ROSEMOUNT AEROSPACE APPENDIX D TOTAL AIR TEMPERATURE SENSOR: XDTAT™ SENSOR

NOVEMBER 12, 2020

Collins Aerospace

XDTAT™ SENSOR

OUTLINE

- Design Overview
- Design Objective
- Design Concept
- Advanced Manufacturing
- Design Performance

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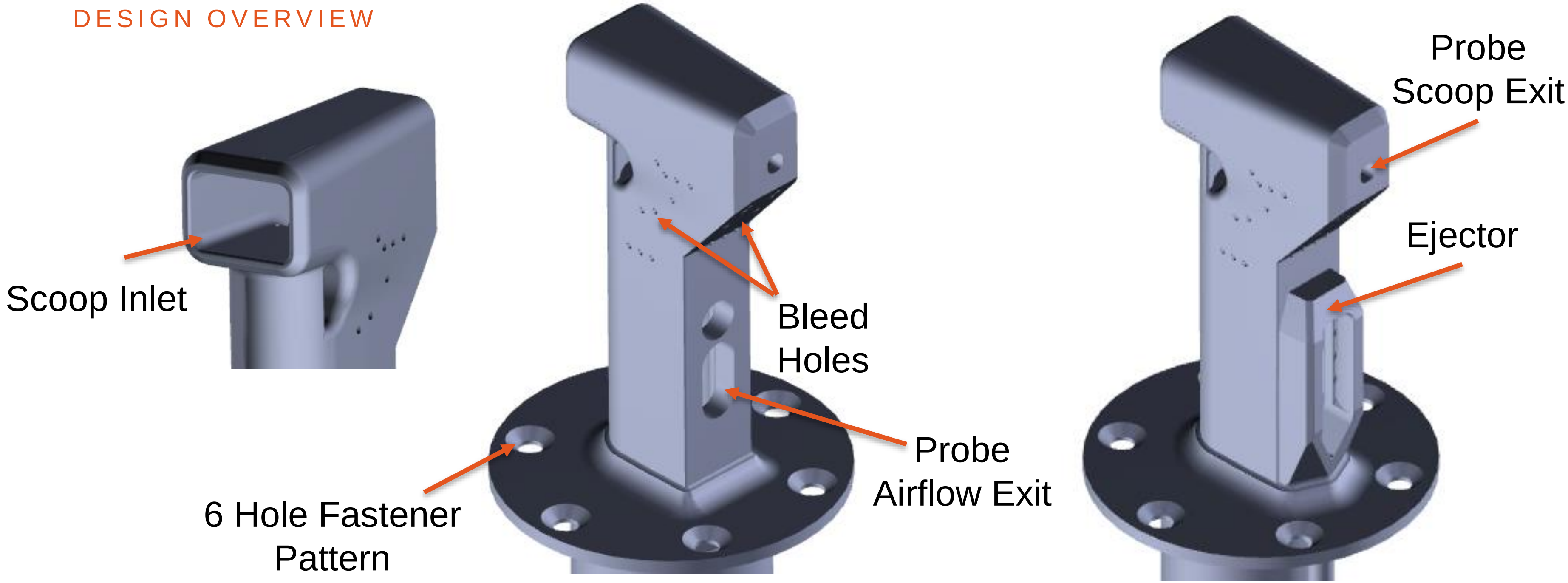
DESIGN OVERVIEW



Non-Aspirated Model

Aspirated Model

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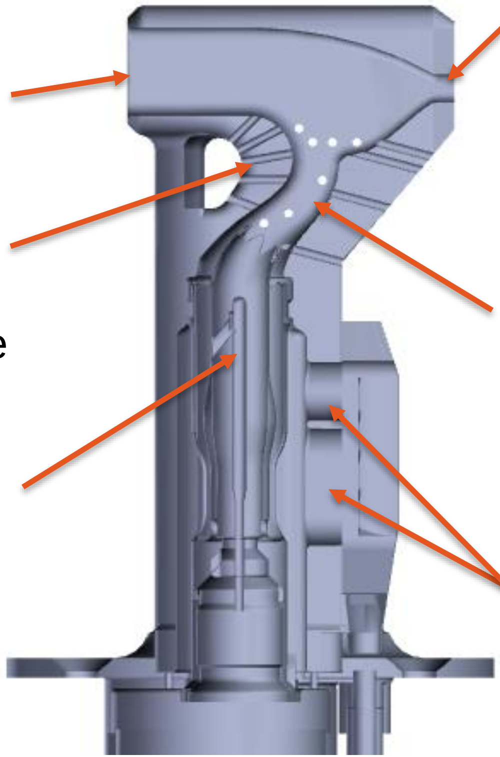
FUNCTION OVERVIEW



