





Aeroprobe Introduction

- Leading producer of Air Data and Multi-Hole Probe Instrumentation
- Trusted partner to designers, engineers, researchers, and pilots since 1993
- Worldwide supplier to the aerospace, automotive, turbomachinery, and wind energy industries
- 20,000 ft² facility located in Christiansburg, VA
- Woman-owned small business

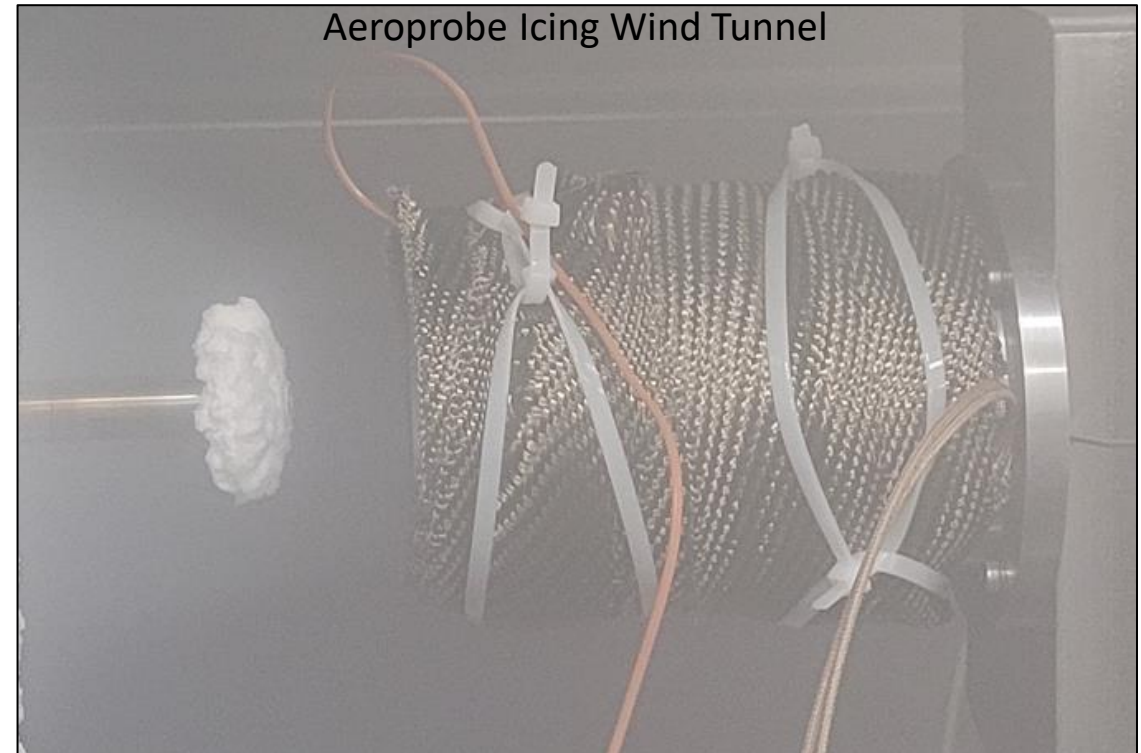




Capabilities

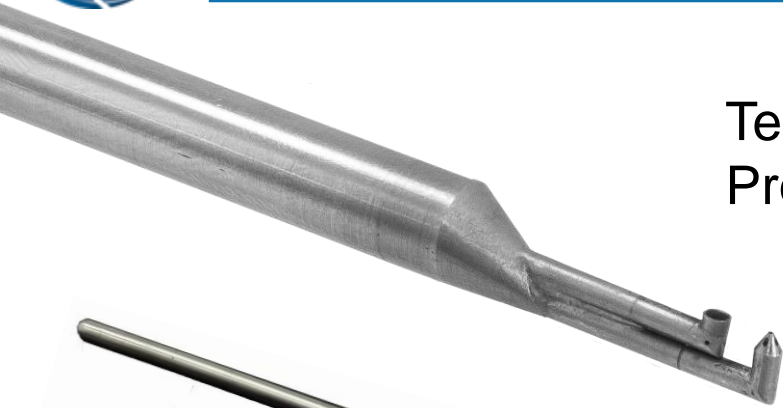


- ISO 9001:2015 Certified Quality Management System
- Manufacturing
 - Conventional & Micro-machining
 - Brazing
 - Laser marking
- Three calibration wind tunnels on-site
 - 10 m/s to Mach 1.8 speed range
 - Cold Flow (Icing) Tunnel
- NIST traceable testing lab
 - Thermal chambers
 - High accuracy pressure sources
 - High potential (Dielectric) at simulated altitude
- Engineering analysis and design
 - Static, modal, and forced response FEA
 - Thermal analysis
 - Design for additive manufacturing





