
# Actuated Electromagnetic System for Ice Removal

## Manufacturing Status Review
## February 4, 2016

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# Overview

# Problem Statement & Objectives

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

*Orion UAV*

**Functional Requirements**

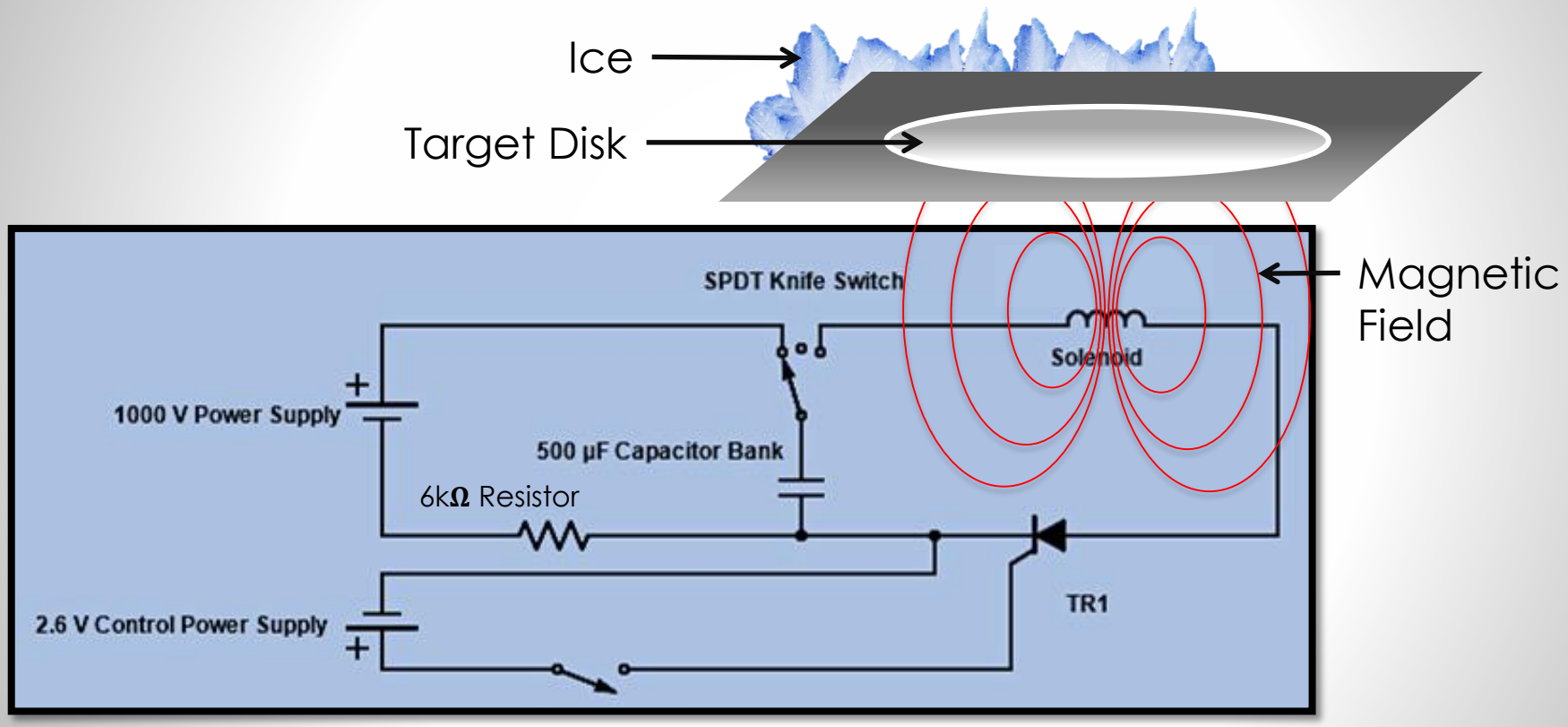
FR.1 - The full-scale system shall be **integrable with the Orion UAV**.

FR.2 - The prototype shall **remove ice**.

FR.3 - The full-scale system shall use **less than 4kW-hr to deice** the wing section.

# Design Overview

## Electromagnetic Deicing Mechanism

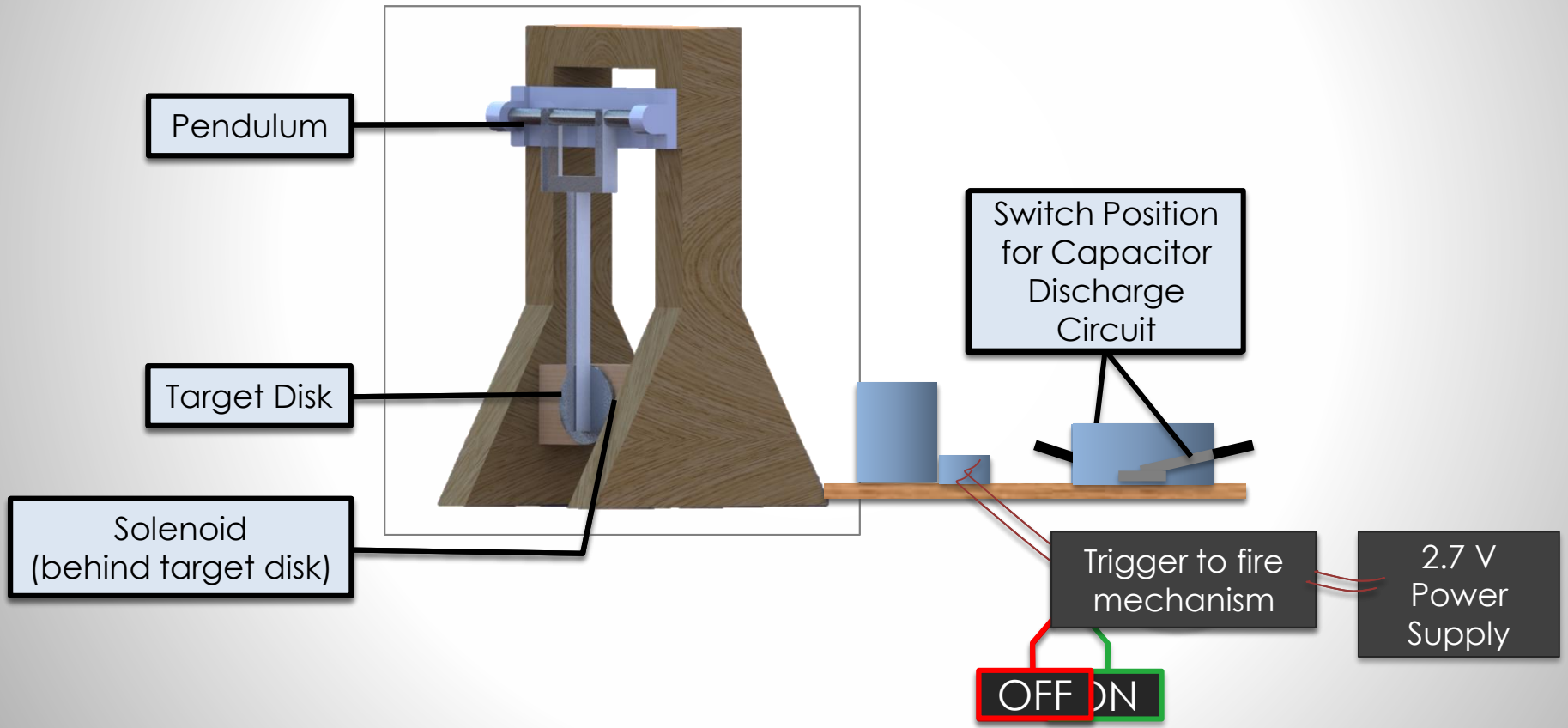



**Deicing Mechanism = Baseline design used for all levels of success**

# Level 1 Success – Design & Conops

**Purpose of Level 1:**

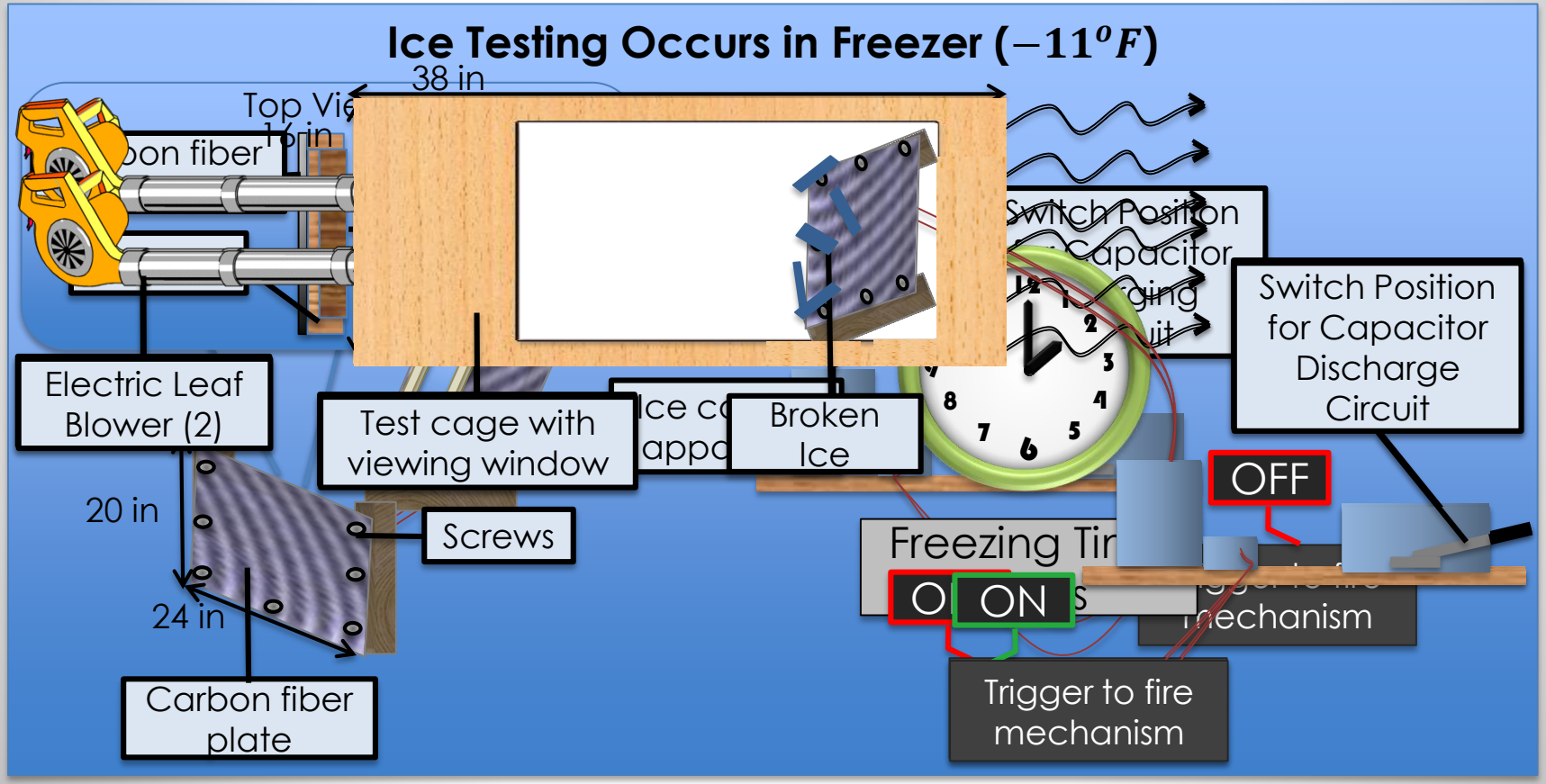
- Proof of Concept of circuit and electromagnetic theory
- Solenoid Force Model verification



