

# CPS/Synergy/Collaborative Research: Cybernizing Mechanical Structures Through Integrated Sensor-Structure Fabrication

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**Challenge:** How to enable highly sensitive and robust real-time diagnosis and prognosis of mechanical structures to increase their functional performance and reliability/durability?

- Structural faults – extremely complicated and continuous in nature, with infinitely many possible patterns and severity levels.
- Active interrogation – promising, but hard to generate high-frequency actuation *inside* a structure; hard to gather sensing information.
- Sensor data analysis – generally insufficient information (small data) for an individual structure, contaminated by noise/uncertainty .

## Solution:

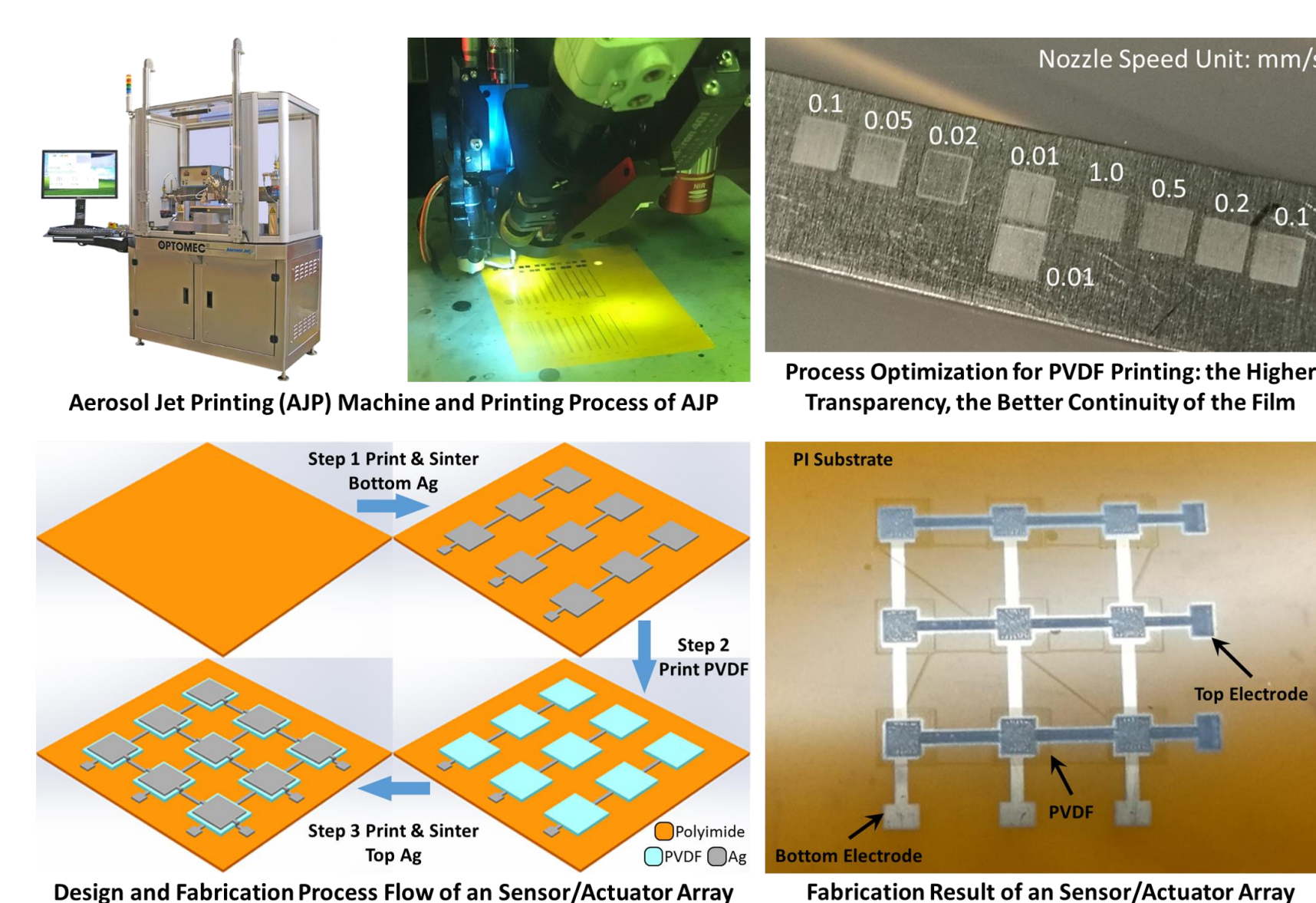
- Design of new additive manufacturing scheme – directly insertion of sensing nerves inside of structure.
- Synthesis of new sensing modality – dual-field electro-mechanical tailoring to realize tunable scanning and active interrogation.
- Formulation of data analytics algorithms – intelligent inference to identify fault location/severity and to guide sensor tuning.

