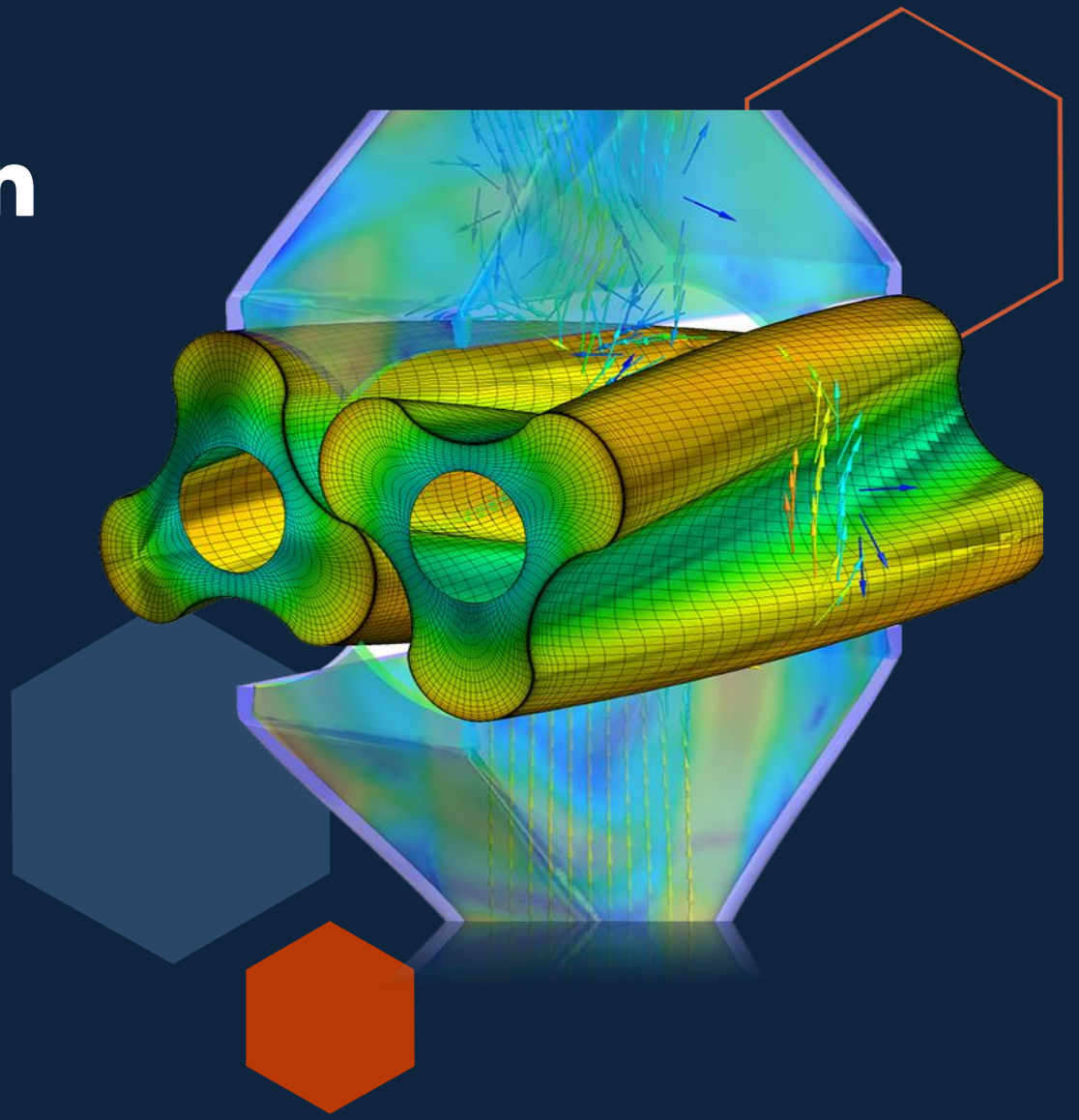
Cryogenic Integration In Modern Materials Manufacturing

Cryogenic Mechanical Systems Development For Polymer-Based Raw Materials Manufacturing

Fernando Velez (*R&D Mechanical Engineer*)



