

Microwave Sensor for Blade Tip Clearance and Structural Health Measurements

The use of microwave based sensors for the health monitoring of rotating machinery is being explored at the NASA Glenn Research Center. The microwave sensor works on the principle of sending a continuous signal towards a rotating component and measuring the reflected signal. The phase shift of the reflected signal is proportional to the distance between the sensor and the component that is being measured. This type of sensor is beneficial in that it has the ability to operate at extremely high temperatures and is unaffected by contaminants that may be present in the rotating machinery. It is intended to use these probes in the hot sections of turbine engines for closed loop turbine clearance control and structural health measurements. Background on the sensors, an overview of their calibration and preliminary results from using them to make blade tip clearance and health measurements on a large axial vane fan will be presented.



Setting the Standard for Automation™

Microwave Sensor for Blade Tip Clearance and Structural Health Measurements

Mark R. Woike
Timothy J. Bencic
NASA Glenn Research Center
Cleveland, Ohio

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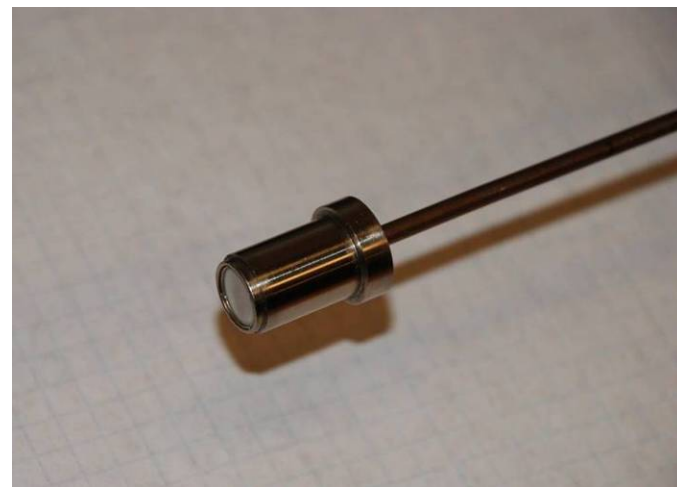
- NASA Glenn Research Center, Cleveland, Ohio
- Electronics Engineer
 - Instrumentation, Data and Control Systems
 - Wind Tunnel and Propulsion Test Facilities
- Currently in the Optical Instrumentation and Non-Destructive Evaluation (NDE) Branch

Microwave Tip Clearance Sensor – Outline

- Sensor Background
- Sensor Calibration
- Testing on an Axial Vane Fan at the Glenn Research Center's 10x10 Wind Tunnel Facility

Microwave Tip Clearance Sensor - Background

- Designed to measure blade tip clearances
- Developed by Radatec, Inc. (currently Vibro-Meter, SA) through NASA's Small Business Innovation Research (SBIR) program
- 5.8GHZ microwave sensor, 0.50" (~13mm) in diameter
 - Sensor is both a transmitting & receiving antenna
 - Reflected signal's phase shift is proportional to distance between sensor and target

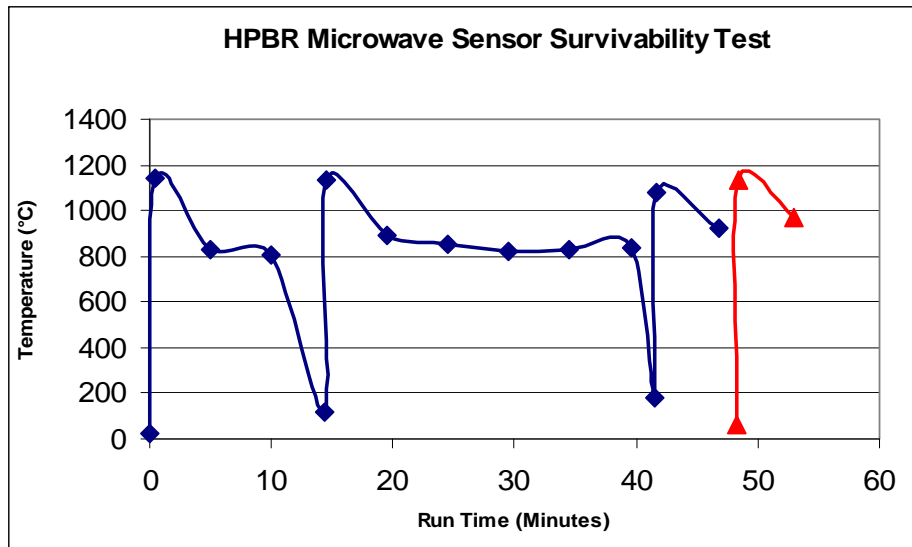


Goals & Benefits of Technology

- Well suited for use in hot sections of turbines
 - Closed loop turbine clearance control
 - Variable geometry control schemes
 - IVHM applications
 - Tip timing measurements
- Benefits of technology
 - Rated for high temperature usage
 - ~2000°F (~1100°C)
 - Tested to ~2200°F (~1200°C) in a high pressure burner rig
 - Accurate at low clearances
 - Goal of accuracies on the order 1 mil (.025mm)
 - Not effected by environmental conditions & contaminants
- Ultimate goal is to use system in an aero engine
 - Near term goals are to calibrate the system and evaluate its use on smaller test rigs