Air enters the scoop inlet

Bleed holes throughout the air passageway remove warm boundary layer air and any moisture that is able to coalesce and run along the walls

The sensing elements sit within the element assembly flow duct which is an unheated structure within the heated outer housing

The majority of the air and any particles in the air do not make the corner to the sensing elements and leave via scoop outlet

A small amount of mostly clean air turns the corner and heads down to the sensing elements

Air that passed by the sensing elements leaves the housing from the probe outlet

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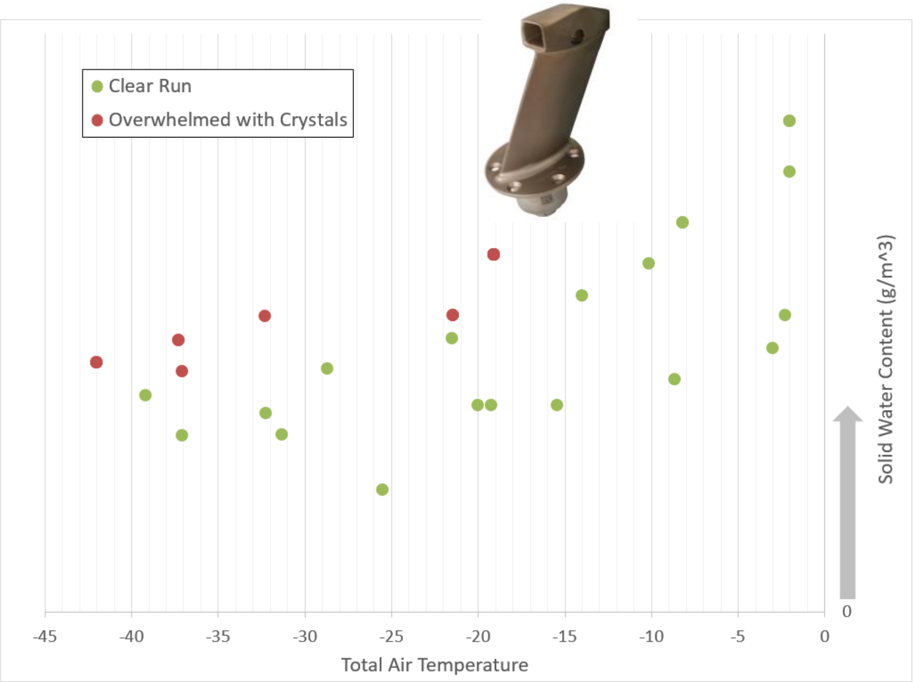
OBJECTIVE FOR THE DEVELOPMENT

- Appendix D requirements were getting more difficult pushing colder temperatures and higher ice crystal content
- At the time the best ice crystal performing Collins TAT was the EPTAT® Sensor and the more difficult conditions were becoming challenging for the EPTAT®
- The typical TAT failure mode for ice crystals is that the scoop becomes overwhelmed and plugs not allowing air to get to the sensing elements



This chart represents real test conditions developed for various aircraft platforms. The green conditions tested clear and the red conditions overwhelmed the EPTAT®