# Level 2 Success – Design & Conops

**Purpose of Level 2:**

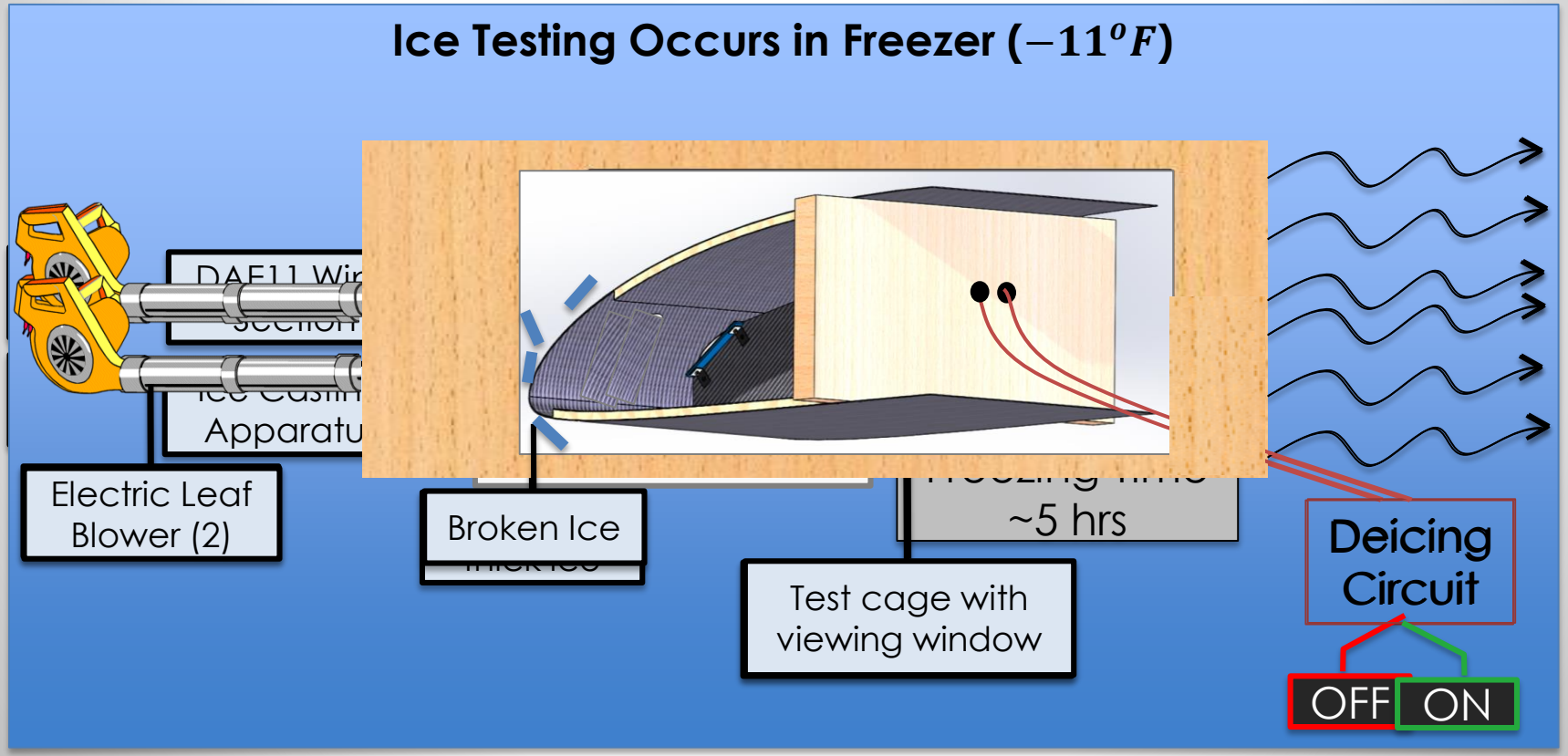
- Testing for ice breaking capabilities on a carbon fiber test article



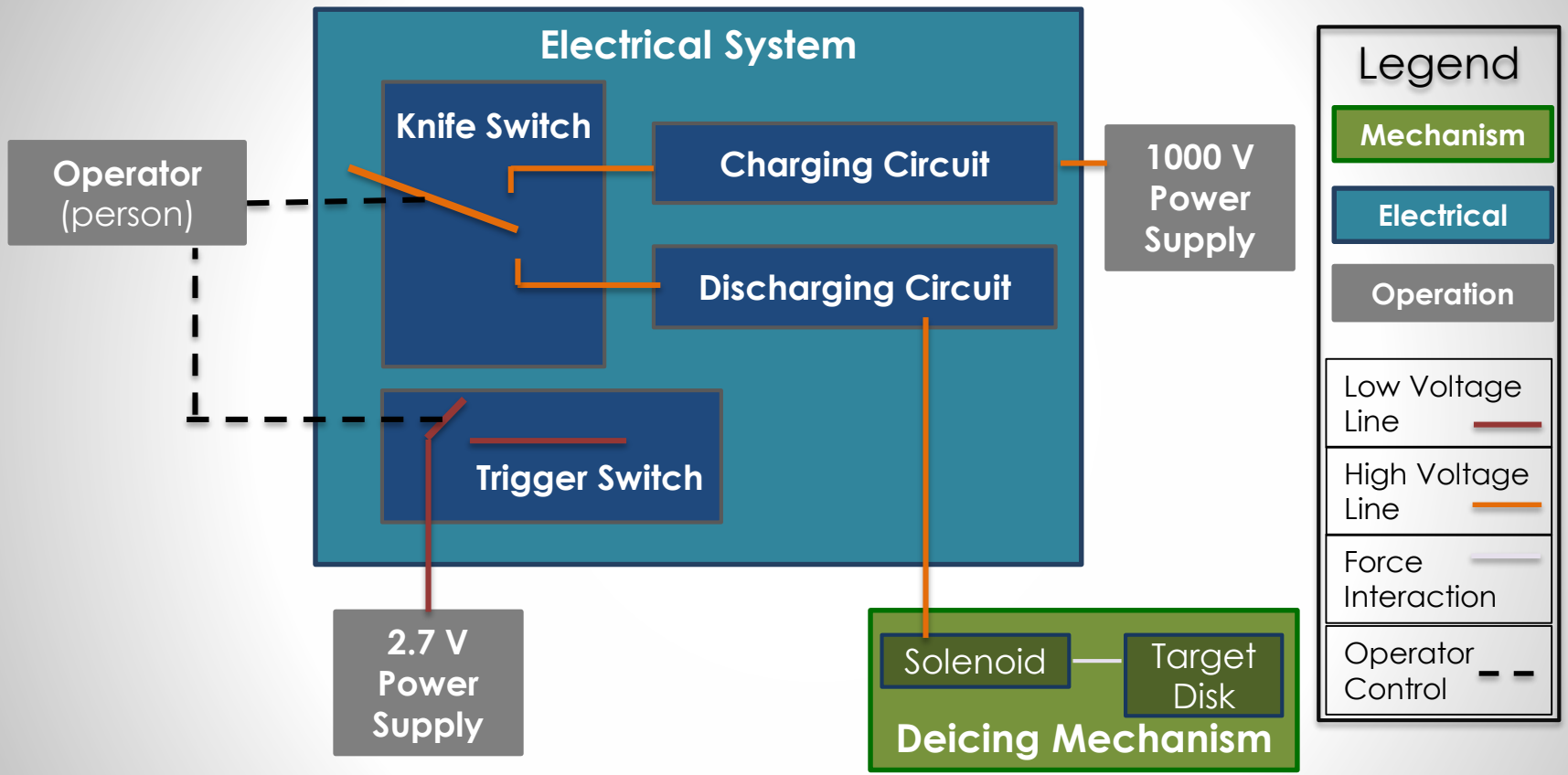
# Level 3 Success – Design & Conops

**Purpose of Level 3:**

- Integration into wing structure like Orion UAV
- Testing in flight like wing section and conditions

