# OSPRI

## **O**ffset **S**-duct **PR**opulsion **I**nlet

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Customer: Air Force Research Laboratory
POC: Capt. Riley Huff

Section 1

# Purpose & Objectives

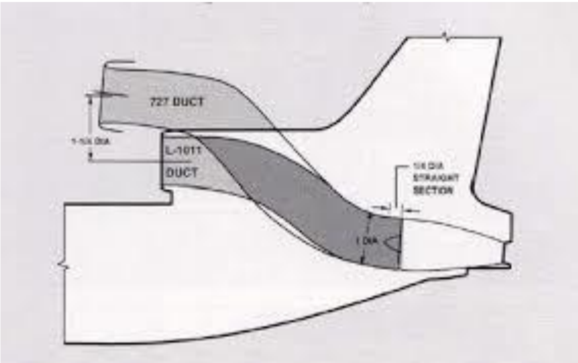
## Problem Statement

The purpose of the OSPRI project is to:

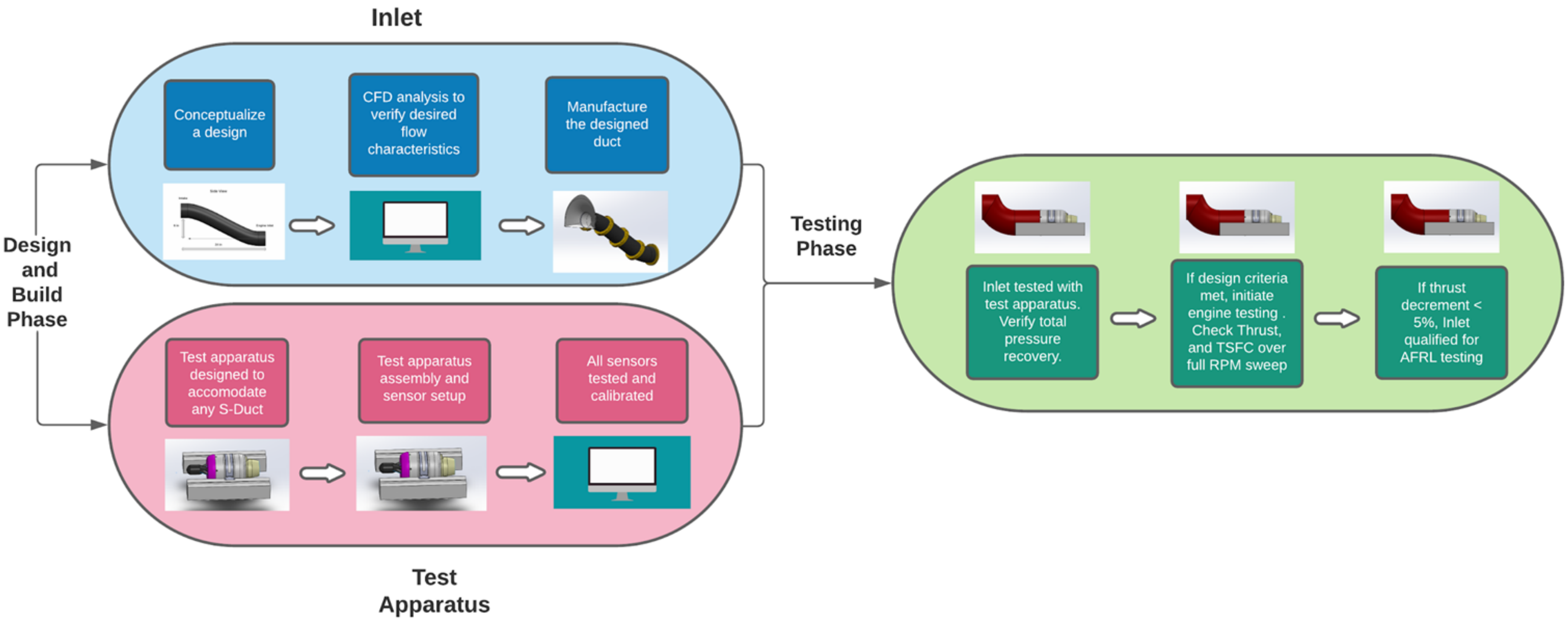
- Design and build an S-duct inlet for use with the JetCat P100-RX turbojet engine, for the Air Force Research Lab's (AFRL's) Aerospace Propulsion Outreach Program (APOP)
- Additionally, OSPRI will design and build a testing apparatus to measure total pressure and distortion distributions in the inlet, and measure fuel flow and thrust produced by the JetCat

# Motivation

- Integrating engines into the fuselage would reduce exposed surface area and overall drag
- S-ducts are susceptible to severe flow separation and poor total pressure recovery
- The Air Force Research Lab (AFRL) has asked 12 schools to come up with potential solutions
- Design point is a static test at standard conditions at Wright-Patterson AFB, Ohio



# Concept of Operations (CONOPS)



# Levels of Success

| Level | Objective |
|---|---|
| 1 | A test rig is designed and manufactured that is capable of measuring all parameters as outlined in the Design Requirements |
| 2 | Experimental Verification of the test rig’s ability to measure thrust and TSFC |
| 3 | Experimental Verification of the test rig’s ability to characterize the flow within a test inlet |
| 4 | Experimental verification of an inlet with total pressure recovery >90% |
| 5 | Experimental verification of nominal engine operation with level 4 inlet attached, with decrements to thrust and TSFC of no more than 10% |
| 6 | Experimental verification of nominal engine operation with inlet attached, with decrements to thrust and TSFC of no more than 5%, and total pressure recovery ≥98% |

Section 2

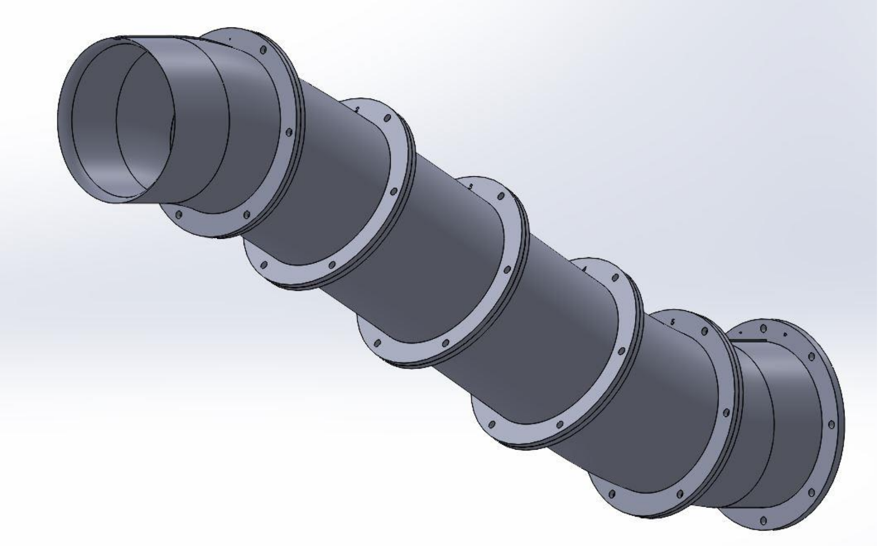
# Design Description

# Inlet Key Design Requirements

1. The inlet shall interface with the AFRL transition piece.
2. The nearest outside edge of the capture area shall have a 6-inch offset from the centerline of the engine.
3. The inlet shall have a total pressure recovery ≥98% across the RPM sweep of the engine.
4. The maximum thrust decrement of the engine shall be ≤5% while the inlet is attached.
5. The maximum TSFC increment of the engine shall be ≤5% while the inlet is attached.
6. A shorter inlet will be scored higher than a longer inlet.

# Top-Level Description - Inlet

- Inlet
  - Inlet Length: 24 inches
    - 6 inch offset
  - Circular cross-section
    - Diameter: 4 inches
    - Uniform along length
  - Sectional
    - Partitioned into 6 segments
    - Pipe flanges for assembly



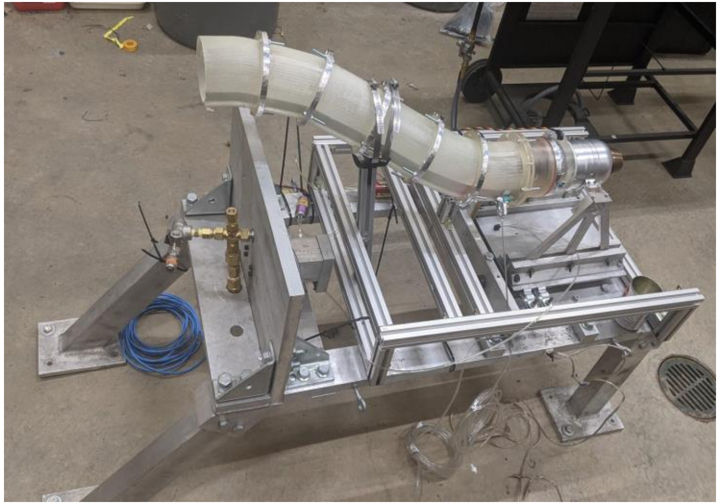
Final Design (CAD model)

# Test Apparatus (TA) Key Design Requirements

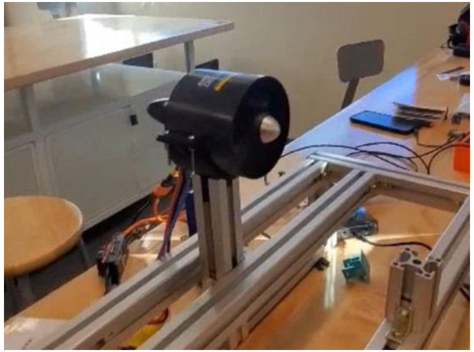
1. The TA shall be capable of mapping the total pressure distribution at the inlet entrance, the Aerodynamic Interface Plane (AIP), and between the first and second turns, at a minimum.
2. The TA shall be capable of measuring key JetCat engine parameters.
    a. TA shall be capable of measuring the thrust produced by the engine.
    b. TA shall be capable of measuring the Thrust Specific Fuel Consumption (TSFC) of the engine.
3. The TA shall be capable of interfacing with multiple different inlet designs.

# Top-Level Description - Test Apparatus

- Compatible with EDF tests and integrates with the JetCat horizontal test stand
- Material: Aluminum 30x30 extrusion
- Adaptable to a variety of inlets for testing (modular design)
- Dimensions
  - Length: 750 mm
  - Width: 483.5 mm

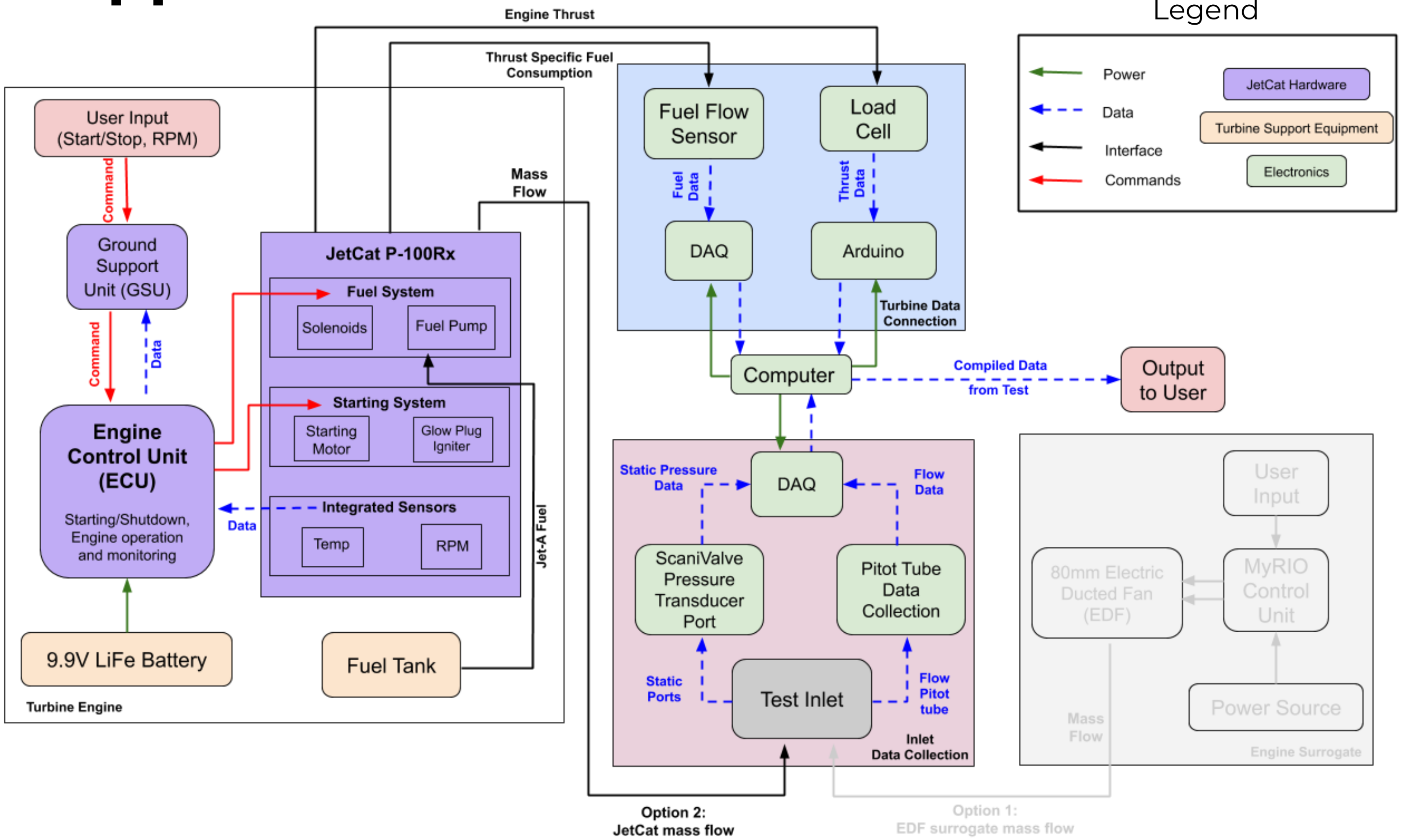


Jetcat testing set-up

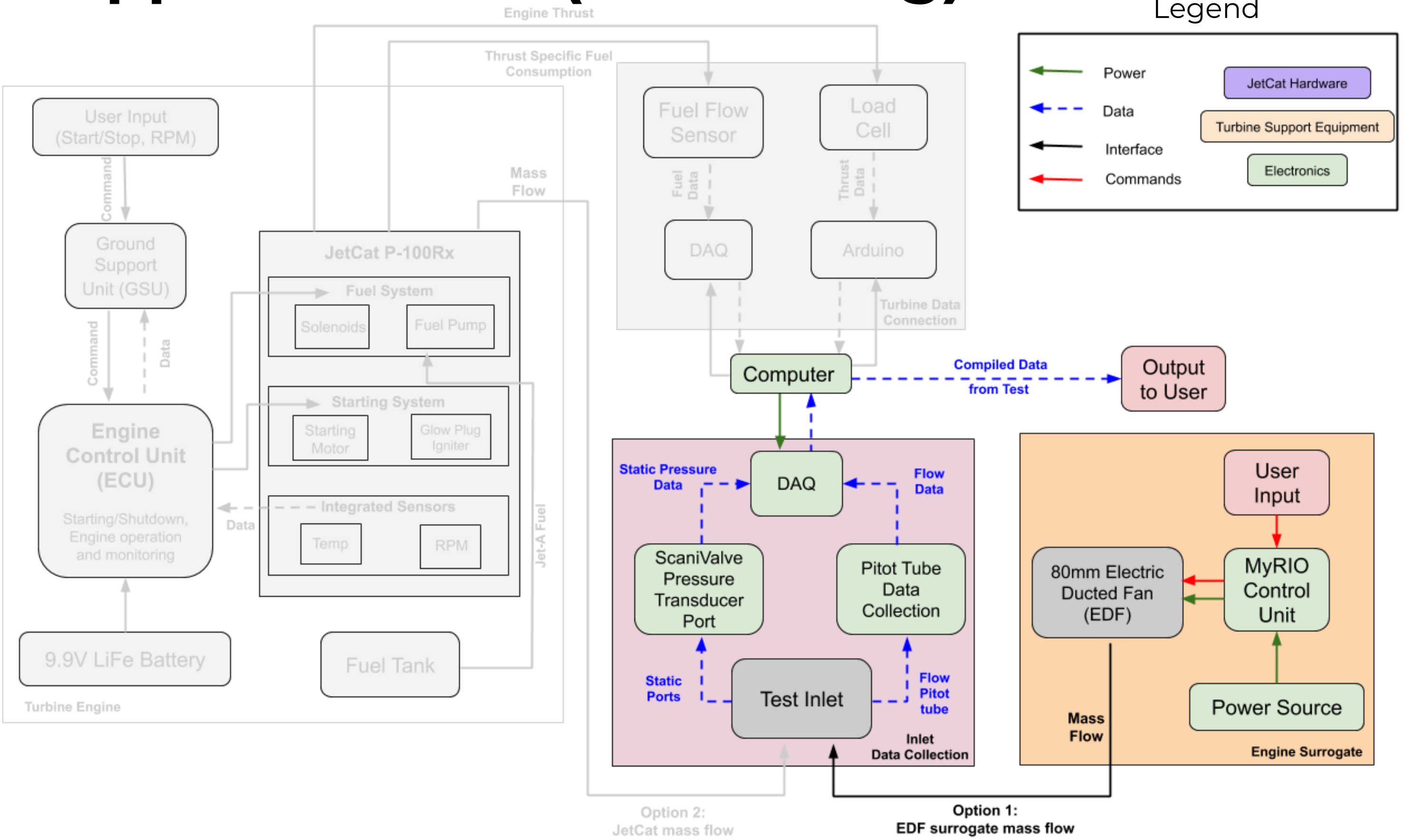


EDF mounted to test stand without inlet

# Test Apparatus FBD

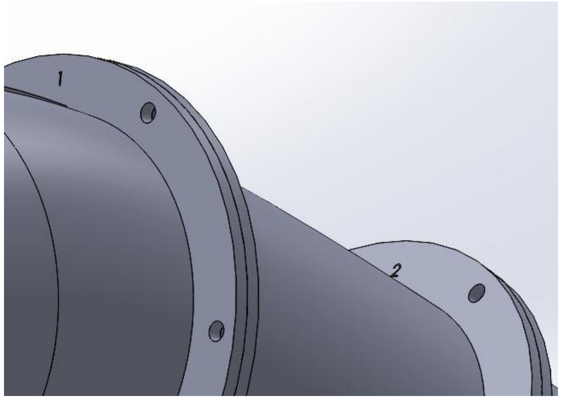


# Test Apparatus FBD (For Testing)



# Post-TRR Design Changes

- Competition Inlet
  - Removal of Pitot rail
    - Not necessary for competition
    - Potential for pressure loss
  - Section Numbers
    - Printed on flange
    - Assembly aid
- Test Apparatus
  - Stand drag during Jetcat testing




Section numbers

# Critical Project Elements (Test Apparatus)

1. Sensors & Electronics:

   *Three main data acquisition functions: Sensor data collection, EDF control, and turbine related sensor data collection*

1. Mass Flow Surrogate:

   *Engine condition replication using Electric Ducted Fans allows for more inlet testing*

1. Support hardware and infrastructure:

   *Test apparatus anchor point providing support for inlet, facilitates EDF and turbine tests*

1. JetCat integrated testing:

   *Testing to calibrate and increase mass flow surrogate fidelity, integrated testing with inlet to provide thrust and TSFC data (customer requested)*

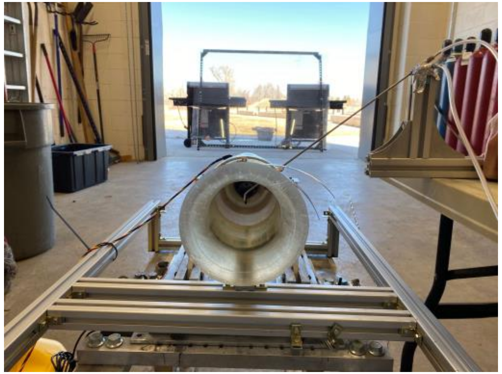
# Critical Project Elements (Inlet)