## Broader Impact (Society):

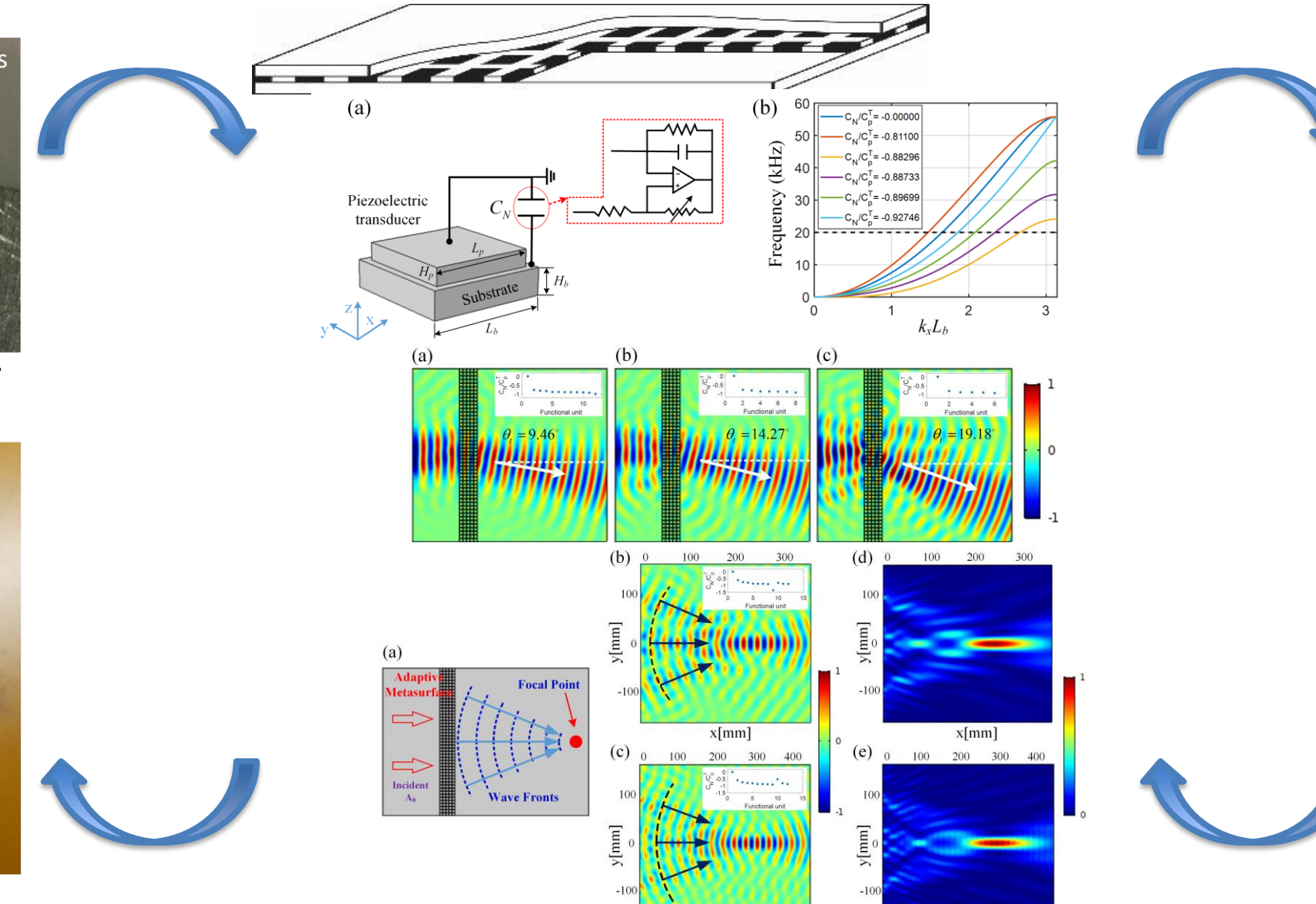
- Intelligent structural system with self-diagnosis capability will cause paradigm shift in structural design and operation.
- Benefit aerospace, mechanical, naval, manufacturing, and other industries.

