



# Smart Pulse Deice System with Integral SHM Sensors

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Innovative Dynamics Inc.

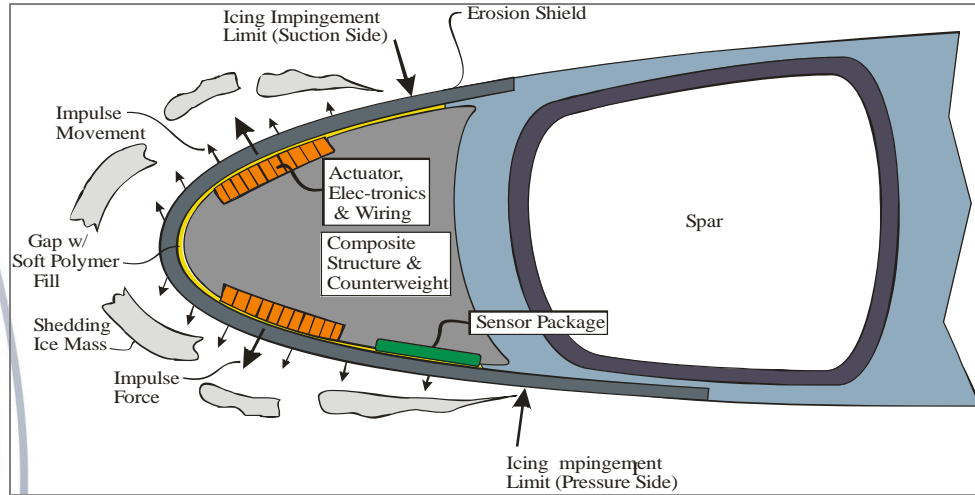
[www.icesight.com](http://www.icesight.com)



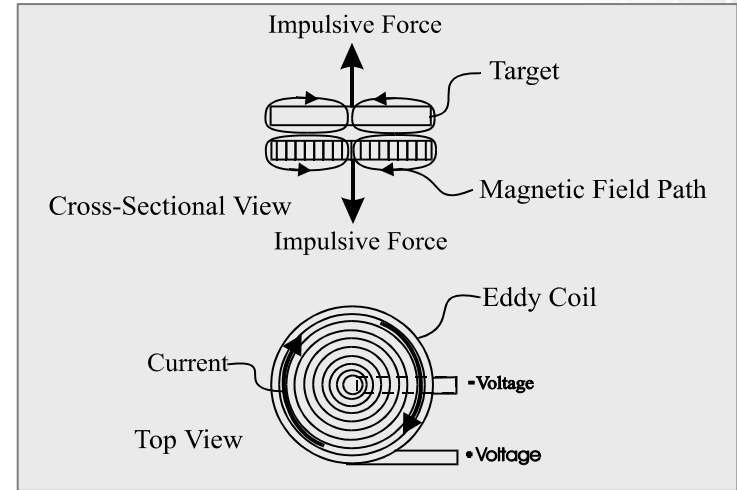
# About Innovative Dynamics

- Develops environmental sensors for aerospace and automotive industries
- Expertise includes sensors, ice protection systems, icing tunnel & in-flight testing
- New Technology Initiatives at IDI
  - Pulsed Deicer for Aircraft and Ships
  - Shape Memory Alloy Rotor Deicer
  - Vibro-Acoustic Structural Sensing
  - Ultrasonic Wear Debris Sensing