1. Methodical Design Process:
   *Considering flow interactions and AFRL scoring*

1. Print Inlet, Transition Pieces:
   *All in SLA, transition pieces provided by AFRL*

1. Assembly, TA Integration, & Testing:
   *Assemble the printed sections and verify design*

1. Final Inlet Printing:
   *Utilize data gathered to manufacture final inlet*



Pitot Integration during Testing

Section 3

# Test Overview

# Tests Conducted

| EDF Tests | JetCat Tests | Other Tests |
|---|---|---|
| ▪ EDF Mass flow verification | ▪ JetCat Functionality | ▪ Sensor Characterization Test |
| ▪ EDF Performance Baseline | ▪ JetCat Performance Verification/Baseline | |
| ▪ EDF Inlet Tests | ▪ JetCat Inlet Tests | |

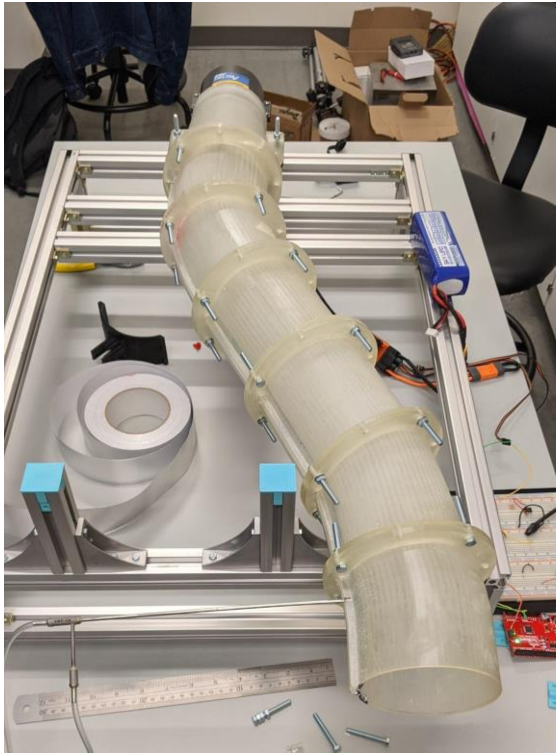
Tests of most importance

# EDF Inlet Testing

***EDF Testing***

- TRL of 5, components and testing software verified in relevant environment
- Test Apparatus Validation tests
- Inlet EDF tests
  - Separation Areas
  - Pitot-Static Probe in varying locations
  - Verification of inlet before use on JetCat

EDF Testing in Wind Tunnel Room

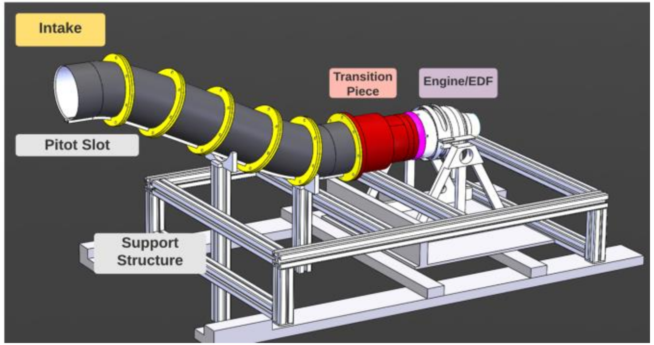


EDF Test Setup

# JetCat Inlet Testing

***Performance Verification/Baselining Tests***

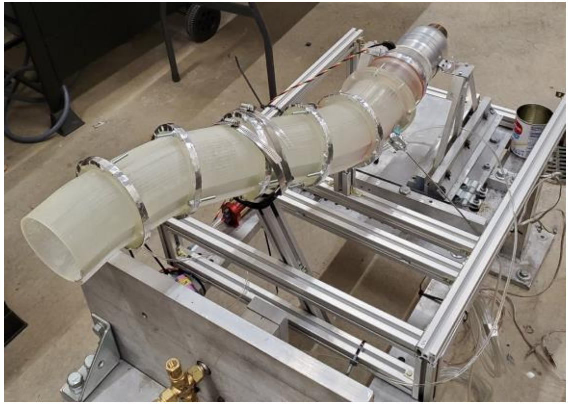
- Stock JetCat test
  - Determine if JetCat runs with facilities
- Mass Flow test
  - Gather stock base mass flow data
- Thrust test
  - Gather stock engine thrust data at Boulder altitude




Final Test Configuration

***Inlet Tests***

- TRL of 6, inlet operated in environment
- Integrated JetCat to inlet tests
  - Characterization of internal flow characteristics
  - Flow data collected at stations 1 and 6
  - Thrust data also collected



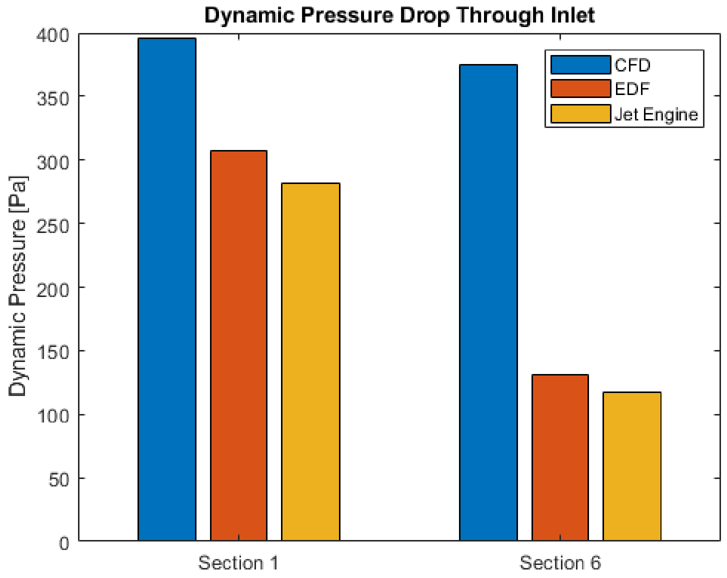
First Integrated Test Preparations

Section 4

# Test Results

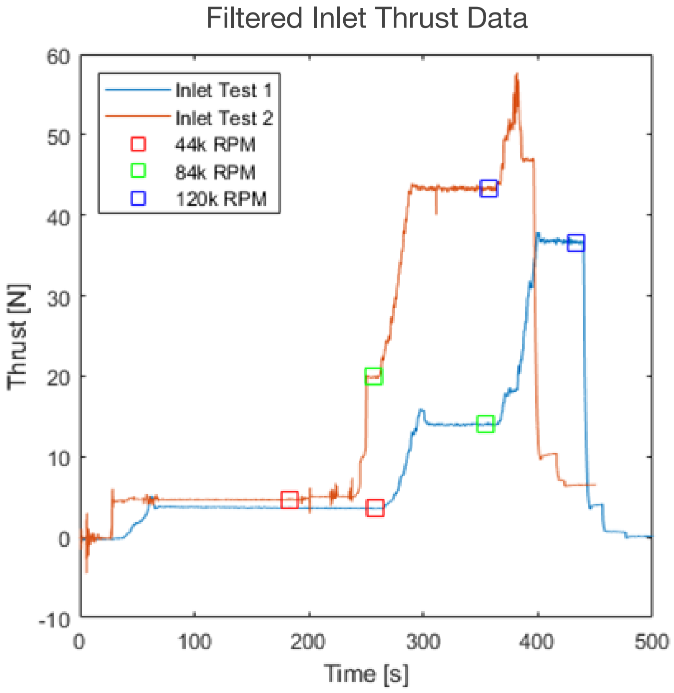
# Inlet Results

- Total Pressure Recovery
  - Anticipated 99.9% from CFD
    - Inviscid incompressible flow
      - Model boundary layer
  - 99.8% at 120 kRPM
    - Low airspeeds and conservative design enables high total pressure recovery
- Flow Distortion
  - Some flow distortion was detected while testing with the EDF
    - Small turbulence in the first bend that resolves itself
- Thrust
  - Large errors due to static friction

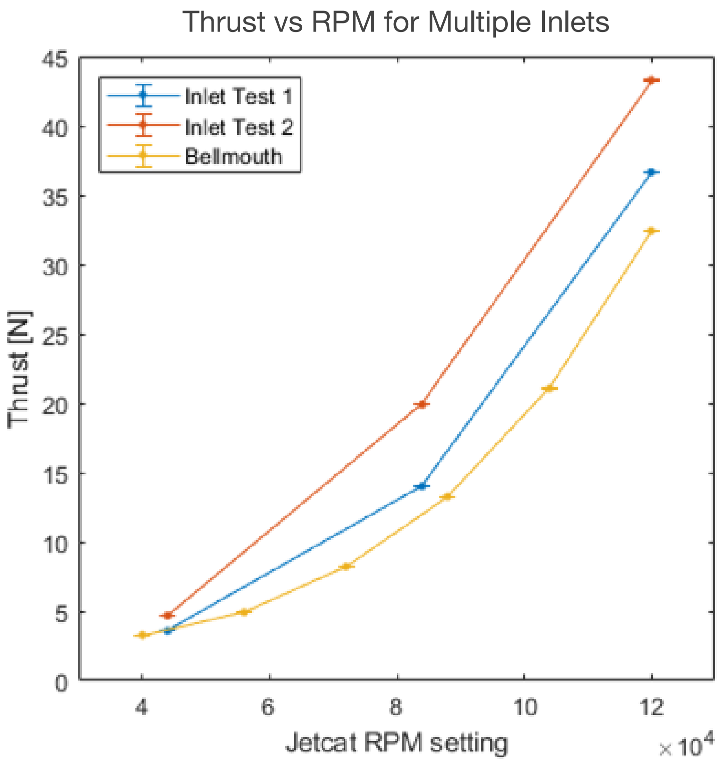


# Collected Thrust Data Issues

- Highly inconsistent thrust results
  - ➢ Two tests of the same inlet varied by 10%
  - ➢ Need to detect decrement of 5%
- Not all tests return to zero force
  - ➢ Suggests slipping and significant static friction
- The same issue likely affected bellmouth testing
  - ➢ Bellmouth saw lowest thrust, the opposite of expectations



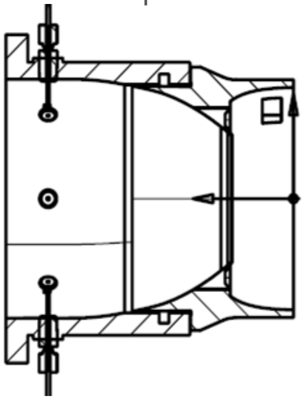
# Collected Thrust Data Issues




**Error Bars:** SD of data, does not include sensor, calibration, or friction uncertainty

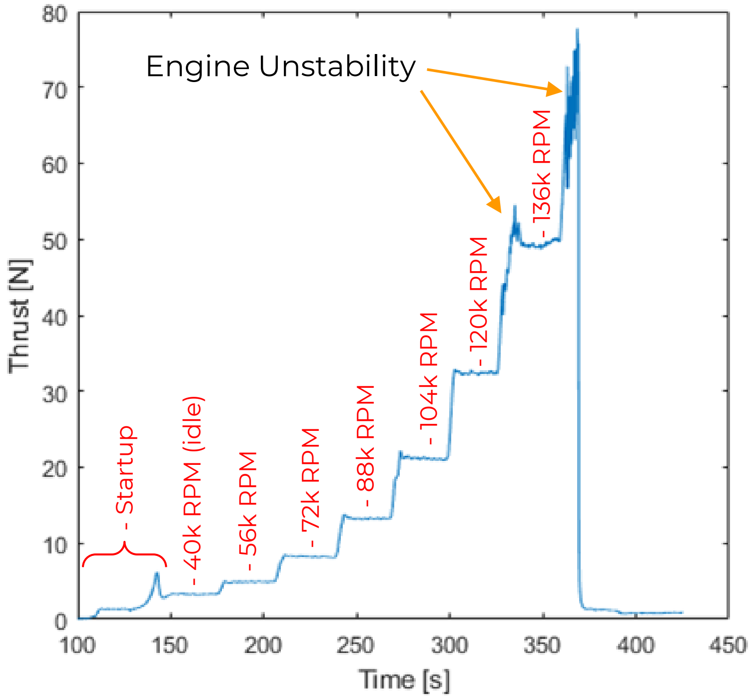
# JetCat Engine Surging

- During testing with bell mouth, encountered unstable engine issues around 130k RPM
  - Audibly distinguishable during tests
- Phenomenon limited our inlet tests to 120k RPM for safety
- Believed to be caused by the extreme turning angle the transition piece makes



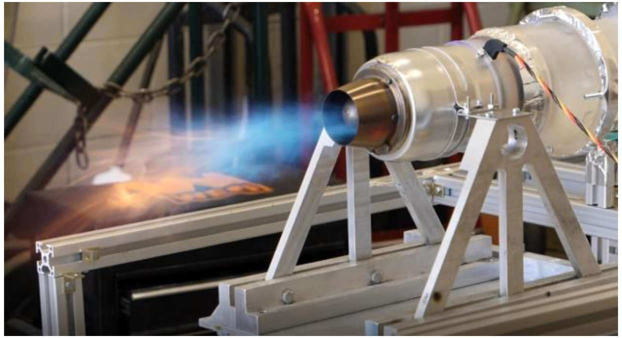
AFRL Transition Piece Cross Section

JetCat Bell Mouth Thrust Data



# Testing Moving Forward

- Thrust Data Collection (retest and recalibration)
  - Collected bad data (more in the next section)
  - Re-calibrate load cell
  - Remove test apparatus frame to eliminate friction
- Fuel Flow
  - Ordered sensors were initially delayed, but ultimately never received due to Covid issues
  - Without the sensors, planning rudimentary data collection with graduated cylinder
- AFRL Transition Piece test
  - Surging Issues at 130K RPM
  - With the surging Issues, AFRL requested a test to collect more data with only their designed transition piece


JetCat Startup During Initial Testing

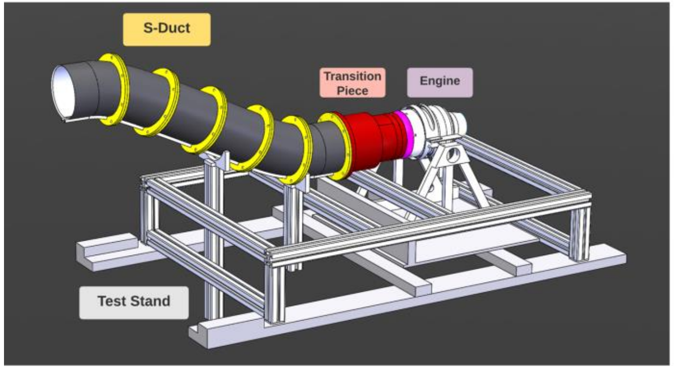

AFRL Transition Piece Affixed to JetCat

Section 5

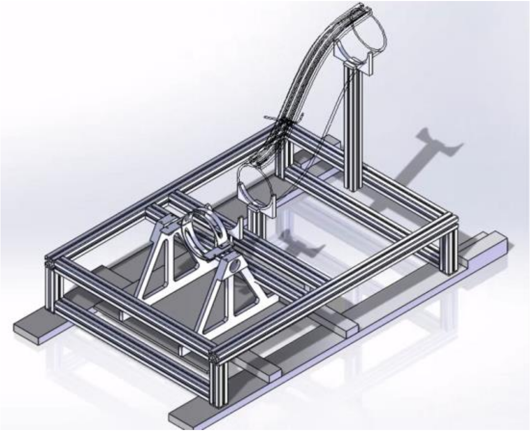
# Systems Engineering

# Design Approach

- Problem:
  - Integrating the inlet with AFRL transition piece
  - How to calculate the total pressure recovery without damaging the engine?
  - Implement a process that is repeatable
- Solution:
  - Designing the inlet around the transition piece
  - First test using EDF to verify performance and then move to engine
  - Building our own testing apparatus to test any designed inlet with the EDF or the engine



Inlet Experimental Setup


Test Stand Model

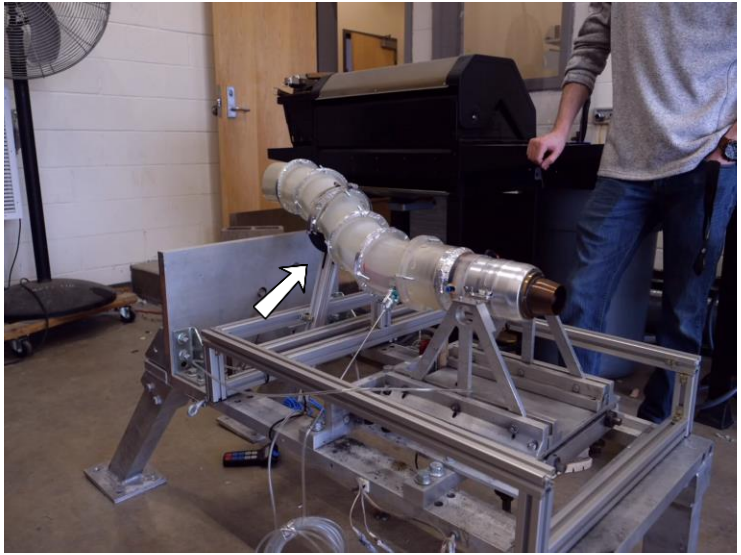
# Risk Assessment

1. Thrust data systematic errors from designed test apparatus
2. EDF doesn’t act as accurate surrogate replicating the JetCat mass flow performance
3. Acquisition of pressure data may disturb the flow
4. Damage to JetCat engine during testing
5. Inlet structure failure during integrated JetCat test

| Risk Matrix | Impact | | | |
|---|---|---|---|---|
| | Insignificant | Minor | Major | Catastrophic |
| Certain >90% | | | | |
| Likely 30-85% | | | 1 | |
| Unlikely 10-30% | | 2 | 3 | 4 |
| Rare <10% | | | | 5 |

# Issues during execution

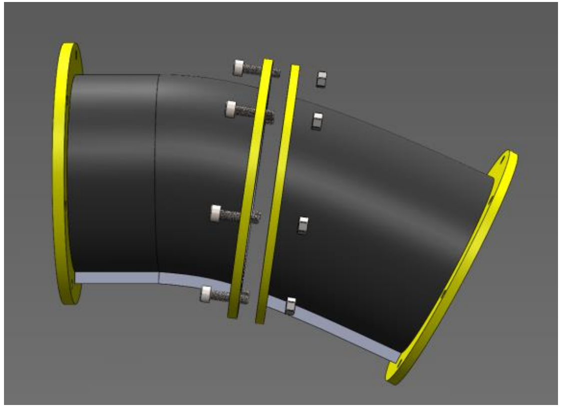
- Test apparatus and inlet integration
  - Taller and bar and cradle adjustments
- Sensor calibration
  - Inconsistent thrust data
- Mechanical loading of all the components after integration
  - Engine and inlet without supports
- Failure to receive important sensors due to inadequate communication with the department.