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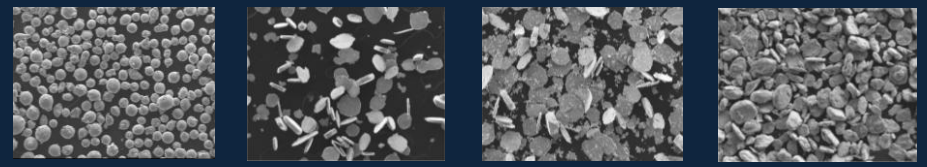
Cryogenic Ball Milling of Metallic Materials

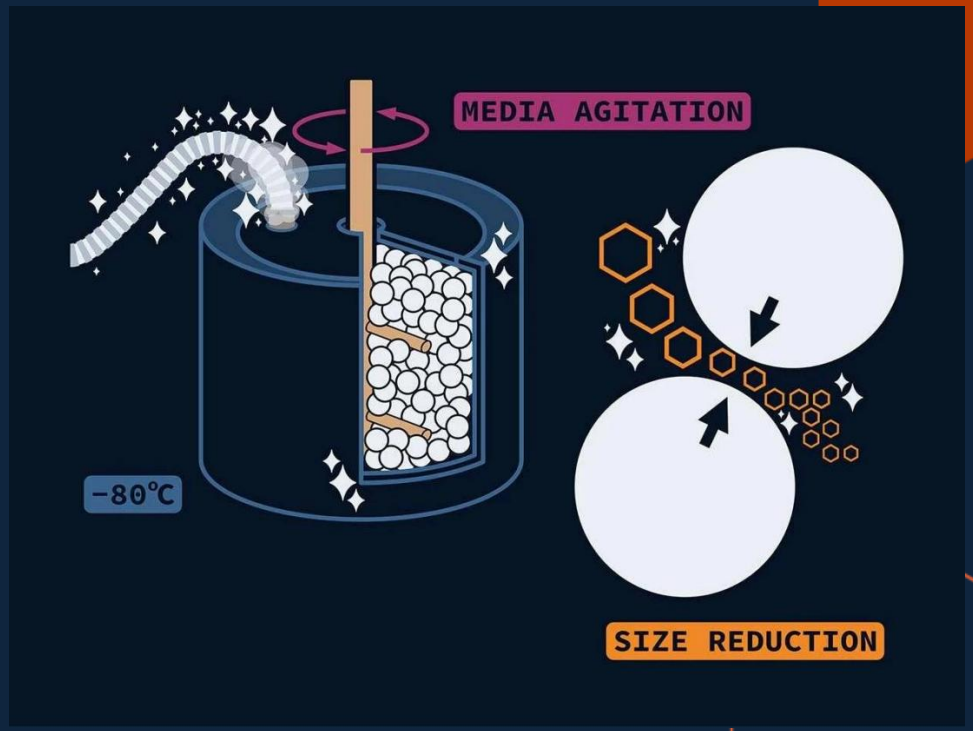
- Cal Nano advances cryogenic metal milling technologies to industrial grinding for commercial production of polymer-based materials
- New R&D engineering efforts in industrial machinery, cryogenic line retrofitting, and particle size reduction methods
- New customers, material processing demand, operating procedures, safety standards, and infrastructure

Metallic Powder Morphology Illustration



As received (Spherical GA powder) | Flattening | High Aspect Ratio Flake | Agglomeration