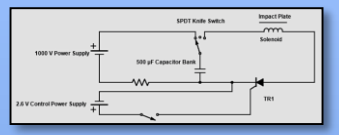


# Functional Block Diagram

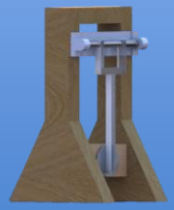


# Critical Project Elements

## Ballistic Pendulum

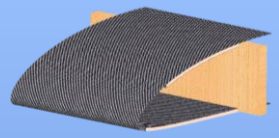



Deicing Mechanism

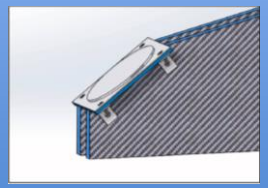


Pendulum Assembly

## Wing Section



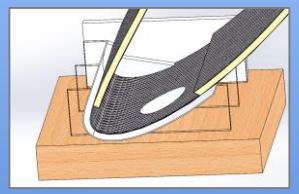
Test Section



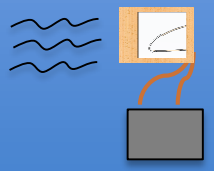
Housing Unit & Support Structure

## Test Setup

Sensors



Ice Casting

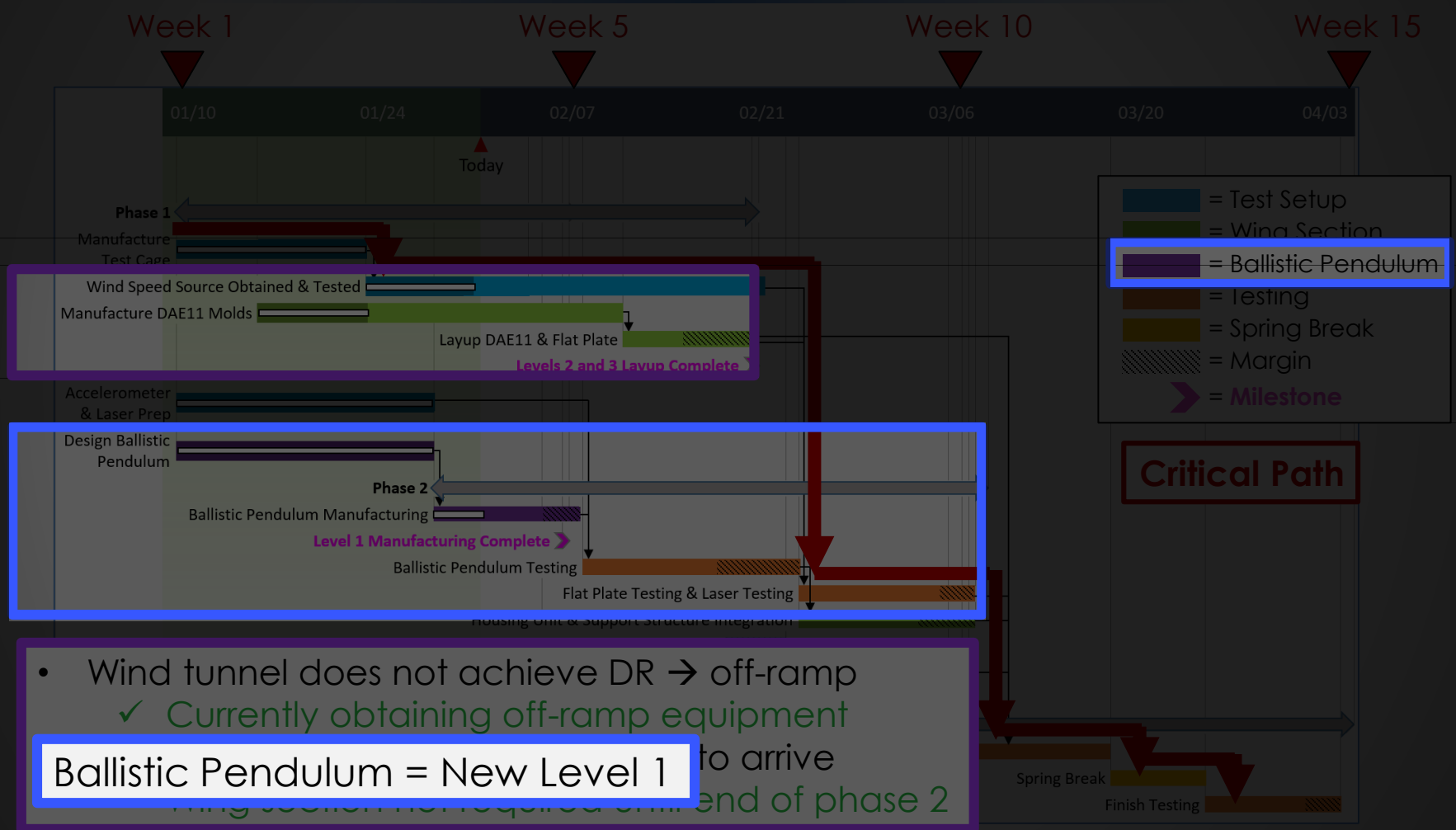


Wind Speed & Test Cage

# Schedule

# Current Schedule

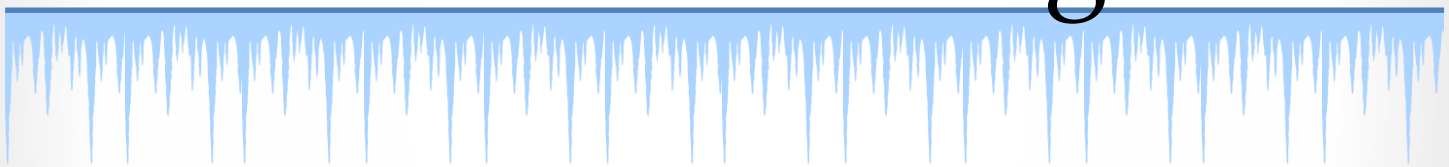
Spring 2016




- Wind tunnel does not achieve DR → off-ramp
  - ✓ Currently obtaining off-ramp equipment
  - to arrive
  - end of phase 2

Ballistic Pendulum = New Level 1

# Manufacturing

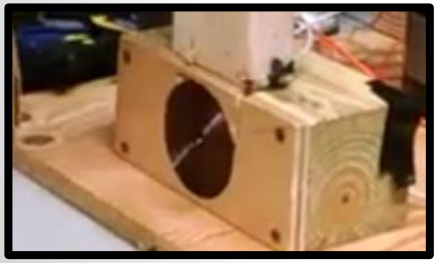


Ballistic Pendulum ⟶ Wing Section ⟶ Test Setup

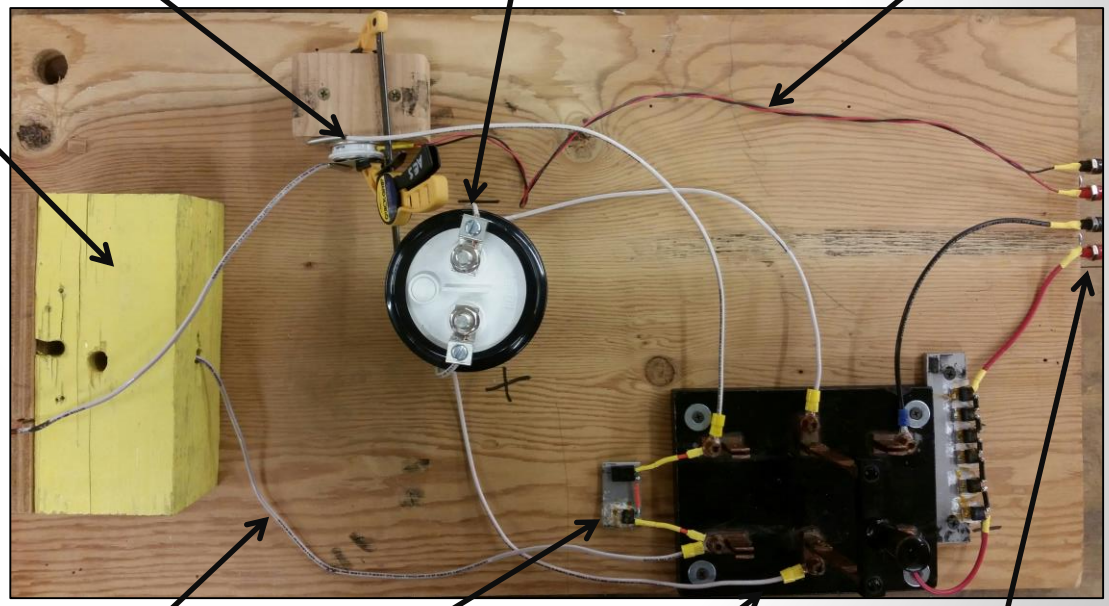
# Ballistic Pendulum – Description

Ballistic Pendulum = **Deicing Mechanism** + **Pendulum Assembly**

**Completed**



*Solenoid in housing block*



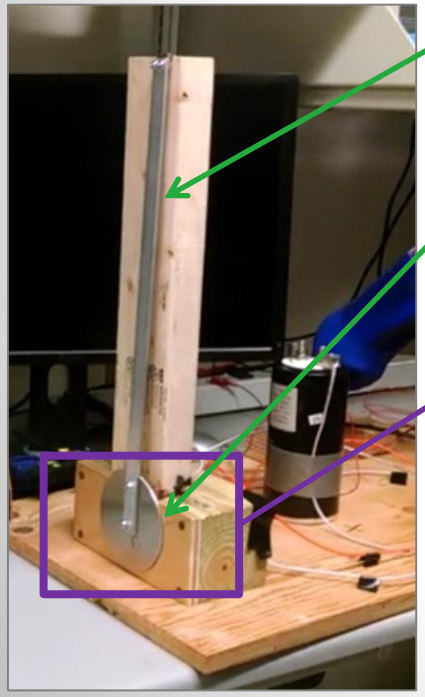

* All circuit components rated for 1000V

# Ballistic Pendulum – Proof of Concept

Ballistic Pendulum = **Deicing Mechanism** + **Pendulum Assembly**

**Completed**

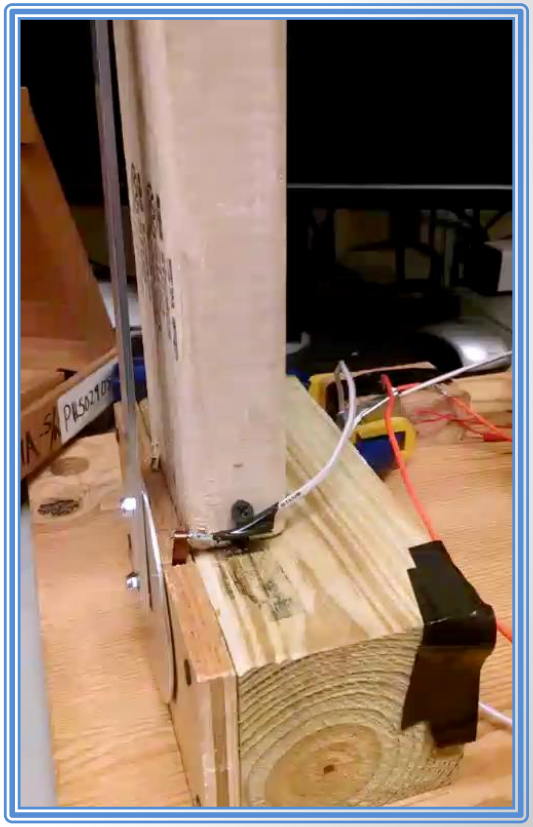
**Pendulum Assembly***




**Solenoid Assembly**


* Deicing mechanism not shown

**Proof-of-Concept Test*** (50V)

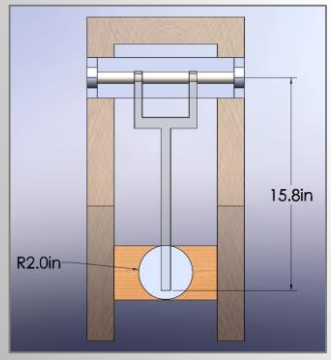


# Ballistic Pendulum - Overview

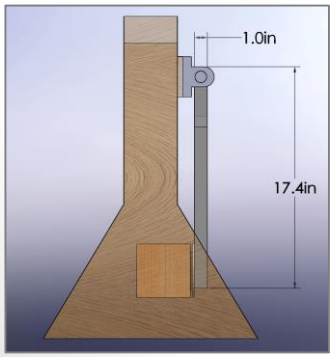
Ballistic Pendulum = **Deicing Mechanism** + **Pendulum Assembly**