# What is a Pulsed Deicer



## Eddy-Current Type Actuator

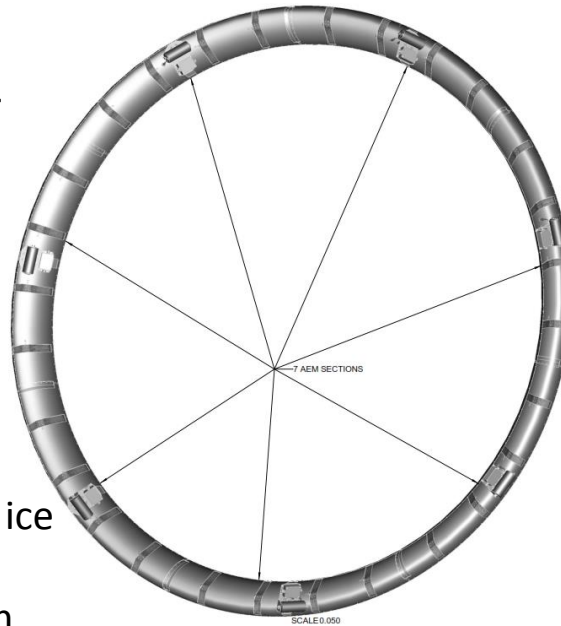


# Pulsed Deicer Uses Significantly Less Power Than Electro-Thermal Systems

- Electro-Thermal Deicer - 1000 watts per ft<sup>2</sup> (continuous)
- Electric Pulsed Deicer - 10 watts per ft<sup>2</sup>

# Integrated Ice Protection System Using SHM Approach

- Actuator mechanics located inside leading edge is mechanically coupled to outer skin
- Low level impulse applied to excite structural modes
- Change in vibration response (mass, stiffness, damping) indicator of anomaly
- External leading edge skin is rapidly accelerated to debond ice accretion
- Very clean shed, rugged design, conforming metal leading edge surface



*Propulsor Duct Deicer*

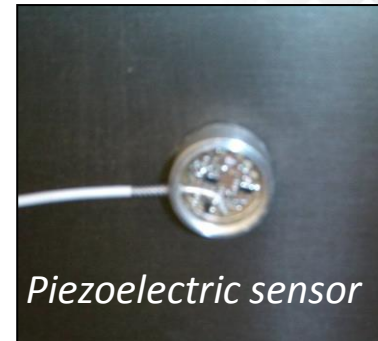


# SHM Diagnostic Capabilities

- A piezoelectric sensor works in conjunction with an impulse actuator
- Sensor is attached to the inside leading edge skin
- Detects the presence of ice by differences in the vibration signature of the structure
- Provides ice accretion monitoring to support automatic deicing control
- Provides system diagnostics such as actuator failure, structural disbonds, etc.