Inlet and JetCat Integration
modifications during testing

# Key Lessons

- Making more adjustable equipment to save time during testing.
- Sensor calibration before every single test to ensure valid data
- Stress analysis on the integrated structure
- Better communication with management
- Set more strict deadlines for the subsystems in order to follow a set timeline



Inlet Sectional Side View

Cradle for the Jet Engine Transition Piece

Section 6

# Project Management

# Project Management Process

- GANTT chart focused
  - Add to/subtract from as necessary
- Semi-weekly run downs of sub-team work
  - Kept team updated on progress as a whole
  - Finding the “Goldilocks” zone was difficult
- Started with slides for each meeting
  - Semi-weekly meetings were planned day-of
- Major tasks were delegated
  - Specific task breakdown was left up to sub-team leads

# But did it work?

- Well…yes and no
- We did progress on our project in a timely manner
- However,
  - Specificity fell off as the semester/year went on
  - GANTT chart fell behind actual project schedule
  - Meeting slides stopped being made
  - Tasks were assigned via Word-of-Mouth, instead of in text/email/etc.
  - Most importantly, communication broke down multiple times

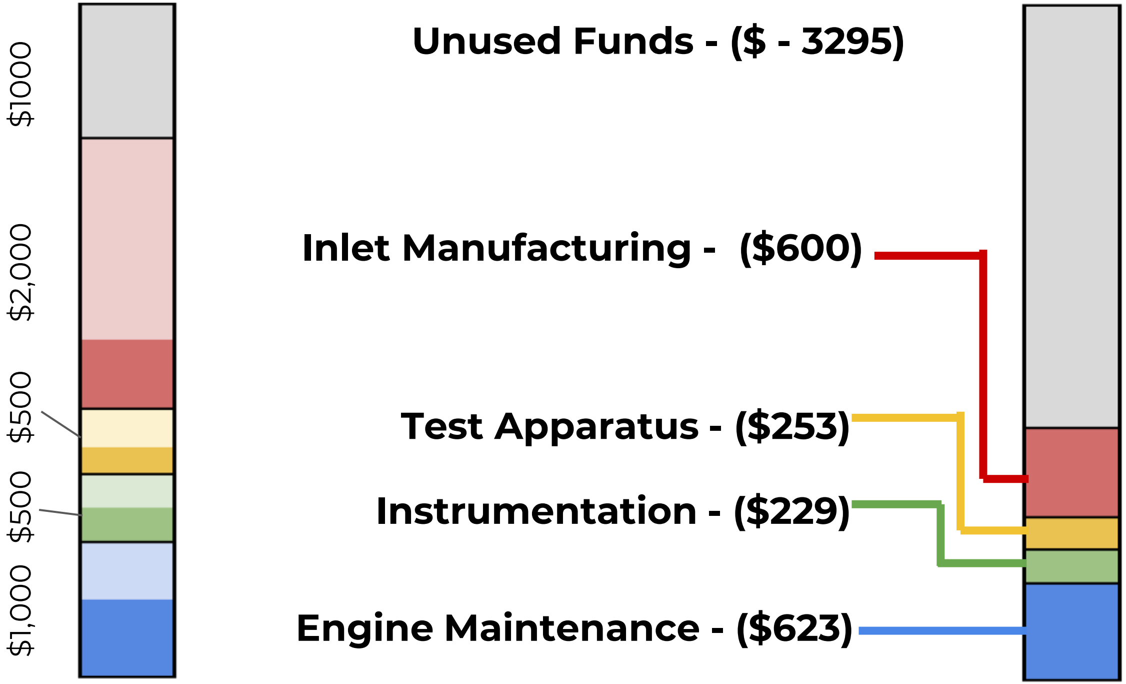
# Lessons Learned

- Be more diligent in updating
  - Products
  - Team
  - Customer throughout process
- Formalize periodic updates
  - Slides/written updates are easier to process
- Plan meeting agendas in advance
  - A better structure leads to less time panicking/more time working
- Follow-up with team members better
  - Avoid micromanaging while ensuring the schedule is being adhered to

# But most importantly…

- ASK FOR ADVICE/GUIDANCE SOONER
  - **And then stick with it!**

# Cost Plan




**FINAL ANALYSIS**

Spent ~ $1705

<40% total $5000 budget

Saved >3x as much as previously estimated

Most of budget allocated to Engine Maintenance & Inlet Manufacturing

# Pricing Analysis

**Total Hours Worked**

**1,647.5**

x $65,000 / year
x $31.25 / Hour

**Price of Worked Hours**

**$51,484.38**

+ %200 Overhead
& $2000 Materials

**Overhead & Materials**

**$156,453.12**

**Total Project Quote**

**$156,500**

# Resources


- [1] Lee, J., Cho, J. ”Effect of aspect ratio of elliptical inlet shape on performance of subsonic diffusing S-duct,” J Mech Sci Technol 32, 1153–1160 (2018). https://doi.org/10.1007/s12206-018-0218-5.
- [2] Anderson, J., Introduction to Flight Eighth Edition, New York City:McGraw Hill education, 2016
- [3] Sun, S., Guo, R.W. 2006. “Serpentine Inlet Performance Enhancement Using Vortex Generator Based Flow Control,” Chinese Journal of Aeronautics
- [4] Tanguy, G. 2016. “Passive flow control study in a convoluted intake using Stereo Particle Image Velocimetry,” The French Aerospace Lab
- [5] Kirk, A. M. 2006. “Active flow control in an advanced serpentine jet engine inlet duct Master's thesis”, Texas A&M University
- [6] Shaw, R., “The Influence of Hole Dimensions on Static Pressure Measurements,” Department of Mechanical Engineering, University of Liverpool, 1 July 1959.
- [7] “Delta-V 32 80mm (EFLDF32) Fan Unit Instructions,” Horizon Hobby, retrieved November 12, 2020.
- [8] Reichert, B.A., and Wendt, B.J., 1994, “Improving Diffusing S-Duct Performance by Secondary Flow Control,” AIAA 32nd Aerospace Sciences Meeting and Exhibit.
- [9] Basawaraj, Hosur, S., 2016. “CFD Analysis of Serpentine Inlet Duct to Enhance the Flow Properties Using Vortex Generator,” International Journal of Innovative Research in Science, Engineering and Technology
- [10] Rabe, A. 2003. “Effectiveness of a Serpentine Inlet Duct Flow Control Scheme at Design and Off-Design Simulated Flight Conditions,” Virginia Polytechnic Institute and State University
- [11] Anderson, B. H., and Gibb, J., "Vortex Generator Installation Studies on Steady State and dynamic Inlet Distortion," AIAA Paper 96-3279, July 1996.
- [12] Dudek, J. C., "Empirical Model for Vane-Type Vortex Generators in an Navier-Stokes Code", AIAA Journal, Vol. 44, No. 8, pp 1779-1789,August 2006.

# Resources

- [13] HARRINGTON-CRESSMAN, PETER J.M., “AIRCRAFT SYSTEM COMPARTMENT DIAGRAM.” Retrieved 10 September 2020. https://www.airlinereporter.com/2015/09/requiem-trijet-masterpiece-lockheed-l-1011-tristar/aircraft-system-compartment-diagram/

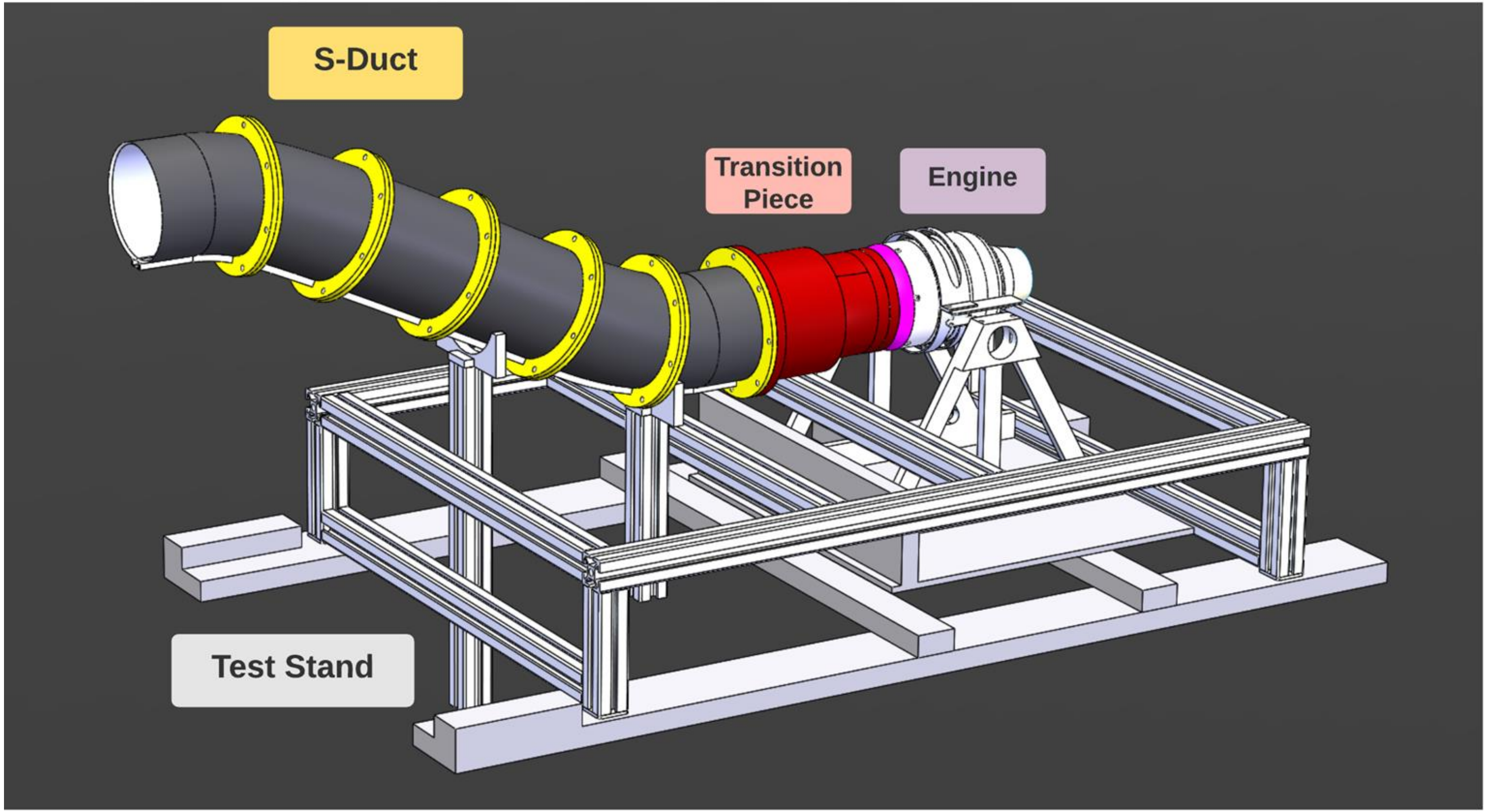
# Additional Slides

## Problem Statement

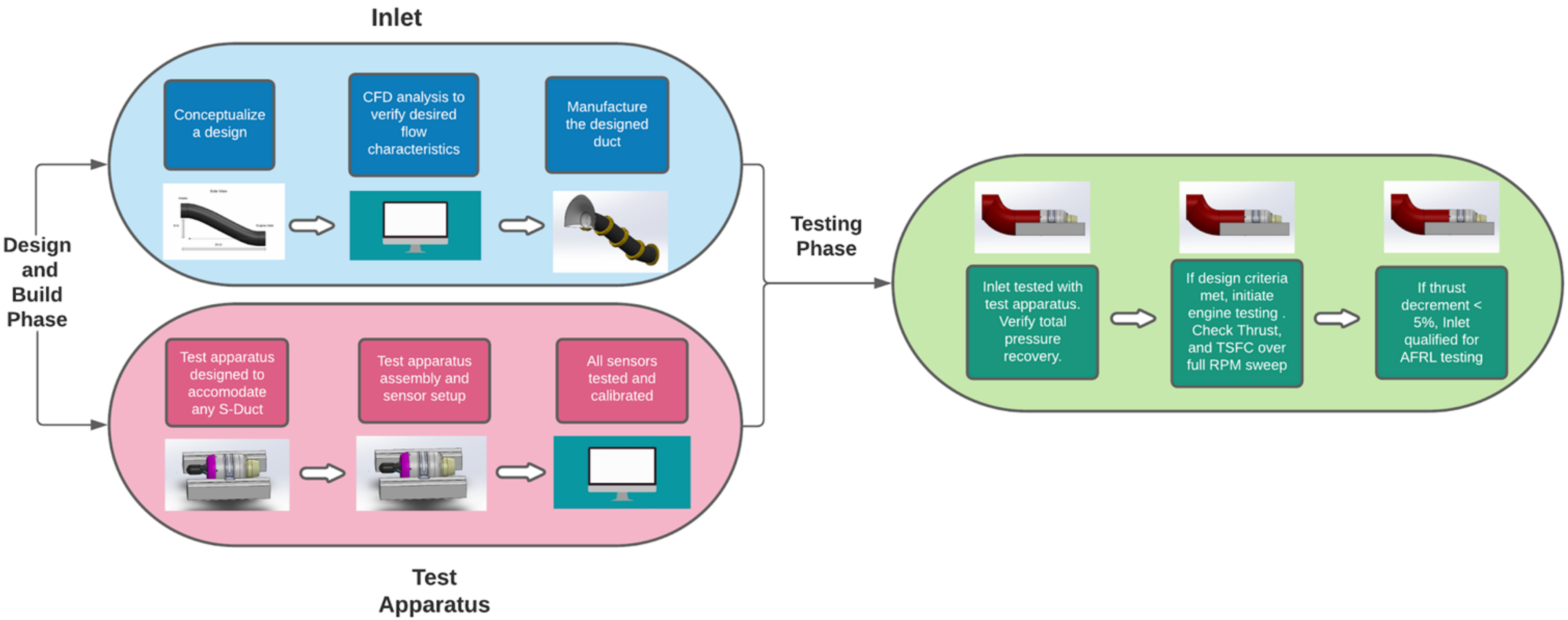
The purpose of the OSPRI project is to:

- Design and build an S-duct inlet for use with the JetCat P100-RX turbojet engine, for the Air Force Research Lab's (AFRL's) Aerospace Propulsion Outreach Program (APOP)
- Additionally, OSPRI will design and build a testing apparatus to measure total pressure and distortion distributions in the inlet, and measure fuel flow and thrust produced by the JetCat

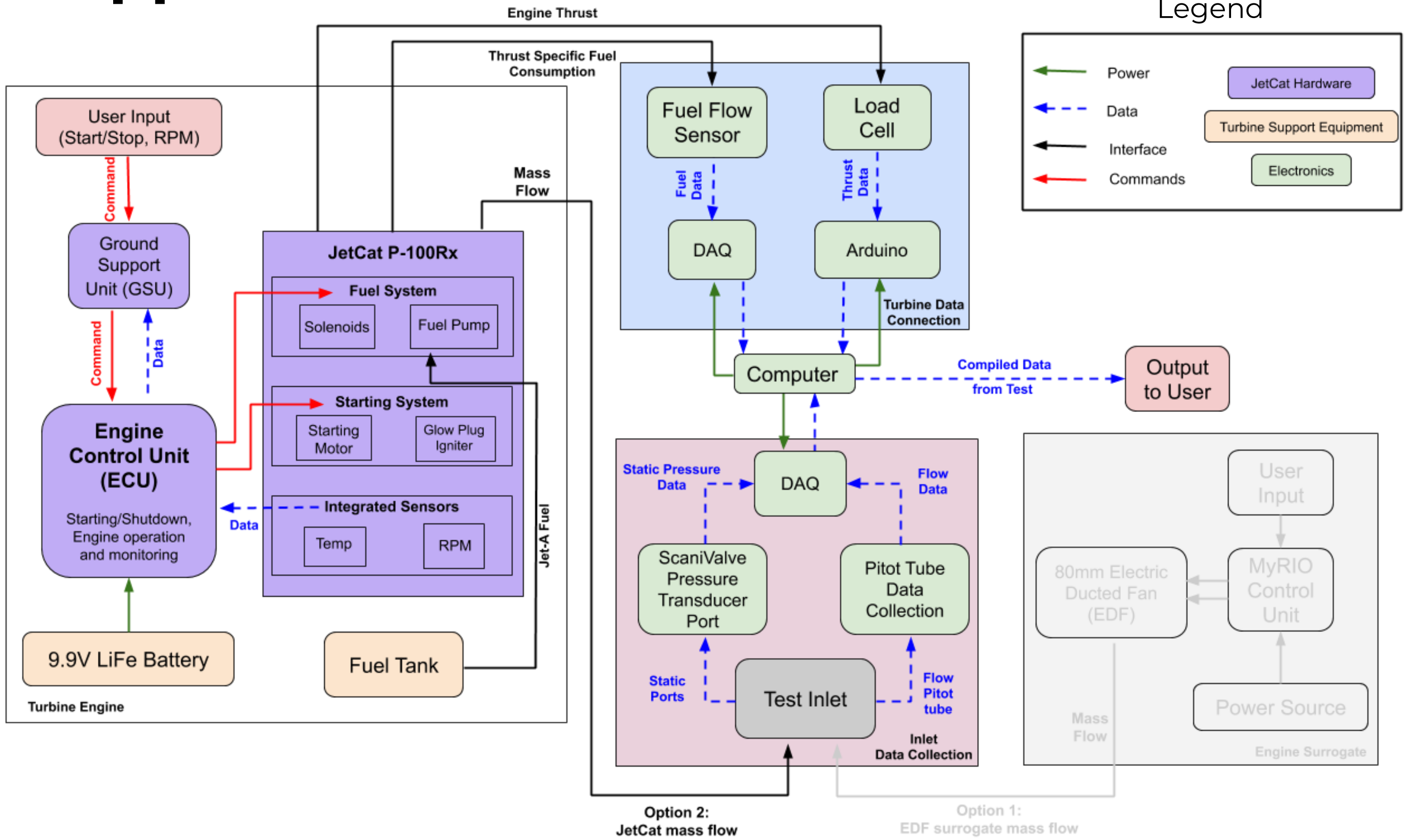
# Project Model



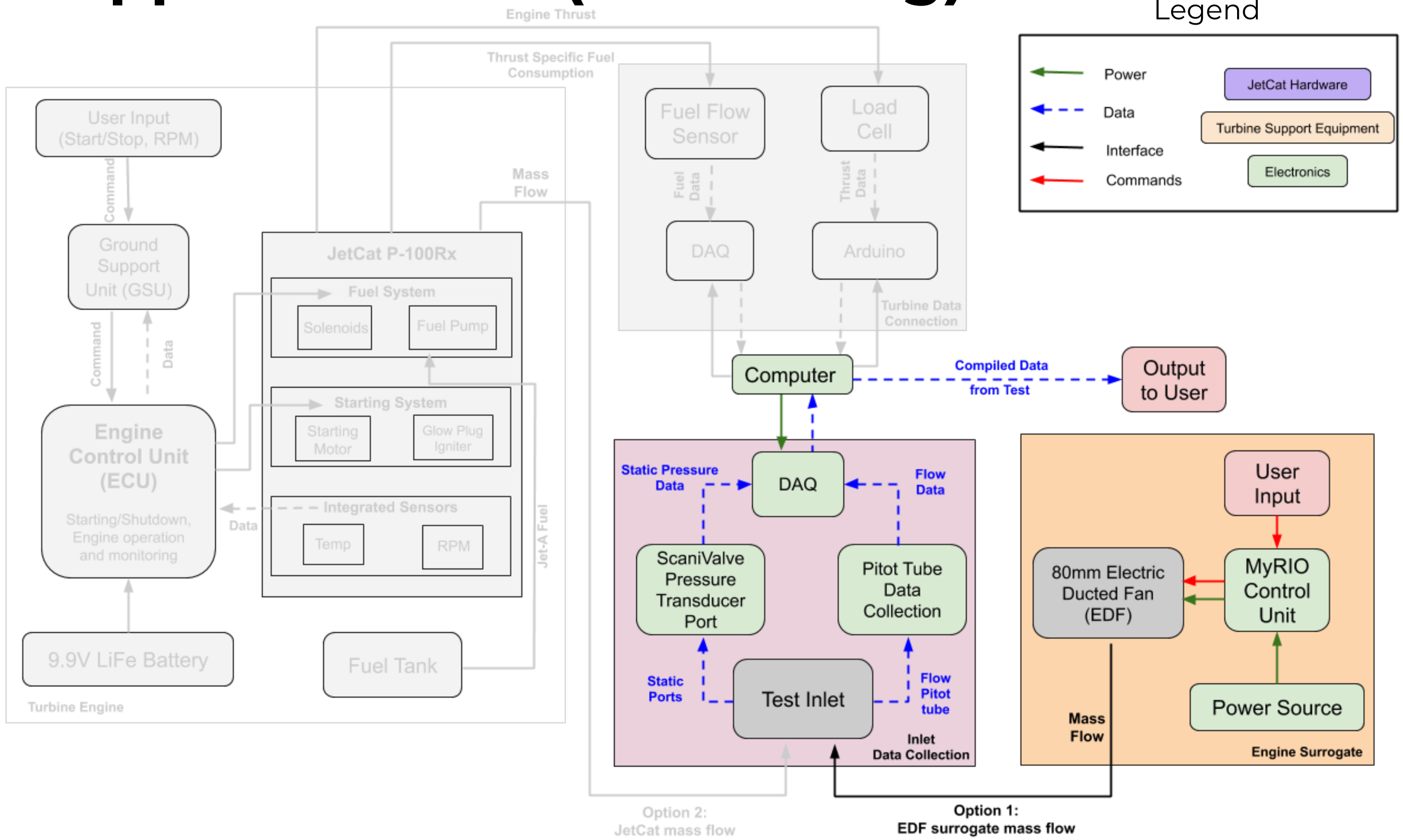
# Concept of Operations (CONOPS)



# Test Apparatus FBD



# Test Apparatus FBD (For Testing)



# Levels of Success

| Level | Objective |
|---|---|
| 1 | A test rig is designed and manufactured that is capable of measuring all parameters as outlined in the Design Requirements |
| 2 | Experimental Verification of the test rig's ability to measure thrust and TSFC |
| 3 | Experimental Verification of the test rig's ability to characterize the flow within a test inlet |
| 4 | Experimental verification of an inlet with total pressure recovery >90% |
| 5 | Experimental verification of nominal engine operation with level 4 inlet attached, with decrements to thrust and TSFC of no more than 10% |
| 6 | Experimental verification of nominal engine operation with inlet attached, with decrements to thrust and TSFC of no more than 5%, and total pressure recovery ≥98% |