**In Progress**

*Pendulum Assembly*




*Front View*




*Side View*

*** All components built in-house**

Aluminum Brace

Aluminum Pillow Bearing

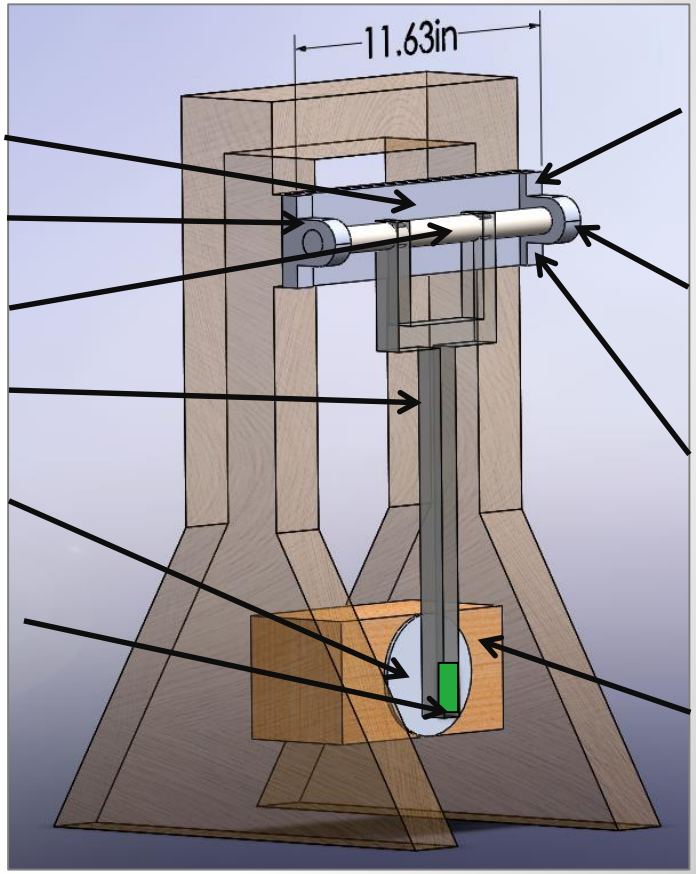
Aluminum Pivot Rod

Acrylic Pendulum Arm

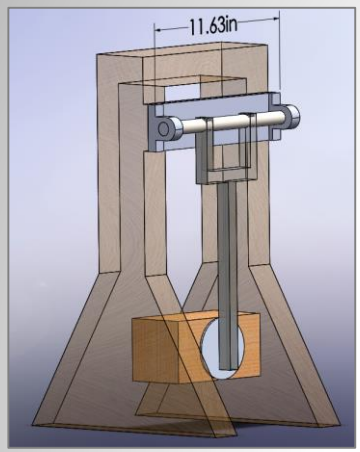
Aluminum Target Disk

Accelerometer

***All materials received except acrylic – 2/2**



# Ballistic Pendulum – Manufacturing Status



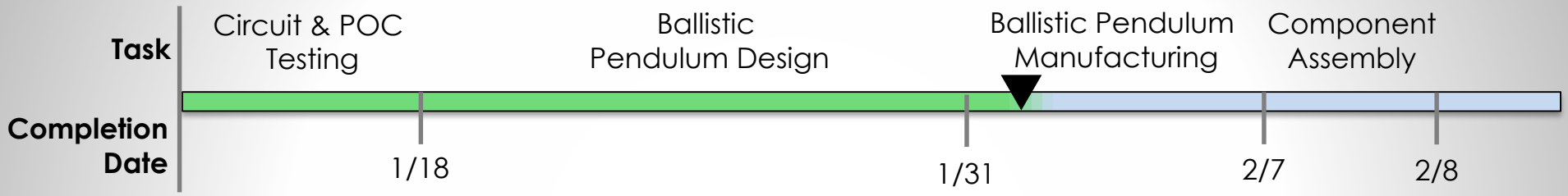

*Ballistic Pendulum*

| Task | Status | Estimated Man-Hours Remaining | Completion Date |
|---|---|---|---|
| Build Deicing Circuit & Test Proof of Concept | **Complete** | --- | 1/18 |
| Build Circuit Safety Cage | **Complete** | --- | 1/31 |
| Obtain Ballistic Pendulum Materials | **Complete** | --- | 2/1 |
| Machine Pillow Bearings | **In Progress** | 4 | 2/8 |
| Machine Acrylic Pendulum Arm | **In Progress** | 3 | 2/8 |
| Machine Aluminum Pivot Rod | **In Progress** | 2 | 2/8 |
| Machine Aluminum Brace | **In Progress** | 1 | 2/8 |

**70% Complete (Man-Hours)**

Total Man-Hours Remaining for Manufacturing Ballistic Pendulum: **10 hrs**

# Ballistic Pendulum – Overall Status




= Up-to-Date Progress

= On-Schedule Marker

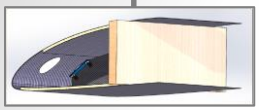
**STATUS:** On Schedule

Manufacturing for level 1 success completed by: 2/8

25% margin in days

# Wing Section – DAE 11 Layup Overview

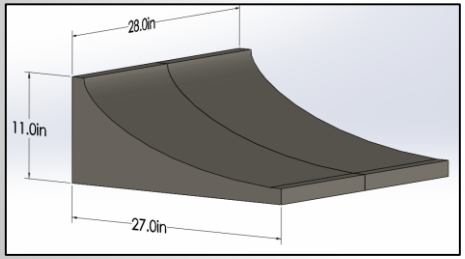
Wing Section = DAE11 Wing Layup + Housing Unit & Support Structure



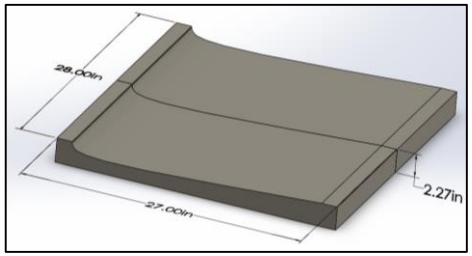
Machine Foam Molds → Prepreg Carbon Fiber Layup →Vacuum Bag → Cure (3 hrs, 250°F)

## In Progress

*Upper Surface Mold*




*Lower Surface Mold*




***Machine Foam Molds (CNC) – Upper & Lower Surfaces***

- *Allow for 14% margin in span during layup*
- *Negative layup with upper and lower surfaces attached*

## Future Work

***DAE11 Layup with Wooden Spar***

- *Includes rib on one end (dragon plate with epoxy)*

*** All materials are received with excess foam and prepreg**

# Wing Section – Housing Unit & Support Structure Overview

Wing Section = DAE11 Wing Layup + Housing Unit & Support Structure

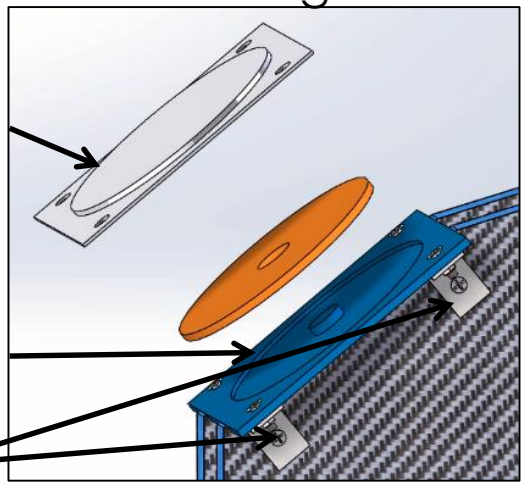
**Future Work**

## Housing Unit

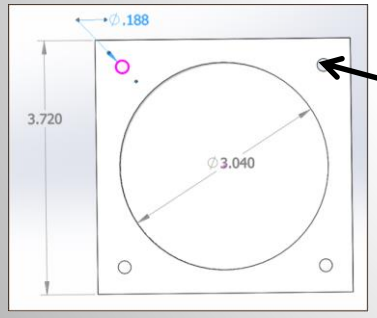
Top Plate (Polyethylene)

Base Plate (Polyethylene)

L-Brackets & Through Holes



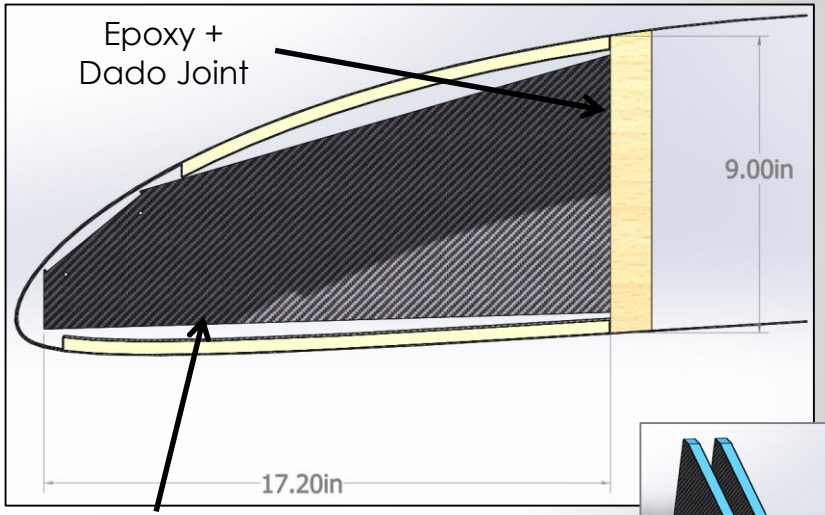
***Solenoid Housing Unit***




Countersink screw

***Top Plate with Dimensions [in]***

## Support Structure

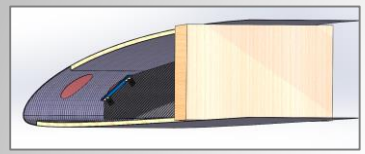



**Carbon fiber (foam core) support structures (Dragon Plate) – laser cut**
(1 support structure = 2 laser cut dragon plates)

***Front View of 1 Support Structure***

***All materials are received**

# Wing Section – Manufacturing Status



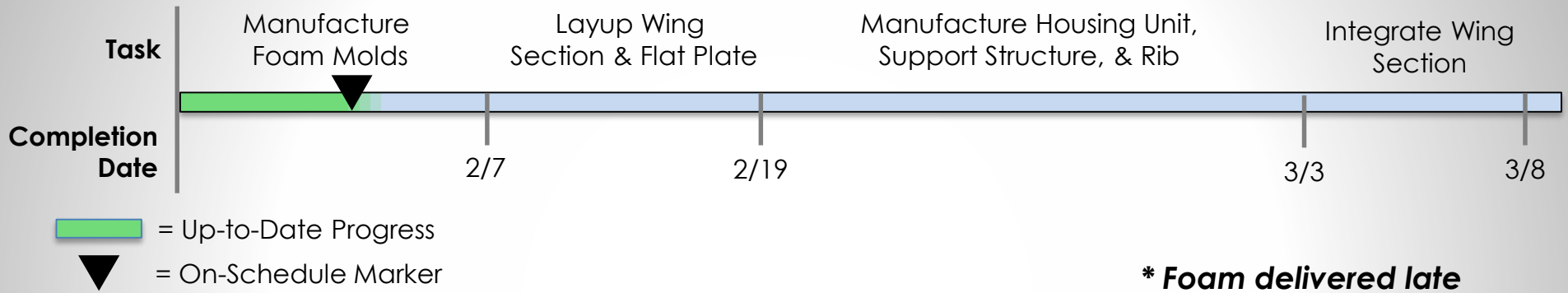
*Wing Section*

| Task | Status | Estimated Man-Hours Remaining | Completion Date |
|---|---|---|---|
| Obtain All Wing Section Materials | **Complete** | --- | 1/24 |
| Machine Foam Molds | **In Progress** | 10 | 2/8 |
| Layup DAE11 & Flat Plate | **Future Work** | 6 | 2/19 |
| Machine Housing Unit | **Future Work** | 5 | 3/3 |
| Cut Support Structure & Rib | **Future Work** | 6 | 3/3 |
| Wing Section Integration | **Future Work** | 4 | 3/8 |