**Scientific Impact:** Develop additive manufacturing technique to cybernize a structure through densely distributed active sensing elements

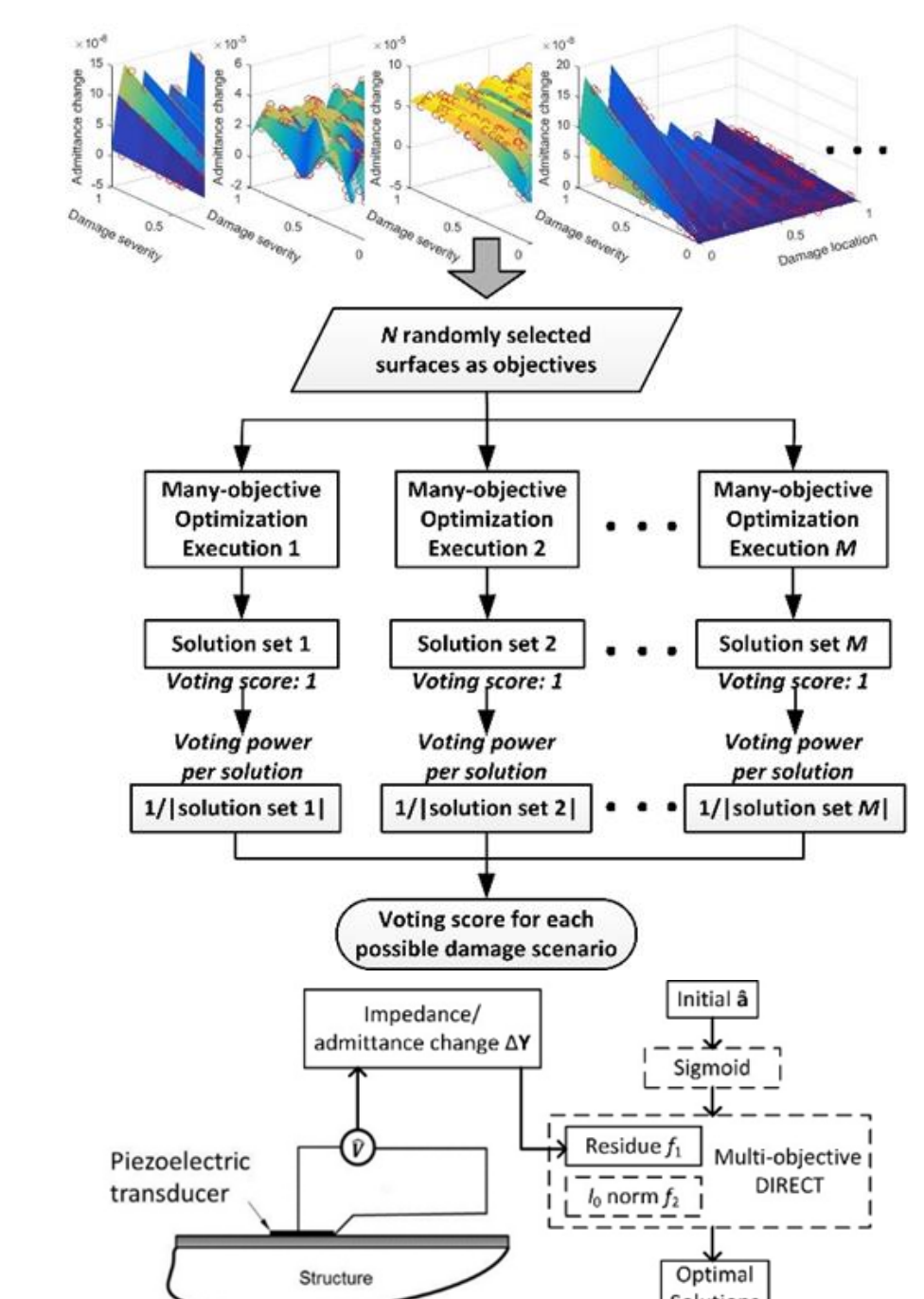
- Adaptive sensor/actuator design with wave guiding and circuitry integration – directional scanning/interrogation.
- Process optimization of additive manufacturing for structure inserted with active transducer array with enhanced electro-mechanical coupling.
- Hybrid inverse analysis algorithms featuring physics-informed data analytics for progressive fault identification, capable of identifying fault location/severity and predicting fault growth



Aerosol Jet Printing (AJP) process optimization for PVDF actuator/sensor array fabrication: high precision with strong electro-mechanical coupling



Piezoelectric metamaterial synthesis with tunable, continuous wave guiding for active interrogation



Fault identification realized by multi-objective and many-objective optimization algorithms

## Broader Impact (Education and Outreach):

- Develop inter-disciplinary teaching modules.
- Contribute to workforce training by promoting sensing/ manufacturing/ data analytics.

## Broader Impact (Potential Application):

- Fundamentally Increase the durability and reliability of composite structures.
- New frontier for intelligent structures made of functional materials