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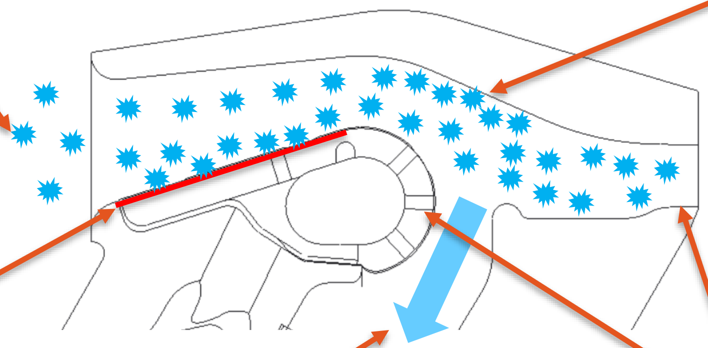
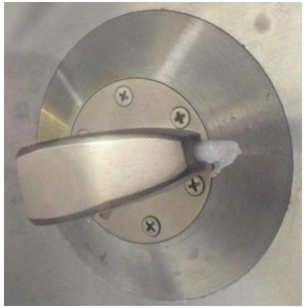
CONCEPT DURING EARLY DEVELOPMENT

The particles collect and bounce off of the critical impact areas. When the ice crystal content is very high they overwhelm the heater in the scoop and combine to make a slush the plugs up the scoop and prevents air from reaching the sensing elements

Liquid or ice particles in the airflow enter the scoop inlet

Airflow ➔





Areas that restrict the flow area and cause impingement of the particles are referred to as Critical Impact Areas

Clean airflow turns the corner down to the sensing elements

Particles that hit the walls coalesce and run out the scoop exit and the bleed holes

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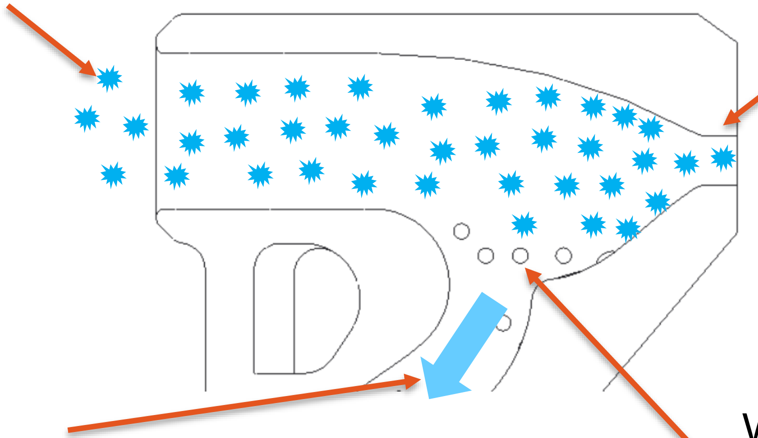
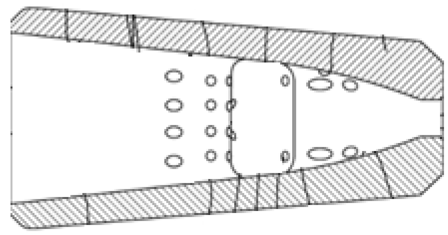
CONCEPT DURING EARLY DEVELOPMENT

The Critical Impact Areas were removed and reduced as much as possible allowing the ice and water particles to flow as freely as possible through the scoop and out the exit hole.

Liquid or ice particles in the airflow enter the scoop inlet





Clean airflow turns the corner down to the sensing elements

Water and warm boundary layer air runs out of the bleed holes.

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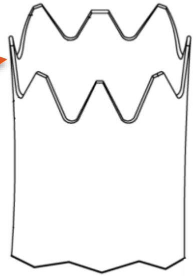
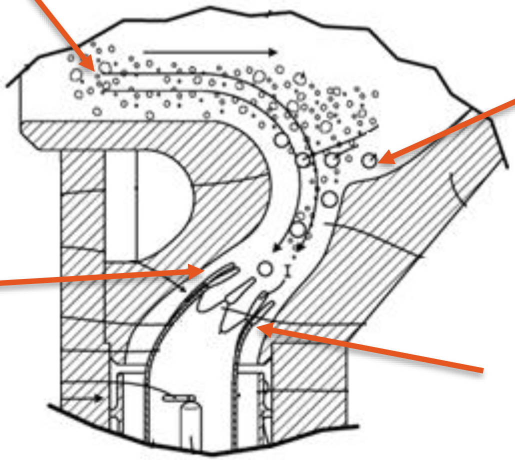
CONCEPT DURING EARLY DEVELOPMENT