# Critical Project Elements (Test Apparatus)

1. LabView & Electronics:
   *Three main functions from LabView control: Sensor data collection, EDF control, and turbine related sensor data collection*

1. Mass Flow Surrogate:
   *Engine condition replication using Electric Ducted Fans allows for more inlet testing*

1. Support hardware and infrastructure:
   *Test apparatus anchor point providing support for inlet, facilitates EDF and turbine tests*

1. JetCat integrated testing:
   *Testing to calibrate and increase mass flow surrogate fidelity, integrated testing with inlet to provide thrust and TSFC data (customer requested)*

# Critical Project Elements (Inlet)

1. Print Inlet Sections:

   *Print inlet sections in a timely and cost effective manner*

1. Print Transition Pieces:

   *Print transition pieces provided by AFRL*

1. Assembly:

   *Assemble the printed sections and get inlet ready for testing*

1. Iterative re-design and second printing:

   *Utilize data gathered to manufacture improved inlet*

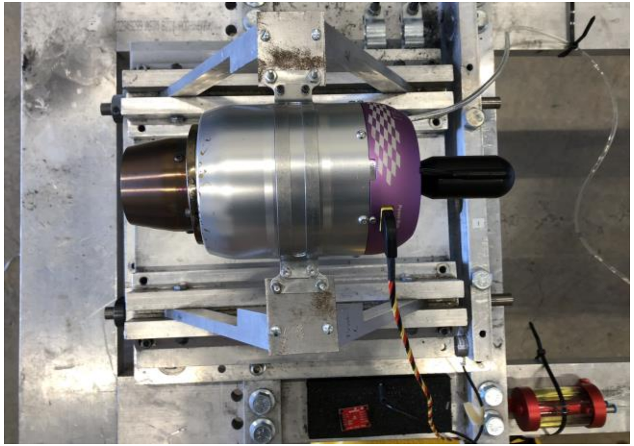
# JetCat Verification Test Status: Complete

**Objective:** Ensure that OSPRI has all required facilities and hardware to run turbine in the aerospace building

**Test Fixtures:** Engine test cell, horizontal engine test stand

**Equipment/Setup:** JetCat engine, engine support equipment, radios (for communication)

**Risk Management:**
- Ensure that there is a functioning turbine to conduct live inlet tests
- 2 man system with radio communication
- Blast proof control room
- Exhaust blast shield
- Clearing FOD immediately near turbine


Turbine mounted on engine cell test stand

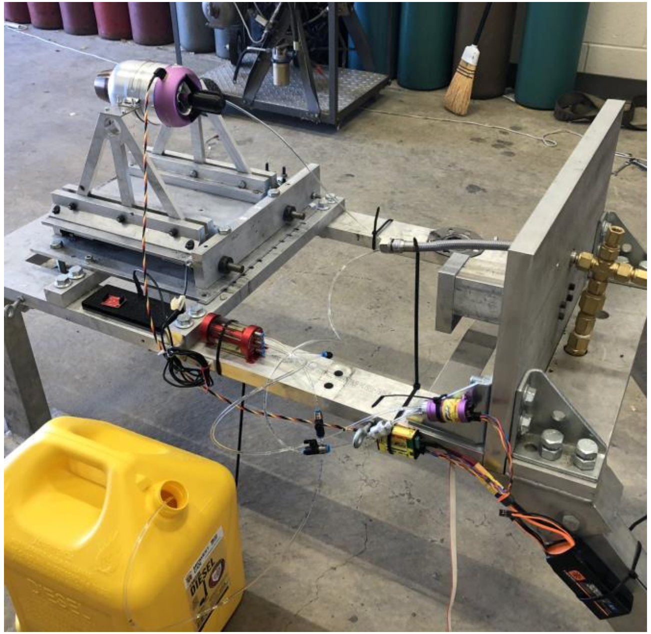
# Procedure and Results (JetCat Verification Test)

**Procedure**

1. Secure turbine and all associated support equipment to the horizontal test stand
   a. Route control cable for GSU into control room
2. Open garage door and set up blast shield
3. Notify professor ready to run turbine
4. Place downrange man outside /radio test ready

**Results**

- 2 successful test runs (~1 min and 5 min)
- Preliminary thrust data collection failed, arduino error



Turbine setup with support equipment in test cell

# Risk Mitigation

1. Thrust data systematic errors from designed test apparatus
    a. Obtain thrust data without test stand to minimize friction on load cell
2. EDF doesn't act as accurate surrogate replicating the JetCat mass flow performance
    a. Acquire larger battery from projects room
    b. Purchase larger EDF
3. Acquisition of pressure data may disturb the flow
    a. Utilize a small diameter pitot-static probe for minimal distortion
4. Damage to JetCat engine during testing
    a. Verify inlet with EDF and verify test procedures
5. Inlet structure failure during integrated JetCat test
    a. Perform stress analysis on inlet in CAD
    b. Make inlet outer wall thicker

| Risk Matrix | Impact | | | |
|---|---|---|---|---|
| | Insignificant | Minor | Major | Catastrophic |
| Certain >90% | | | | |
| Likely 30-85% | | 3 | | |
| Unlikely 10-30% | | 2 | 1 | 4 |
| Rare <10% | | | | 5 |

# JetCat Baseline Test **Status:** In Progress

**Objectives:** Obtain JetCat thrust and thrust specific fuel consumption data

**Test Fixtures:** Engine test cell, horizontal engine test stand

**Equipment/Setup:** JetCat engine, engine support equipment, Scanivalve & pitot probe, radios (for communication)

**Risk Management:**

- Data collected will provide baseline which will be used in performance analysis
- 2 man system with radio communication
- Blast proof control room
- Exhaust blast shield
- Clearing FOD immediately near turbine

# Procedure and Results (JetCat Baseline Test)

**Procedure**

1. Secure turbine and all associated support equipment to the horizontal test stand
    a. Route control cable for GSU into control room
2. Set up load cell with the data collection arduino for thrust data
3. Set up and connect fuel flow sensor to fuel tubing
4. Open garage door and set up clast shield
5. Notify professor ready to run turbine
6. Place downrange man outside/radio test ready

**Results**

- Test not conducted
- Goal: Measure corresponding thrust and TSFC

# Wind Tunnel Sensor Characterization Test **Status:** Outstanding

**Objective:** Characterize steady state flow pressure data consistency to calibrate data sampling configuration.

**Test Fixtures:** Wind tunnel

**Equipment/Setup:** Pitot Probe, Scanivalve, LabView Pressure DAQ software

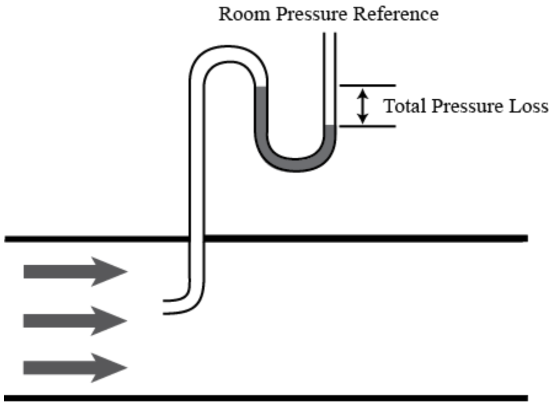
**Risk Management:**

- Ensures accurate flow data measurements in later experiments
- Operate wind tunnel on existing procedures
- Single operator in the wind tunnel room

# Procedure and Results (Wind Tunnel Sensor Characterization Test)

## Procedure

1. Secure pitot probe in wind tunnel test section & connect to scanivalve
   a. Measure total pressure referenced against room pressure
   b. Represents the total pressure loss of the Wind Tunnel Inlet
2. Collect pressure data at a variety of steady state flow velocities (5, 10, 15, 20 m/s) using OSPRI device & software




## Results

- Test not conducted
- Goal: Characterize pressure measurement uncertainty at steady state conditions

# JetCat Mass Flow Data Collection Test **Status:** Outstanding

**Objectives:** Verify previous JetCat mass flow model calculations.

**Test Fixtures:** Engine test cell, horizontal engine test stand, inlet test frame, AFRL transition piece

**Equipment/Setup:** JetCat engine, engine support equipment, bellmouth inlet, pitot probe, scanivalve, labview

**Risk Management:**

- Data collected reduces error for the mass flow rates of the surrogate
- Prior tests with JetCat to ensure safe operation of the JetCat turbine
- 2 man system with radio communication
- Blast proof control room/exhaust blast shield
- Clearing FOD immediately near turbine

# Procedure and Results (JetCat Mass Flow Data Collection Test)

**Procedure**

1. Secure turbine and all associated support equipment to the horizontal test stand
2. Connect pitot probe to scanivalve (located in control room for safety)
   a. Route control cable for GSU into control room
3. Secure bellmouth to frame and AFRL transition piece on turbine
4. Open garage door and set up blast shield
5. Notify professor ready to run turbine
6. Place downrange man outside/radio test ready

Straight Bellmouth

**Results**

- Test not conducted
- Goal: Collect mass flow at 5 representative point within the JetCat's RPM sweep

# EDF Mass Flow Verification Test **Status:** Outstanding

**Objectives:** Verify EDF is capable of computed requirements and actual JetCat mass flow data & correlate throttle input to mass flow

**Test Fixtures:** Wind Tunnel Room, Bell mouth, Test Apparatus, EDF transition piece

**Equipment/Setup:** EDF, 4-6 S battery, Pitot Probe, Scanivalve

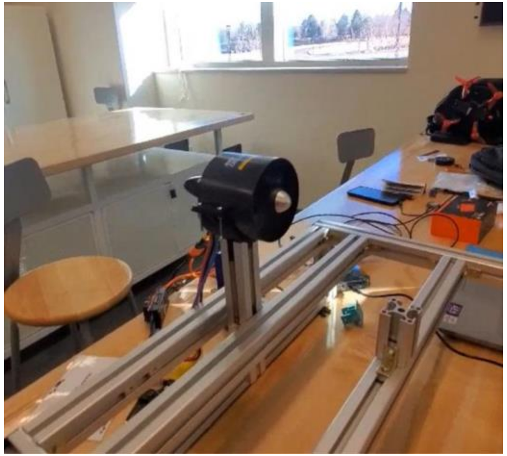
**Risk Management:**

- Risk reduction by using EDF instead of JetCat for preliminary inlet tests
- Test Apparatus being used to secure the EDF

# Procedure and Results (EDF Mass Flow Verification Test)

**Procedure**

1. Attach the EDF to the bellmouth inlet
2. Set up pitot tube to measure dynamic pressure
3. Note distance and position of probe from EDF
4. Calculate mass flow at various total throttle % setting (25%, 50%, 75%, 100%)
    a. Begin with a 4S battery
    b. If necessary, increase power with a 6S battery



EDF mounted to test stand

**Results**

- Test not conducted
- Goal: Confirm that selected EDF is adequate
- Goal: Develop an equation relating throttle to mass flow

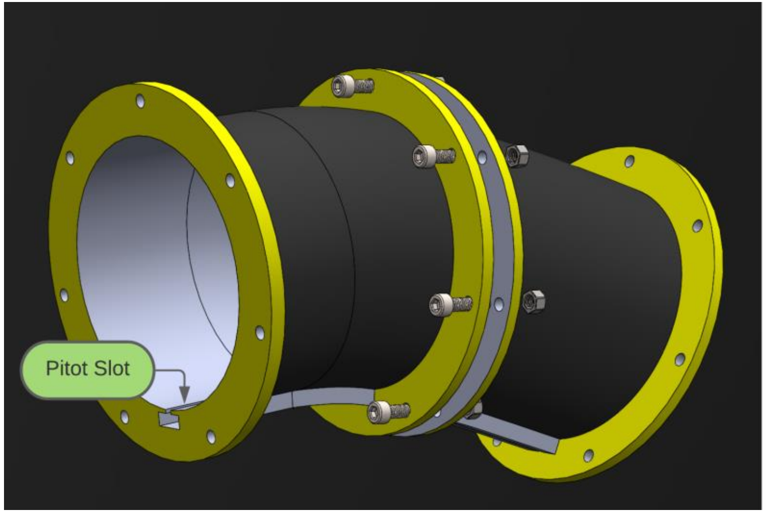
# Inlet Verification

**Primary Aspects to verify:**

- Total pressure recovery from intake to exit (>98%)
- Thrust decrement < 5%
- TSFC decrement < 5%
- Primary scoring criteria

**Test Fixtures:**

- Slot design to insert a pitot tube
- Test stand attached to a load cell




Inlet Sectional Side View

# Inlet Verification EDF

**Why the EDF?**

- To prevent damages to the JetCat in case of poor inlet performance

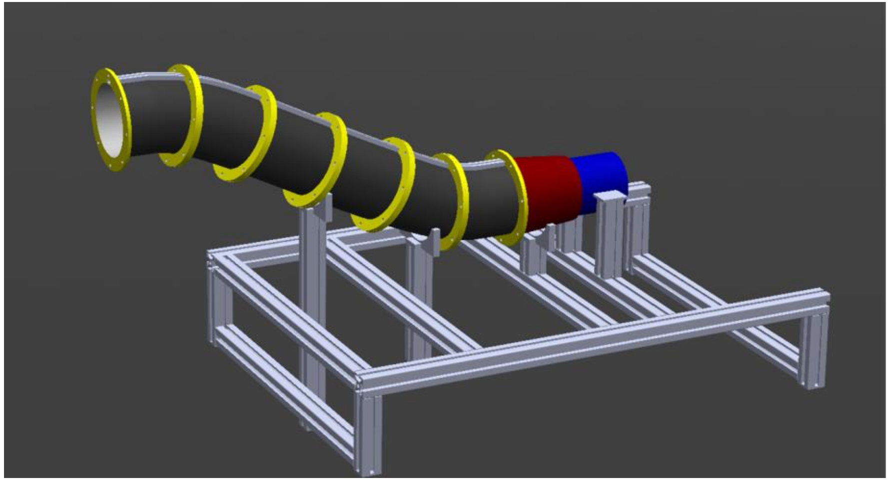
**Equipment/Setup:**

- Extensively uses  test apparatus
- Engine test room used for testing

**Risk Management:**

- Sensors calibrated using wind tunnel in the aerospace building
- Additional support structure to hold the inlet

**Anticipated Start Date:** March 6th



Experimental Setup with EDF

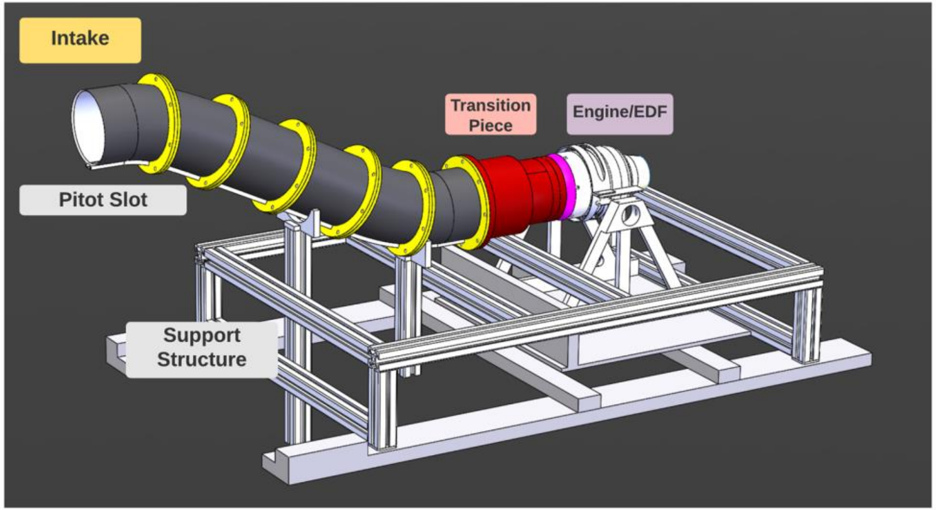
# Inlet Verification JetCat

**Verification:**
- Measure thrust and TSFC performance
- Final testing before AFRL testing

**Equipment/Setup:**
- Test apparatus plus the existing experimental stand
- Engine test room used for testing

**Risk Management:**
- Inlet pressure recovery verified and tested on the EDF
- Same sensors used for consistent data

**Anticipated Start Date:** March 15th

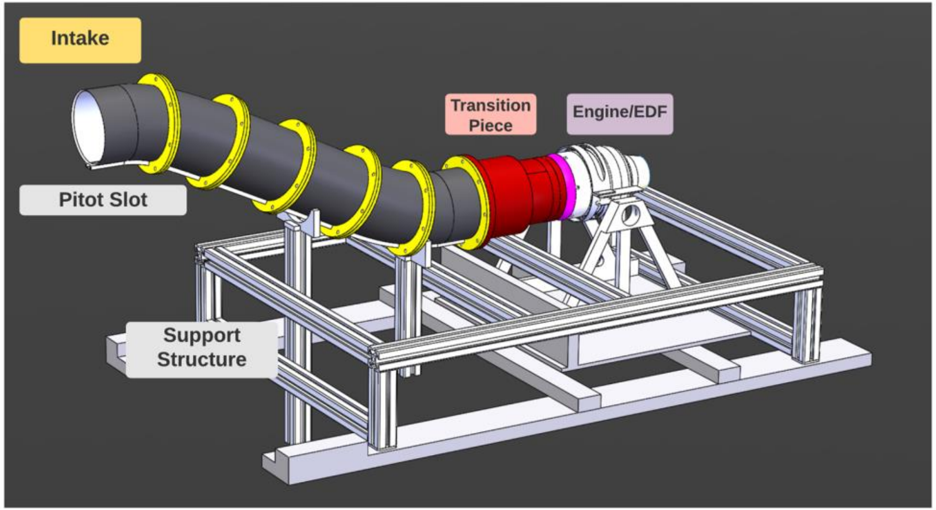



Inlet Experimental Setup

# Procedure and Results (Inlet Verification)

## Testing Procedure

1. Verify inlet and EDF/engine assembly is seated in TA.
2. Insert pitot tube into slotted inlet section
    a. Perpendicular to sidewalls
    b. 5 test points
    c. Patch slot(s) with HVAC tape
3. Power EDF, collect dynamic pressure data.
4. Collect thrust data from load cell
5. Repeat steps 2, 3 and 4 moving toward compressor face




Inlet Experimental Setup

## Results

- Goal: Have an array of pressure values along inlet
- TSFC calculated using data

# Expected Result and Model Verification

**Verification:**

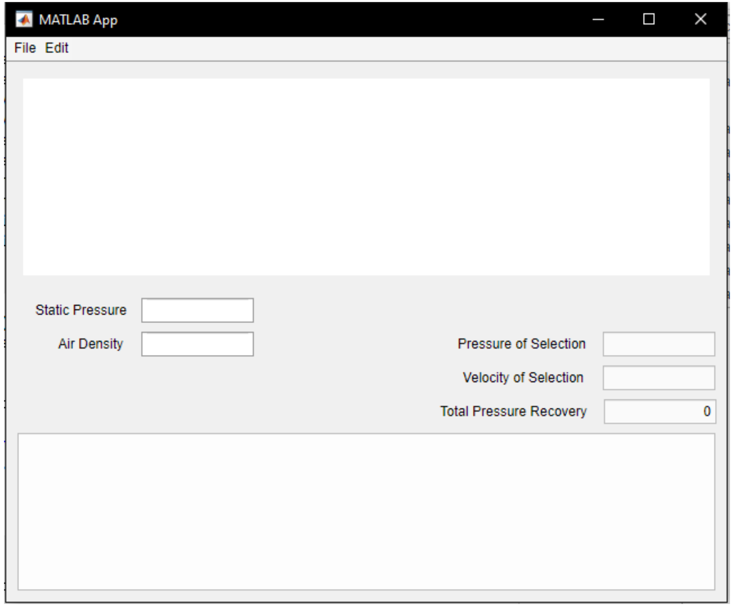
- Using the pitot tube, EDF, and jet engine to capture cross-sectional dynamic pressure profiles of the inlet.

**Expected Success:**

- Verify high Total Pressure Recovery % > 98%.
- Verify flow separation points and boundary layer formations as predicted.

