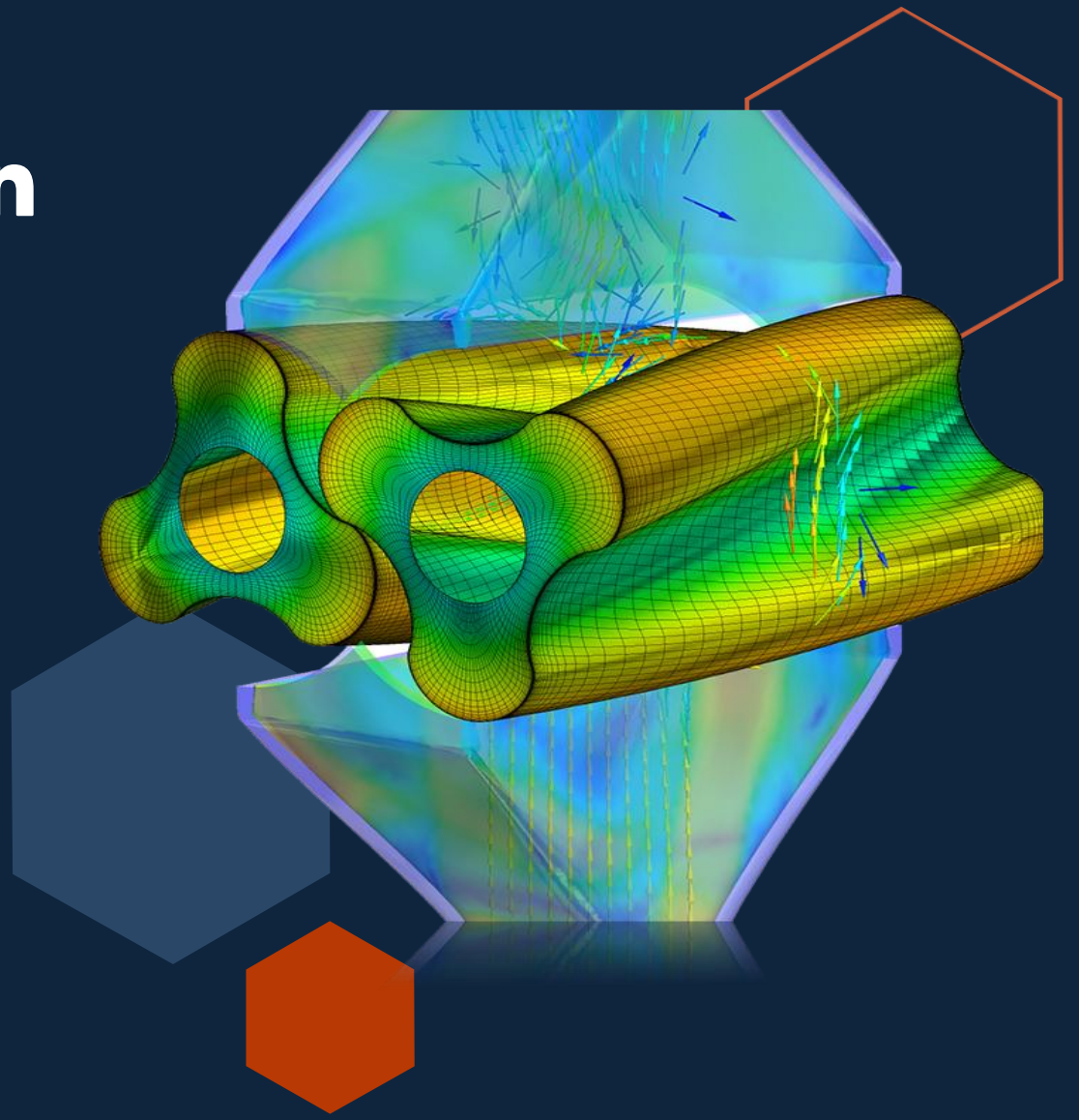
# Cryogenic Integration In Modern Materials Manufacturing

*Cryogenic Mechanical Systems Development For Polymer Materials Manufacturing*

**Fernando Velez** (*R&D Mechanical Engineer*)



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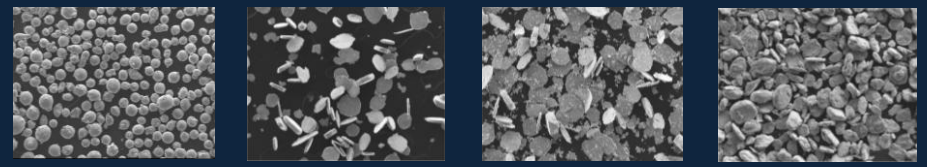
# Cryogenic Ball Milling of Metallic Materials

