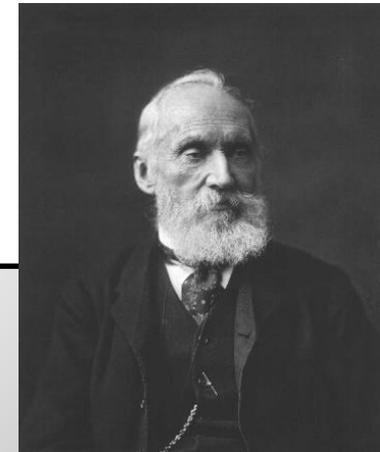
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# Yesterday's View of Science

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*“The grandest discoveries of science have been but the rewards of accurate measurement and patient long-continued labour in the minute sifting of numerical results.”*

– Lord Kelvin (1883)



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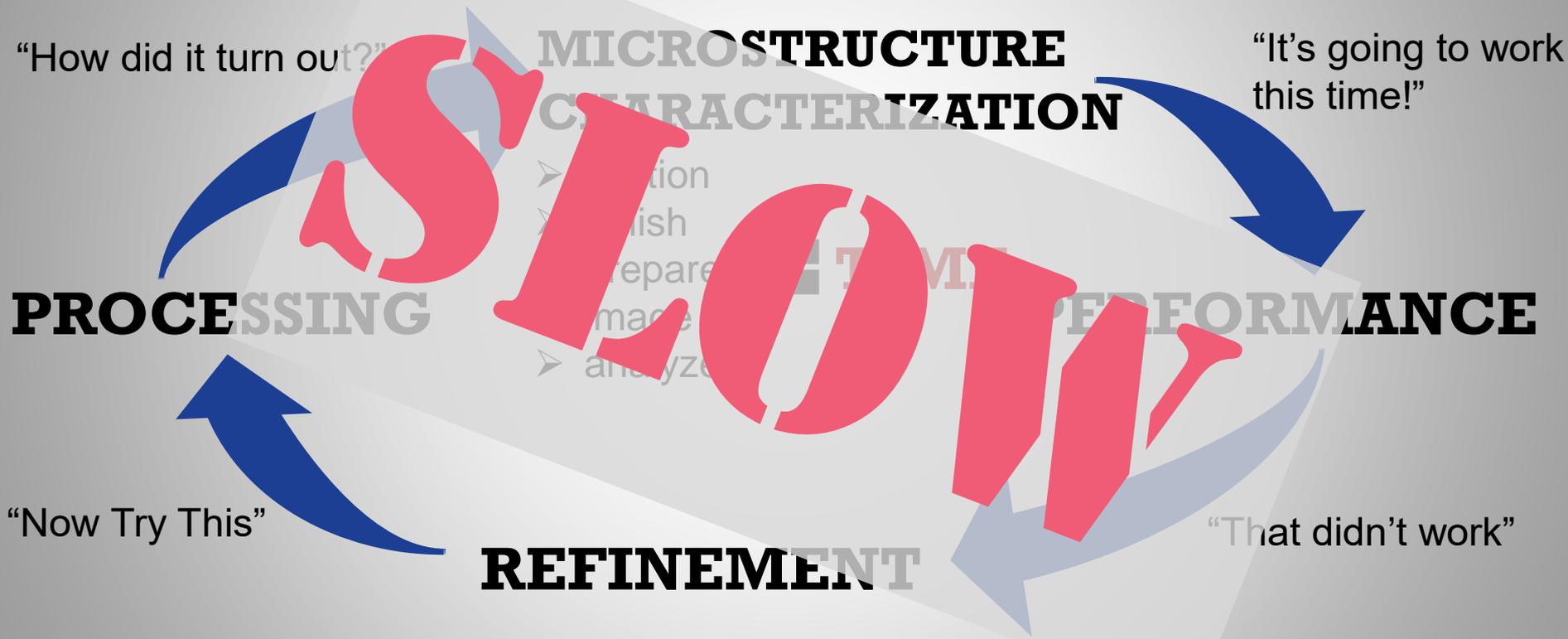


# Overcoming the Rate Limitations



NEED TO KNOW: Processing → Structure → Performance

Traditional approach to materials discovery



**RESULT: Tired, inefficient material discovery and development, (10's of samples)**



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# High-Throughput Experimentation (HTE) Speed