**Further Developments:**

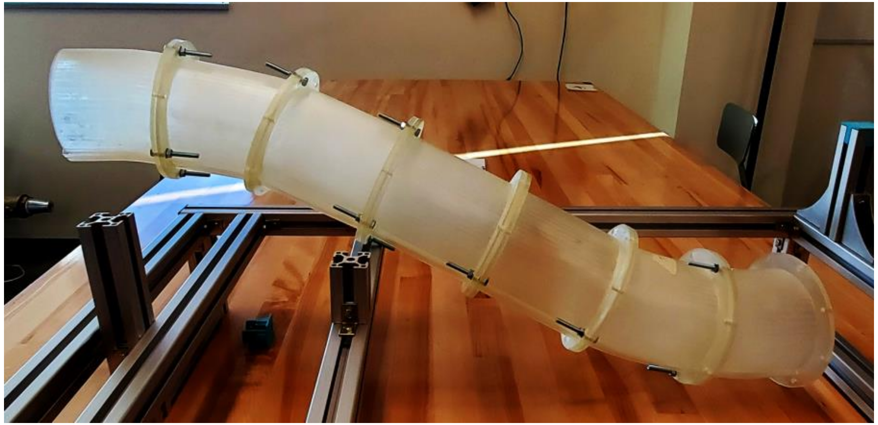
- Working on 3D CFD to further improve the fidelity of the CFD models, as well as improve the redesign workflow.




MATLAB GUI that will help calculate total pressure recovery from the data expected

# Current Status

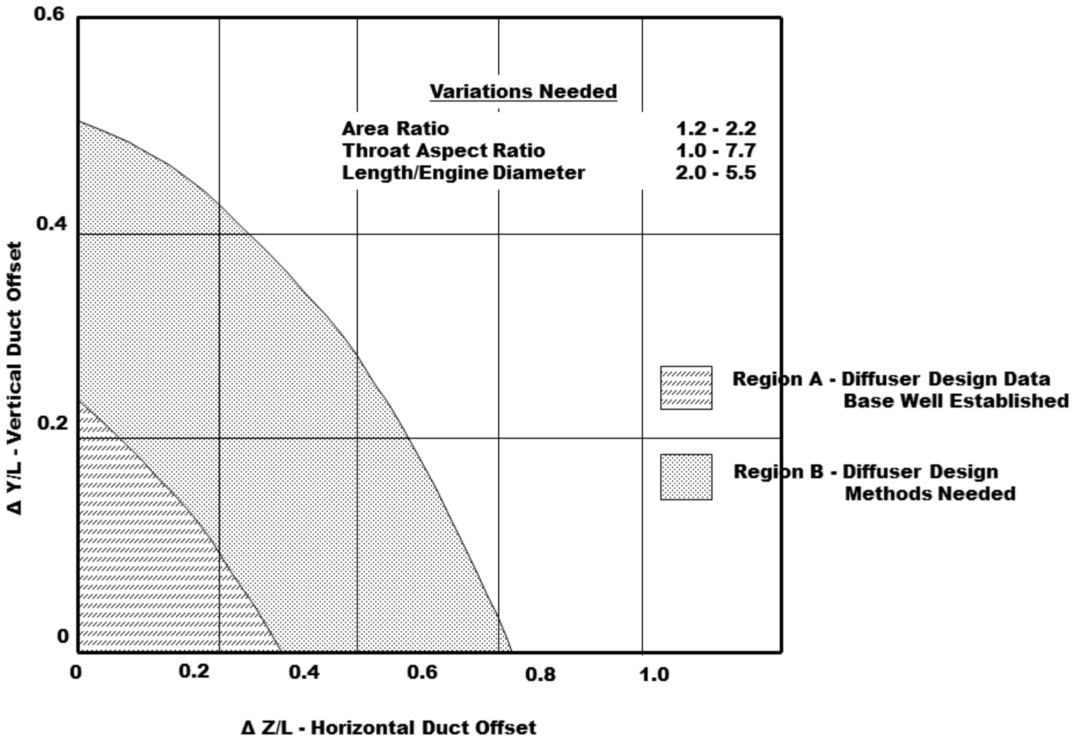
- Inlet Assembled
- Ready for initial verification test



First Inlet Iteration Assembly

# Inlet Slides

# Inlet Length Guide



# Vortex Generator Example Visualization [10]

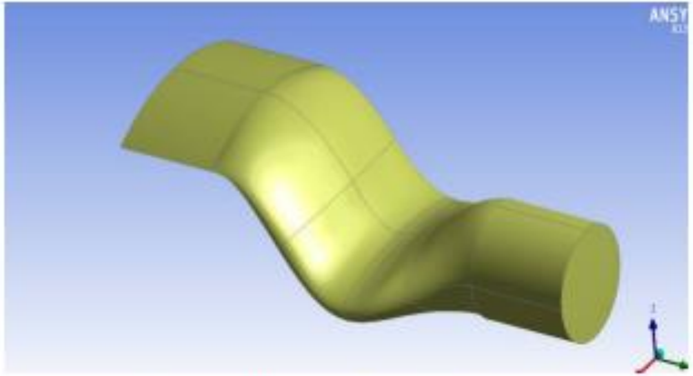



Figure-1 Baseline serpentine duct model

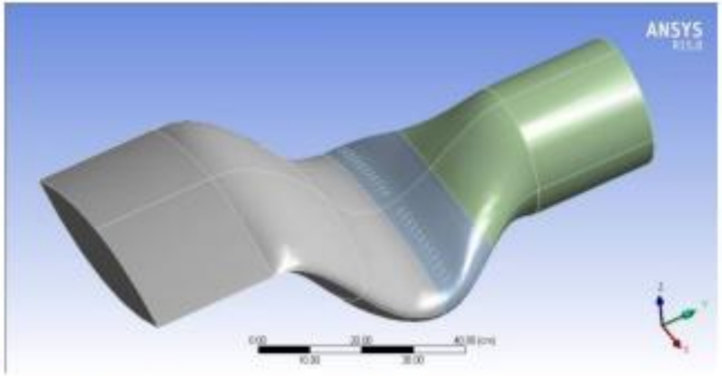
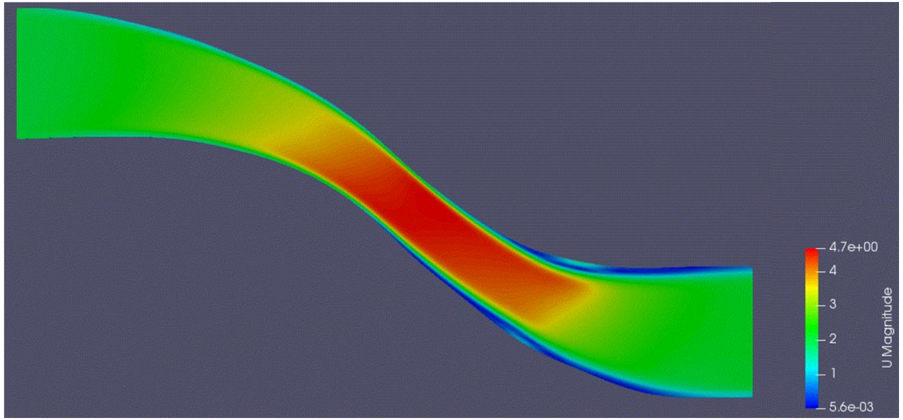


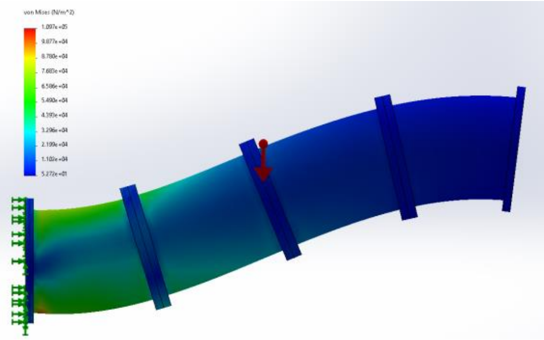

Figure-2 Serpentine duct with vortex generators

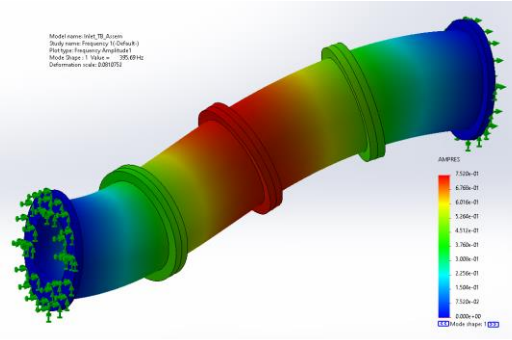
# CFD Results (Design 05) using icoFoam

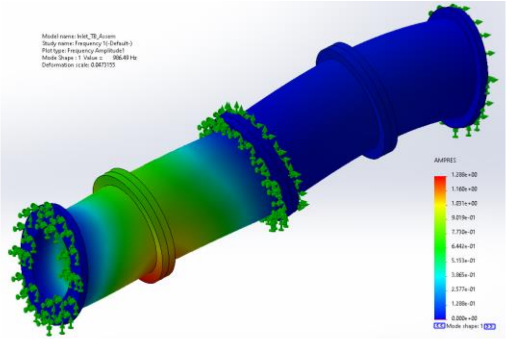



Re#: ~2350 (Transition-Turbulent Flow)

# Stress and Vibration Analysis




- Free standing Static

- Restrained at ends only
- 1st failure mode at 396 Hz

- Restrained at ends and throat
- 1st failure mode at 986 Hz

- Tests conducted with Formlabs Standard (Clear) material properties
- Inlet: L = 24 in AR = 1

# Challenges

- ➔ Crack in flange of Inlet section
  - 2 cm length
  - Does not extend to the actual inlet
  - Pressing forward with use


Top View

# Outsourced Quotes

➔ The 3D Printing Store

## Quote

3DPS
3D PRINTING STORE
Powered By

| | |
|---|---|
| Date: | January 25, 2021 |
| Valid Until | February 24, 2021 |
| Customer: | Tim Breda |

**Customer Info:**

| | |
|---|---|
| Company | |
| Client | Tim Breda |
| Email | Timothy.Breda@colorado.edu |
| Number | |

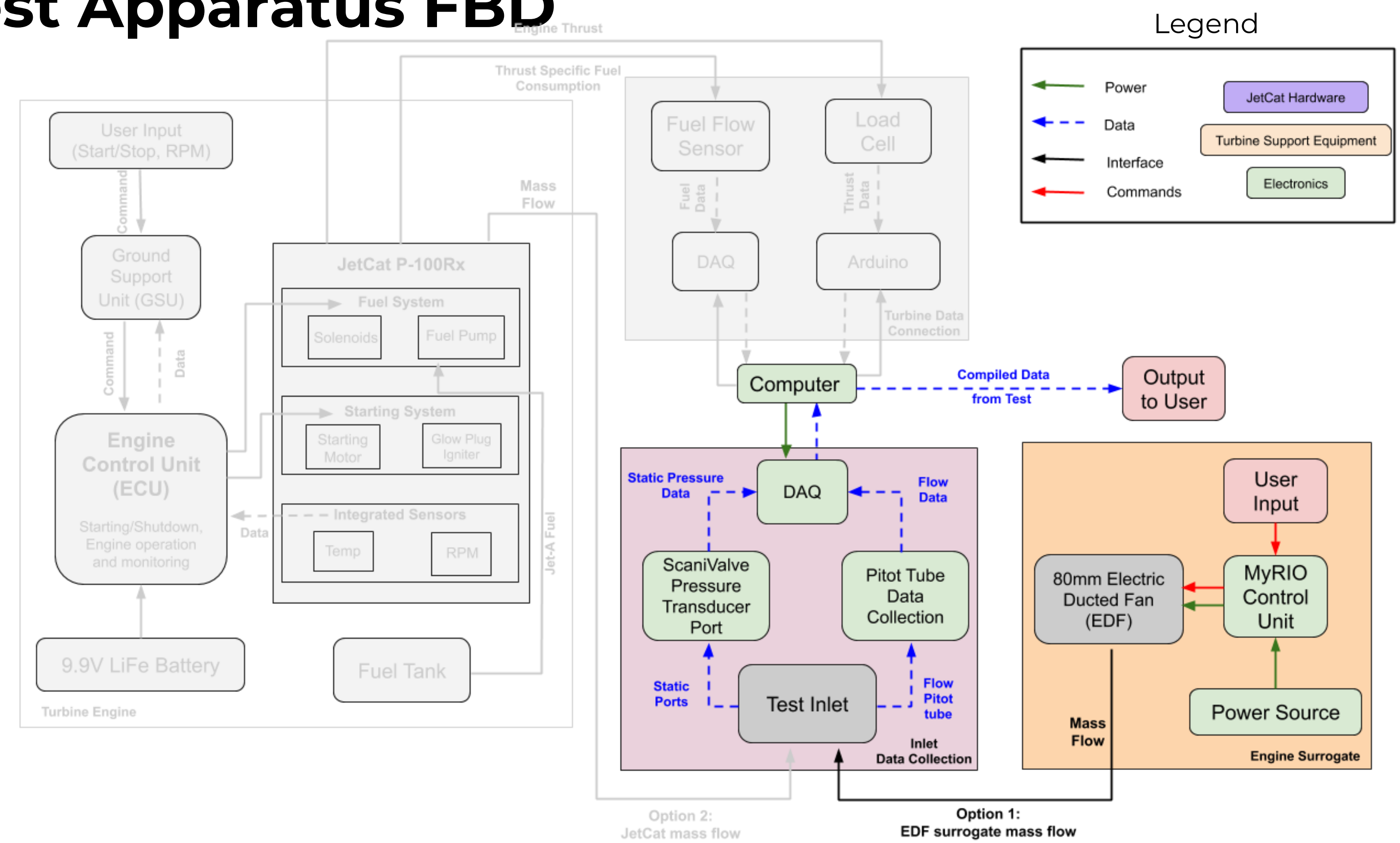
**Quote/Project Description**

50 um EDF transition and Inlet and Inlet transition and Jetcat 1x each
Hard Black-Photocentric

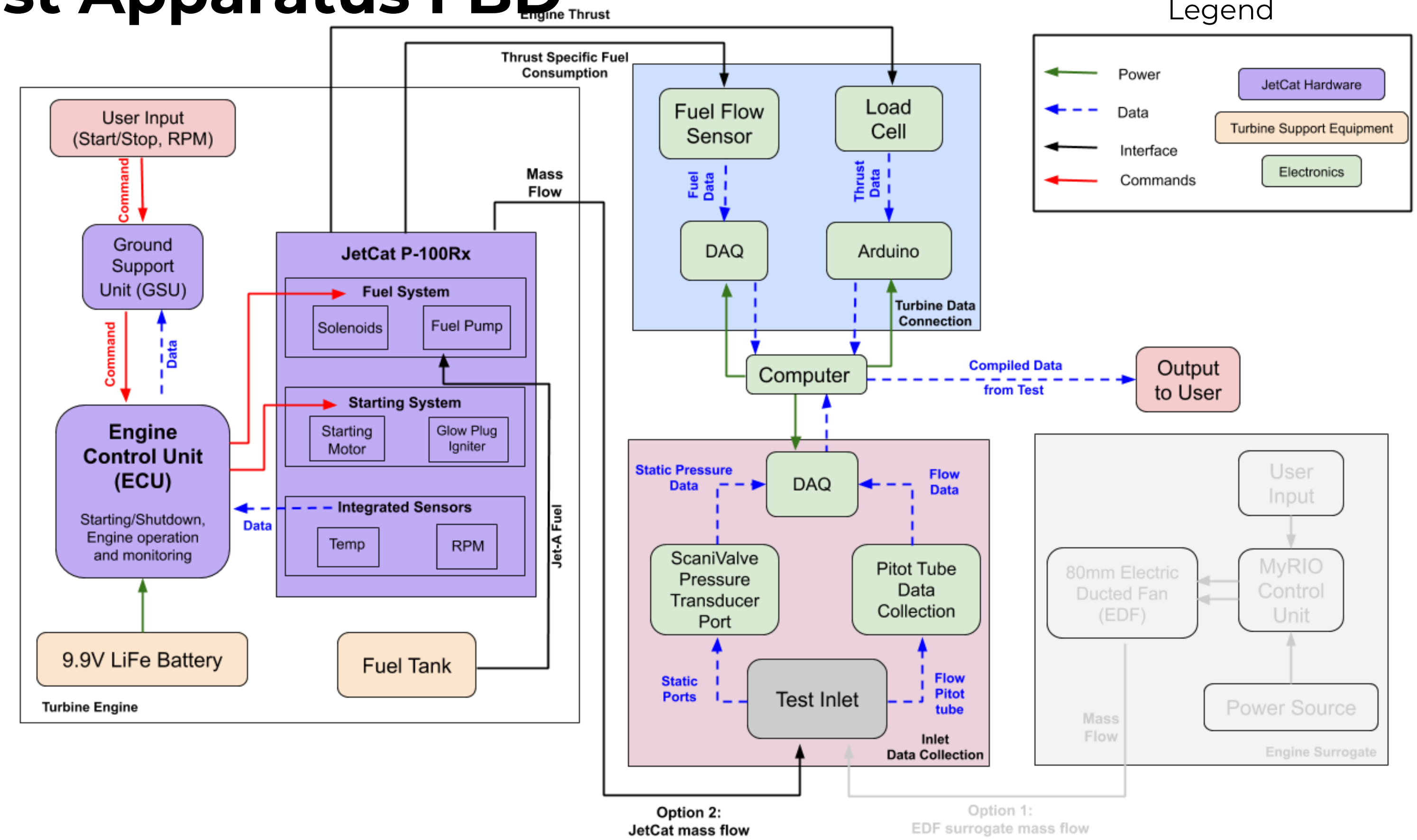
| Line Item | Service | Description | Quantity | Unit | Price | Line Total |
|---|---|---|---|---|---|---|
| 1 | Print | 50 um EDF transition and Inlet and Inlet transition and Jetcat 1x each Hard Black-Photocentric | 1.00 | Each | $780.09 | $780.09 |
| 2 | Sanding | | 2.00 | Hours | $35.00 | $70.00 |
| 3 | Support Removal | | 2.00 | Hours | $10.00 | $20.00 |
| 4 | | | | | | |
| 5 | | | | | | |