**10% Complete (Man-Hours)**

Total Man-Hours Remaining for Manufacturing Wing Section: **31 hrs**

# Wing Section – Overall Status




**STATUS:** On Schedule *

**** Foam delivered late***
*→ Schedule allowed for adjustment in layup completion date*

Manufacturing for level **2** wing section completed by: 2/19

20% margin in days

Manufacturing for level **3** wing section completed by: 3/8

30% margin in days

# Test Setup – Sensors Description

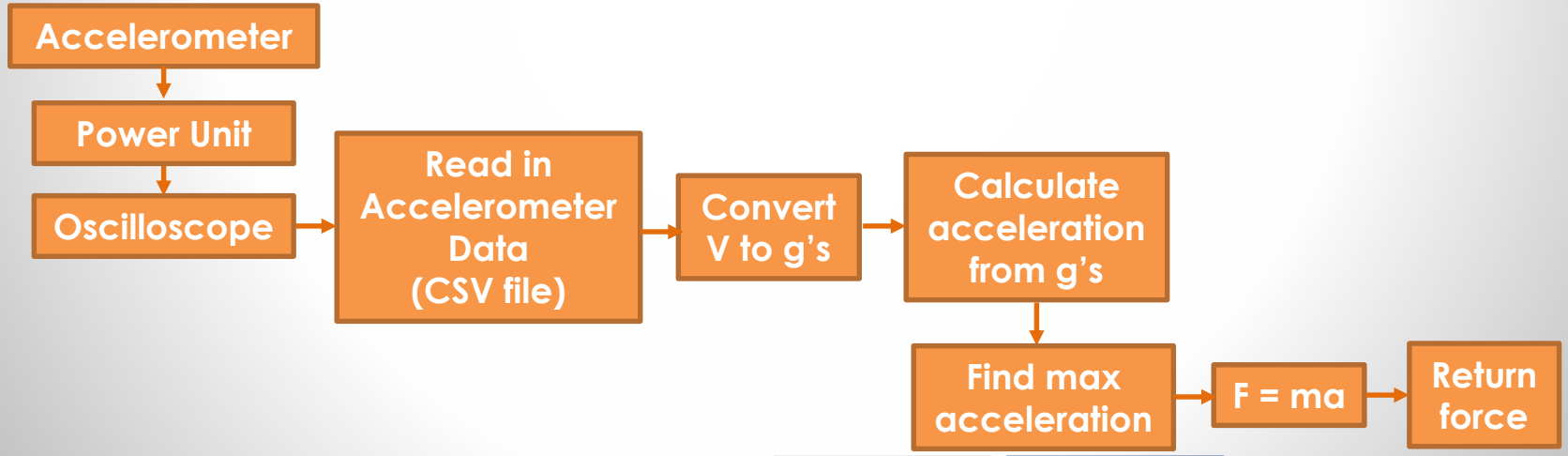
Test Setup = **Sensors** + **Wind Source** + **Ice Casting**

**Sensor Goal** → Verify force model and ANSYS model with **force calculation**

**Methods to Calculate Force**

- Accelerometer (acceleration) → **Ballistic Pendulum (Level 1)**
- High Speed Camera (height of pendulum arm) → **Ballistic Pendulum (Level 1)**
- Laser (deflection) → **Carbon Fiber (Levels 2 & 3)**

**Completed** **Accelerometer Software Development:** Force Calculation Function



# Test Setup – Wind Source Description

Test Setup = Sensors + **Wind Source** + Ice Casting

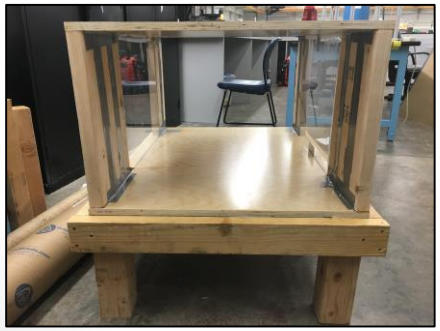
## Test Cage

**Completed**

*Side View of Test Cage*

***Cross-Section***
*25 in x 16 in*

*Front View of Test Cage*



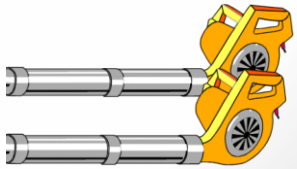
## Wind Source

**In Progress**

Original Source: Wind Tunnel
→ Cannot achieve wind speed requirement

- Off Ramp -

**2 Leaf Blowers**
Currently achieving 25% lower than required average wind speed through simulation



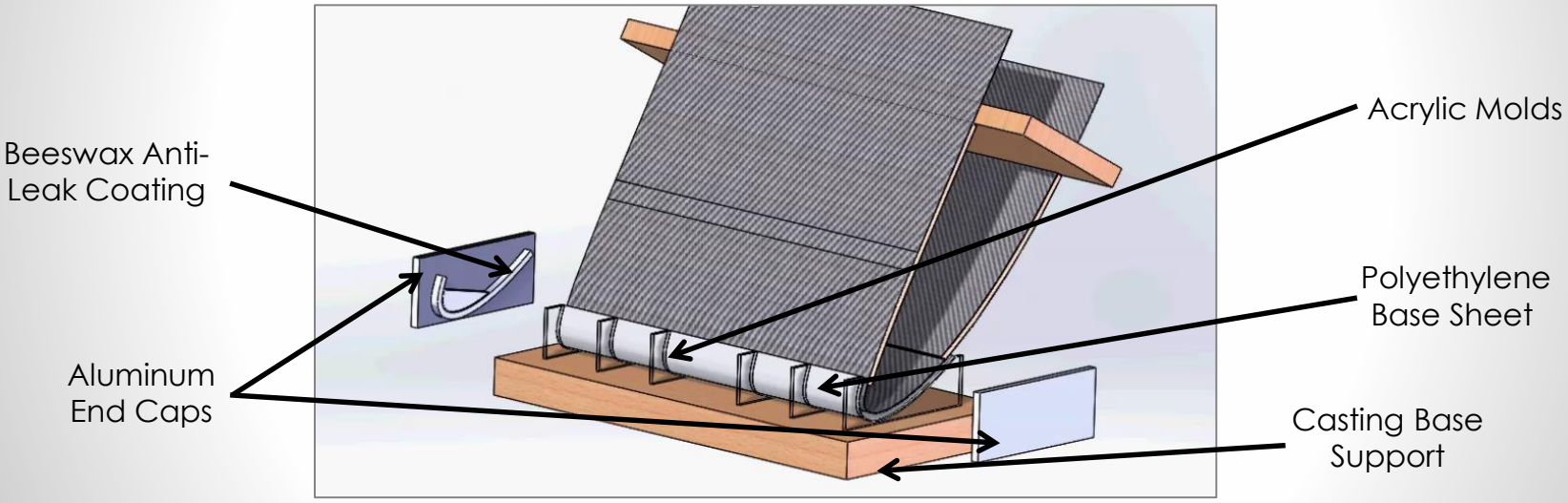
*** Currently in possession of 1 leaf blower, in process of obtaining 2nd**

# Test Setup – Ice Casting Apparatus Description

Test Setup = Sensors + Wind Source + Ice Casting

**Future Work**

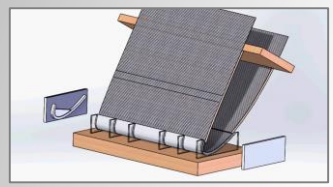
## Ice Casting Apparatus




**Note: end caps held in place with clamp**

*** Currently in possession of all materials for ice casting apparatus**

# Test Setup – Manufacturing Status

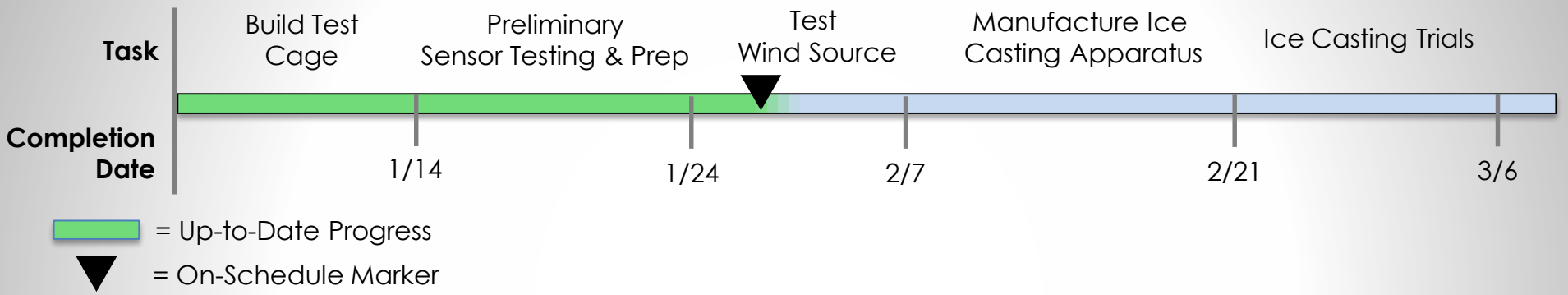


**20% Complete (Man-Hours)**

| Task | Status | Estimated Man-Hours Remaining | Completion Date |
|---|---|---|---|
| Obtain all materials for test cage & ice casting, build test cage | **Complete** | --- | 1/18 |
| Preliminary Laser Test | **Complete** | --- | 1/22 |
| Accelerometer Code & Preliminary Test | **Complete** | --- | 1/23 |
| Obtain Second Leaf Blower | **In Progress** | 1 | 2/19 |
| Machine Aluminum End Caps | **Future Work** | 7 | 3/3 |
| Cut Acrylic Molds | **Future Work** | 5 | 3/3 |
| Ice Casting Integration | **Future Work** | 3 | 3/8 |