RESULT: Stre

development,

PROCESSING

PERFORMANCE TESTING

D  
A B D  
B

## High-Throughput Screening Example



Robots used to rapidly screen millions of drug compound combinations

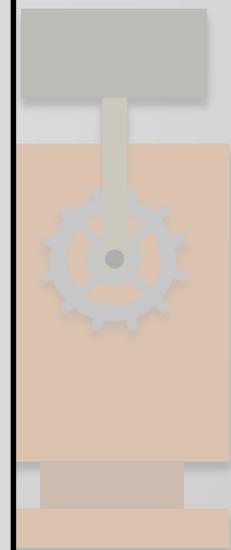
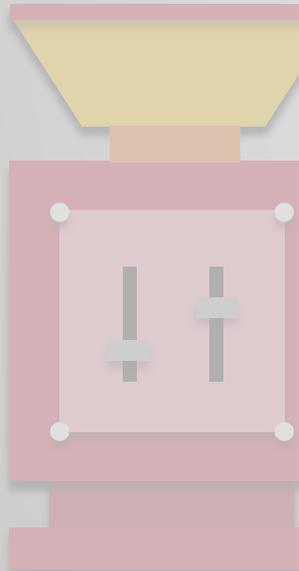


Photo top: Maggie Bartlett, NHGRI (Wikimedia)  
Photo bottom: Chris Frazee, UW-Madison HTS

High-throughput screening **drives** early-stage drug discovery.

**“Big rewards to quickly finding a life-saving drug”**

Results:  
A B C : X  
A B D : X  
D B C : ✓





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# Our Modern Approach to Discovery **ARL**

## High-throughput Experimentation

### 1 Combinatorial, High-Volume Ceramic Processing

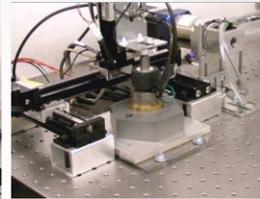
### 2 High-Throughput Microstructure Characterization using Electric Fields

### 3 Intelligent Ballistic Testing

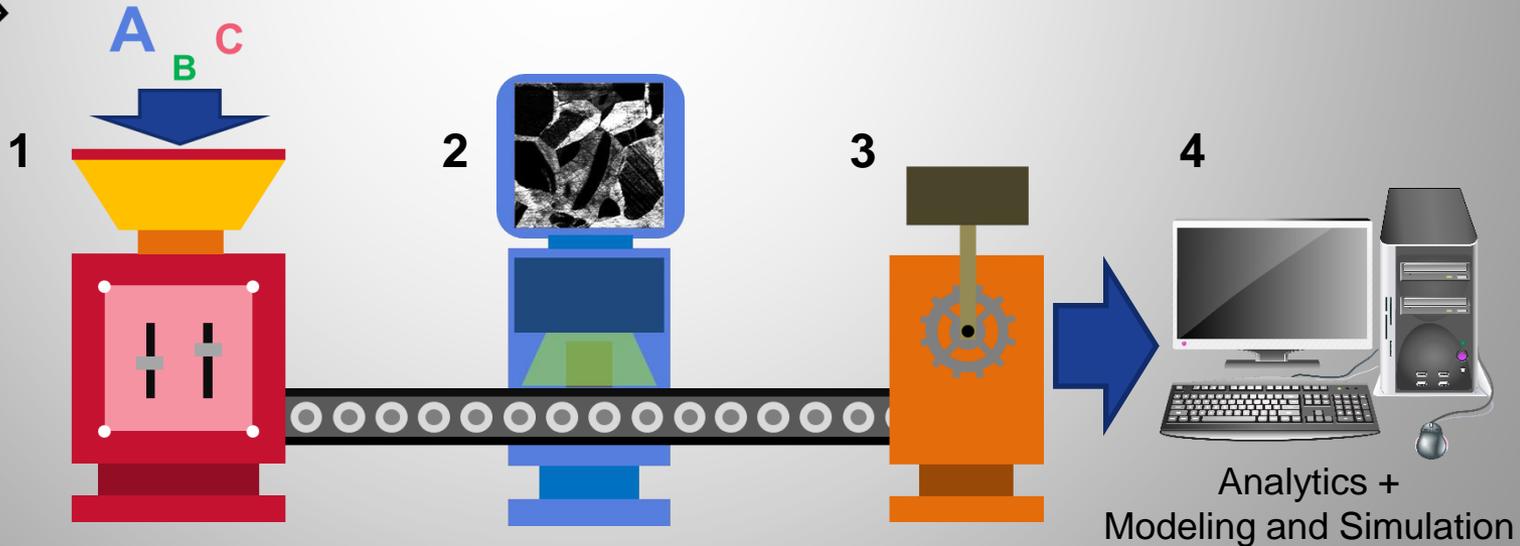
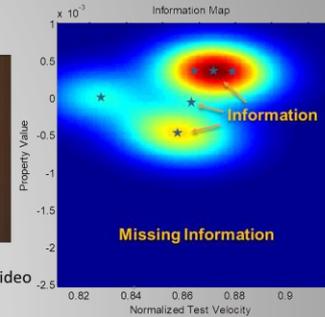
COORSTEK