# Test Apparatus Slides

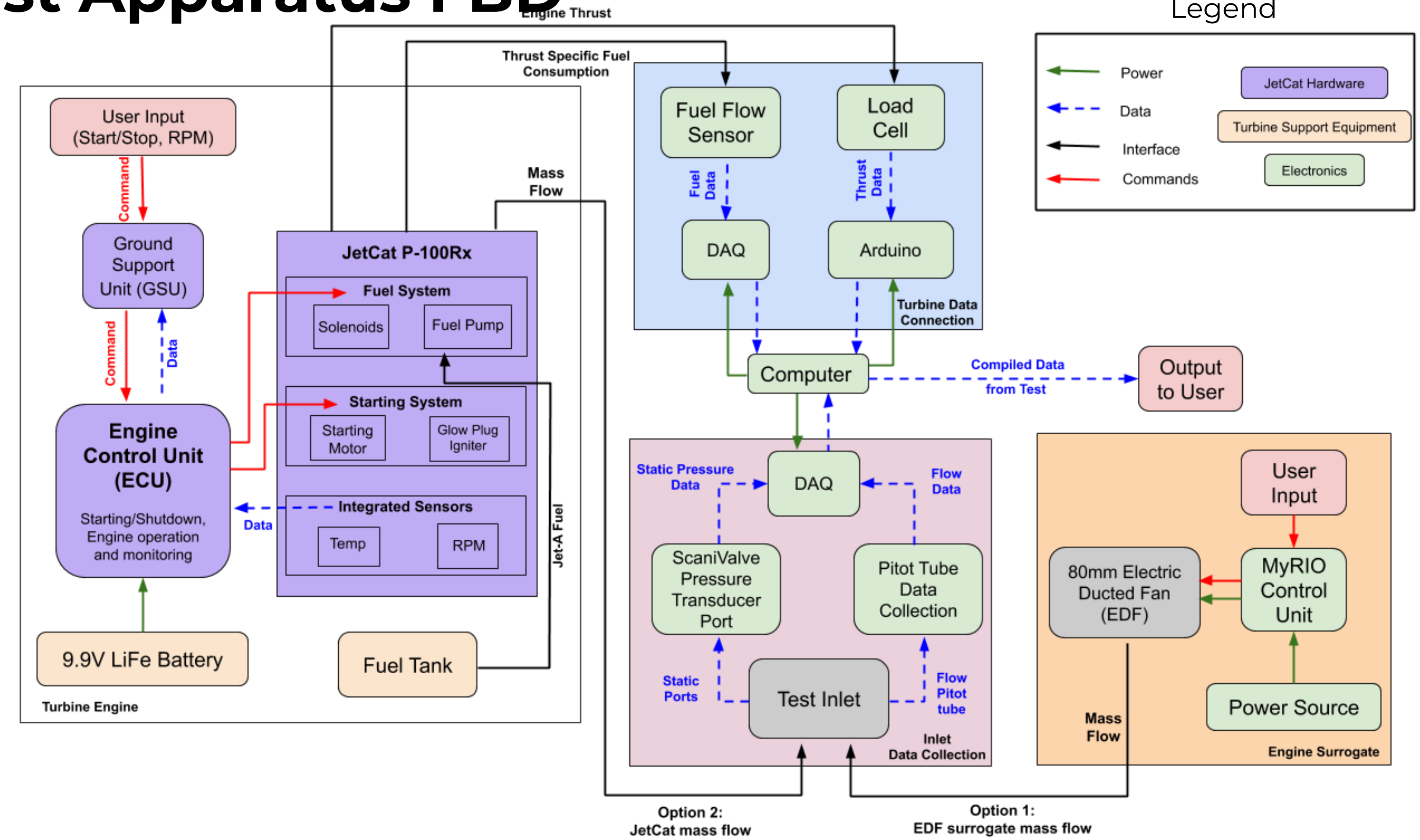
# Test Apparatus FBD



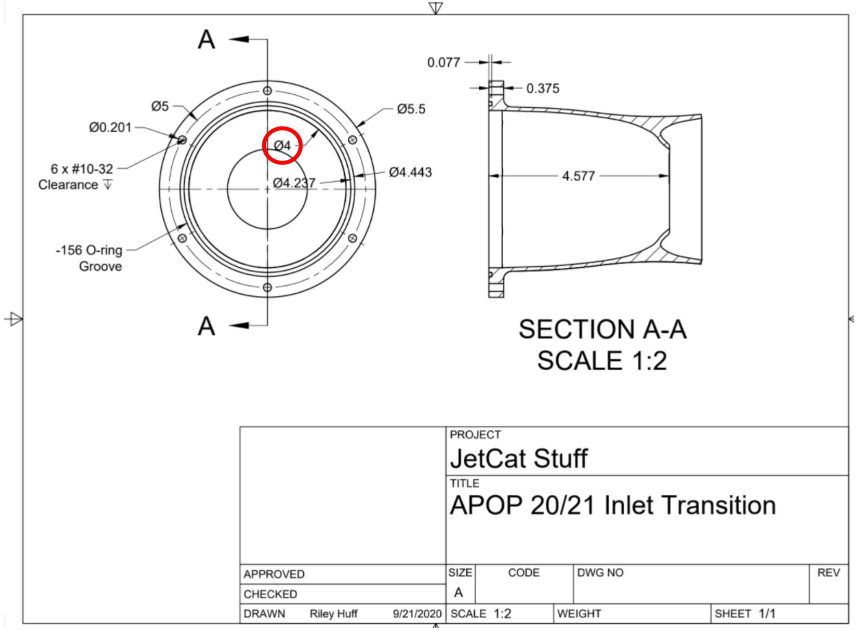
# Test Apparatus FBD



# Test Apparatus FBD



# Mass Flow Surrogation




$$\dot{m} = \rho \, v \, a$$

$$v = \frac{.23 \, \frac{kg}{s}}{\frac{\pi}{4} (0.1016m)^2 * (1.225 \, \frac{kg}{m^3})}$$

$$v = \mathbf{23.16} \, {}^{\mathbf{m}}/_{\mathbf{s}}$$

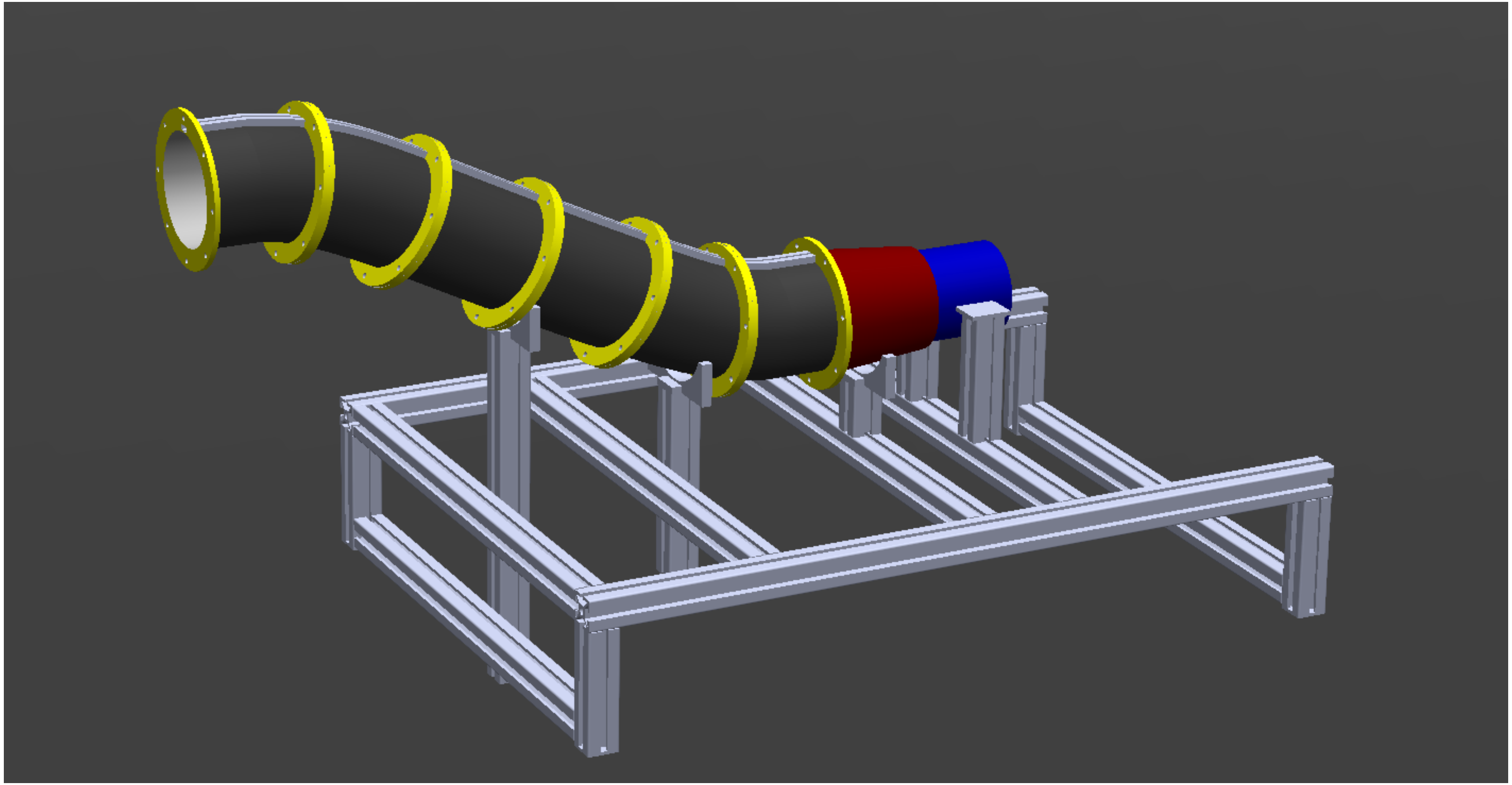
**Assumptions:**

Circular cross section

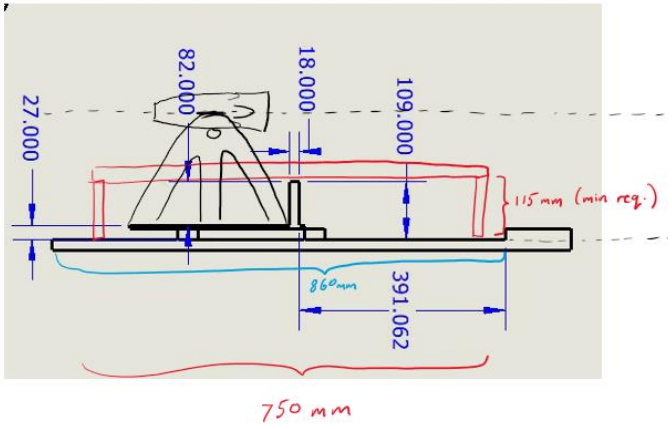
Constant area cross section

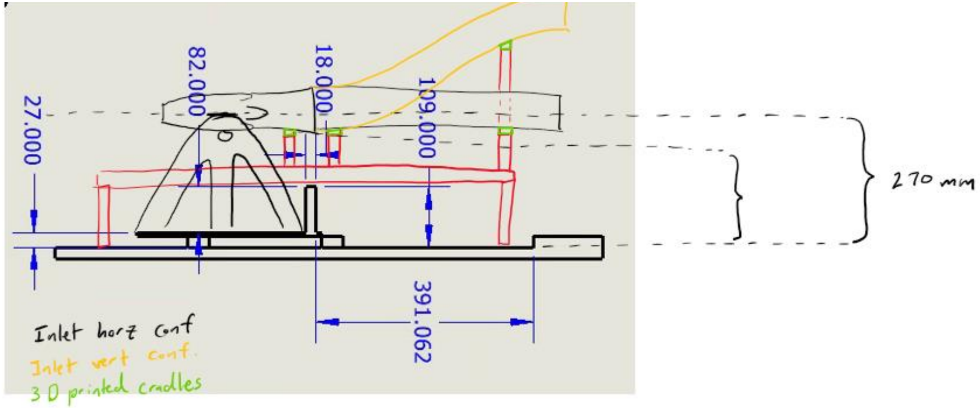
Standard atmospheric conditions

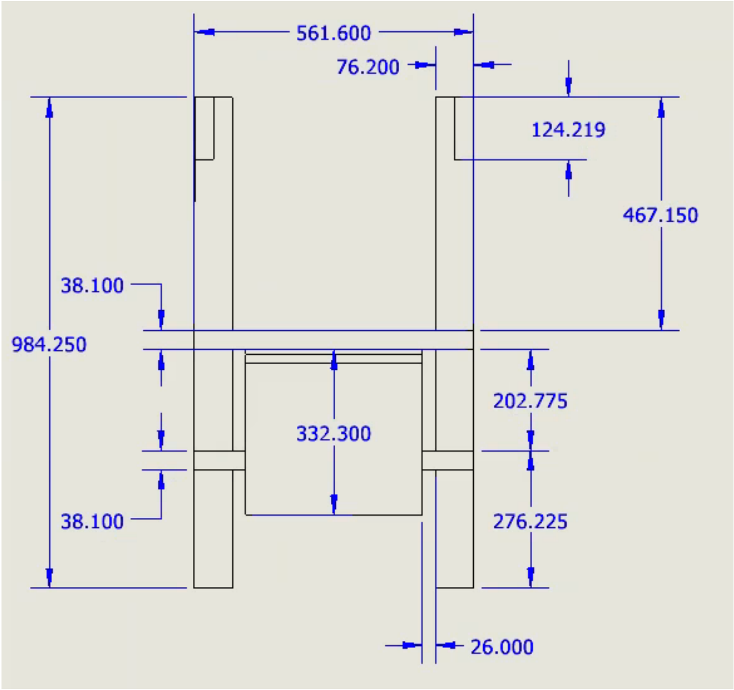
# Inlet Testing with EDF



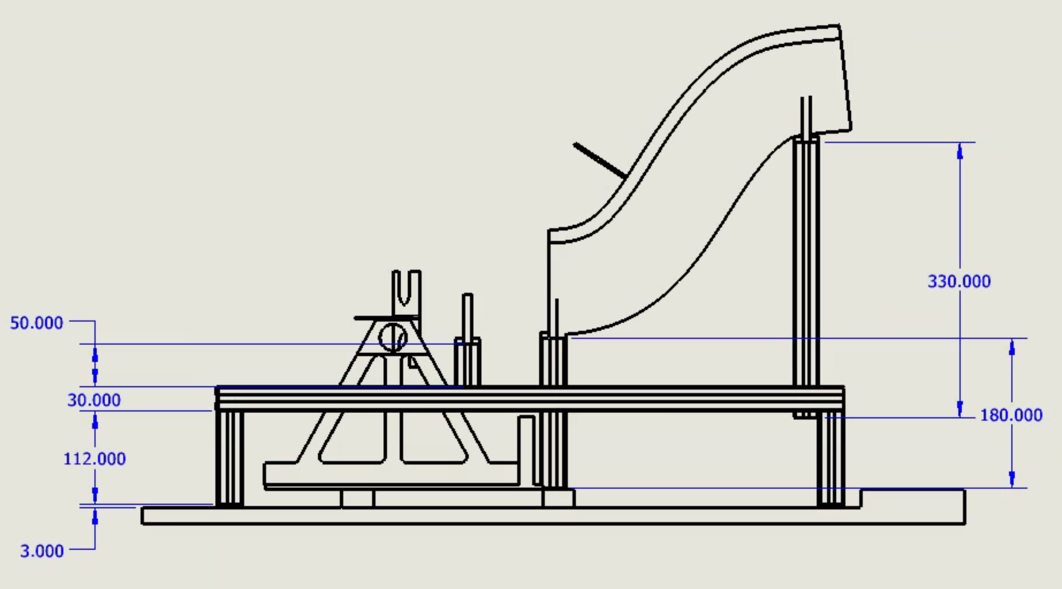
# Test Stand Design Process

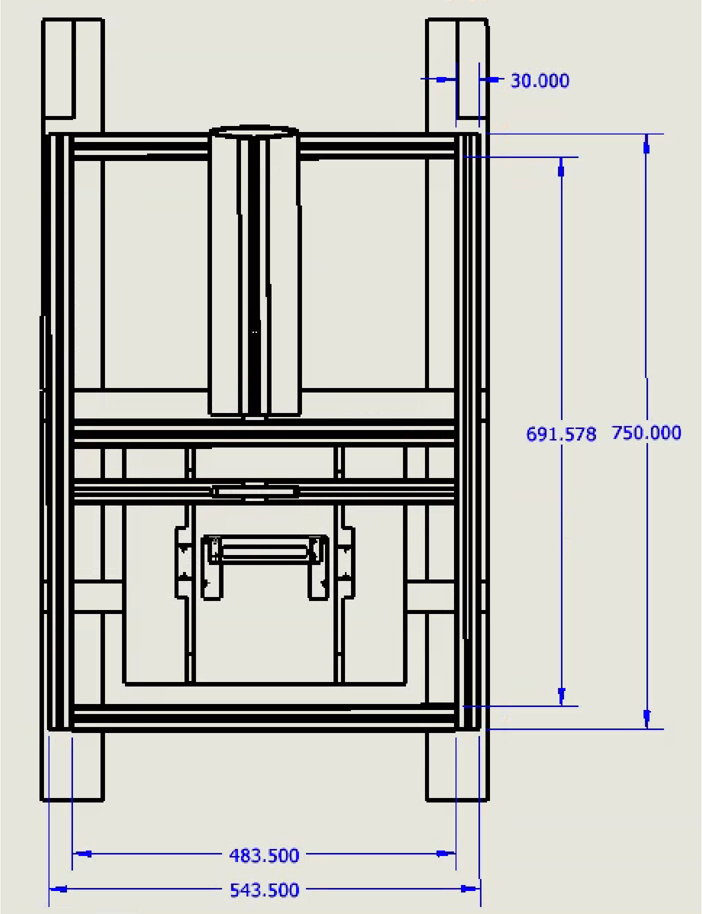


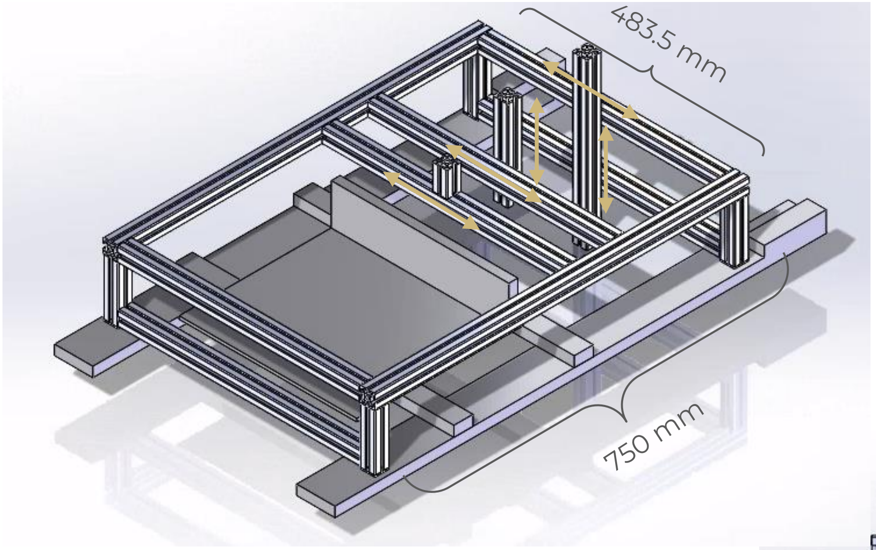



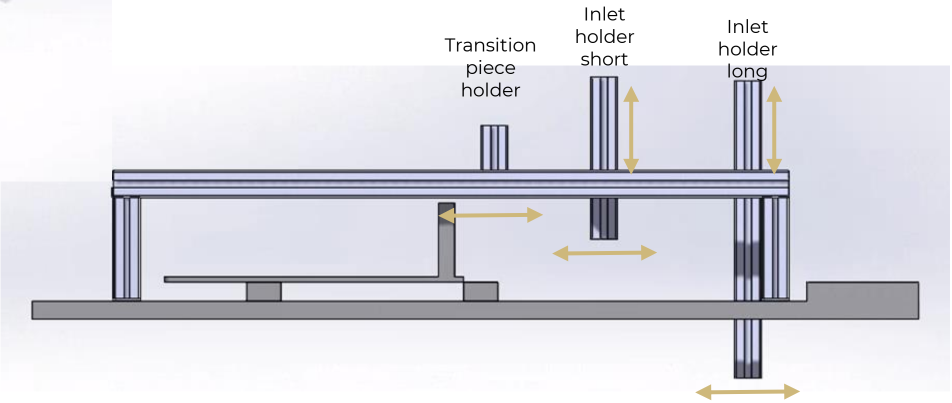
# Test Stand Frame



# Test Stand Frame

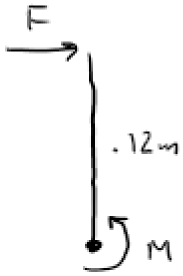


# Test Stand Design Process

| Item | Quantity | Length (mm) | Pice Per | Price Total |
|---|---|---|---|---|
| Struts Across | 6 | 483.5 | $5.31 | $31.86 |
| Struts Along | 2 | 750 | $8.25 | $16.50 |
| Vertical Stand Supports | 4 | 112 | $4.47 | $17.88 |
| EDF Trans Piece | 1 | 50 | $4.47 | $4.47 |
| Inlet Trans Piece | 1 | 50 | $4.47 | $4.47 |
| EDF Holders | 2 | 120 | $4.47 | $8.94 |
| Inlet Holder Short | 2 | 180 | $4.47 | $8.94 |
| Inlet Holder Long | 1 | 330 | $3.63 | $3.63 |
| End Caps | 4 | HFC6-3030 | $1.79 | $7.16 |
| EDF mount L brackets | 6 | HBLFSSW6 | $3.13 | $18.78 |
| Frame L Brackets | min of 40 (11 packs) | - | $1.98 (4 pack) | $21.78 |
| Channel Nuts | min of 80 | HNTT6-4 | package of 100 | $36.56 |
| M4 screws 10 mm | min of 80 (40 packs) | 10 | 0.98 (2 pack) | $39.20 |
| M4 screws 12 mm (EDF) | min of 8 (5 packs) | 12 | 0.98 (2 pack) | $4.90 |
| | | | Total | $225.07 |

# Test Stand Design Process




$$M = (dist)(Force)$$

$$F = \sim 2.3\ kg = 22.5553\ N$$

$$M = (120\ mm)(22.5553 N) = 2706.64\ N \cdot mm$$

$$Flexure\ Formula: \sigma_b = \frac{M \cdot (y\ dimension)}{I_y}$$

$$From\ 30x30\ Aluminum\ Extrusion\ Documentation:$$

$$I_y = 2.83\ x\ 10^4\ mm^4$$

$$y\ dimension = 30\ mm$$

$$\sigma_b = \frac{(2706.64\ N \cdot mm)(30 mm)}{2.83\ x\ 10^4\ mm^4} = 2.86923\ {}^{N}/_{mm^2}$$

