Actuated Electromagnetic System for Ice Removal

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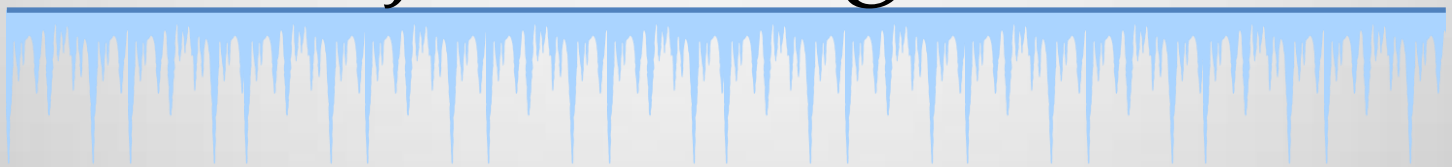
Agenda

1. Project Background
2. Design Description
3. Design Verification and Validation
4. Conclusion

Project Background



Project Background

Problem: Ice buildup on aircraft wings in flight

- Decreases Lift-to-Drag Ratio (L/D)
- Reduces mission capabilities
- In extreme cases can result in a crash

Ice formation on wing.[1]

Orion UAV [2]

Application: ORION Aircraft

- 5 day continuous flight time
- 132 ft. wing span
- Cruising altitude of 20,000-30,000 ft. at 65 kias

Requires: Low mass, low power deicing system to increase flight path possibilities without decreasing capabilities

Problem Requirements

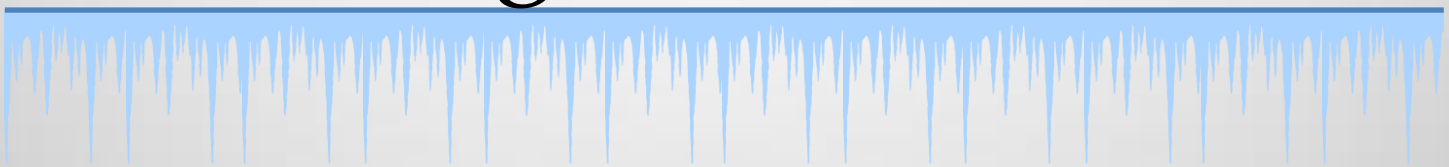
Problem Statement: Design, build, and test a small-scale prototype of a deicing system for the Orion UAV.

Functional Requirements

1. The full-scale system shall be **integrable with the Orion UAV**.
2. The prototype shall **remove ice**.
3. The full-scale system shall use **less than 4kW-hr to deice** the wing section.

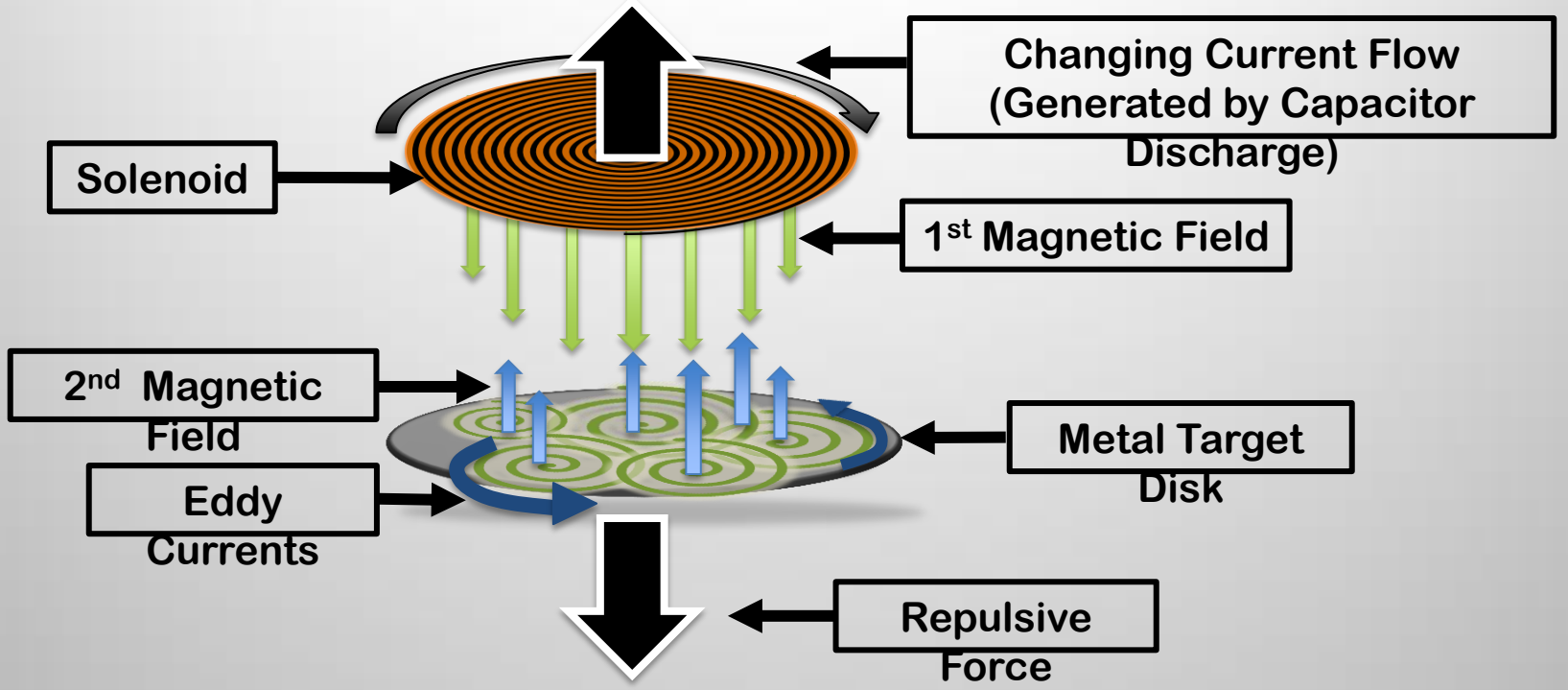
Orion UAV in flight [3]