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MANTECH**  
Manufacturing Technology



Comprehensive projectile characterization, high-speed video determination of pitch/yaw

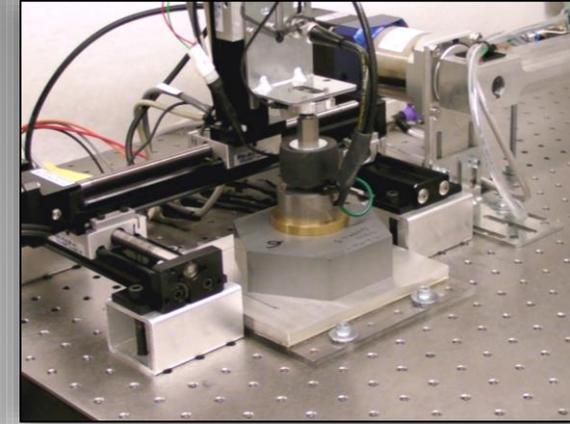
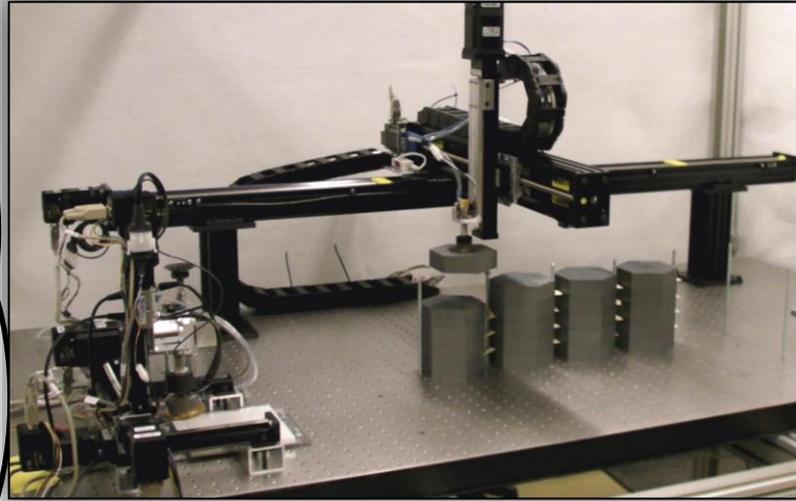
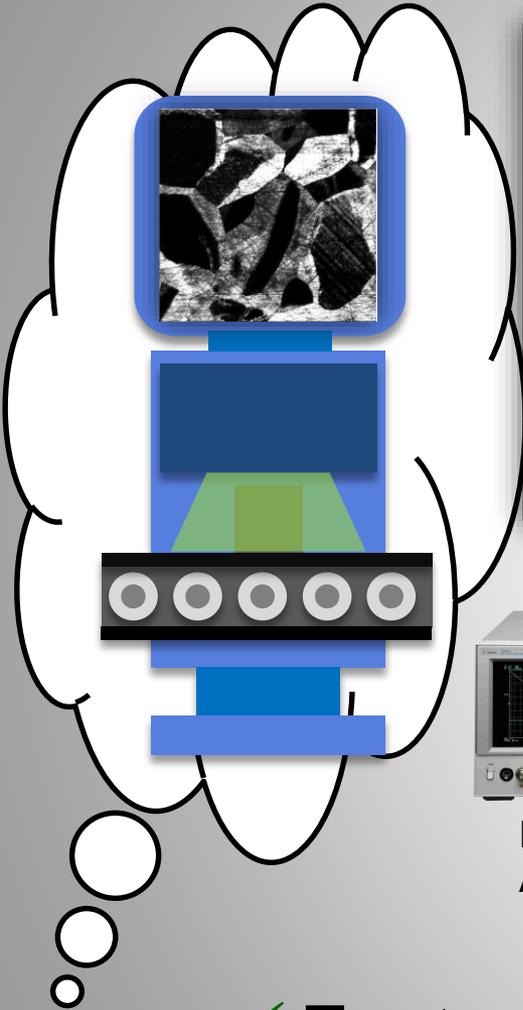