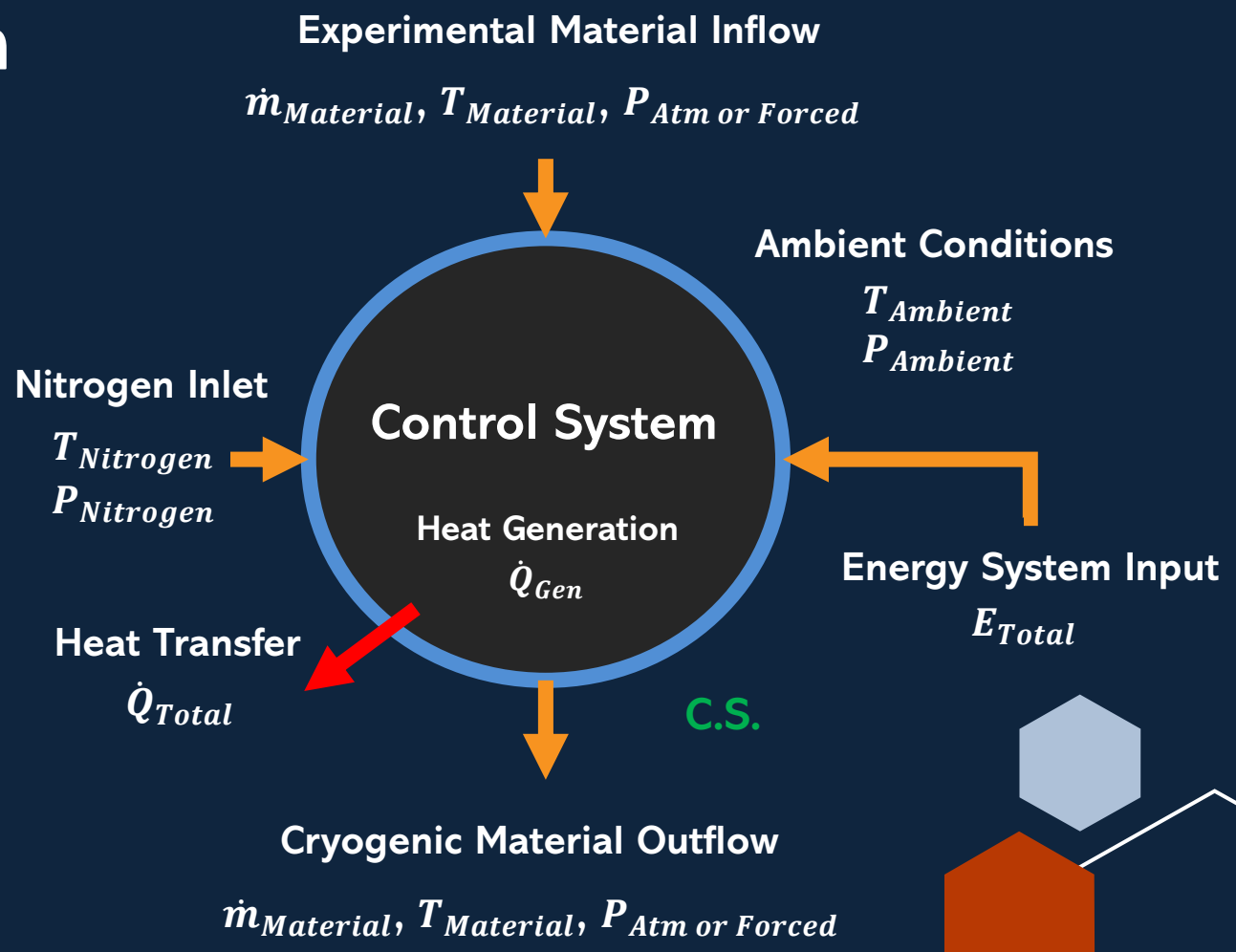
Cryogenic Material Processing



Cryo-milling: Material embrittlement through low temperature environments. High energy impact reduces the particle sizes of various materials into extremely finer powders

Cryogenic Integration In Polymer Materials

- Strategic R&D investments in polymer-based raw-materials manufacturing prototypes
- Gaseous nitrogen replaces cryo-liquids for industrial grinding of polymer materials
- Polymer-based materials operate at distinct glass transition temperatures
- Prototype technology requires new engineering design and experimental testing
- Mechanical systems offers greater control in polymer particle size reductions



Mechanical Engineering Methodology

Step 1: Material Reactivity

Considerations:
- Hybrid Machine Performance
- Natural/Forced Flow
- Maximum Feed Rates
- Heat Development
- Material Heat Mitigation

Computational Analysis
- CAD, FEA, CFD, Etc.
- Accurate?

Experimental Data Collection
- Thermocouples, Pressure Sensors, Flow Meters, Etc.
- Data Acquisition in Harsh Environments

Step 2: Nitrogen Retrofitting

Considerations:
- Optimal Material Temperatures/Pressures
- Applicable Nitrogen Phase-States
- Ideal/Non-Ideal Conditions in System
- Control Volume Analysis of Combined Properties
- Gaseous Nitrogen Mass Flow Rates

Nitrogen Material Testing
- Prototyping & Experimentation
- Harsh Environmental Factors
- Nitrogen Material Reactivity

Step 3 Cryogenic Material Processing

Considerations:
- Analysis of Experimental Data
- Particle Size Sample Testing
- Cryogenic Sampling & Quality Testing
- Material Glass Transition Temperatures

Desired Material?