Design Overview

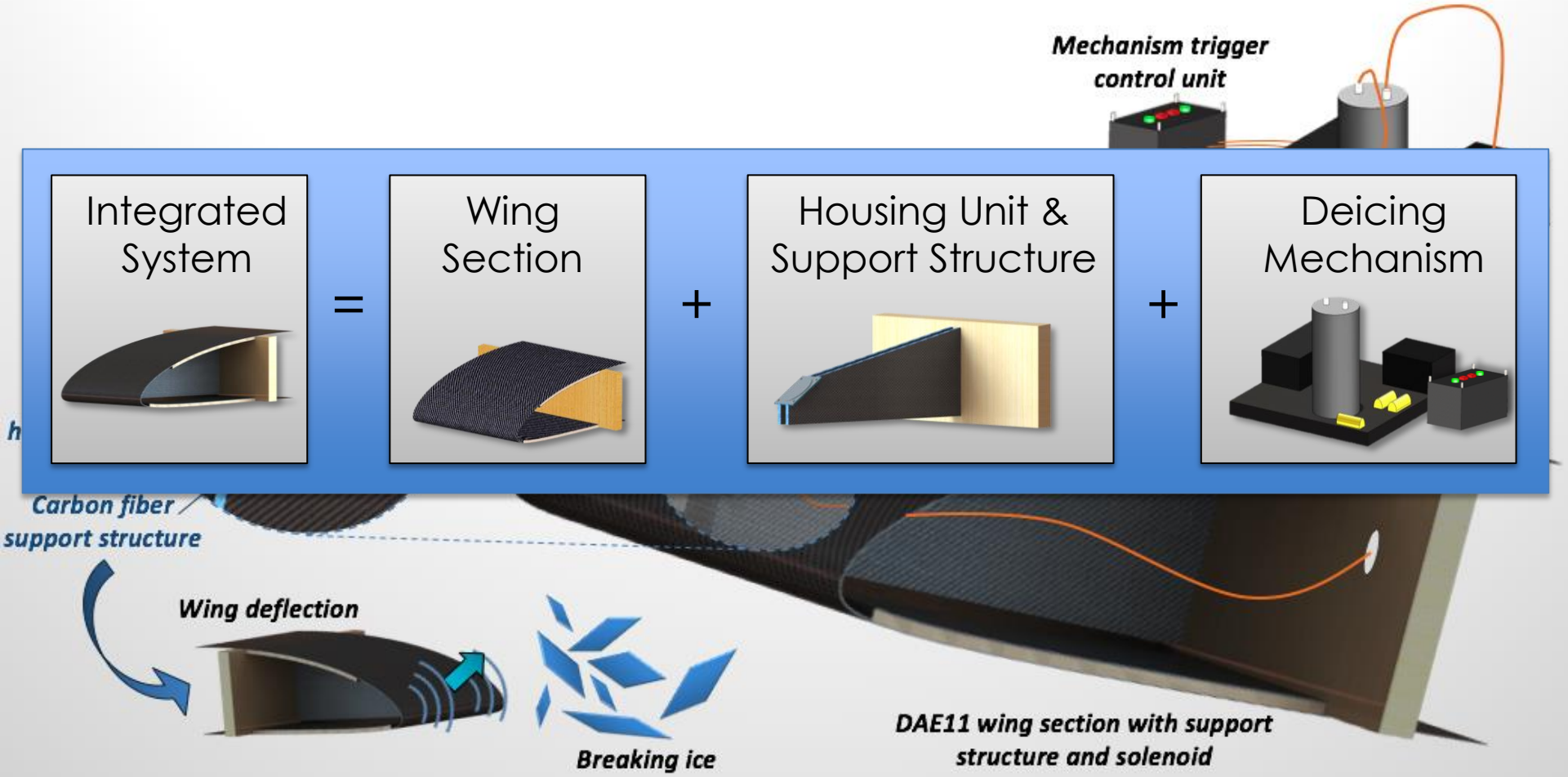


Electromagnetic Solution

Generate a force using electromagnetics- force impacts leading edge of wing and breaks ice



Solution Integration



Design Verification and Validation

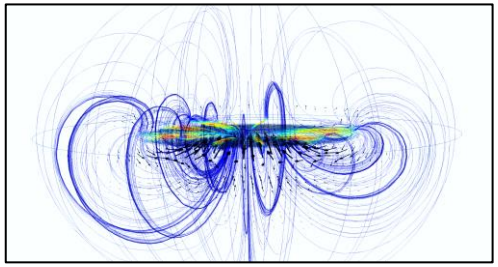
Modeling

Modeling Goals

1. Find force produced by designs
2. Find force required to break ice
3. Check that force does not damage material
4. Refine force, material, and ice values with testing

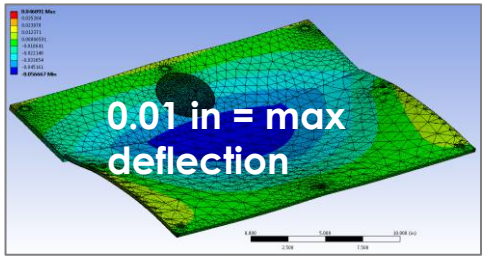
Solenoid Force Model

- COMSOL- Calculate force based on solenoid and target disk parameters



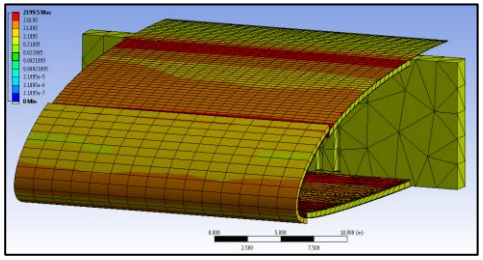
Flat Plate Model

- ANSYS- Calculate expected deflection of material under force



Wing Section Model

- ANSYS- Calculate force required to break ice
- Model that no structural damage occurs with lifetime