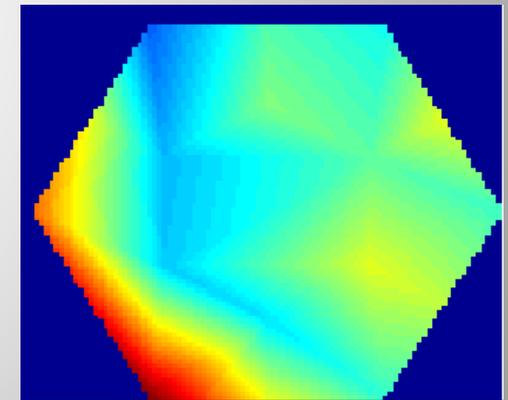
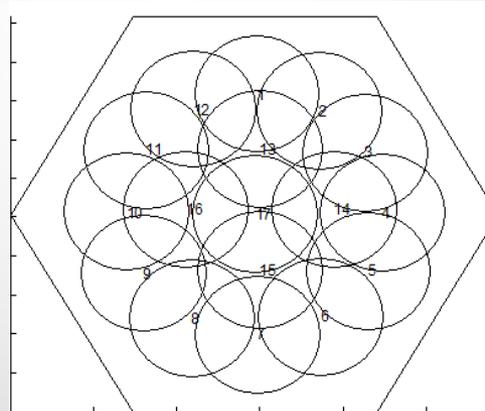
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# High-Throughput Armor Characterization

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Impedance  
Analyzer



- ✓ **Fast and Non-Destructive**
- ✓ **100's of samples measured at a time**



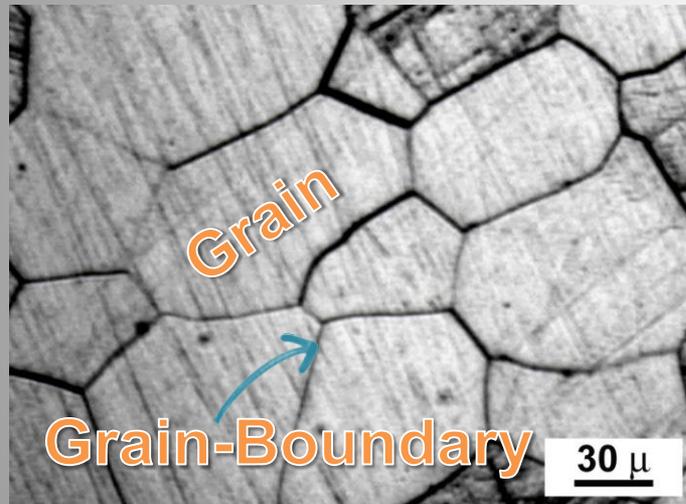
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# How it Works