Total Man-Hours Remaining for Manufacturing Wing Section: **16 hrs**

# Test Section – Overall Status

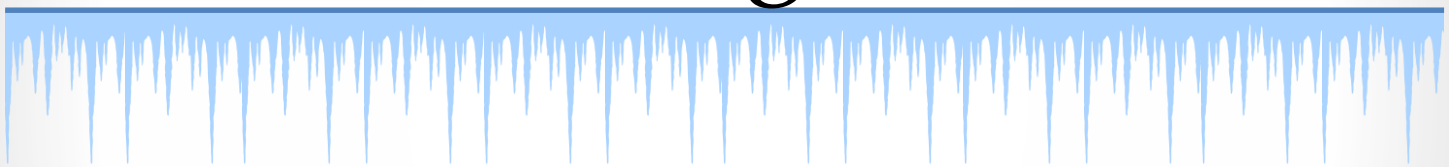



**STATUS:** On Schedule

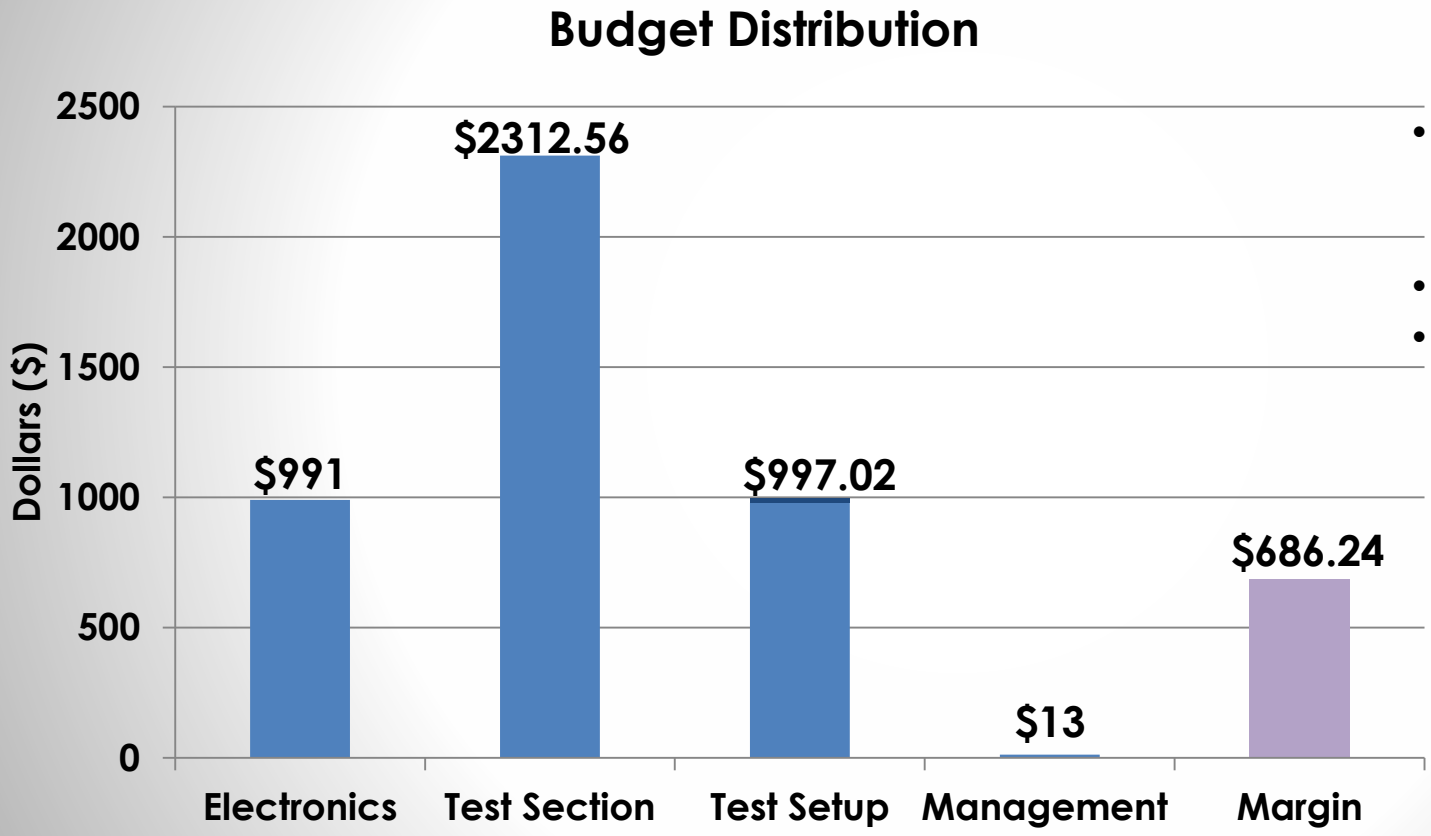
Manufacturing for level **3** test section complete by: 3/6

33% margin in days

# Budget



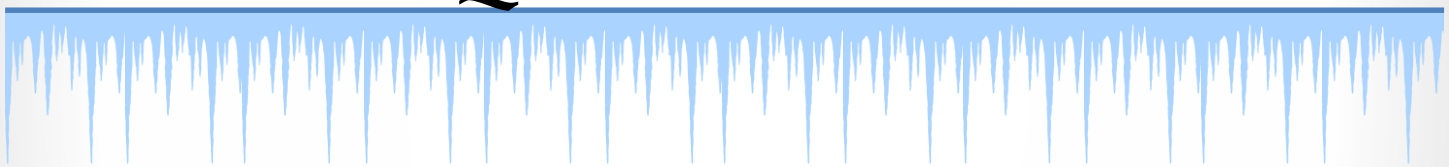
# Budget Status




**Potential Uses of Margin**

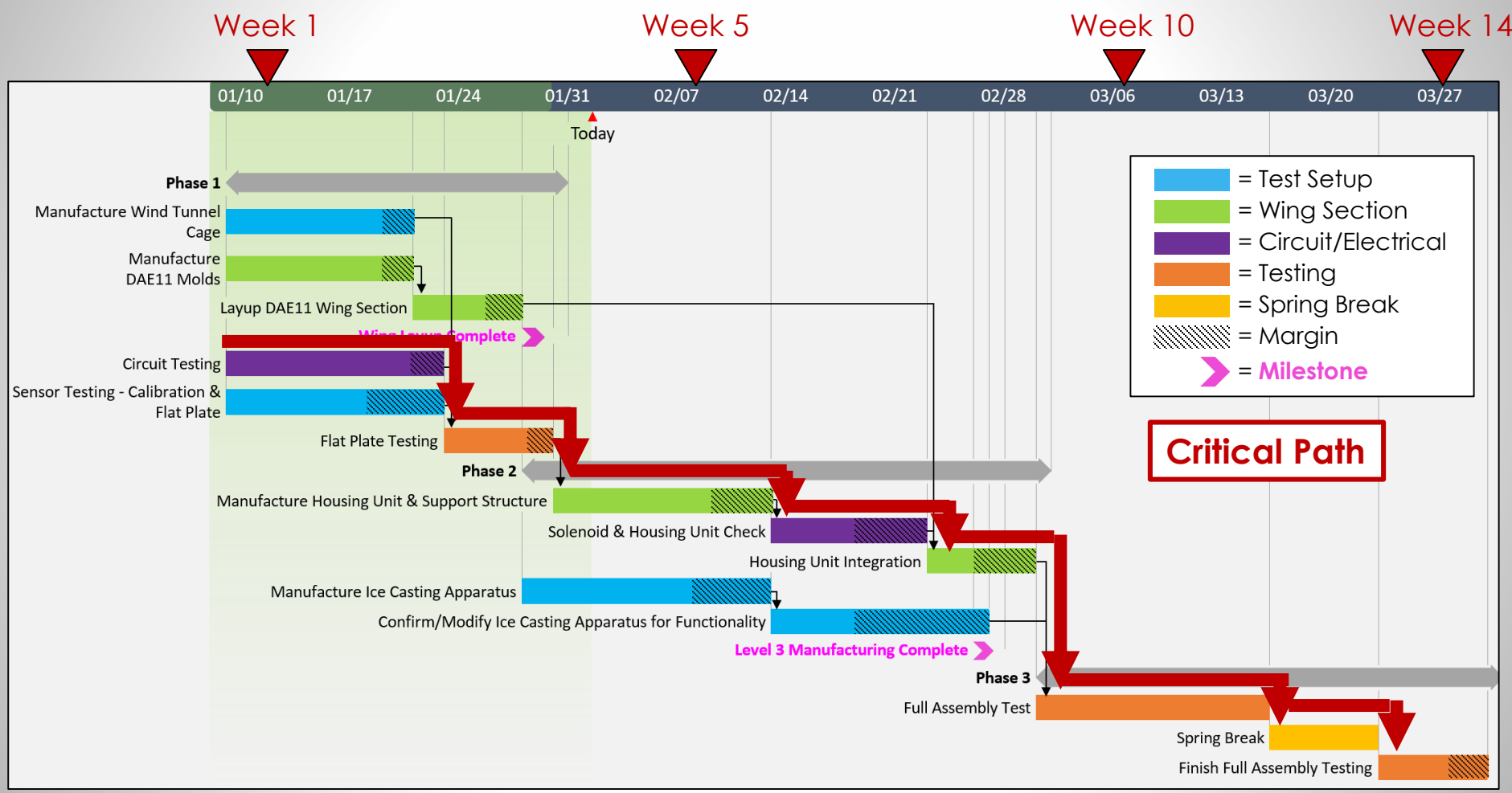
- Additional…
  - Thyristors
  - Capacitor
- Leaf blower(s)
- Improvement of electronic set up