Products & Services



Test & Measurement Probes

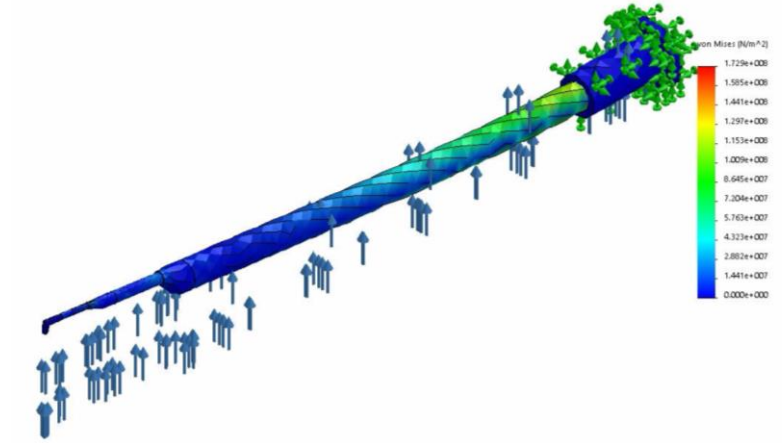


Flight Probes

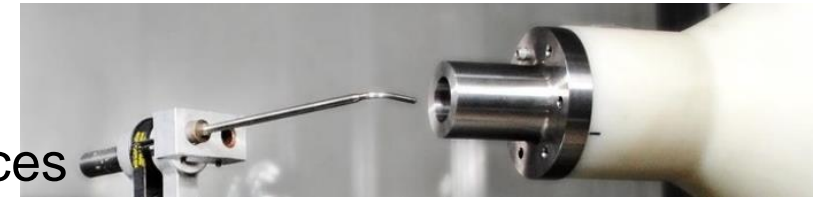


Air Data Systems

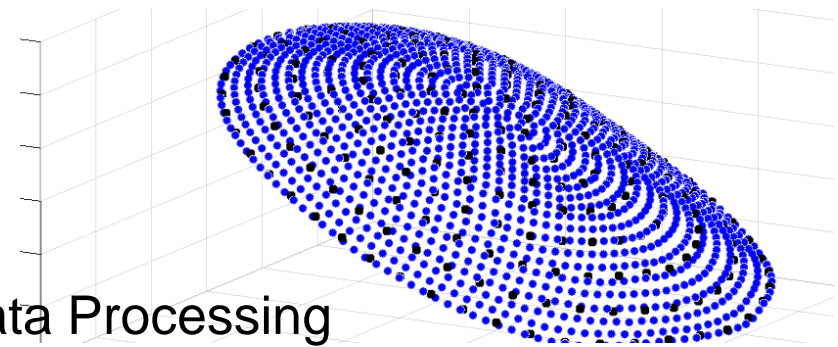
Engineering Analysis & Design



Calibrations Services



AEROFLOW™ Data Processing

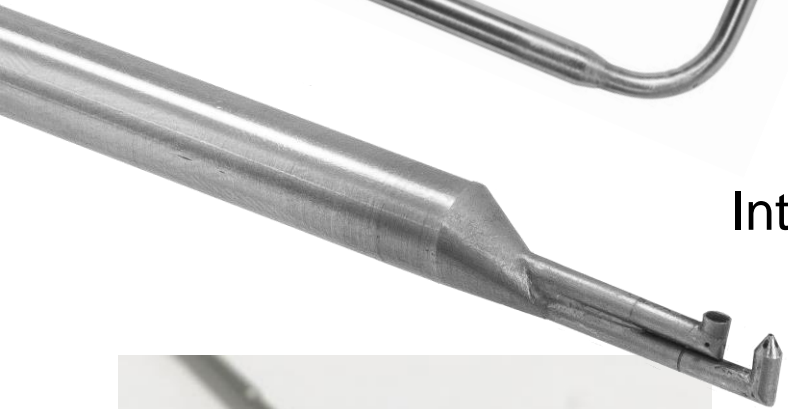




Test & Measurement Probes



Conventional



Integrated Thermocouple



Boundary Layer

Omniprobos



Rakes



High Temperature