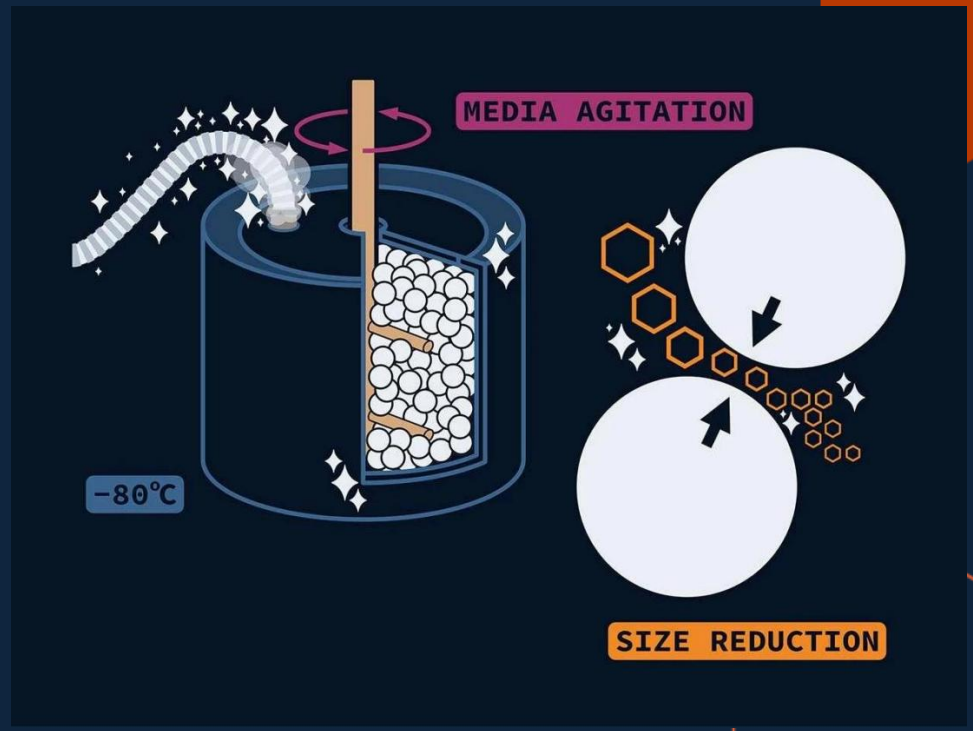
- Rising interest in advancing cryogenic metal milling technologies to industrial grinding for commercial production of polymer-based materials
- New R&D engineering efforts in industrial machinery, cryogenic line retrofitting, and particle size reduction methods
- New customers, material processing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