Castellation on the top of the flow duct



Liquid or ice particles in the airflow enter the scoop inlet

Most particles go out the back of the scoop with a few turning the corner down to the sensing elements



Small amount of ice grows on the unheated tips of the element assembly

Because the surface area in which the ice grows is small the attachment is not good and the ice sheds small growths frequently not allowing a large blockage of airflow

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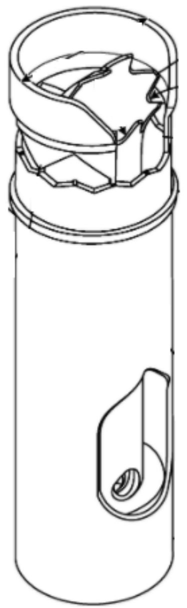
LEVERAGING NEW MATERIALS AND MANUFACTURING TECHNOLOGIES

- XDTAT™ leverages advanced manufacturing processes that make the part more precisely built with less piece parts
- One of the processes used was additive manufacturing for the internal element assembly flow path and the ejector
- The leveraging of AM processes achieves the following
  - Allows for geometry that would be very difficult to produce using traditional manufacturing methods
  - More precise geometry lowering part to part variation
  - Reduction of the number of piece parts reducing the number of joints and potential failure locations



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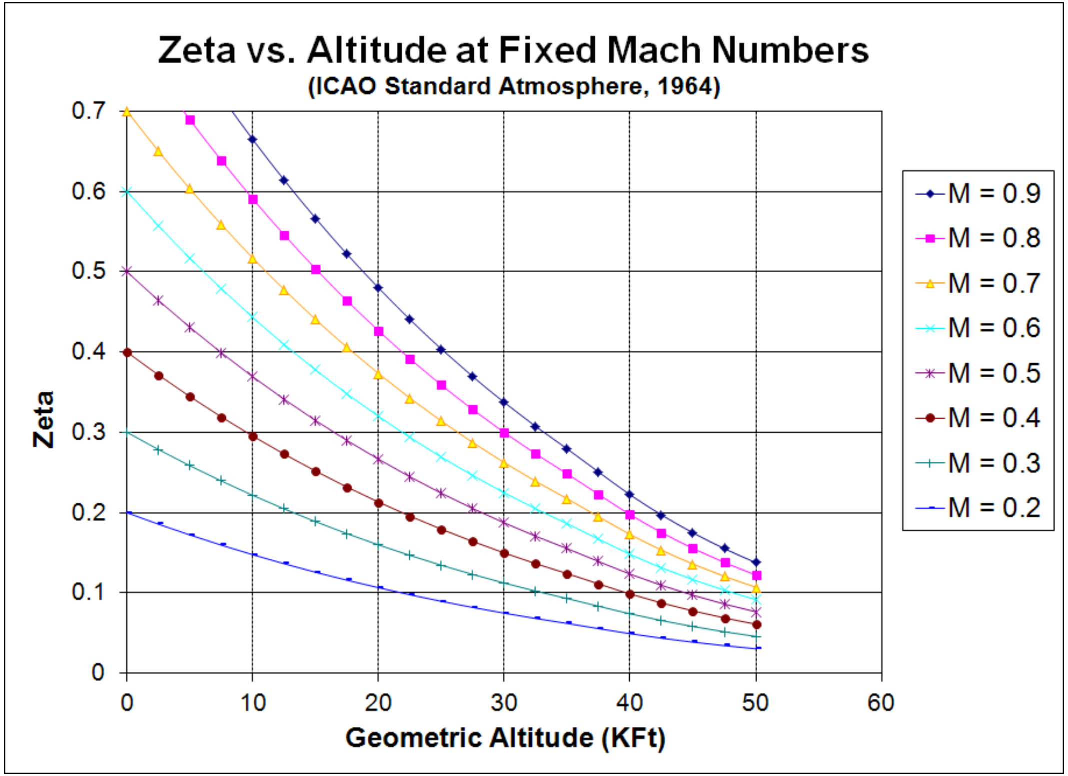
DESIGN PERFORMANCE