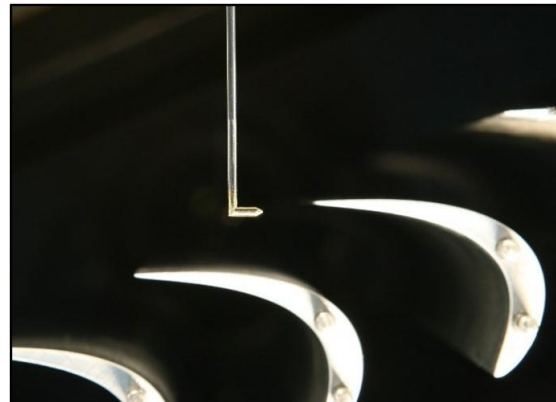




Initial Markets for the Multi-hole probe Technology

Aeroprobe initially focused on providing total pressure, total temperature and multi-hole probe solutions to researchers for wind tunnel and turbo machinery markets.

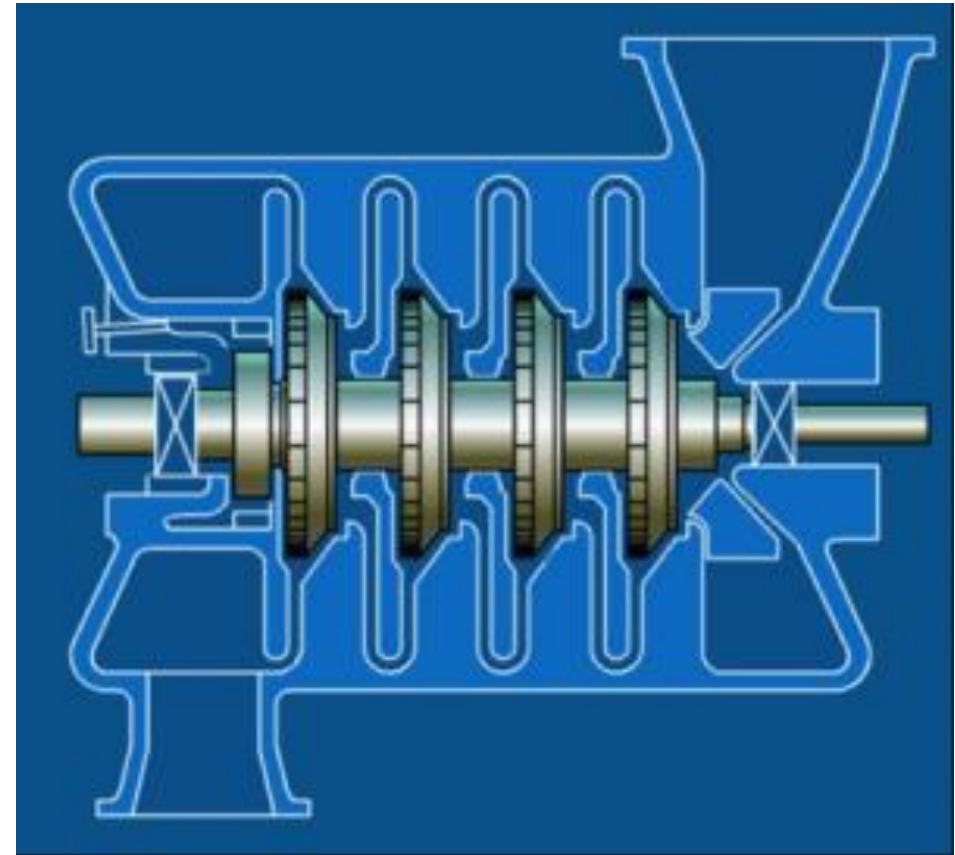
Aeroprobe developed a micro-machining technology to allow for the probes/rakes to be installed in locations that had previously not been possible.