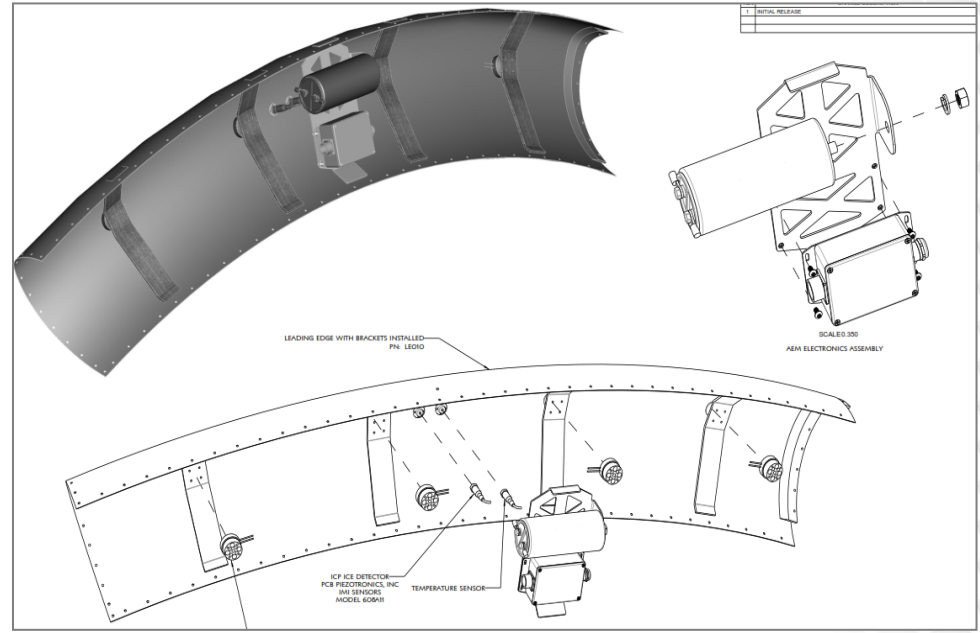
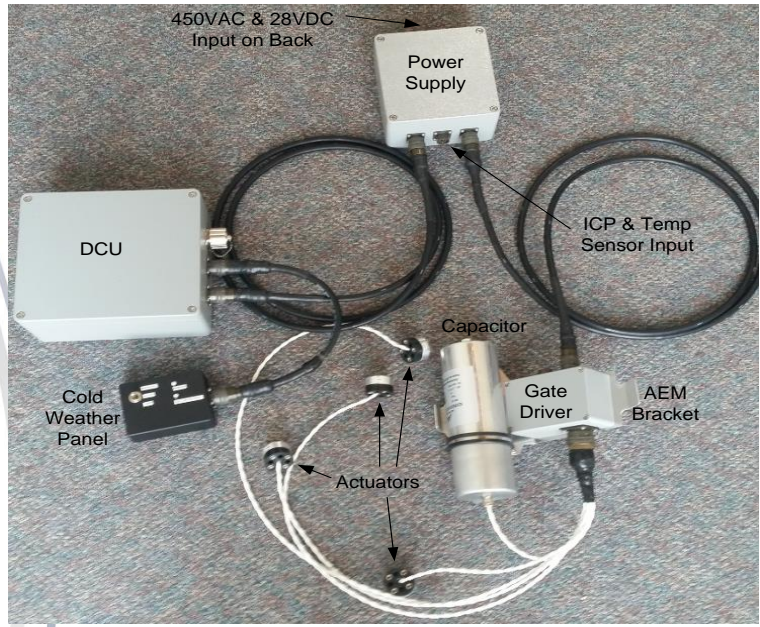
*Deicing Actuator*



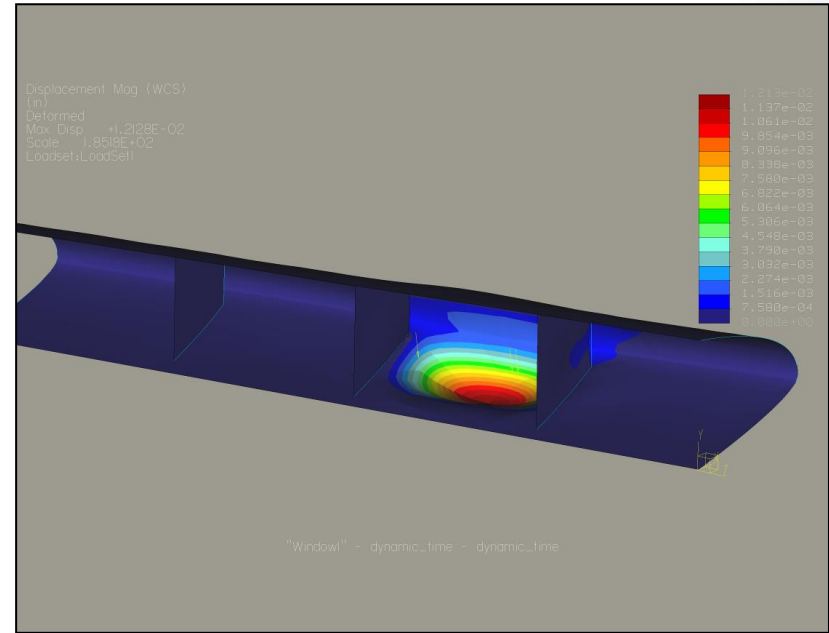
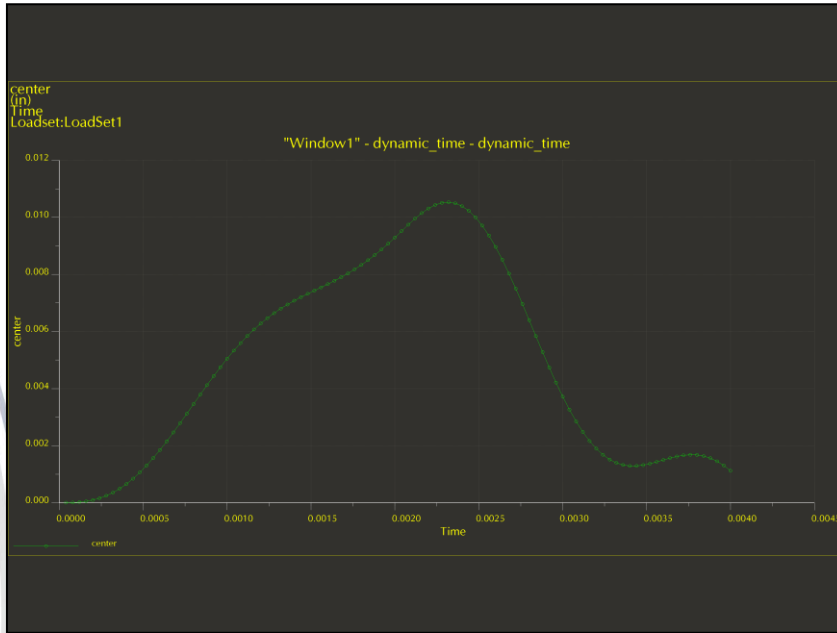
*Piezoelectric sensor*