- Zeta is a flow rate that is Mach compensated for altitude
- "Dimensionless" Value
- Zeta Defined as:
  - $$Zeta = M * \frac{\rho}{\rho_0}$$
- Where:
  - $\frac{\rho}{\rho_0} = Density\ Ratio$
  - $\rho = Density\ at\ Altitude$
  - $\rho_0 = Sea\ Level\ Density$
  - $M = Mach$
- Density Ratio determined per ICAO Standard Atmosphere (1964)



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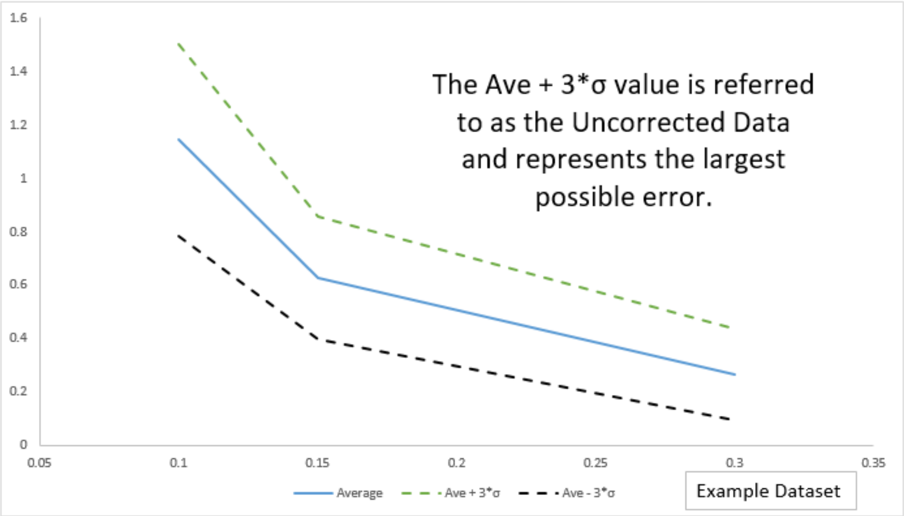
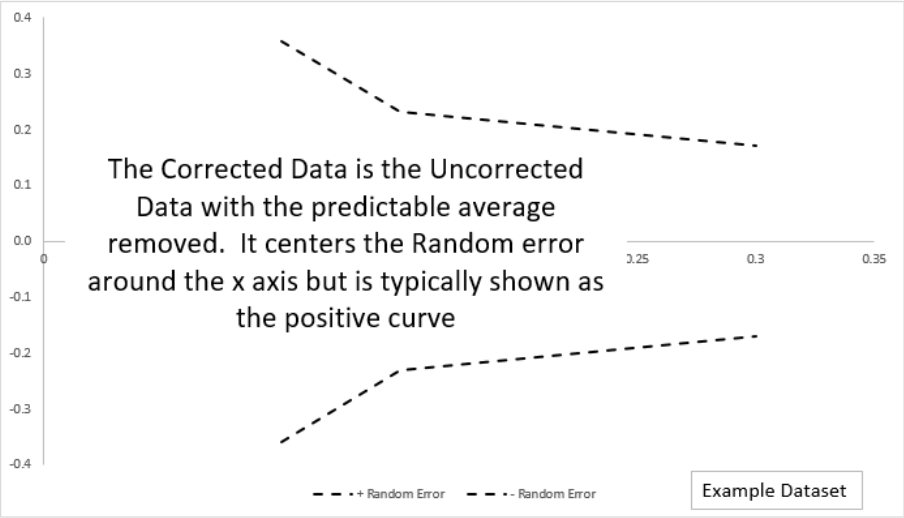
DESIGN PERFORMANCE

- To develop performance curves a number of test units are wind tunnel tested to collect an average and standard deviation (σ) from the data set
- To ensure we account for at least 99.7% of the possible testing outcomes we multiple σ by 3
- Using the onboard flight computer we can remove average or predictable data from the live reading