**Mechanical Properties of Aluminum Extru**

| | JIS Standard (Reference) | JIS S |
|---|---|---|
| Series | HFS Series | |
| Material (JIS Symbol) | A6N01SS-T5 Aluminum Alloy | |
| Tensile Strength (N/mm²) | 245 or more | |
| Proof Stress (N/mm²) | 205 or more | |
| Longitudinal Elastic Modulus (N/mm²) | 69972 | |
| Brinell Hardness (HB) | 88 | |
| Surface Treatment | Anodize 9μm or more | |

https://us.misumi-ec.com/pdf/fa/2012/p2_0493.pdf

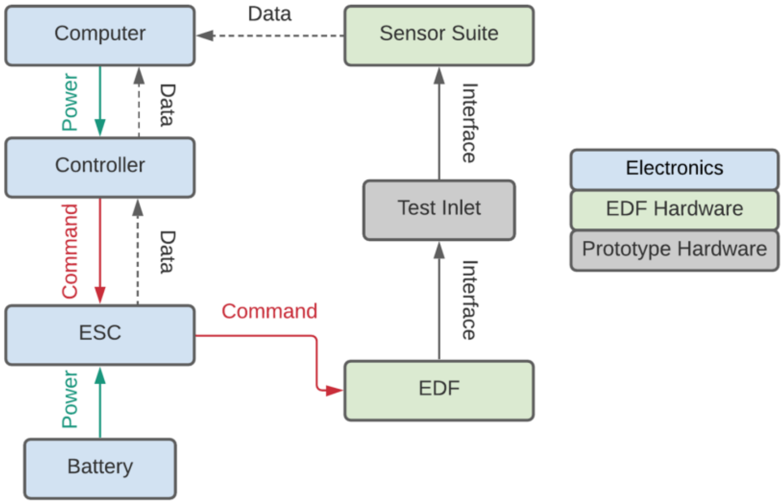
# EDF Control

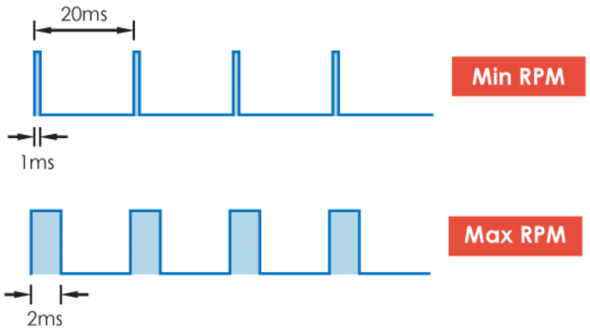
## Electronic Speed Control (ESC)

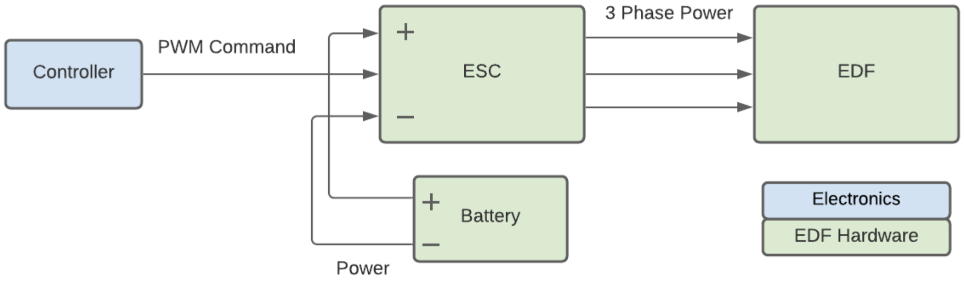
- Exact components dependant on EDF

## **ESC Signal** for RC EDFs

- 50 Hz PWM, 5-10% duty cycle

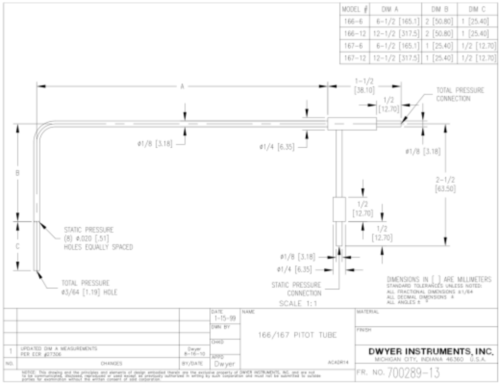


# Total Pressure Measurement: Pitot Probe

- Dwyer 167-6 pitot probe
  - $1/8_{th}$ inch diameter probe
  - 1.5 inch probe length
  - 6 inch insertion length
- $0.00098 \leq A_{probe}/A_{inlet} \leq 0.0099$
  - Area of probe over area of inlet at minimum and m
  - Minimal flow interference
- Probe accurate to within 0.5%
  - Only accurate at minimum of 5 m/s airflow
  - Accuracy converges above this speed
- Total & static pressure measured using scanivalve



# Equflow Flow Measurement Instrument

- Working closely with professor Trudy Schwartz to understand how t
- Instrument output is a square wave and counting the frequency wil
- Typically use a microcontroller or NI DAQ with a counter/timer char square wave, encoder, etc measurements.
- In the past teams have used the NI 9401 digital input module to rea
- Disposable to reduce clogging and inaccuracies. Will need to purch tests.
- Max turbine flow rate: 0.36 L/min
- Min turbine flow rate: 0.06 L/min (at idle)
- 0045 model flow rate: 0.1 - 1.8 L/min (with minimum flow of 0.06 L/m
- Pack of 10 Replacements (€ 400.00 ~ $470)
- https://www.equflow.com/product/pfa-click-housing-flow-sensor
- https://www.equflow.com/product/pfa-flow-tube-4-5-for-click-housing-tul

# Test Apparatus Spending

| Category | Item | Unit Price (USD) | Amount | Total Price |
|---|---|---|---|---|
| Test Stand Aluminum | Struts Across | $5.31 | 6 | 31.86 |
| | Struts Along | $8.25 | 2 | 16.5 |
| | Vertical Stand Supports | $4.47 | 4 | 17.88 |
| | EDF Trans Piece | $4.47 | 1 | 4.47 |
| | Inlet Trans Piece | $4.47 | 1 | 4.47 |
| | EDF Holders | $4.47 | 2 | 8.94 |
| | Inlet Holder Short | $4.47 | 2 | 8.94 |
| | Inlet Holder Long | $3.63 | 1 | 3.63 |
| Test Stand Accessories | End Caps | $1.79 | 4 | 7.16 |
| | EDF mount L brackets | $3.13 | 6 | 18.78 |
| | Channel Nuts | $36.56 | 1 | 36.56 |
| | M4 Screws 10 mm | $0.98 | 40 | 39.2 |
| | M4 Screws 12 mm | $0.98 | 5 | 4.9 |
| | Corner L Bracket (1) | $2.13 | 2 | 4.26 |
| | Corner L Bracket (2) | $2.42 | 10 | 24.2 |
| | Set Nut (M3-0.5) | $0.56 | 6 | 3.36 |
| | Set Screw (M3-0.5x6) | $0.56 | 6 | 3.36 |
| | Shipping | $19.36 | 1 | 19.36 |
| Total | | | | 203.29 |

# Instrumentation & Maintenance Spending

| Category | Item | Unit Price (USD) | Amount | Total Price |
|---|---|---|---|---|
| Massflow Surrogate | EDF | $39.99 | 1 | 39.99 |
| | ESC | $35.49 | 1 | 35.49 |
| Test Stand Instrumentation | Pitot Tube | $93.00 | 1 | 93 |
| | Tubing | $0.60 | 100 | 60 |
| Total | | | | 228.48 |

| Category | Item | Unit Price (USD) | Amount | Total Price |
|---|---|---|---|---|
| Initial Engine Parts | Starter Motor | $89.99 | 1 | 89.99 |
| | LiFE Battery | $49.99 | 1 | 49.99 |
| | EC3 M to XT60 F Adapter | $1.99 | 1 | 1.99 |
| | EC3 F to XT60 M Adapter | 1.99 | 1 | 1.99 |
| Packaging Supplies | Bubble Wrap | $6.62 | 1 | 6.62 |
| | Cardboard Box | $6.99 | 1 | 6.99 |
| | Sales Tax | $1.20 | 1 | 1.2 |
| Turbine Ground Support | 4mm tubing | $1.29 | 3 | 3.87 |
| | Festo Ball Valve 4mm | $21.47 | 2 | 42.94 |
| | Festo Blanking Cap 4mm | $2.21 | 3 | 6.63 |
| | iTrap40 Classic Pro 4mm | $85.54 | 1 | 85.54 |
| | Plastic Syringe | $10.38 | 1 | 10.38 |
| | Diesel Fuel Can | $26.15 | 1 | 26.15 |
| Shipping | Outbound (1) | $34.84 | 1 | 34.84 |
| | Outbound | $117.00 | 1 | 117 |
| | Inbound | $50.00 | 2 | 100 |
| Total | | | | 586.12 |

# Test Plan

| Test | Materials | Location | Special Access |
|---|---|---|---|
| **TA** Turbine Operation verification | JetCat Engine | Engine Test Cell | Yes - R2R Schedule* |
| **TA** Instrument Verification | Test App, Wind Tunnel | Aero Wind Tunnel | Yes - R2R Schedule* |
| **TA** Turbine mass flow test | JetCat Engine, Test App | Engine Test Cell | Yes - R2R Schedule* |
| **TA** EDF Verification | Test App, EDF | Aero Wind Tunnel | Yes - R2R Schedule* |
| **TA** Turbine sensors calibration test | Test App, Inlet, JetCat | Engine Test Cell | Yes - R2R Schedule* |

* - R2R Schedule only allows Team OSPRI to be on campus 2 days/week

# Test Plan cont.

| Test | Materials | Location | Special Access |
|---|---|---|---|
| **Inlet** EDF Testing | Test App, Inlet, EDF | Wind Tunnel | Yes - R2R Schedule* |
| **TA** Turbine baseline test | JetCat Engine, Test App | Engine Test Cell | Yes - R2R Schedule* |
| **Inlet** Turbine integrated inlet testing | JetCat Engine, Test App, Inlet | Engine Test Cell | Yes - R2R Schedule* |

* - R2R Schedule only allows Team OSPRI to be on campus 2 days/week

## System 1: EDF testing

| Task number | Due date | Task/description | Dependent on task: | Building access required | Complete |
|---|---|---|---|---|---|
| E.1.a | 24 Jan | EDF transition piece design/print | N/A | N | Y |
| E.1.b | 24 Jan | EDF/Transition Piece cradles design/print | N/A | N | Y |
| E.1.c | 24 Jan | Bell Mouth design/print | N/A | N | Y |
| E.1.d (TA.1) | 24 Jan | Inlet frame assembly | N/A | N | Y |
| E.2 (TA.2) | 31 Jan | Labview scannivalve functionality | N/A | Y | Y |
| E.3 (TA.3) | 3 Feb | Wind tunnel sensor calibration test | E.2 (TA.2) | Y | Y |
| E.4 | 5 Feb | EDF systems functionality test with temporary control and frame integration | E.1 | - | Y |
| E.5 | 10 Feb | EDF mass flow verification test | E.1, E.2, E.3, E.4 | Y | Y |
| E.6 | 12 Feb | Labview EDF control functionality | E.4 | N | |
| E.7.a | 19 Feb | EDF control verification tests | E.6, J.5 | N | |
| E.7.b | 19 Feb | Turbine to EDF mass flow calibration tests | E.1, E.2, E.3, E.4 | Y | |
| E.8 | 19 Feb | Inlet testing | E.1-E.8 | Y | |

Indicates test which needs scheduling

## System 2: JetCat Turbine testing

| Task number | Due date | Task/description | Dependent on task: | Building access required | Complete |
|---|---|---|---|---|---|
| J.1.a | 24 Jan | AFRL transition piece print | N/A | N | Y |
| J.1.b | 24 Jan | Bell mouth design/print | N/A | N | Y |
| J.1.c | 24 Jan | Transition piece print | N/A | N | Y |
| J.1.d (TA.1) | 24 Jan | Inlet frame assembly | N/A | N | Y |
| J.3 (TA.2) | 31 Jan | Labview scannivalve functionality | N/A | N | Y |
| J.4 (TA.3) | 3 Feb | Wind tunnel sensor calibration test | J.3 (TA.2) | Y | Y |
| J.2 | (Org 27 Jan ) 15 Feb | JetCat verification run | N/A | Y | Y |
| J.5 | 15 Feb | JetCat mass flow verification test | J.1, J.2, J.3, J.4 | Y | |
| J.6 | 21 Feb | Labview Equiflow fuel flow sensor functionality | N/A | N | |
| J.7 | 24 Feb | Flow sensor/load cell calibration test | J.6 | Y | |
| J.8 | 26 Feb | JetCat baseline test | J.3, J.4, J.5, J.6, J.7 | Y | |
| J.9 | 26 Feb | Inlet testing | J.1 - J.8, E.8 | Y | |

Current as of 26 Feb 2021

University of Colorado Boulder

OSPRI

| Setup | | Engine start checklist | |
|---|---|---|---|
| Required items | | Pre start | |
| P-100Rx | Proj Room/Test cell | Load cell stop block | Remove |
| ECU | Proj Room/Test cell | Load cell arduino | Powered on (if used) |
| GSU | Proj Room | Sensor/tubing | Secured (if used) |
| Long Cord | Proj Room | Scannivalve | Connected/Powered on |
| Battery | Charged | Data collection | Reading data |
| Support items | Proj Room/Test cell | Radio check | Good comms |
| Fuel can | Test cell | Downrange man | In place outside cell |
| Radios | Proj Room/Test cell | Downrange | Clear of personnel |
| | | Test cell | Clear of personnel |
| Test cell setup | | | |
| Professor | Notify | Engine Start | |
| Garage Door | Open | Professor | Notified/present |
| Fume fan | On | ECU power | Depress for 5 sec |
| Plexiglass | Lean against garage door | Menu selected | Run |
| Blast area | Clear | Engine control man | Radio start ready |
| Mount engine | x4 bolts | Downrange man | Radio blast area clear |
| Engine | Secure | Set and Spool | Depress |
| Fuel Pump | Secure | Automatic startup | Let self stabilize |
| ECU | Secure | | |
| GSU lead | Routed into control room | Test control | |
| GSU | Connected (in control room) | Throttle Increase | Spool and plus |
| Battery | Connected and secure | Throttle decrease | Spool and minus |
| | | Immediate max | Spool and min/max |
| Fuel line purge | | Immediate idle | Spool and run |
| Fuel tank | Insert fuel line | | |
| UAT | Air Purged | Shutdown | |
| UAT Shuttoff valve | Open | Engine control man | Radio test termination |
| Pump Shuttoff valve | Open | Set and Spool | Depress |
| Engine fuel line | Disconnect | Automatic cooling | Let self cool |
| ECU Power | Depress for 5 sec | Pump Shuttoff valve | Close |
| Menu selected | Test Function | UAT Shuttoff valve | Close |
| Change Value | Hold on purge page | | |
| Fuel line | Air purged | | |
| Fuel line | Reconnect | | |

# Management Slides

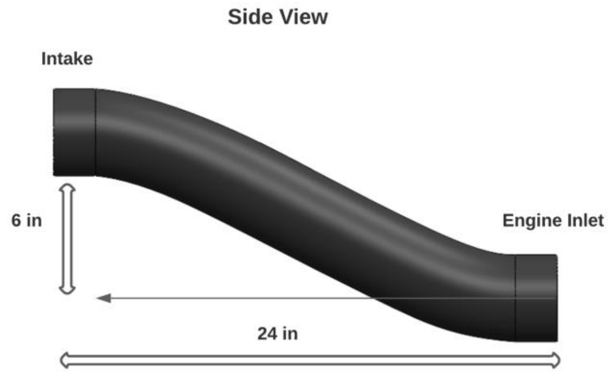
# Functional Requirements

OSPRI functional requirements stem from the APOP's Statement of Work provided to the CU Aerospace Engineering Department and the OSPRI team:

1. Design, build, and validate an S-duct inlet for use with the JetCat P100-RX turbojet engine that performs according to AFRL's objectives.
2. Design, build, and validate a test rig capable of measuring critical inlet performance metrics and inform inlet design.

# Inlet Design Requirements

1. The inlet shall interface with the AFRL transition piece
2. The nearest outside edge of the capture area sha
   centerline of the engine.
3. The inlet shall have a total pressure recovery ≥98
   engine.
4. The maximum thrust decrement of the engine sh
   attached.
5. The maximum TSFC increment of the engine sha
   attached.
6. The inlet shall have an axial length between 20 inches and 28 inches, with the objective being 20 inches (or shorter, if feasible).*
   a. Requirements changed from PDR

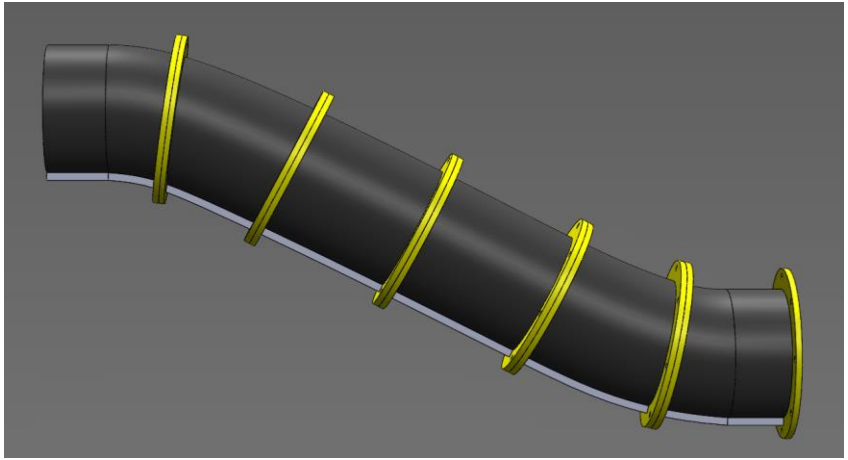


# Test Apparatus (TA) Design Requirements

1. The TA shall be capable of mapping the total pressure distribution at the inlet entrance, the Aerodynamic Interface Plane (AIP), and between the first and second turns, at a minimum.
2. The TA shall be capable of mapping the distortion distribution throughout the inlet.
3. The TA shall be capable of measuring key JetCat engine parameters.
    a. TA shall be capable of measuring the thrust produced by the engine.
    b. TA shall be capable of measuring the Thrust Specific Fuel Consumption (TSFC) of the engine.
4. The TA shall be capable of interfacing with multiple different inlet designs.