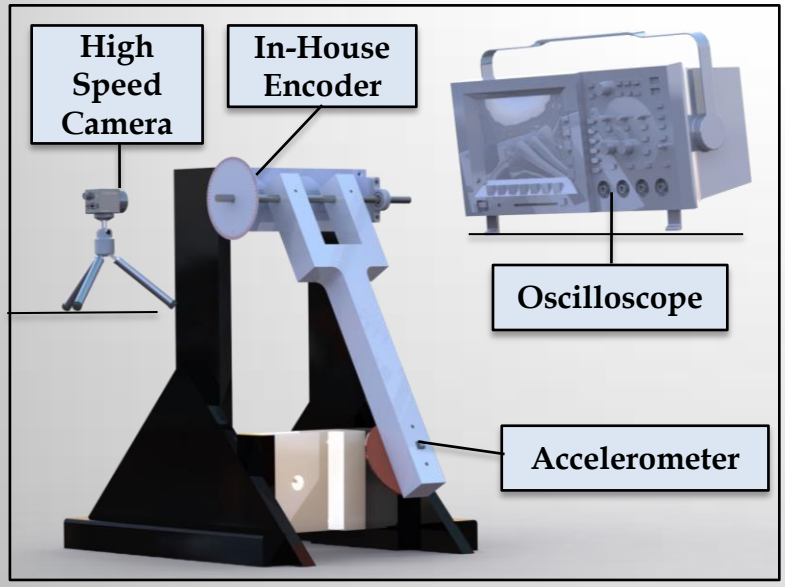


High Level Test Overview

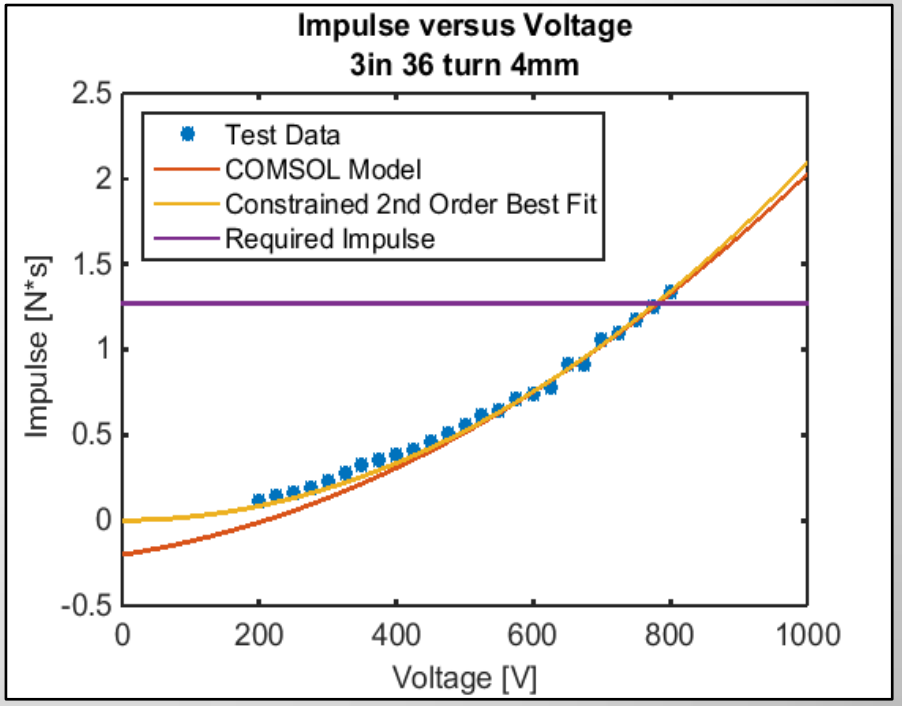
TEST	PURPOSE
Ballistic Pendulum Test	• Verify Solenoid Force Model • Gather experimental data on solenoids
Laser Deflection Test (Flat Plate)	• Measure the deflection to verify material properties via Flat Plate Model
Ice Breaking Test (Flat Plate & Wing Section)	• Verify force required to break ice • Prove functionality while meeting power and integration requirements