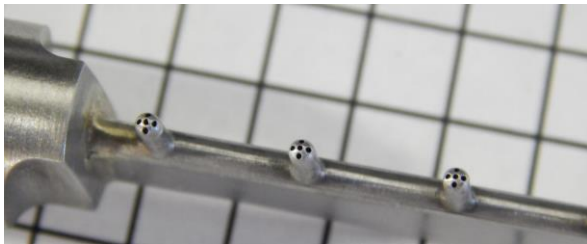
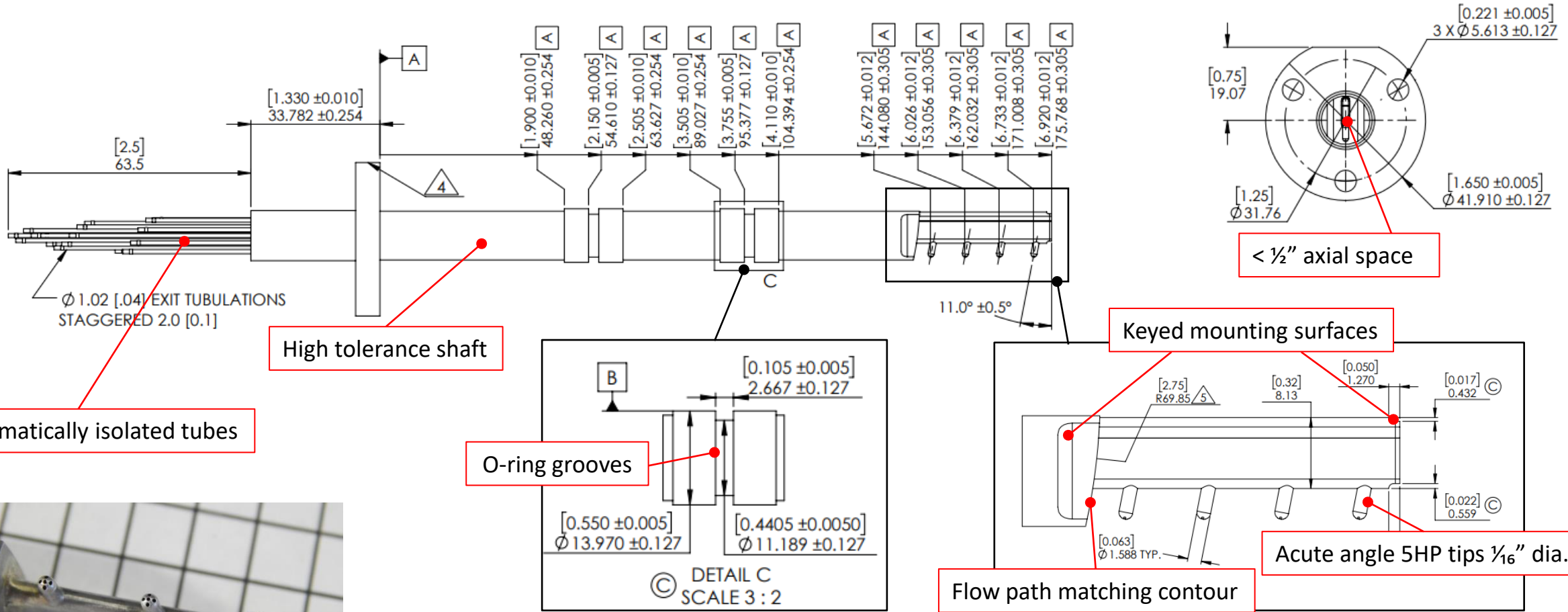
Example: Centrifugal Compressor

- Pressure and swirl measurements between centrifugal compressors stages
- Must survive surge (hammershock) conditions
- 100 psi, 500 °F, 0.5 Mach
- 1¼” span between hub and shroud
- Less than 1” of axial space available