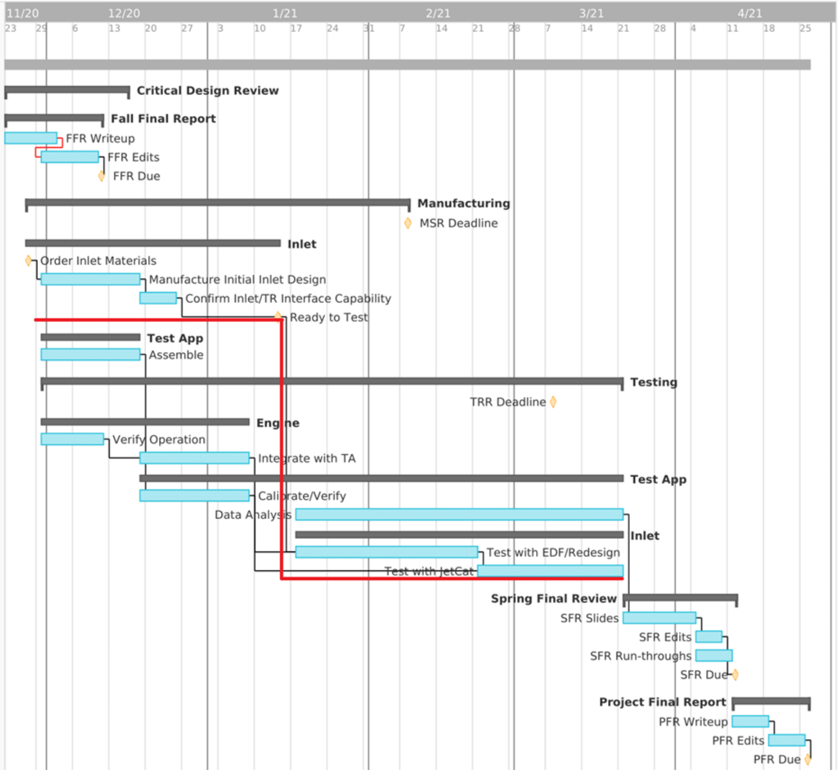
# Timeline Moving Forward

1. Printing, post-processing, and assembling the first inlet (Complete by Feb. 14th)
2. Testing the first iteration to measure performance (Complete by Feb. 20th)
3. Start Printing the second iteration (Complete by Feb. 22nd)
4. Performance analysis for second iteration (Complete by Mar. 10th)
5. Finalize and Manufacture Final Design (Complete by Apr. 1st)



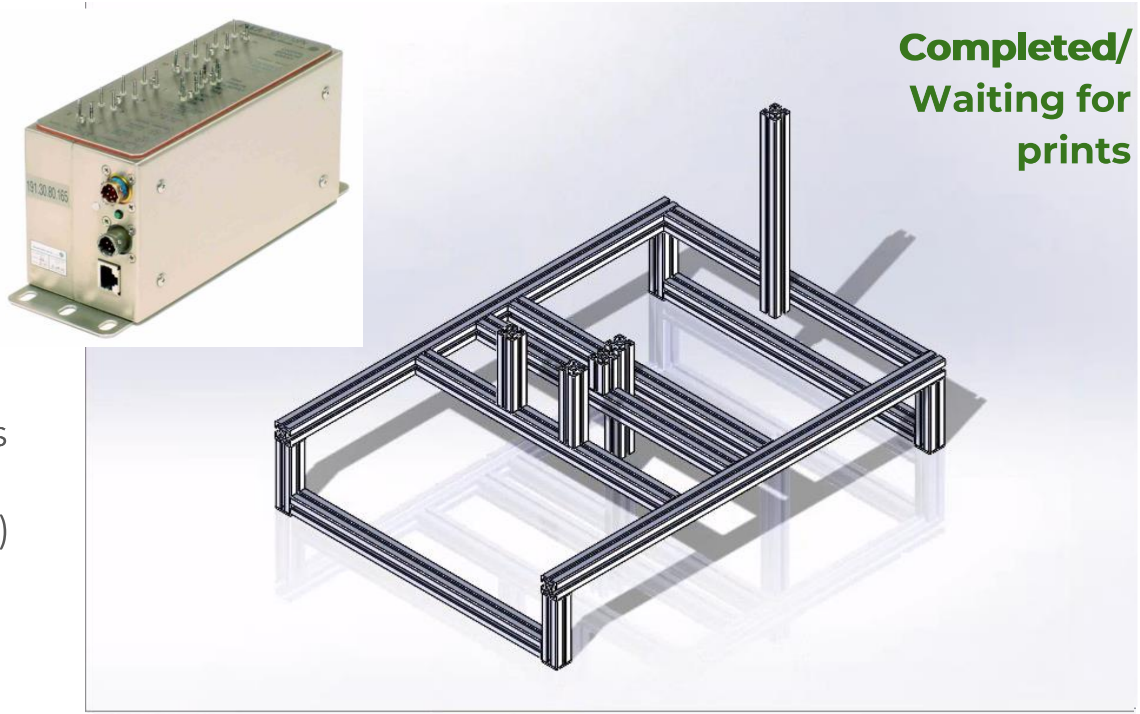
# Work Plan

| OSPRI | start | end | 0h | 0% |
|---|---|---|---|---|
| **Critical Design Review** | 11/20/20 | 12/16/20 | 0h | 0% |
| **Fall Final Report** | 11/23/20 | 12/11/20 | 0h | 0% |
| FFR Writeup | 11/23 | 12/02 | 0 | 0% |
| FFR Edits | 11/30 | 12/10 | 0 | 0% |
| FFR Due | 12/11 | 12/11 | 0 | 0% |
| **Manufacturing** | 11/27/20 | 02/08/21 | 0h | 0% |
| MSR Deadline | 02/08 | 02/08 | 0 | 0% |
| **Inlet** | 11/27/20 | 01/14/21 | 0h | 0% |
| Order Inlet Materials | 11/27 | 11/27 | 0 | 0% |
| Manufacture Initial Inlet Design | 11/30 | 12/18 | 0 | 0% |
| Confirm Inlet/TR Interface Capability | 12/19 | 12/25 | 0 | 0% |
| Ready to Test | 01/14 | 01/14 | 0 | 0% |
| **Test App** | 11/30/20 | 12/18/20 | 0h | 0% |
| Assemble | 11/30 | 12/18 | 0 | 0% |
| **Testing** | 11/30/20 | 03/21/21 | 0h | 0% |
| TRR Deadline | 03/08 | 03/08 | 0 | 0% |
| **Engine** | 11/30/20 | 01/08/21 | 0h | 0% |
| Verify Operation | 11/30 | 12/11 | 0 | 0% |
| Integrate with TA | 12/19 | 01/08 | 0 | 0% |
| **Test App** | 12/19/20 | 03/21/21 | 0h | 0% |
| Calibrate/Verify | 12/19 | 01/08 | 0 | 0% |
| Data Analysis | 01/18 | 03/21 | 0 | 0% |
| **Inlet** | 01/18/21 | 03/21/21 | 0h | 0% |
| Test with EDF/Redesign | 01/18 | 02/21 | 0 | 0% |
| Test with JetCat | 02/22 | 03/21 | 0 | 0% |
| **Spring Final Review** | 03/22/21 | 04/12/21 | 0h | 0% |
| SFR Slides | 03/22 | 04/04 | 0 | 0% |
| SFR Edits | 04/05 | 04/09 | 0 | 0% |
| SFR Run-throughs | 04/05 | 04/11 | 0 | 0% |
| SFR Due | 04/12 | 04/12 | 0 | 0% |
| **Project Final Report** | 04/12/21 | 04/26/21 | 0h | 0% |
| PFR Writeup | 04/12 | 04/18 | 0 | 0% |
| PFR Edits | 04/19 | 04/25 | 0 | 0% |
| PFR Due | 04/26 | 04/26 | 0 | 0% |



# Test Apparatus Breakdown/Overview

- Inlet test frame
- Inlet cradles
- Power plant to inlet transition piece
- Sensor suite
  - Scanivalve
  - Pitot probe
  - Static pressure ports
  - LabView controlled
- Electric Ducted Fan (EDF)
- Turbine test stand
- JetCat P100-Rx
- AFRL designed transition piece




Test Apparatus Model Overview

# Test Apparatus Status Overview

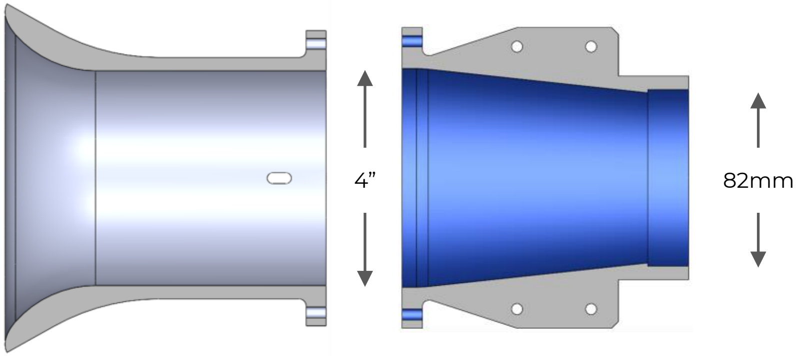
| | |
|---|---|
| Frame Assembly | **Completed (Due 24 Jan)** |
| Transition piece/cradles | **Completed (Due 24 Jan)** |
| EDF Integration and Verification | **On Track (Due 5 Feb)** |
| Labview Development and Verification | **On Track (Various Due dates)** |
| Sensors Verification | **On Track (Due 3 Feb)** |
| JetCat Engine and Testing | **Setback (Various Due dates)** |

# Frame Assembly Status (Completed)

- Assembly completed
- All sliding posts yet to be tightened
- Extremely rigid, lightweight
- To be moved to Aero Building soon

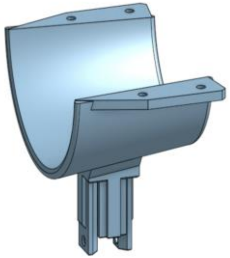
# Transition pieces/cradles status Completed

- JetCat Transition Piece
  - Design provided by AFRL
  - **Completed 24 Jan**
- EDF Transition Piece
  - **Completed 24 Jan**
- Straight bell-mouth inlet
  - Mass flow calibration
  - **Completed 24 Jan**
- Cradles
  - Bolted design for EDF Transition
  - Hose Clamp design for Jetcat
  - **Completed 24 Jan (print in progress)**




Straight bell-mouth Inlet and EDF Transition piece

Cradle for the Jet Engine Transition Piece



Cradle for the EDF Transition piece

# EDF Integration Status **On Track (Due 5 Feb)**

- EDF and ESC (Electronic Speed Controller)
  - The finance department did not order last semester
  - Ordered again and **delivered January 27th**
- 6 cell LiPo battery
  - Provided by the electronics lab
- Maximum mass flow validation
  - Targeting 0.23 kg/s
  - Using a servo tester for control
- Mass flow calibration
  - Using Labview for precise control

# LabView Development Status (On Track)

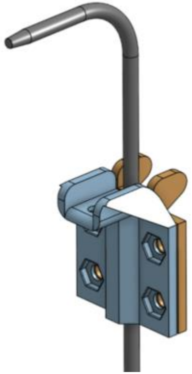
- Stages of Development
  - Stage 1: **Scanivalve functionality** **(Completed Jan 31st)**
    - For pressure measurements (Sample rate: 500Hz)
    - Extract required existing Wind Tunnel code
  - Stage 2: **EDF Control functionality** **(Complete by Feb 12th)**
    - For fan flow control
    - Integrate cDaq & NI 9401 (digital I/O module)
  - Stage 3: **JetCat Fuel Flow Sensor functionality** **(Complete by Feb 21st)**
    - For fuel flow measurements
    - Integrate NI 9215 (analog in module)

# LabView Development Status cont (On Track)

- LabView Software
  - Working closely with Josh Mellin
  - Troubleshooting and debugging
  - Tasks to do:
    - Finalize software for fuel flow
    - Finish VI interface to connect with TA rig
    - Verify data acquisition outputs (graphs, plots, etc)
  - cDaq (+ Digital Module, Analog Module): **Checked Out**

    **cDAQ-9171, NI-9401, NI-9215 w/ BNC** modules

# Sensors & DAQ Status On Track (Due 3 Feb)



- cDaq (+ Digital Module, Analog Module): **Checked out**
- Labview Module Development: **Development underway**
- Sensors : **Acquired**
  - Pitot Probe: **Acquired**
    - Slotted Inlet Mount: **Designed & Printed**
  - Fuel Flow Probe: **Acquired**
- Scanivalve: **Available upon request**

Upcoming tests

- Wind tunnel **sensor calibration** test: **(Complete by 3 Feb)**
  - Calibration of pitot probe using 6 or more known airspeeds in the windtunnel

# JetCat P-100RX Status (Setback)

- Engine issues (warranted services by JetCat Americas) **(Est. return: 12 Feb)**
  - *Fall semester:* Starter motor and front sensor board burnt out, sticky bearings
  - *27 Jan:* After servicing, surface mounted chip fell off of front sensor board
- Upcoming tests
  - JetCat **initial verification** test: **(Complete by 27 Jan moved to 15 Feb)**
    - Unmodified test to verify functionality with CU facilities and procedure familiarization
  - JetCat **mass flow verification** test: **(Complete by 15 Feb)**
    - Collect mass flow data through entire RPM sweep to calibrate mass flow surrogate
  - JetCat **baseline** test: **(Complete by 26 Feb)**
    - Collect thrust data and fuel flow (TSFC) data through entire RPM sweep

# Test Apparatus Future Outlook

| System 1: EDF testing | | | | | |
|---|---|---|---|---|---|
| Task number | Due date | Task/description | Dependent on task: | Building access required | Complete |
| E.1.a | 24 Jan | EDF transition piece design/print | N/A | N | Y |
| E.1.b | 24 Jan | EDF/Transition Piece cradles design/print | N/A | N | Y |
| E.1.c | 24 Jan | Bell Mouth design/print | N/A | N | Y |
| E.1.d (TA.1) | 24 Jan | Inlet frame assembly | N/A | N | Y |
| E.2 (TA.2) | 31 Jan | Labview scannivalve functionality | N/A | Y | Y |
| E.3 (TA.3) | 3 Feb | Wind tunnel sensor calibration test | E.2 (TA.2) | Y | |
| E.4 | 5 Feb | EDF systems functionality test with temporary control and frame integration | E.1 | ? | |
| E.5 | 10 Feb | EDF mass flow verification test | E.1, E.2, E.3, E.4 | Y | |
| E.6 | 12 Feb | Labview EDF control functionality | E.4 | N | |
| E.7.a | 19 Feb | EDF control verification tests | E.6, J.5 | N | |
| E.7.b | 19 Feb | Turbine to EDF mass flow calibration tests | E.1, E.2, E.3, E.4 | Y | |
| E.8 | 19 Feb | Inlet testing | E.1-E.8 | Y | |

| System 2: JetCat Turbine testing | | | | | |
|---|---|---|---|---|---|
| Task number | Due date | Task/description | Dependent on task: | Building access required | Complete |
| J.1.a | 24 Jan | AFRL transition piece print | N/A | N | Y |
| J.1.b | 24 Jan | Bell mouth design/print | N/A | N | Y |
| J.1.c | 24 Jan | Transition piece print | N/A | N | Y |
| J.1.d (TA.1) | 24 Jan | Inlet frame assembly | N/A | N | Y |
| J.3 (TA.2) | 31 Jan | Labview scannivalve functionality | N/A | N | Y |
| J.4 (TA.3) | 3 Feb | Wind tunnel sensor calibration test | J.3 (TA.2) | Y | |
| J.2 | (Org 27 Jan ) 15 Feb | JetCat verification run | N/A | Y | |
| J.5 | 15 Feb | JetCat mass flow verification test | J.1, J.2, J.3, J.4 | Y | |
| J.6 | 21 Feb | Labview Equiflow fuel flow sensor functionality | N/A | N | |
| J.7 | 24 Feb | Flow sensor/load cell calibration test | J.6 | Y | |
| J.8 | 26 Feb | JetCat baseline test | J.3, J.4, J.5, J.6, J.7 | Y | |
| J.9 | 26 Feb | Inlet testing | J.1 - J.8, E.8 | Y | |

Indicates test which needs scheduling

Current as of 31 Jan 2021

# Test Apparatus Future Outlook

Wind Tunnel Sensor Calibration
by 03 Feb

EDF Function Verification
by 05 Feb

EDF Mass Flow/Systems Verification
by 05 Feb

JetCat Mass Flow Verification
by 15 Feb

EDF Control Verification/ **Inlet Testing**
by 19 Feb

Load Cell, Fuel Flow Sensor Calibration
by 24 Feb

JetCat Baseline
by 26 Feb

**JetCat Inlet Testing**
by 28 Feb

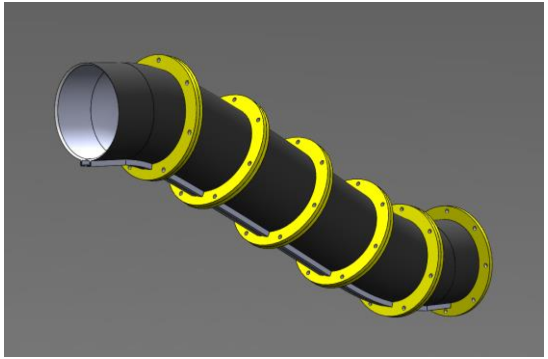
# Challenges

- **Timeline**
  - Need to construct and perform verification and validation before any inlet testing can begin
  - Quicker test apparatus is ready, the more inlet iterations can be tested
- Repeated issues with JetCat P-100RX
- Integrating all sensors into cohesive LabView package

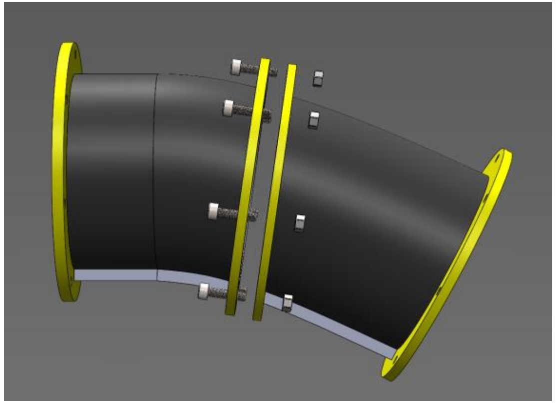
# Initial Plan

- Originally planned FDM printers for prototype
  - Extensive post-processing
  - High chance of inconsistent surfaces
- Switched gears to SLA
  - Planned for access to 3 FormLabs SLA printers
  - Inlet made to be sectioned to fit smaller print volume
- Assembly
  - Using 7 M5 bolts and nuts

Model



Assembly



# Status

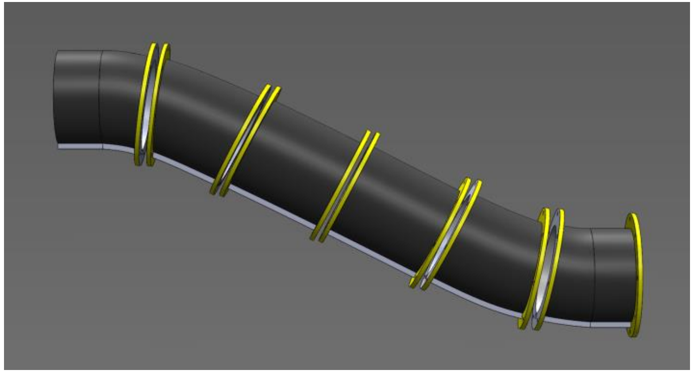
- Currently, initial design is being printed by the PILOT
  - Finished first of six inlet sections **On Track (Due Feb 14)**
  - Paused queue in order to print parts need for test assembly
  - Dealing with upcoming issues with manufacturing

Inlet Section

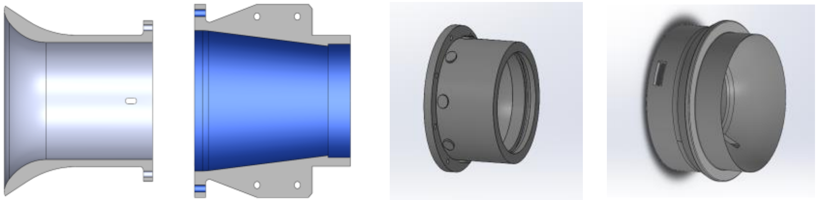
APOP Transition (Inlet Side)

# Challenges

- Printer Reliability Problems
  - IdeaForge printers unuseable
  - Working with only 1 printer
- Print Quality
  - ~25 microns - 50 microns
  - Limited Print volume
- Part Prioritization
  - Transition pieces then inlet
  - 10 SLA parts in queue



Inlet Sectional View



Transition Pieces

# Challenges

- ➔ Cost
  - Outside vendor quotes
    - ~$800 for just 4 parts
    - ~$600 in ASEN machine shop for all 10 parts

| Line Item | Service | Description | Quantity | Unit | Price | Line Total |
|---|---|---|---|---|---|---|
| 1 | Print | 50 um EDF transition and Inlet and Inlet transition and Jetcat 1x each Hard Black-Photocentric | 1.00 | Each | $780.09 | $780.09 |
| 2 | Sanding | | 2.00 | Hours | $35.00 | $70.00 |
| 3 | Support Removal | | 2.00 | Hours | $10.00 | $20.00 |
| 4 | | | | | | |
| 5 | | | | | | |

The 3D Printing Store Quote

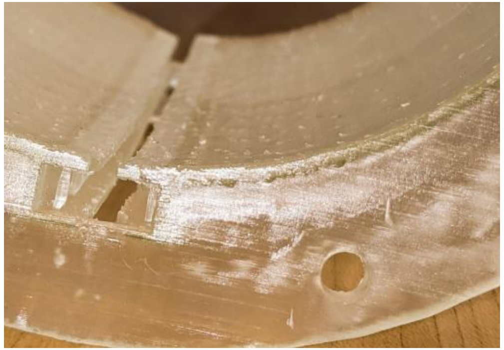
- ➔ Manufacturing Defects
  - Crack along flange of printed Inlet section
  - Will fix with epoxy patch

Cracked Inlet Sectional

# Challenges

- Post-Processing
  - Sanding inside surface as needed
  - Support structure dependent on individual print

Transition Section



Inlet Section

# Inlet Timeline

Printing, post-processing, and assembling the first inlet
by 14 Feb

Testing the first iteration to measure performance
by 20 Feb

Start Printing Second Iteration
by 22 Feb

Performance Analysis for Second Iteration
by 10 March

Finalize and manufacture final design
by 1 April