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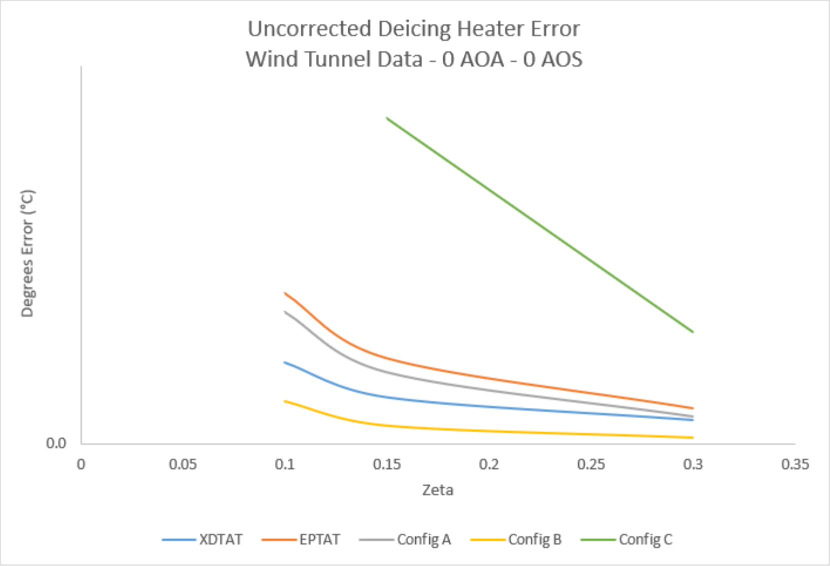
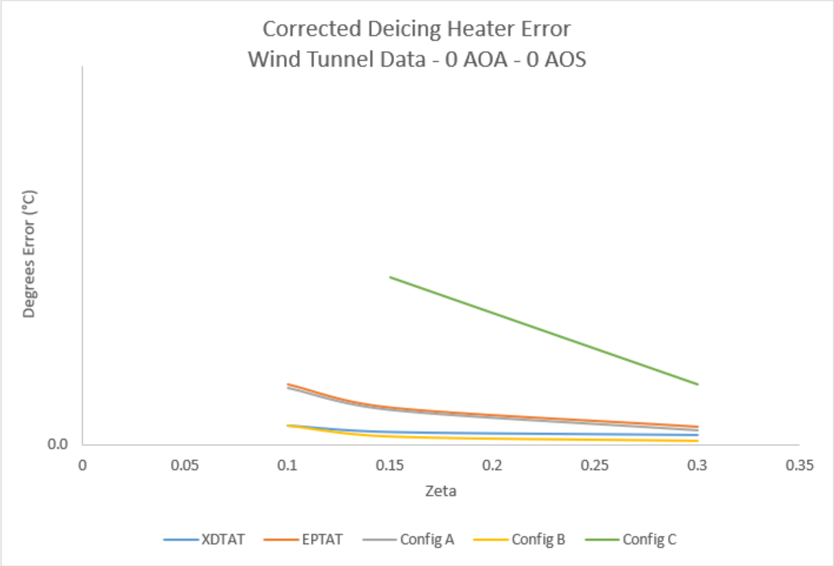
DESIGN PERFORMANCE

- Deicing Heater Error (DHE) – Error due to the anti-icing heater imbedded in the housing. This error makes the measurement artificially high.