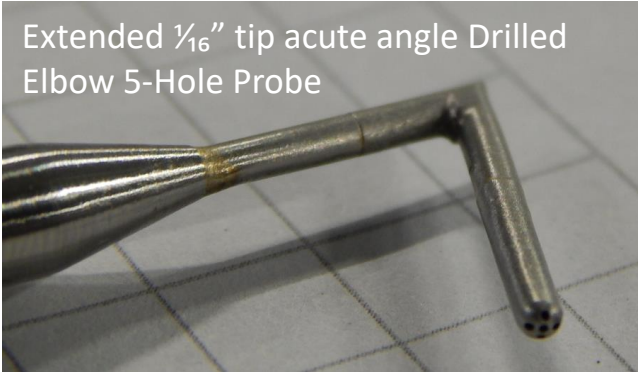
Example: Centrifugal Compressor



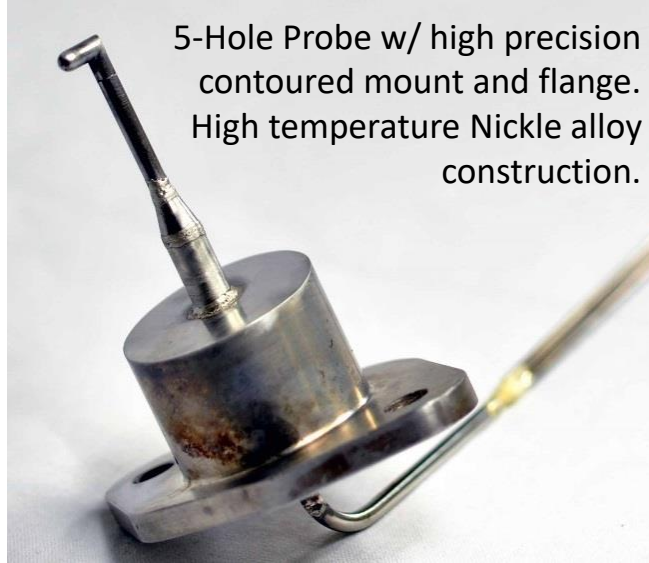


More probes

Extended $\frac{1}{16}$ " tip acute angle Drilled Elbow 5-Hole Probe



5-Hole Probe w/ high precision contoured mount and flange. High temperature Nickel alloy construction.



Double tip 5-Hole Probe with embedded thermocouple for refrigerant flow measurement.



1x



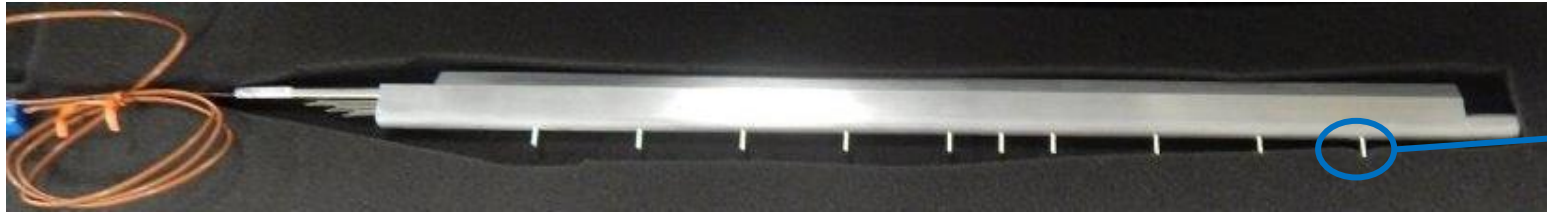
10x



Titanium ring (0.5 m diameter) for in-flight helicopter engine inlet measurements with 12 3D printed Kiel/TAT rakes.



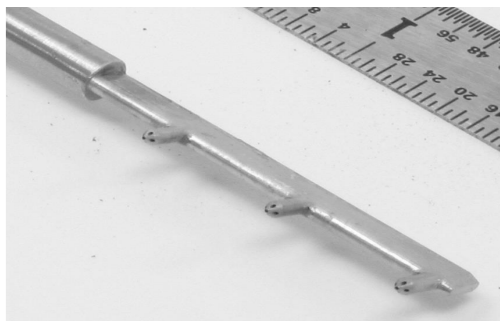
More rakes



Kiel rake for thrust reverser measurements, 1 meter long.



Rake body with detachable 3.2 mm diameter 5-Hole Probes.



5-Hole Probe Rake with 3 tips, 1.6 mm diameter probe tips.



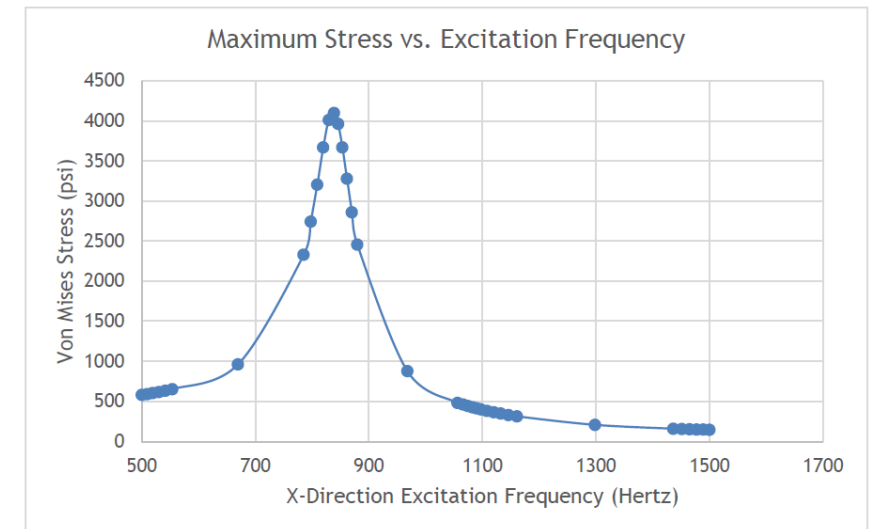
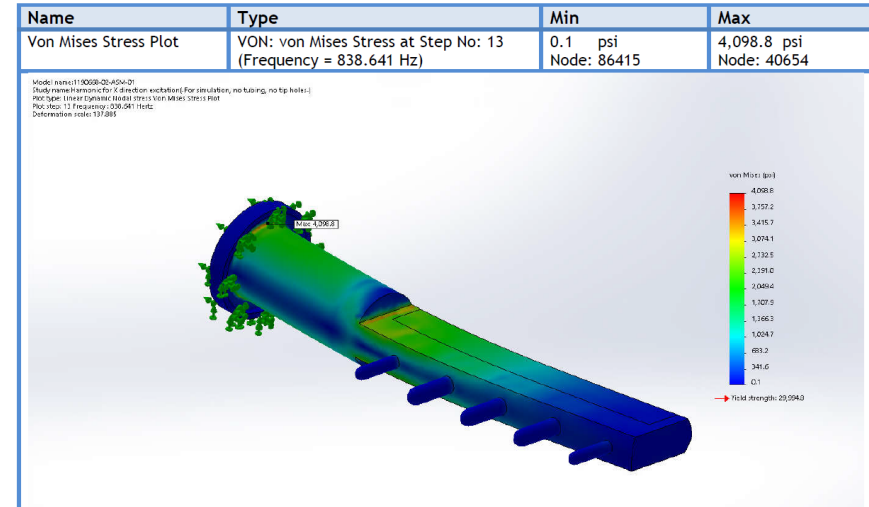
Engineering Analysis & Design