# Questions?



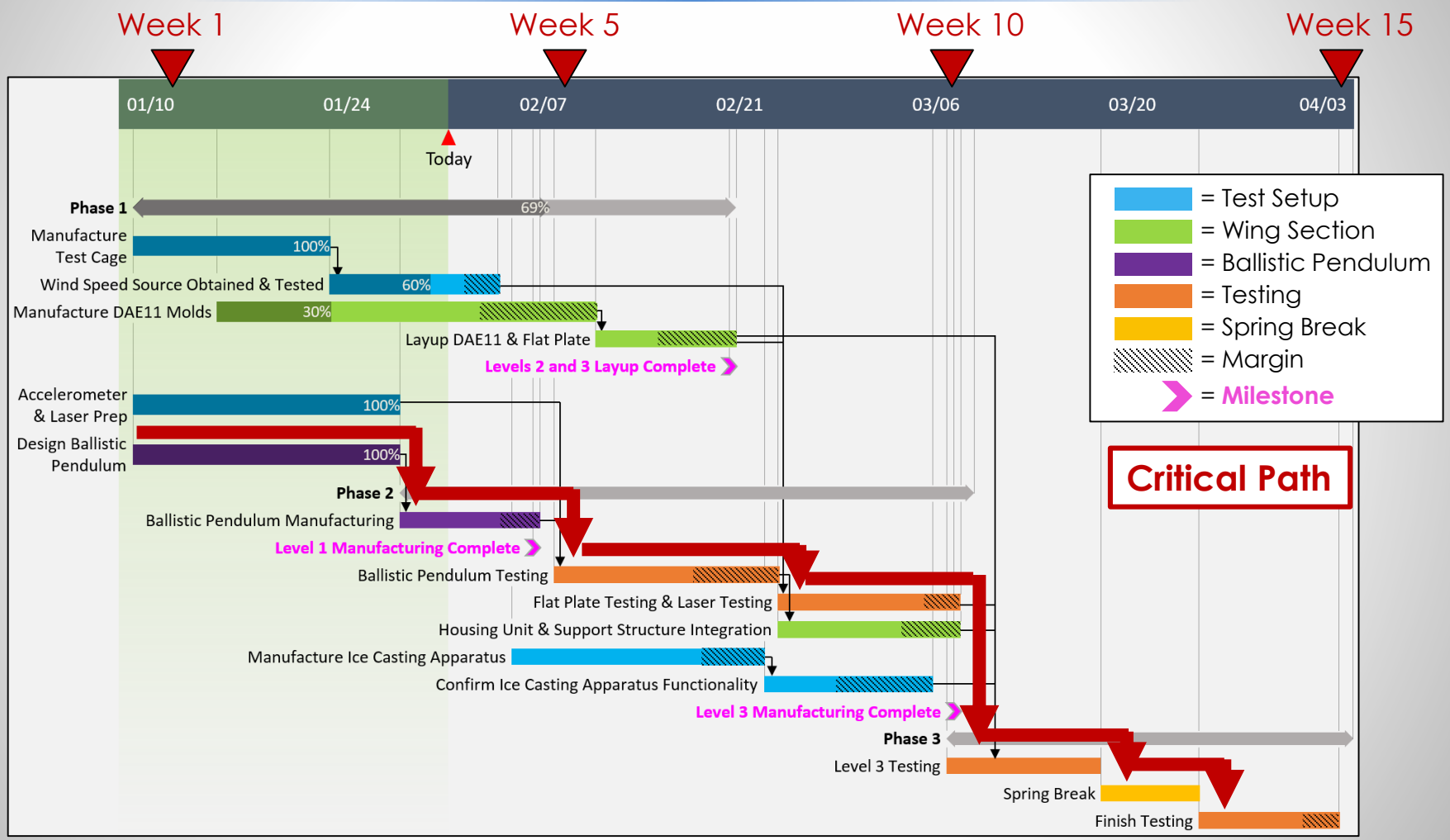
# Previous Work Plan (CDR)

Spring 2016

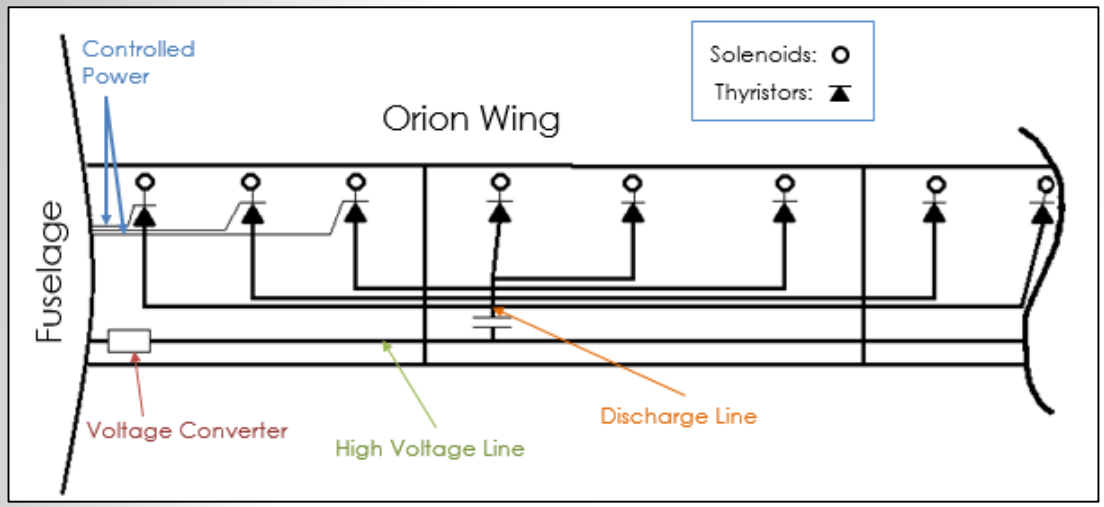


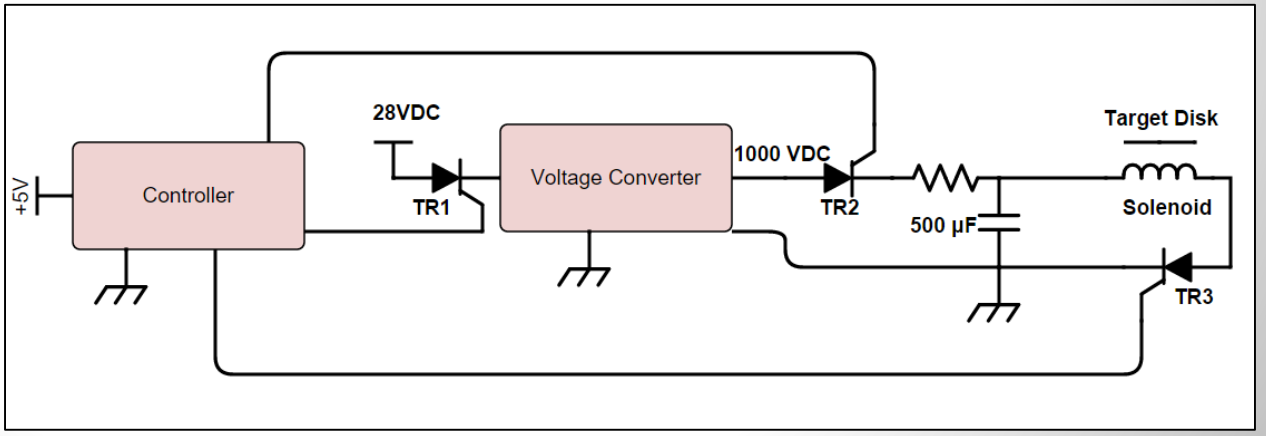
# Current Work Plan Backup

Spring 2016



# Full-span Backup



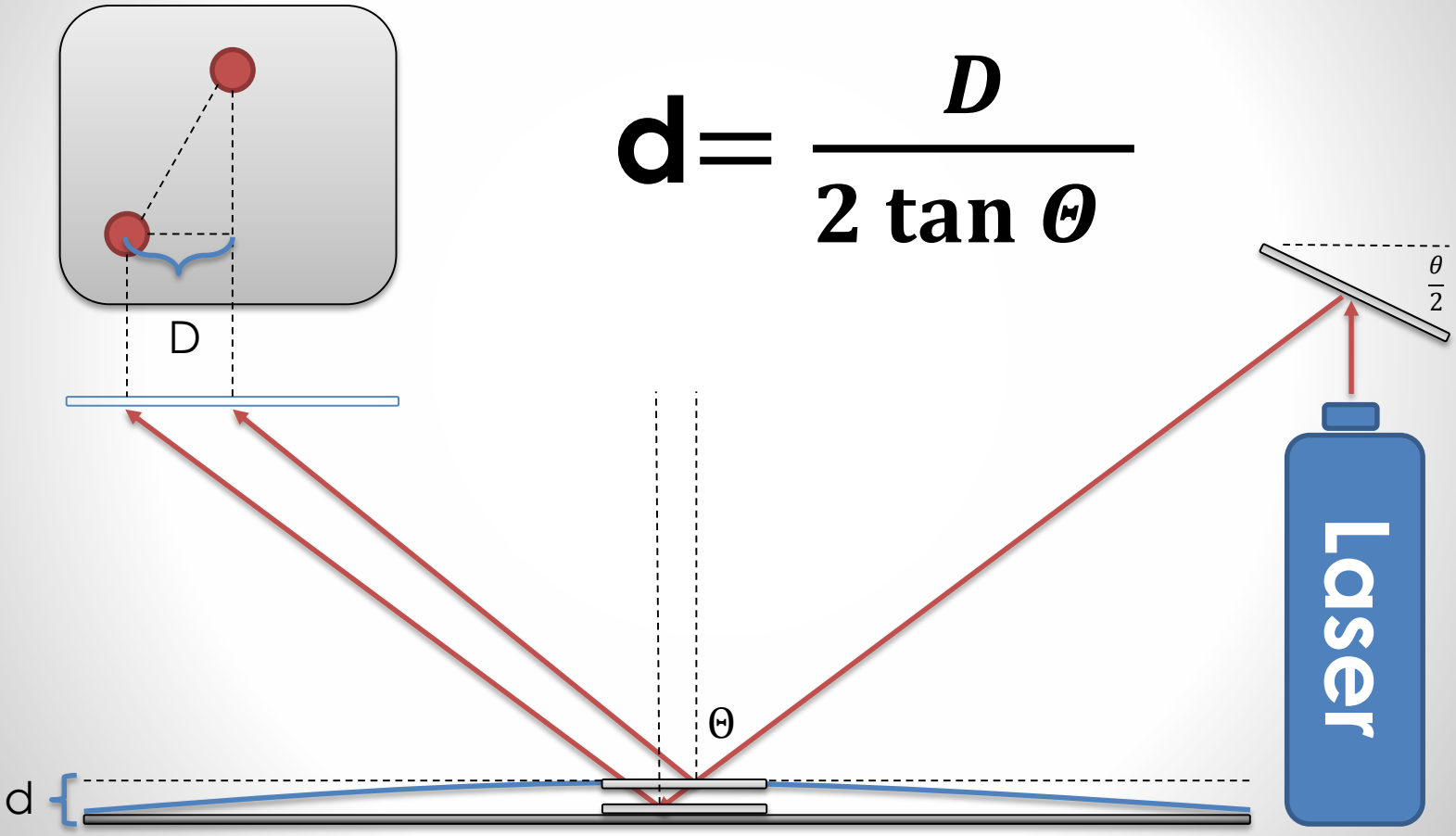



# Full-span Weight Budget

| Item | Weight (lb) |
|---|---|
| Solenoids + Target Plates (76) | 38.3 |
| Housings (76) | 69.3 |
| Capacitors + Mounting (10) | 27.2 |
| Wire + Mounting | 30.7 |
| Voltage Converters | 55.0 |
| Total | 221 lb |