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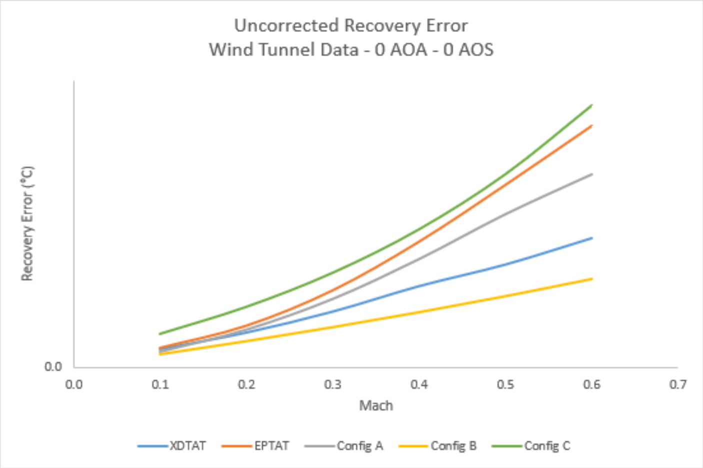
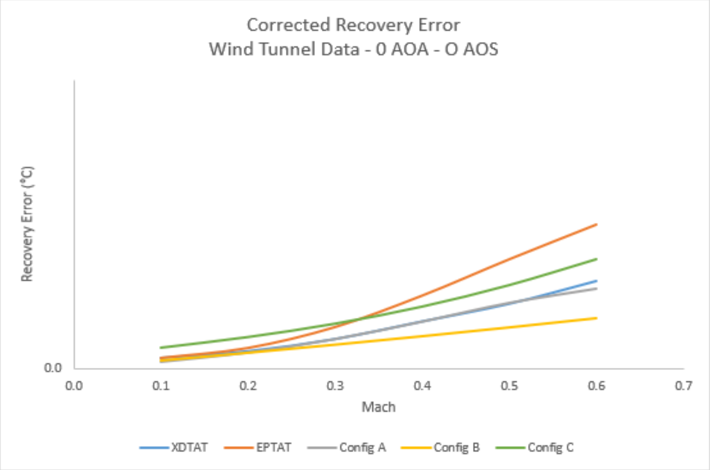
DESIGN PERFORMANCE

- Recovery Error (RE) – A Total Air Temperature measurement is the static air temperature and the temperature increase due to slowing down the airflow. For a TAT sensor you can't slow the airflow all the way down to zero. Recovery error is the error related to the speed at which the air moves through the part.





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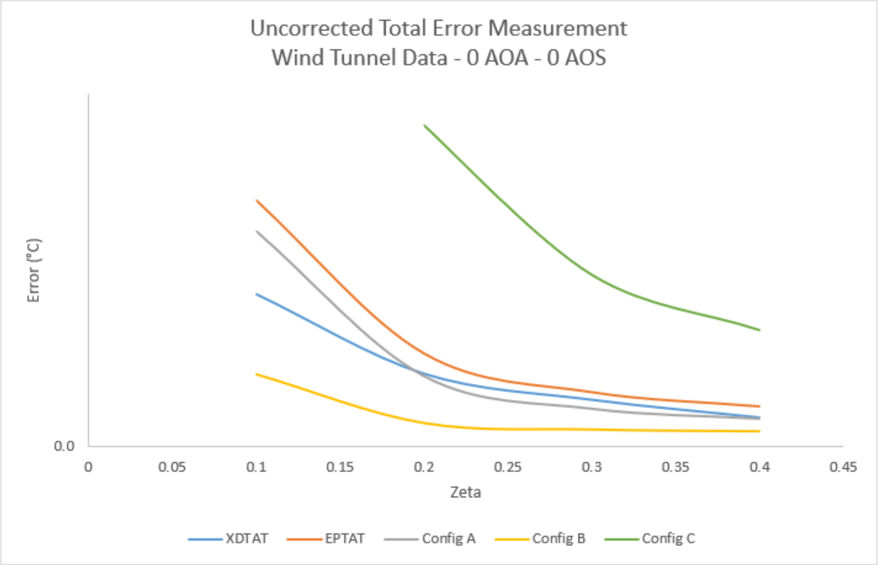
- Total Error – This error is calculated combining all the different static errors intrinsic with a TAT measurement. Those errors include DHE, RE, and Self Heating Error (SHE)