Finite Element Analysis (FEA)

- Static and modal analysis
- Forced response (dynamic) analysis
- Thermal analysis

Acoustic Response Analysis

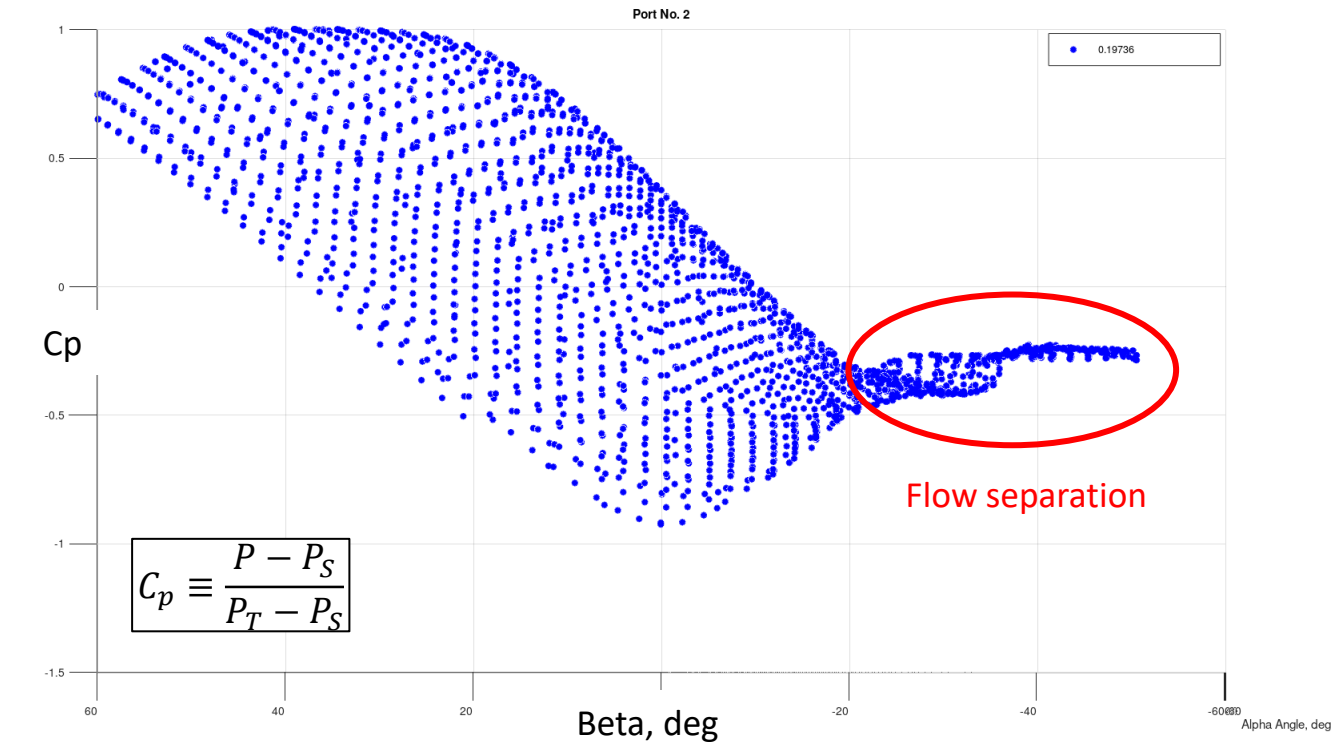
- Fluctuating pressure & temperature
- Inertial & compression effects
- Transducer deflection
- Step changes in tube temperature & molecular properties
- Experimental validation via acoustic calibration