# Ice Protection Hardware



# Leading Edge Dynamic FEM Analysis



- Material: Al6061-0.090 thick
- 80lb load applied as 0.004sec impulse
- Load applied within area 8.2"x1.5" centered between ribs
- All outer edges of leading edge have been fully constrained.



# Pulsed Deicer Icing Test – Boeing IRT



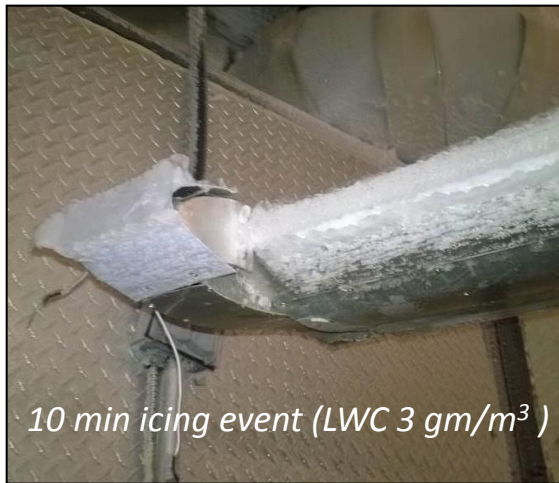
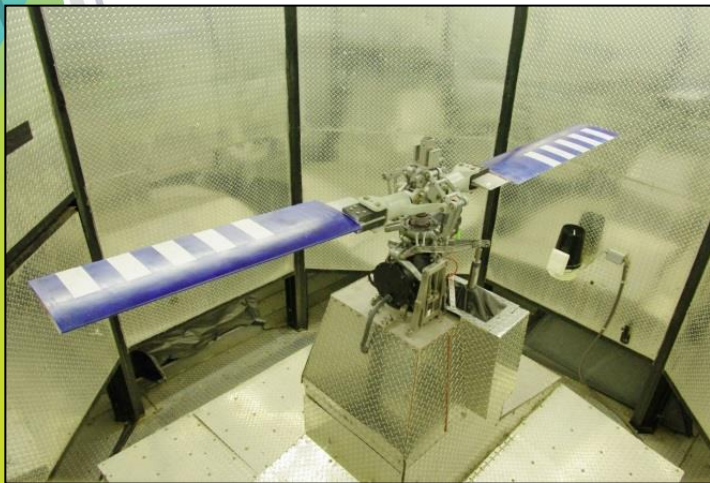
Ice buildup after 45 min hold