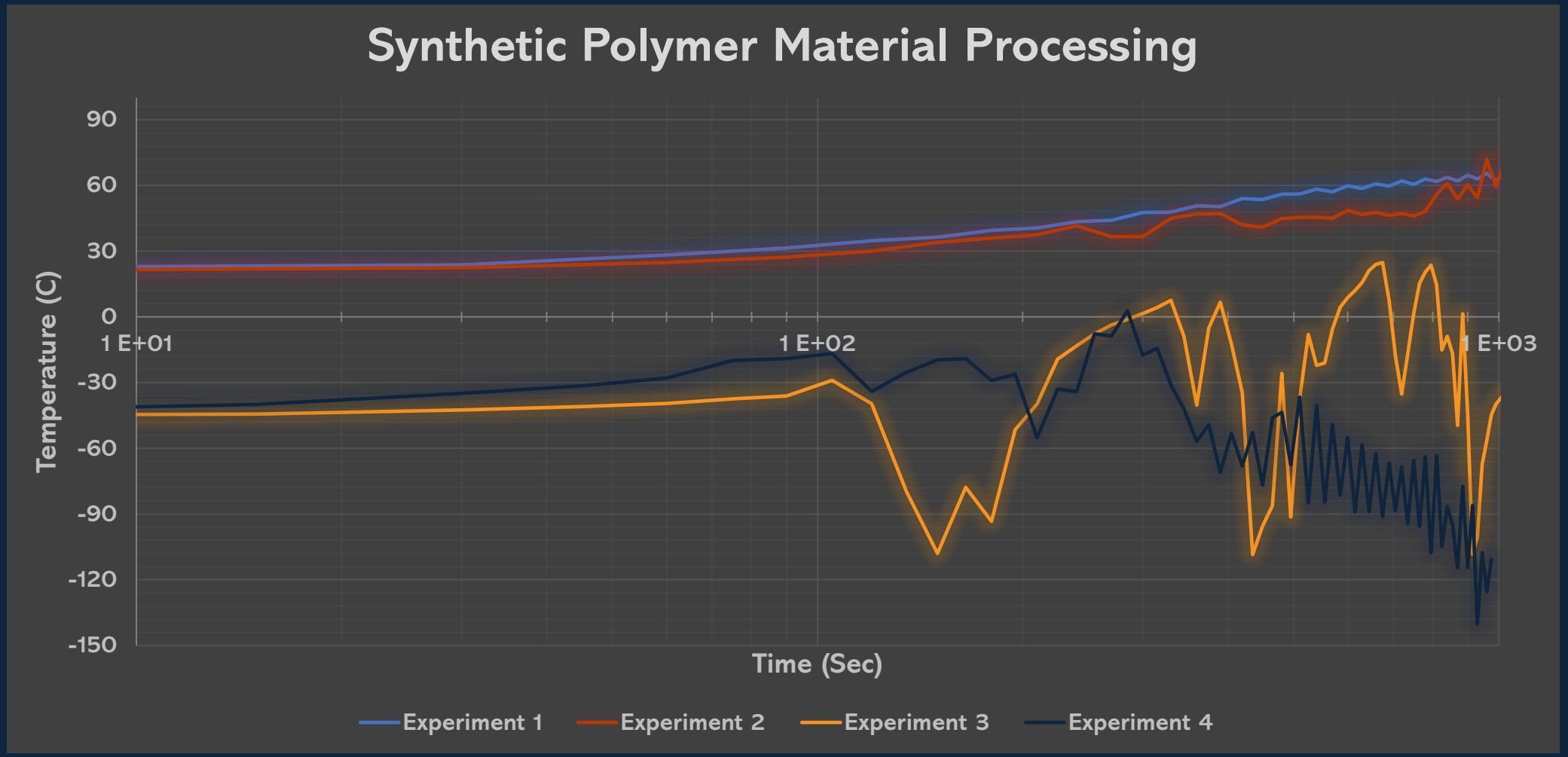
No

Iterative Optimization
- Subcomponent Redesign, Nitrogen Phase-State Adjustments, Thermodynamic Calculations, Etc.