Calibration Services

- NIST traceable
- 10 m/s to Mach 1.8 calibration range
- Recovery factor calibrations
- Up to 3000 discrete calibration points per Mach number





AEROFLOW 3 Software

Applies aerodynamic calibrations to multi-hole probe pressure measurements

Proprietary algorithm developed over the past 5 years.

- Optimized error minimization scheme achieves best possible accuracy
- Specific port arrangement not necessary
- Separation detection per port allows for widest possible angular range
- Very fast computation time
- Variable gas constants
- Applies recovery factor calibration

Developer's Version (DLL)

- Integrates with C/C++, Python, LabView, Matlab, and C#
- Example source code provided

Graphical User Interface (GUI) Included

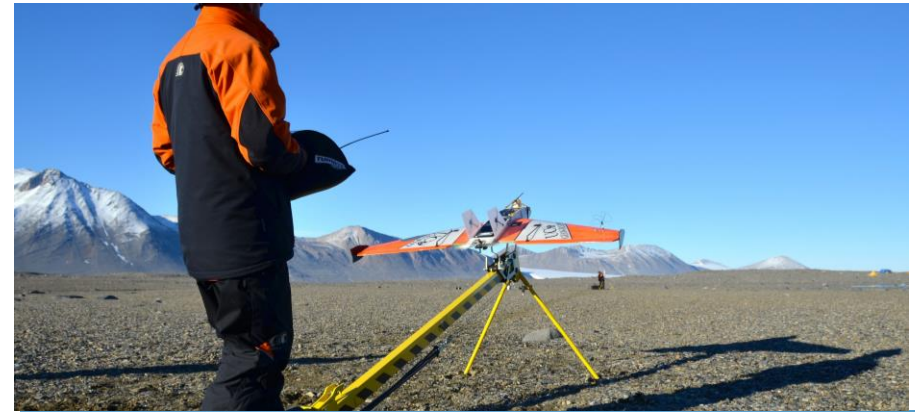


Unmanned Flight Market

Starting around 2005 AeroProbe started the effort to design probes and pressure scanners for the growing unmanned flight market.

Market Demands:

- Robust to survive rougher flight conditions
- Small
- Light Weight
- Integrated Static ring option
- Optional Heater for anti-icing capability
- All weather capability





Flight Probes

Pitot & Pitot-Static

- Designed to meet AS8006 performance standard
- Drained & Heated (optional) designed to meet AS5562 Rain & Ice standard
- Low weight (as low as 50 grams)
- Configurable for specific platforms & envelopes
- Compatible with Micro Air Data Computer



Air Data Probes (5-Hole Probes with Static Ring)

- Replaces combination of pitot static probe with AoA / AoS vanes with single smaller lighter probe. No moving parts
- Allows for flow angle measurements up to +/-40° of AoA and AoS
- Anti-icing (optional)
- Compatible with Micro Air Data Computer





Micro-Air Data Computers



PEGASUS

Qualified to MIL-STD and DO standards

181 grams
1.1 Watts
66 x 79 x 41 mm



ENDEAVOR

Extended AoA and AoS range

202 grams
1.1 Watts
66 x 79 x 41 mm



DESTINY

Qualified to MIL-STD and DO standards
Integrated AHRS

181 grams
1.1 Watts
66 x 79 x 41 mm



ORION

The most rugged
Qualified to enhanced testing standards

220 grams
1.1 Watts
Ø95 x 28 mm



VOYAGER

Integrated GPS/INS

285 grams
1.7 Watts
66 x 79 x 41 mm



Micro-Air Data Computer

The micro-Air Data computer when used in conjunction with the multi-hole Air Dat probe allow for direct measurement of:

- Airspeed – Indicated and True*
- Flow Angles (Angle of Attack and Angle of Sideslip)
- Static and Total Pressure
- Barometric Altitude

With optional internal Attitude Heading Reference System (AHRS) the micro–Air Data Computer can also add to the following information to the data stream

- Three Euler angles (Pitch, Yaw and Roll)
- X,Y and Z acceleration and rate

Real Time output via RS232 or RS422 Serial Connection
8GB Internal Data Storage





What the system offers – why is this important

What does the complete Micro Air Data System offer:

- High guaranteed accuracy
 - Air Speed +/- 1m/s or 1% which ever is greater
 - Pitot Static Probes to 5 degrees half cone
 - Air Data Probes to 20 or 40 degrees
 - Flow Angles with Air Data Probe to +/-1 degree
 - Accuracy at 2Ω
- Size, Weight and Power (SWaP)
- Ruggedized Design that been tested and certified compliant to various military and commercial standards for low temperature, shock, vibration and combined environmental requirements.