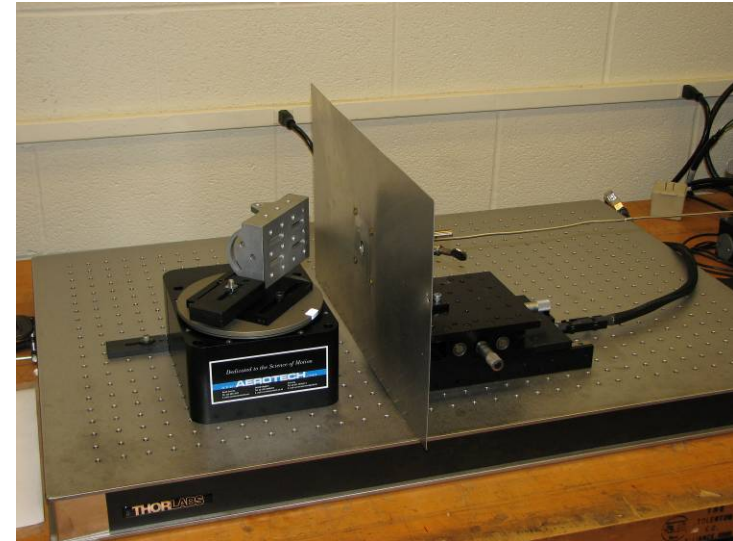
High Pressure Burner Rig Testing

Microwave probe evaluated for survivability and operation in a combustion environment using jet fuel in GRC High Pressure Burner Rig to 2200°F (1200°C). No clearance information obtained only center frequency and reflected energy because of test setup.