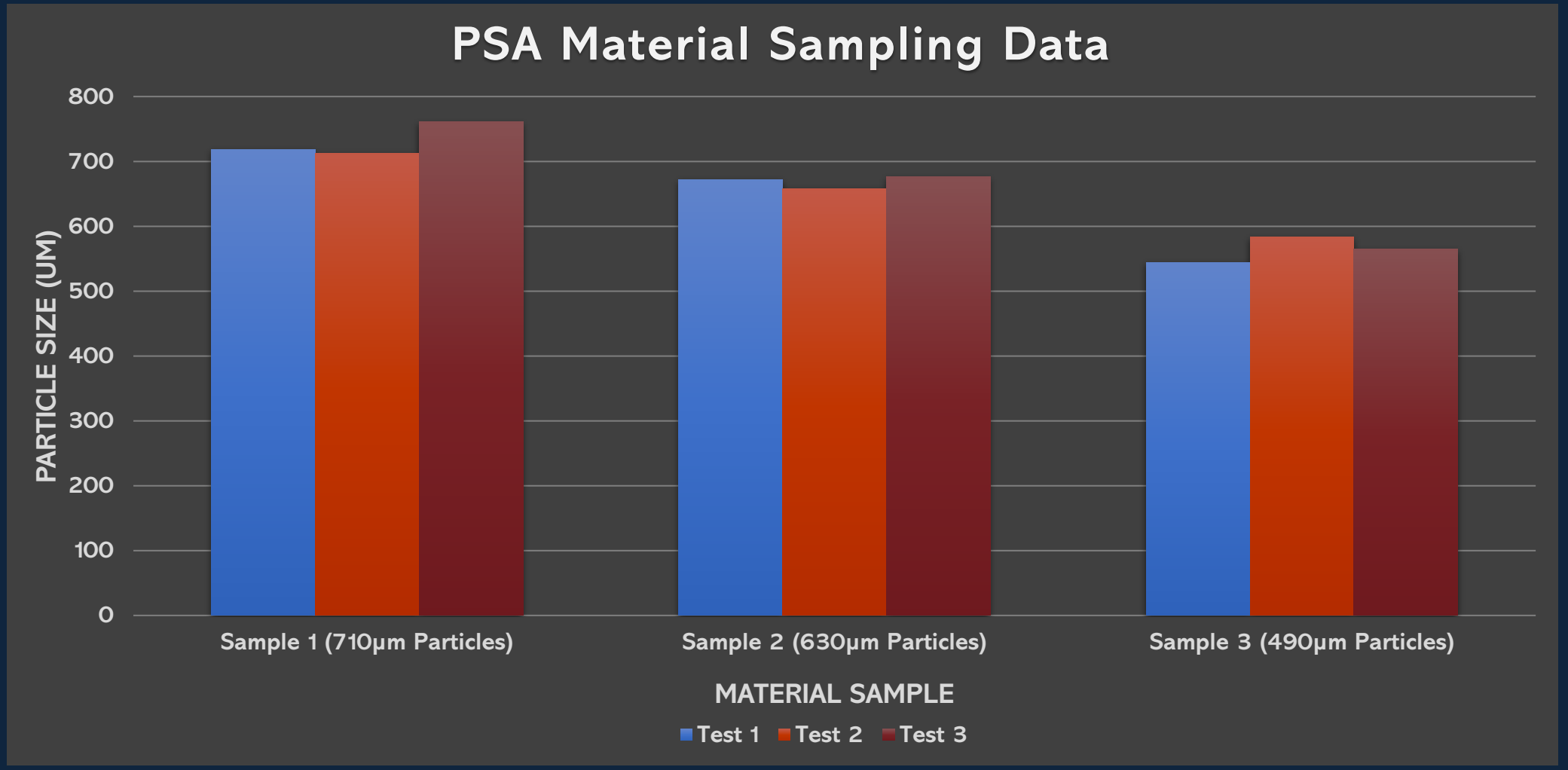
Yes

Industrialize Process
- Source Applicable Equipment, Develop Supply Chains, Scale Production, Standardize Procedures, Etc.