What the system offers – Accuracy

Wind Tunnel Performance Testing in AeroProbe's free jet wind tunnel facility allows each individual probe to be tested at up to nine velocities (from 10m/s up to $M=0.95$). This test data is then used to create a unique calibration file for each probe which is then used by the micro-Air Data to accurately convert measured tip pressures into airspeed information and flow angle data when using a 5 Hole Air Data Probe.

As compared with using a GPS/INS system to estimate the vehicles AoA/ AoS, output of the micro-Air Data System, with the 5-Hole Air Data Probe, offers accurate **MEASURED** AoA/AoS





Accuracy – Measured vs Calculated



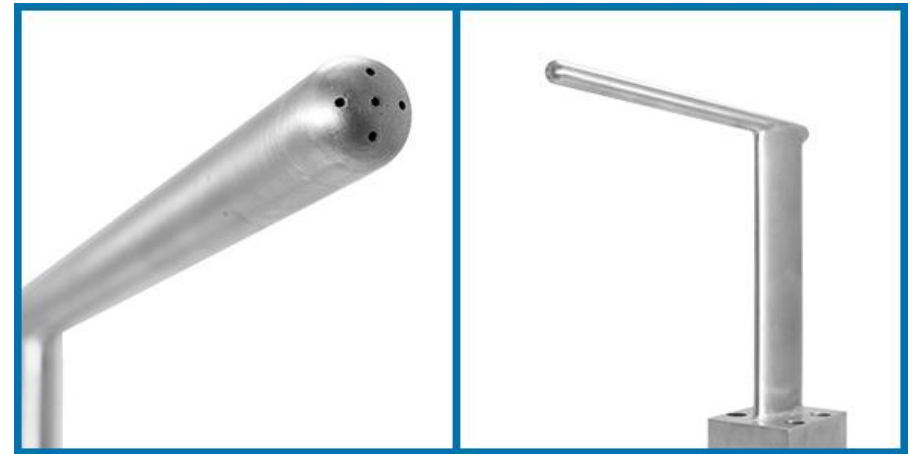
What the system offers – SWaP

As mentioned earlier this morning every gram of weight savings relates to significant increase in revenue.

As compared to a vane style probe (Swiss Air Data FTB-1) designed specifically for the unmanned platforms the Aeroprobe 3.2mm Air Data Probe can up to 180 grams (20 grams vs 200 grams) and even with the 9.5mm Heated Air Data Probe saves up to 100 grams in probe weight.

Other advantages is that the 5 Hole probe are:

- No moving parts
- Reduced Aerodynamic Drag





High Altitude Flight Market

- **2008** – First Heated 5-Hole Probe based system sold to US based HALE manufacture – one of the initial designs for the micro–Air Data Computer
- **2015** - Another US Based company purchased 5-Hole Probe based system – used 2nd Generation of micro–Air Data Computer with new sensor packages for use up to 20,000m
- **2018** – UK based Prismatic purchased 3rd Generation micro–Air Data System –greater temperature range and more ruggedized enclosure to meet more stringent environmental requirements





High Altitude Flight Market - SWaP

What did these customers all need:

- Heated Probe
 - Initial design weighed roughly 150 grams
 - Newer configurations roughly 100 grams.
- Lower Power Consumption
 - Heater - 42W
 - Micro Air Data Computer
 - Original Computer Models – 3.2W
 - 3rd Generation Models – 1.1W





Looking to the future

Future developments include:

- Newer, more accurate sensors.
 - AS8002B barometric altitude measurement compliance.
 - Possible higher maximum operating altitude.
- Overcoming the all-weather limitation of the 5-Hole probe design
 - With the continued growth in the Urban Air Mobility market – certification requirements similar to manned flight – new probe designs are required to meet FAA and other international qualification body requirements.
- Smaller and Lighter
 - Alternate housing for micro Air Data Computer for those customers that do not need to meet the ruggedized requirements
 - Heater designs to allow for incorporation into smaller probes