Metallic Powder Morphology Illustration



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

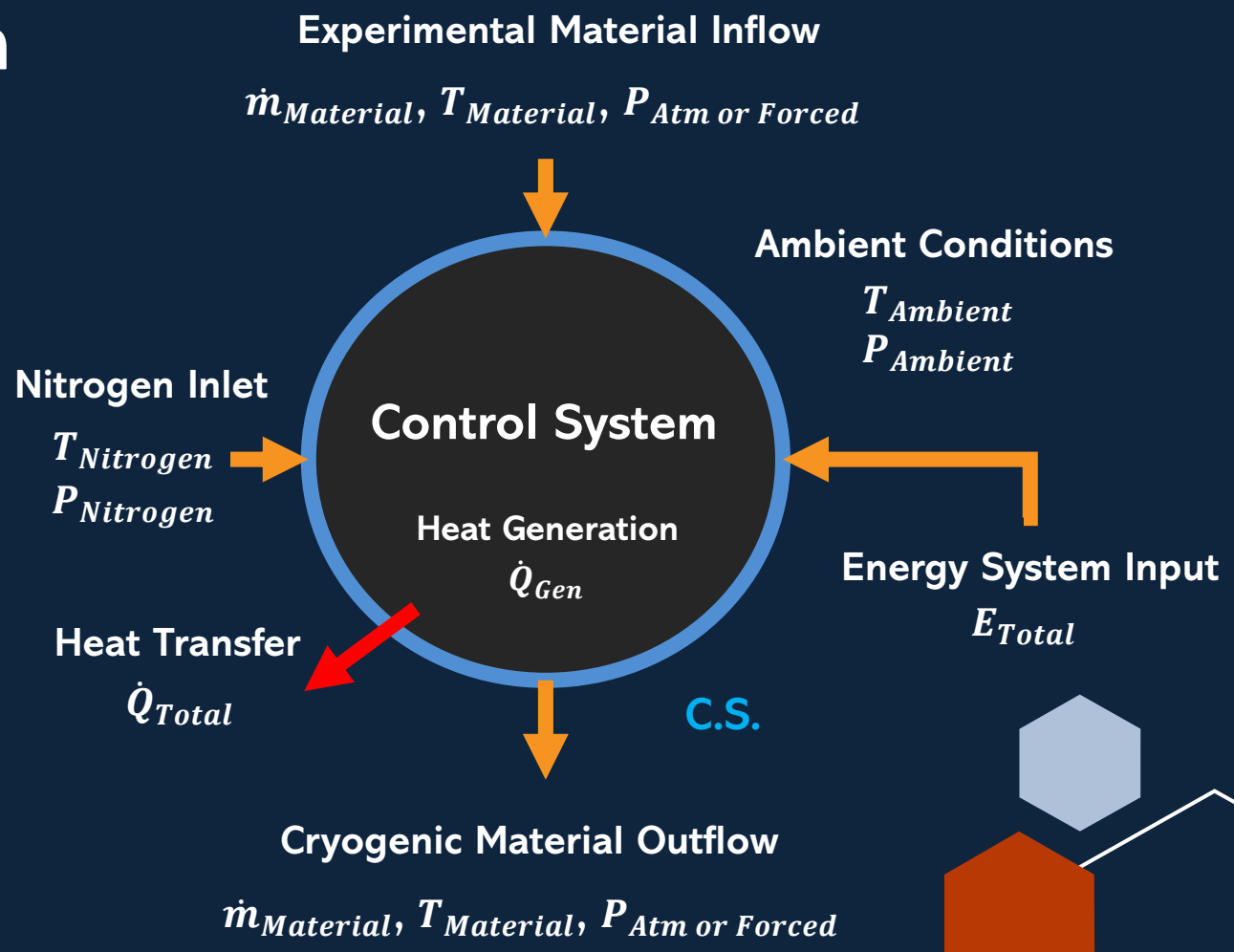
## Cryogenic Material Processing




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

## 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

## Nitrogen Integration

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

## Cryogenic Material Processing

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

Desired Material?

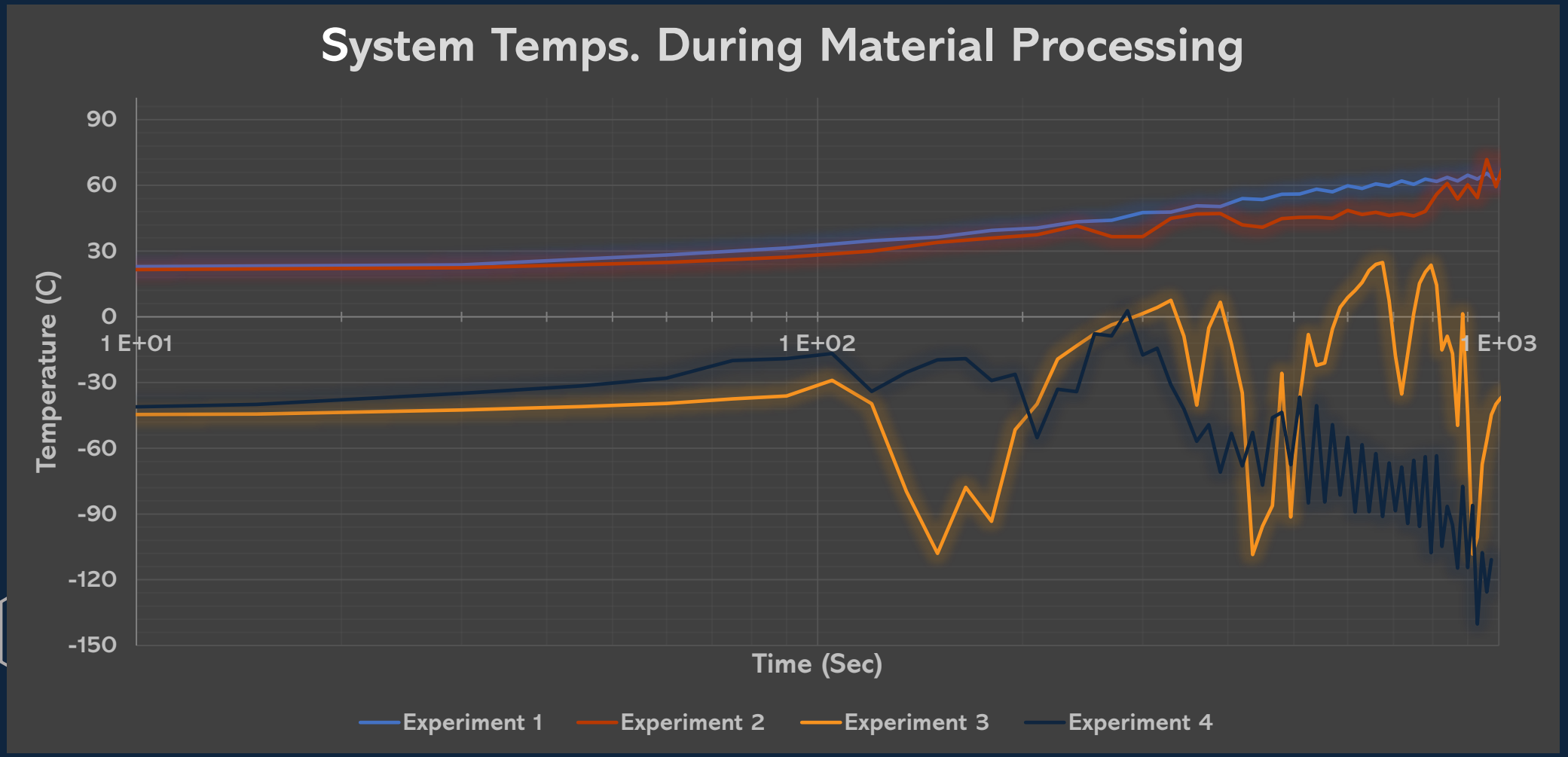
No
- Subcomponent Redesign, Nitrogen Phase-State Adjustments, Thermodynamic Calculations, Etc.