Actuator removes 5" glaze ice pack

# Pulsed Deicer Icing Test - AERTS

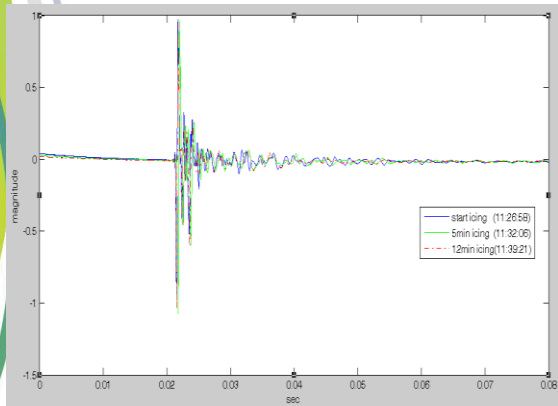
- Closed loop ice protection system tested at Penn State University Atmospheric Environmental Icing Tunnel (AERTS)
- Icing cloud generated with precision spray nozzles
- Rotor icing test section on blade tip



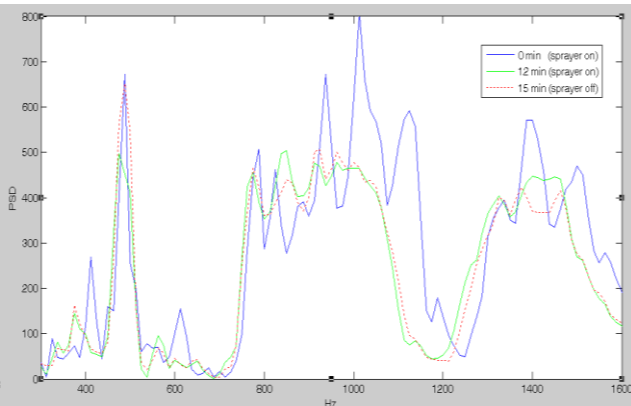
# Sensor Response and Icing Condition Indicator

- Mechanical impulse generates time signal
- Frequency domain data shows icing trend
- Change in vibration response (mass, stiffness, damping) indicator of anomaly
- Condition indicator follows ice thickness
- Baseline condition indicates ice removal

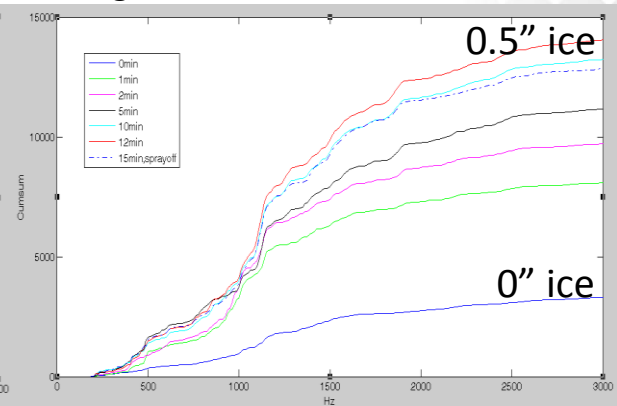
*Impulse Response*



*Frequency Response*



*Icing Condition Indicator*



# Pulsed Deicer Advantages?

- Energy efficient, relatively low power
- Energy to achieve high G levels on thick skin aircraft on the order of 500 Joules per ft<sup>2</sup> or ~5KW for 737 category Aircraft
- Eliminates need for Hot Engine Bleed Air
- No RUNBACK or REFREEZE Ice
- Pulse can work through composite skins
- Can remove ice layers of 0.050" and greater
- On Demand activation with SHM Sensors