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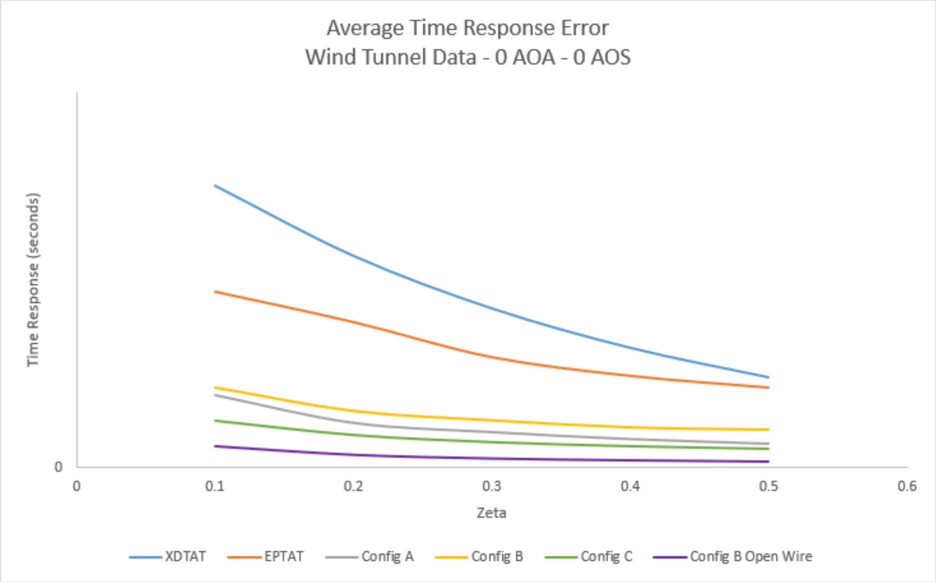
- Time Response Error (TRE) is error due to the sensors ability to adjust to a sudden temperature change.



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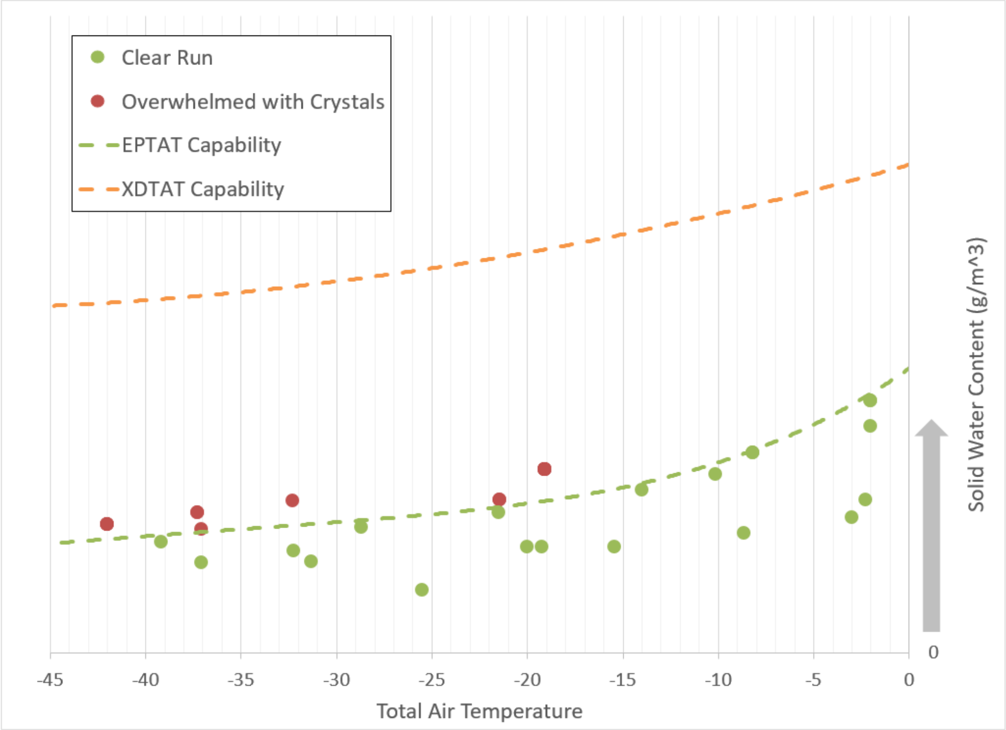
DESIGN PERFORMANCE

- The XDTAT™ was extensively tested to Liquid Water and Ice Crystal Conditions during development
- Rain, Liquid Water Content, Cycling and Mixed Phase conditions tested equivalent to previous TAT models
- The XDTAT™ Sensor was developed to handle high ice crystal content and achieves this as displayed by the chart to the right



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QUESTIONS

Questions?

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