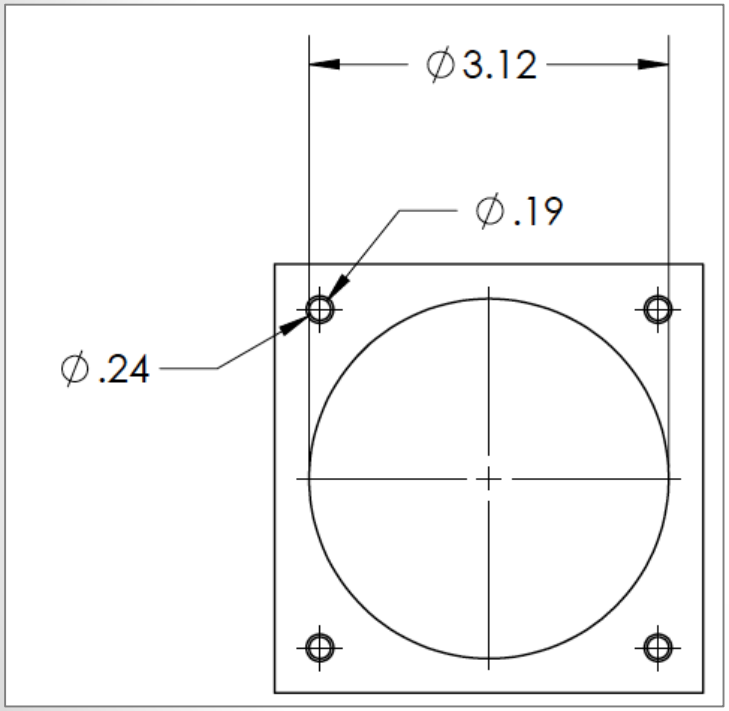
# Sensors Backup

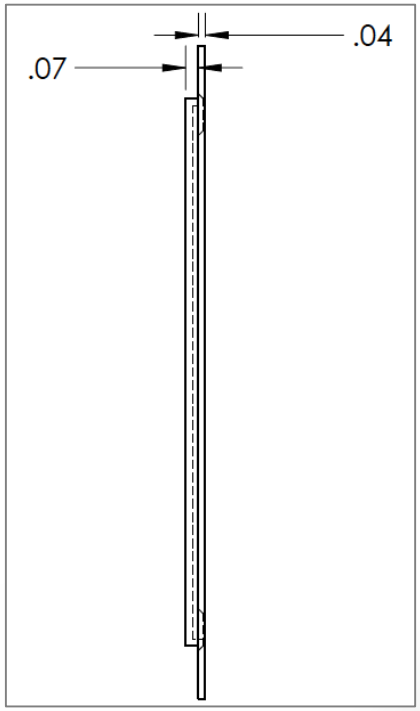
$$d = \frac{D}{2 \tan \theta}$$



# Wing Section Backup – Housing Unit

**Housing Unit SolidWorks Designs**



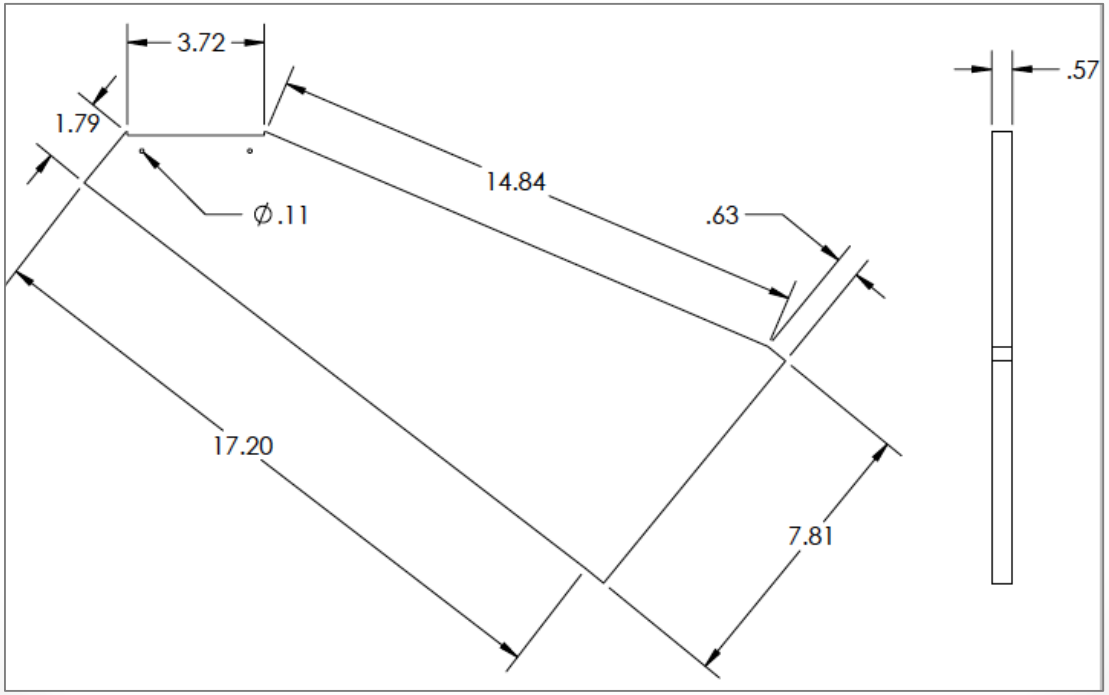




* All units in inches

Tolerance = 0.01 inches

# Wing Section Backup – Support Structure

## Support Structure SolidWorks Designs

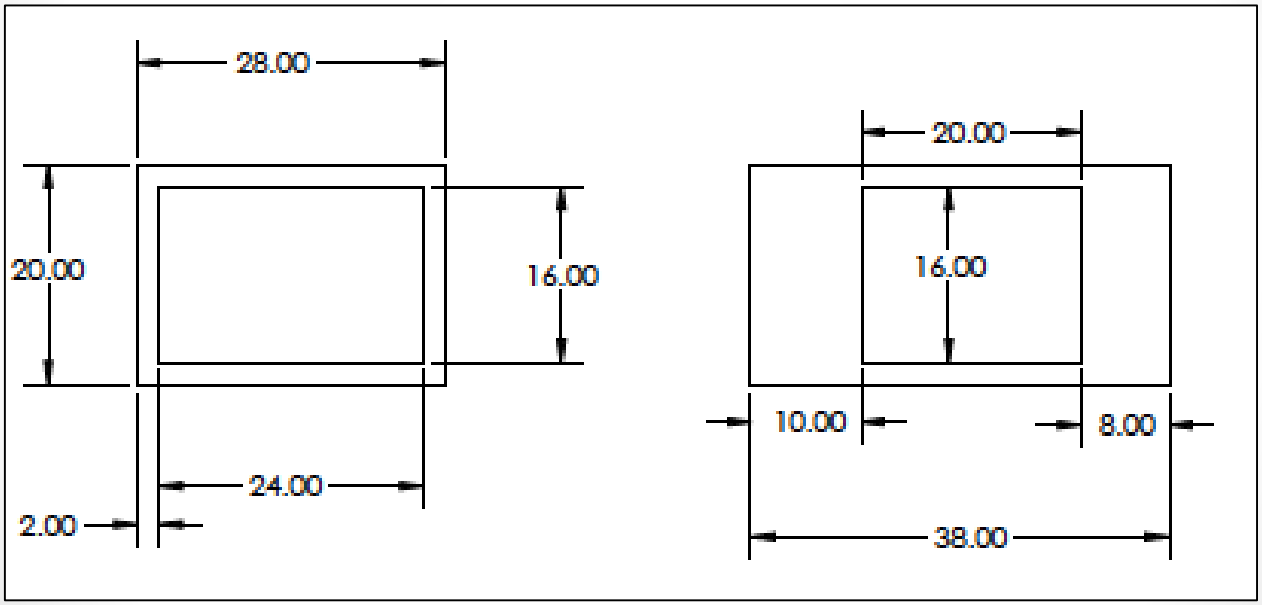



* All units in inches

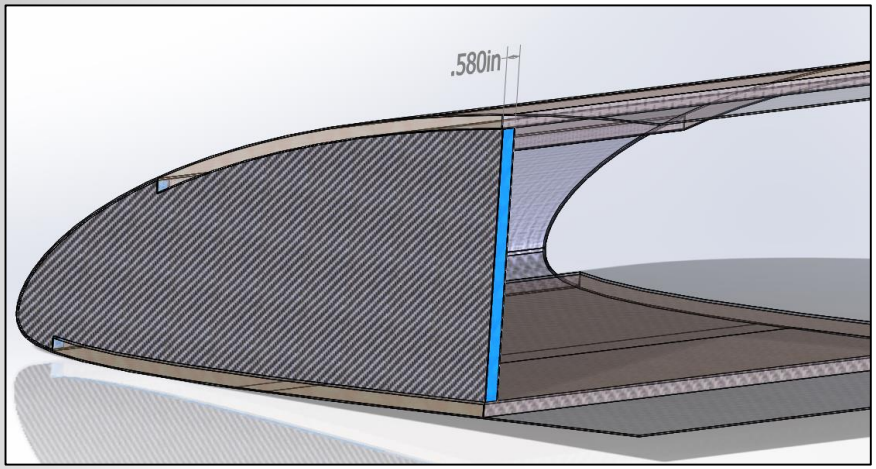
Tolerance = 0.01 inches

# Test Cage Backup

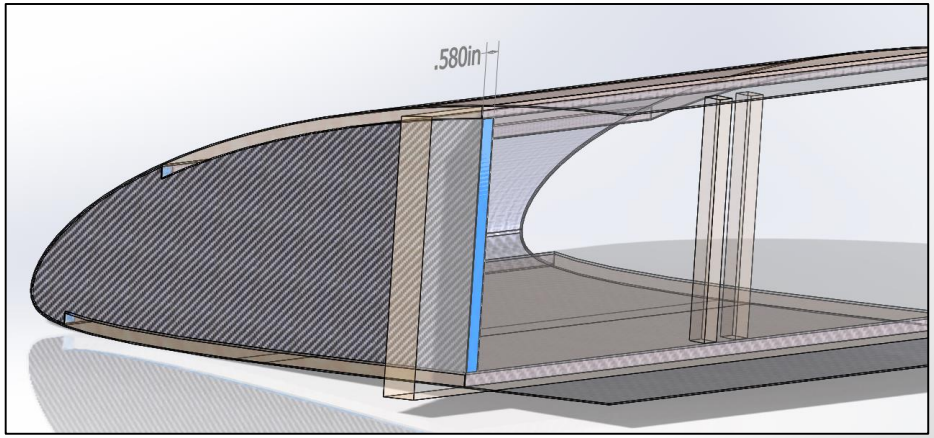
Test Cage (all units in inches)



# Wing Section Rib Backup




Dragon Plate Rib
(Carbon Fiber plates with foam core)



# Test Setup Backup

Leaf Blower Simulation

→ Two Leaf blowers simulated in test cage with exit velocity = 250 knots