Cryo-Burr Mill Temperature Achievements



Polymer Particle Reduction Analysis



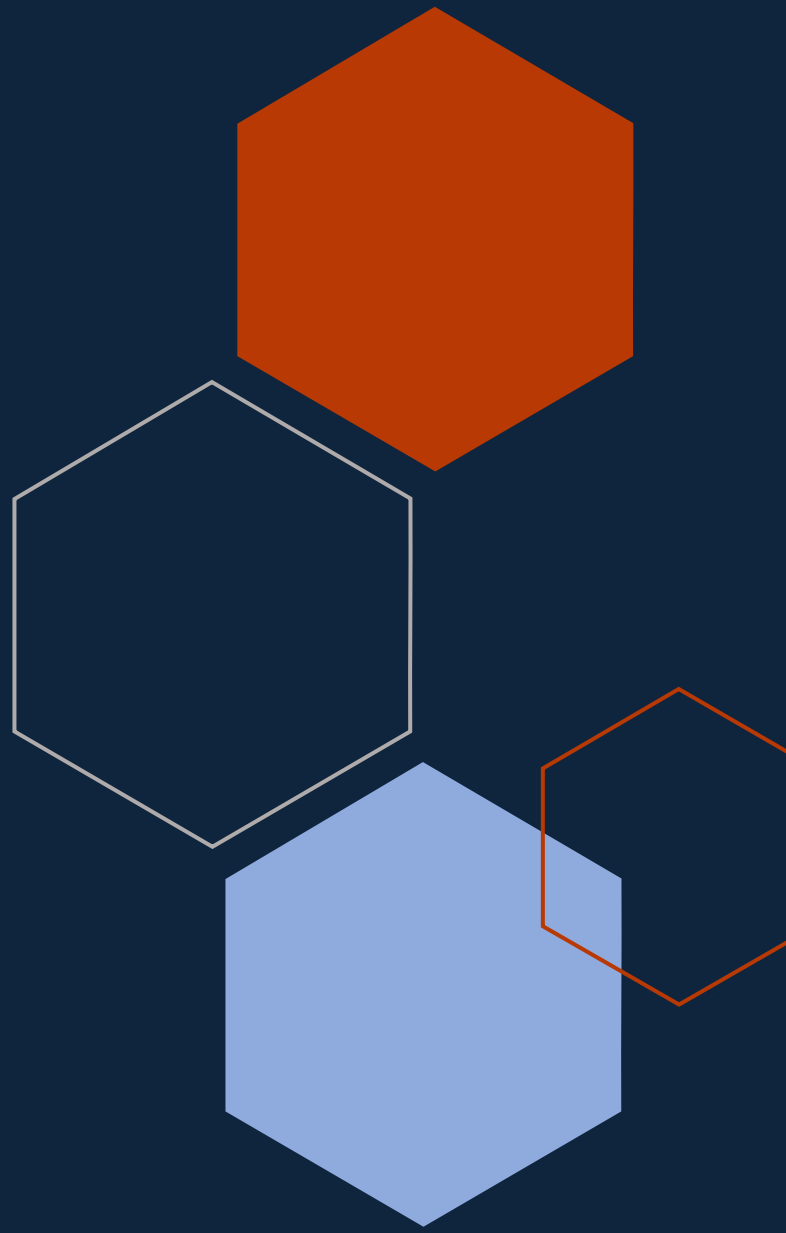
Manufacturing Financial Overview

- Cryogenic mechanical hybrid systems resulted in large-scale production success at lower costs and personnel
- Cryogenic material processing technology allowed for further particle reductions in polymer-based materials and an increase in material production
- New customer orders from AbTech Industries Inc. resulted in company technology investments, rapid market entry, and greater product demand

Quarter	Particle Reduction (µm)	Production Growth (lb./day)	Customer Demand
Q1	~710	~50	1,000 lb. / month
Q2	~490	~410	4,000 lb. / bi-weekly

Future Cryo-Burr Initiatives

- Increase robustness of cryogenic hybrid systems
- Integrate further safety standards & operations
- Identify new opportunities and industry sectors
- Scale infrastructure & material quality
- Expand growth trends through new materials



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