Ballistic Pendulum Testing

Test Setup



Results

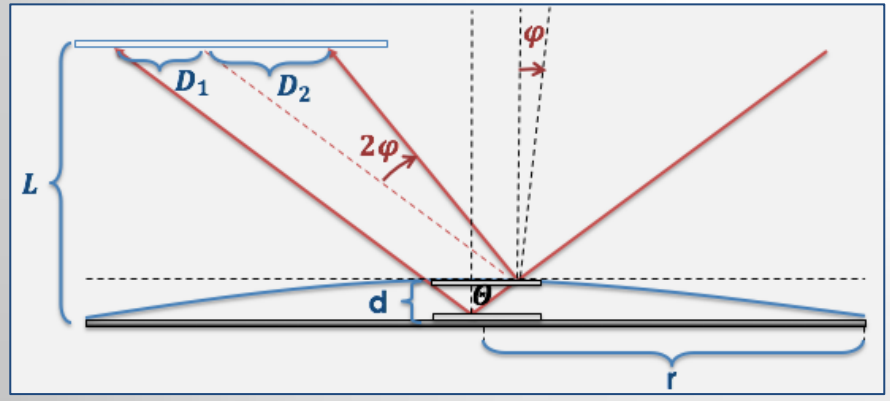


Conclusion

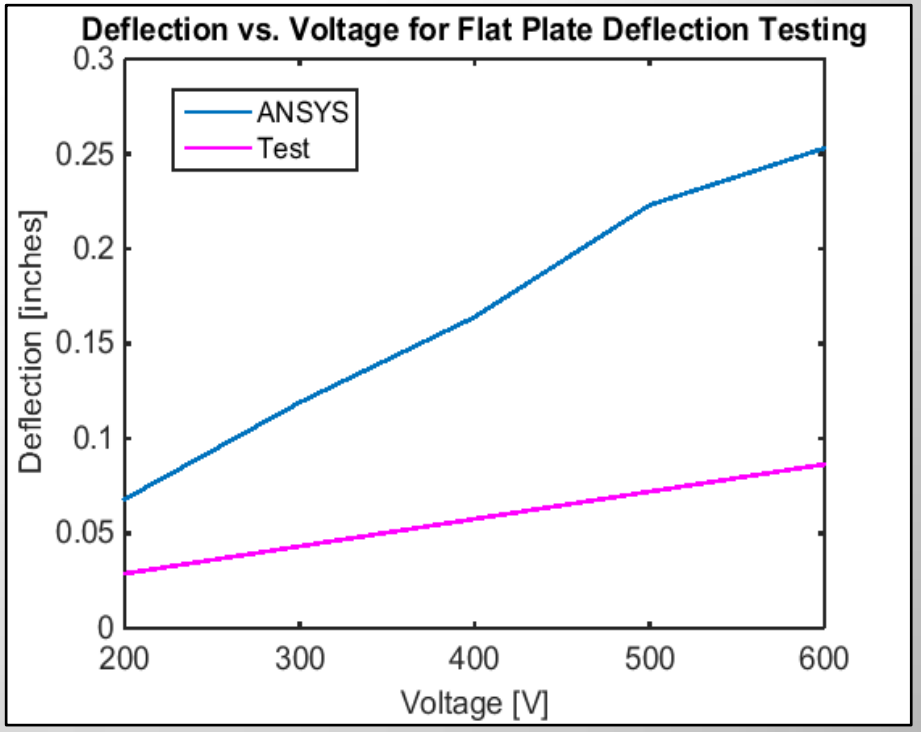
- Model predicted impulse matches test results
- Modeling software limitations- based on experimental data trends, solenoid design was improved upon

Flat Plate Testing

Test Setup



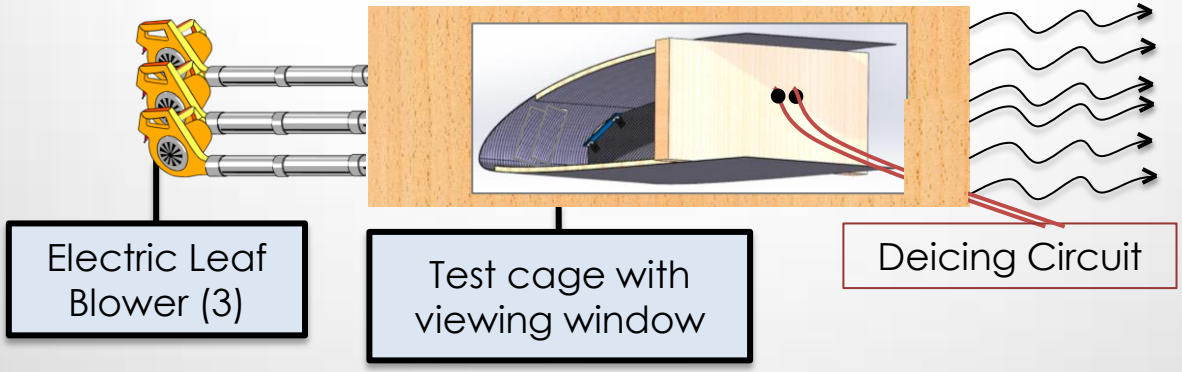
Results



Conclusion

- Experimental deflection is less than modeled
- Adjustments to material values

Wing Section Testing



Start

After 1 Impulse

After 2 Impulses

After 3 Impulses

Conclusion

- ANSYS model predicts requiring 40.5 lb. force to break ice with one impulse
- Required 3 impulses at 40.5 lb. force

Ice Breaking Test

Conclusion

Conclusion of Testing

1. Solenoid Design
- Verified force required to break ice can be produced
- For given voltage, larger diameter creates larger impulse but possible size limited by wing shape and manufacturing

2. Materials
- Carbon fiber deflects less then expected- less strain
- Values used for ice adhesion have uncertainty

3. Functionality
- Solution does break ice
- Less deflection then predicted means more impulses required to completely clear wing

Full Scale Integration

Orion UAV takeoff [4]

From testing, 1 Solenoid clears 2 ft. section of ice off wing section

→ For full-span, deicing requires **62 solenoids + Housing + Supporting Circuitry**

Total Mass Estimate = 200 lb.

Total Power Estimate = 310 W to recharge and fire at 5 minute intervals

Note: requires further testing to account for extra rigidity of ORION wing ribs and further testing on ice crack and shed areas

Ice Breaking Demo

Come see a demo of breaking ice at
2:30 pm

Sources

[1] "Aurora's Orion MALE UAV Aims For 120-hr. Flight," Aviation Week. Sept. 17, 2013.

[2] "Aurora Orion UAV Could Cut ISR Costs 80%," Aerospace. Nov. 30, 2010.

[3] *Aurora Flight Sciences*. AFS website. Accessed April 13, 2016

[4] "Orion Unmanned Aircraft World Record Confirmed," Aurora Flight Sciences. July 1, 2015.