**Iterative Optimization**

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

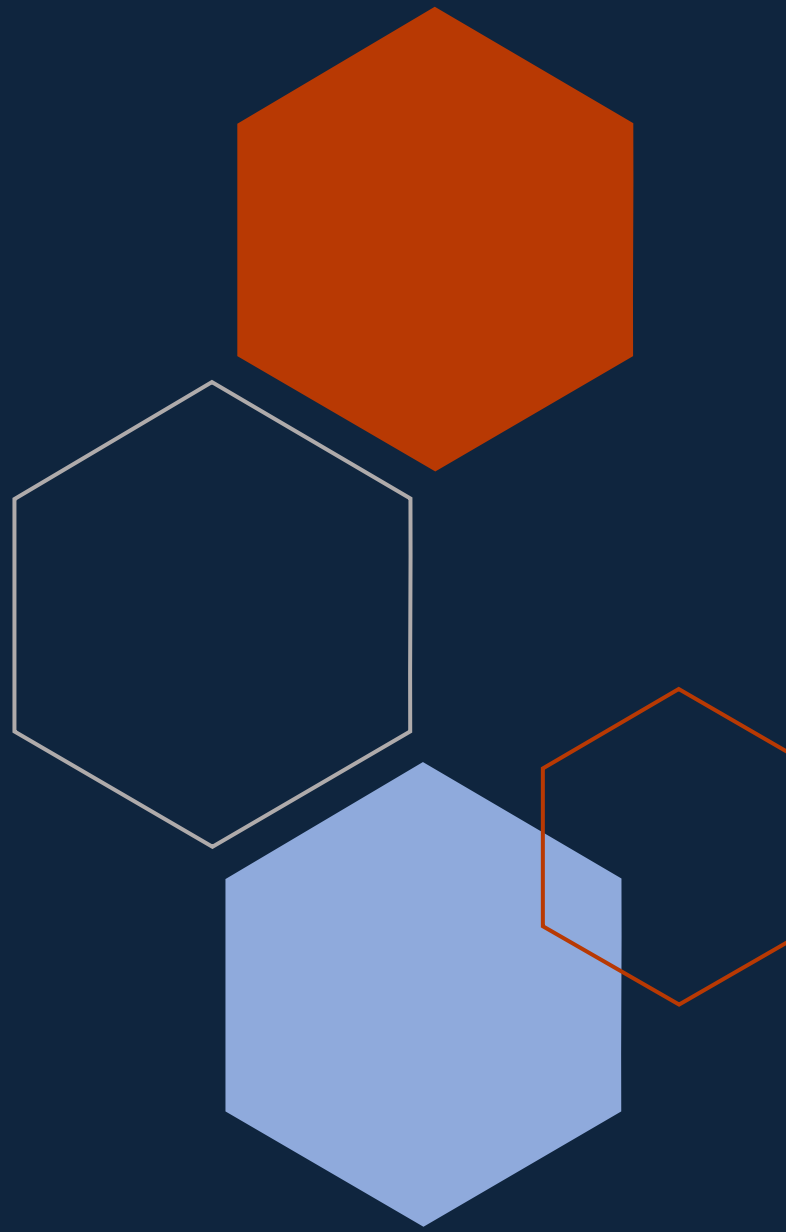
**Industrialize Process**

# Cryogenic Temperature Achievements



# Future Cryogenic 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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