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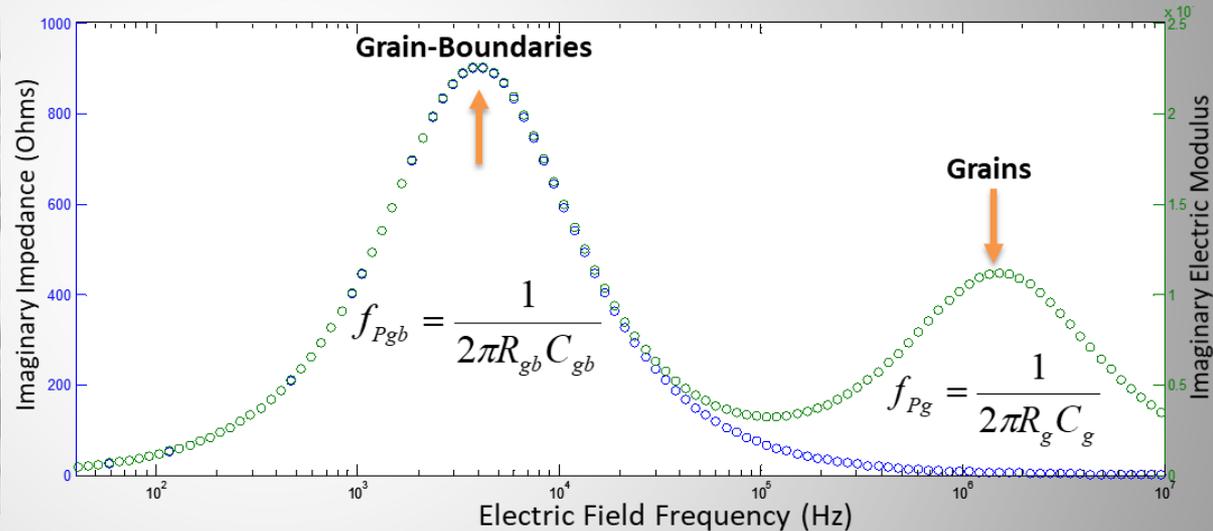
**Goal: Link armor structures to processing and performance**

## Microstructure



Wikimedia commons

## Impedance Spectrum Analysis



**Electrical measurements tell us A LOT about the structure**

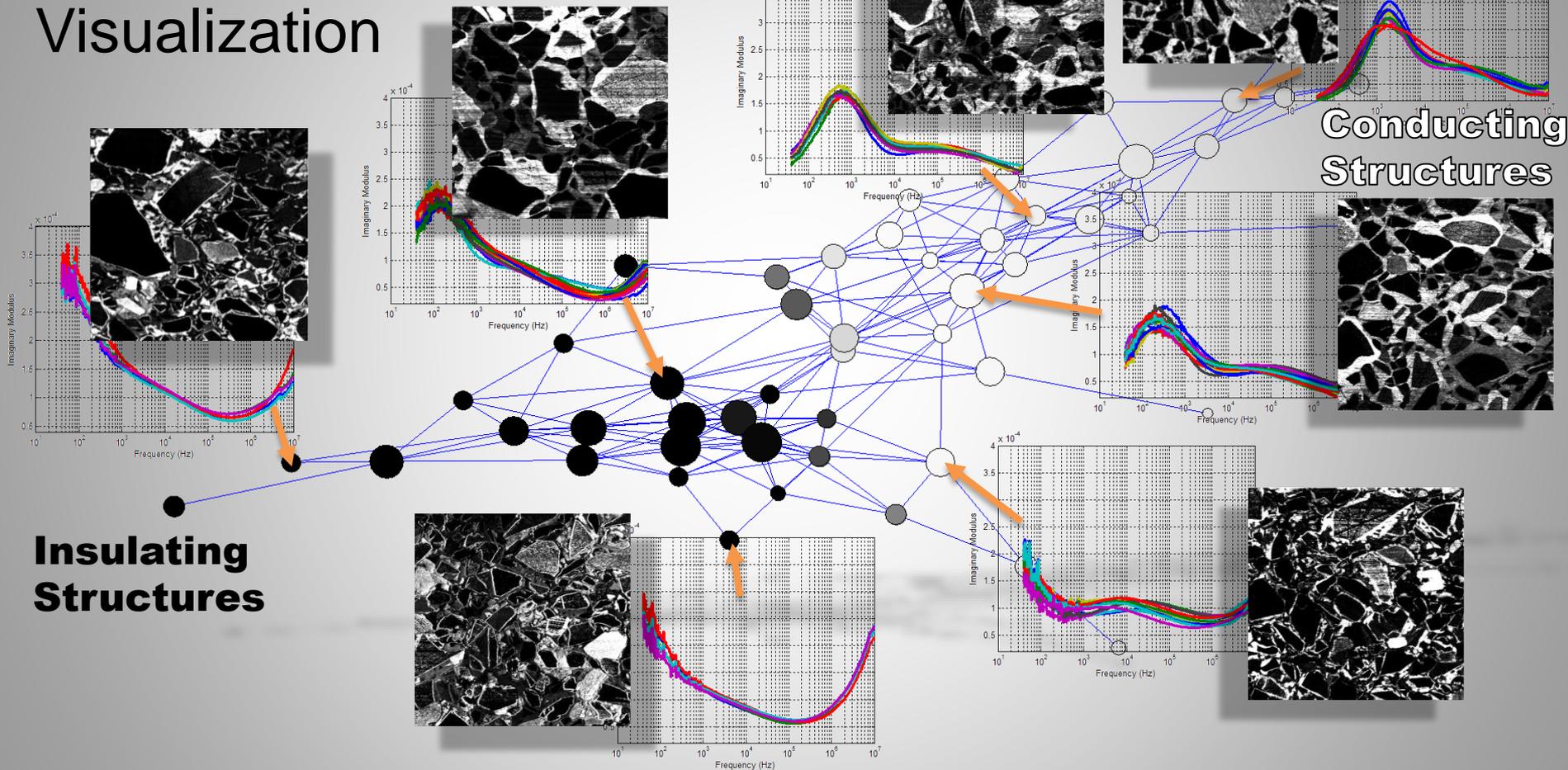


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# So Much Information!



## BIG Data Visualization



**Making links between Processing → Structure → Performance**



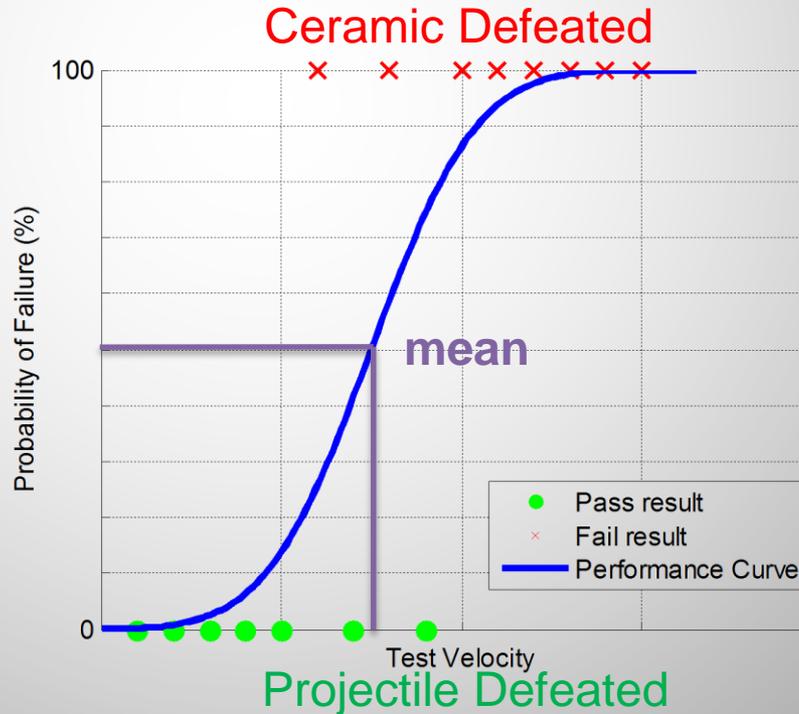
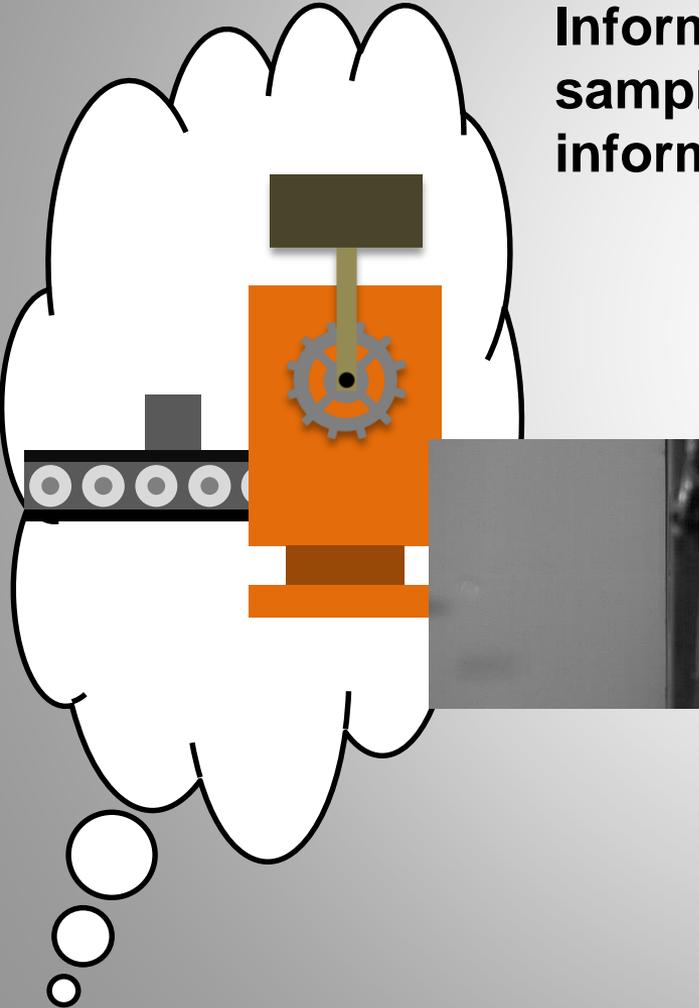
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# A Better Way to Test Performance



## How to *efficiently* evaluate the structure's performance?

Information-based testing used to determine the sample order and projectile velocity that **MAXIMIZES** information.





# Best Performing Structures Discovered!

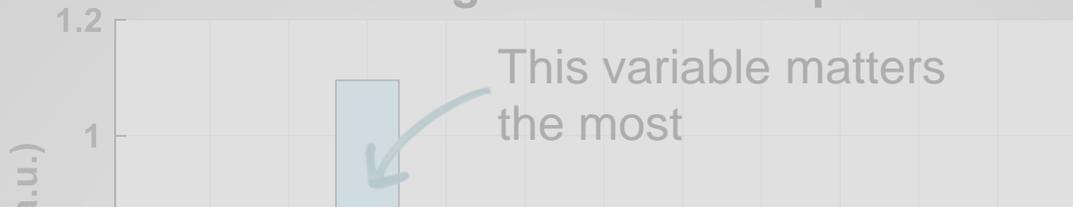


Now we know WHAT is the better armor



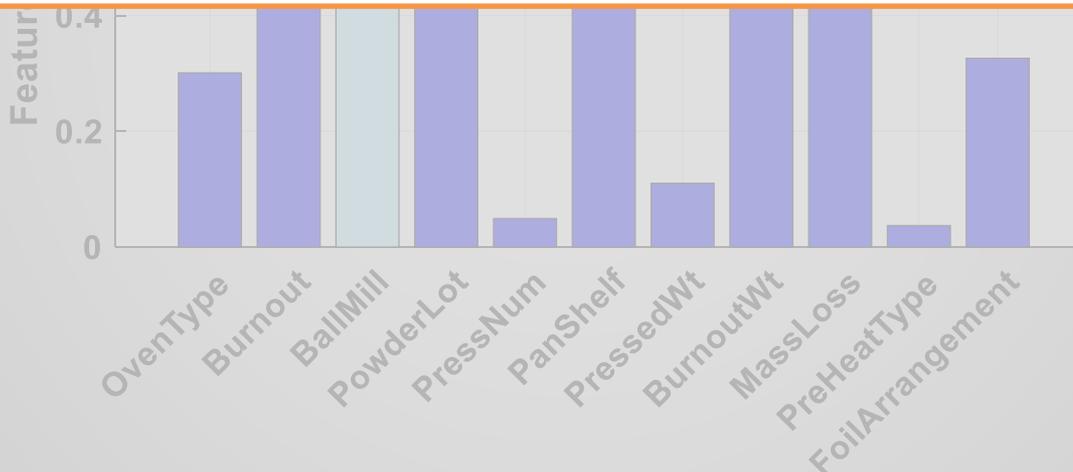
# Best Processing Controls Discovered!

## Processing Parameter Importance



### **RESULT:**

Knowledge of the structure, prediction of the performance, and better manufacturing.



Now we know HOW to make better armor



# A Fast-Paced Future for Science



*In the future,  
science is automated and discoveries are abundant.†*

## Science of the Past



Discovery

goldrushtradingpost.com

## The Future of Science



Discoveries!

alluvialgoldmachine.com

†Golt, M. *Increase the Impact and Abundance of Discoveries, Innovations, and Transitions by Automating Science.* U.S. Army Research Laboratory Special Report, ARL-SR-0400, July 2018.