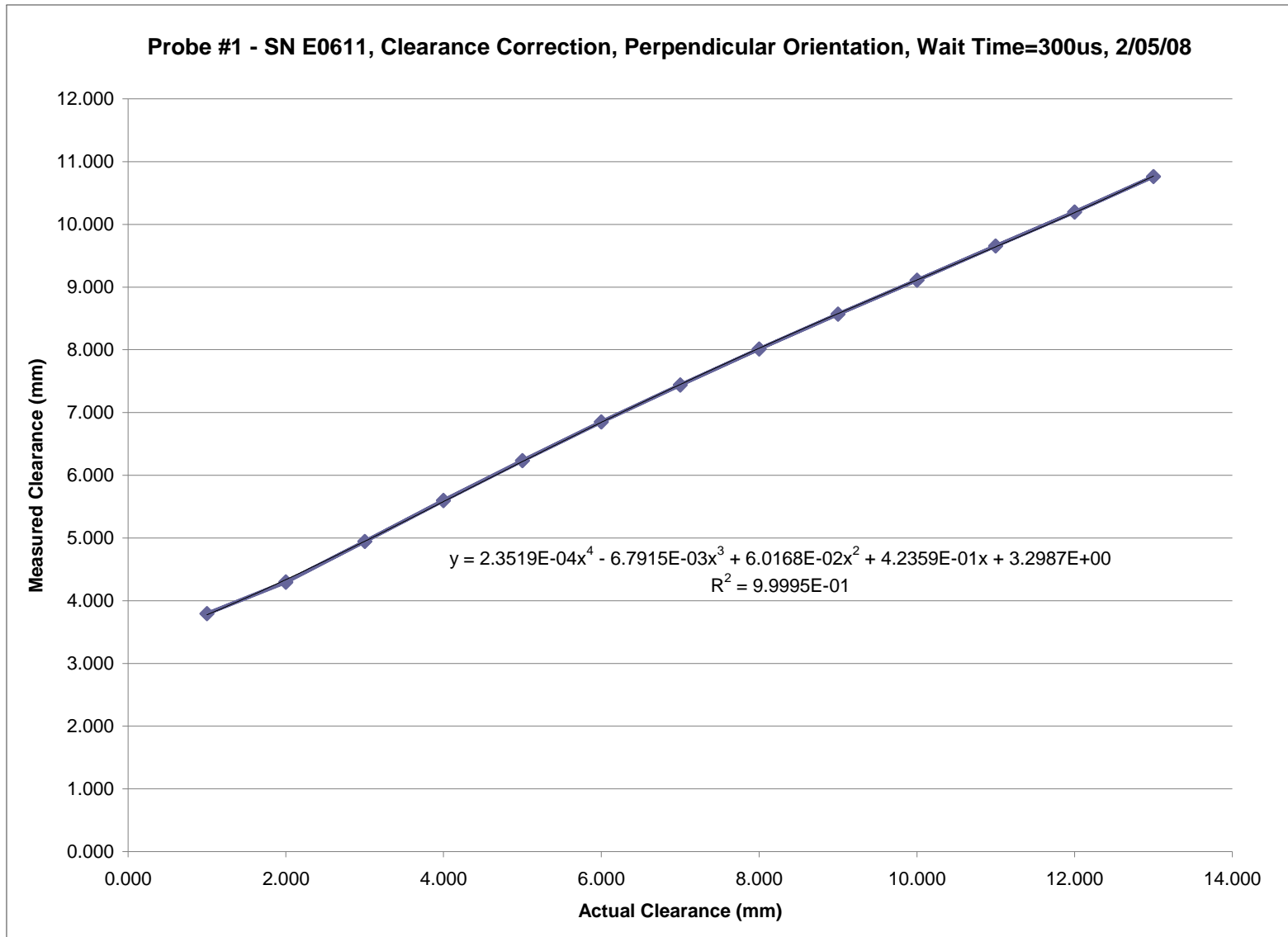


Sensor Calibration

- Calibrated two microwave probes
 - System makes an average measurement of the geometry within the spot size that is projected on the blade
 - Need to map this average reading to the actual minimum clearance.
- Calibration Set up
 - Rotary table for blade
 - Linear positioning table for sensor
- Calibrated against two geometries
 - Thin compressor blade
 - Thick box to simulate Axial Vane Fan blade

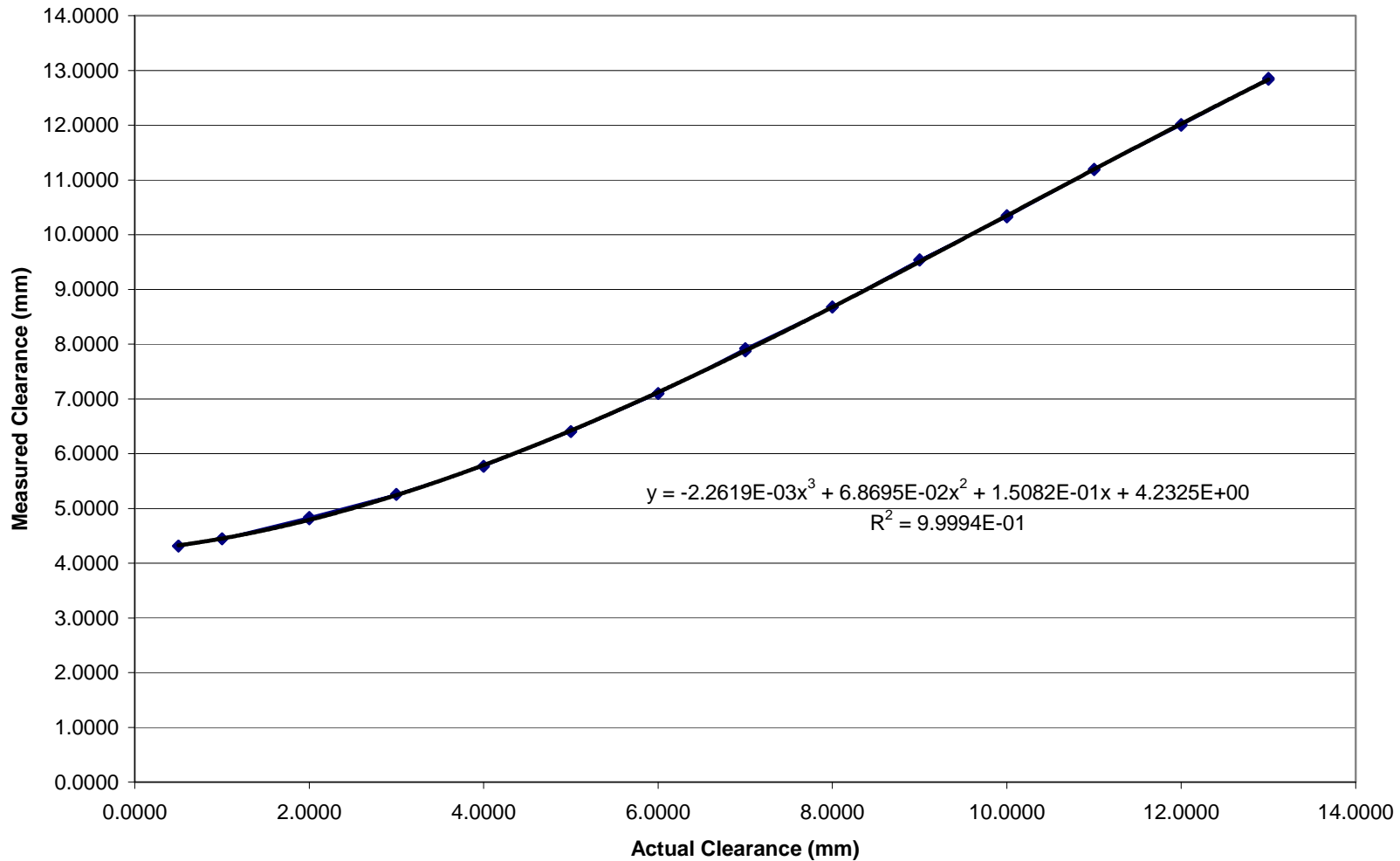


Calibration – Thick Blade



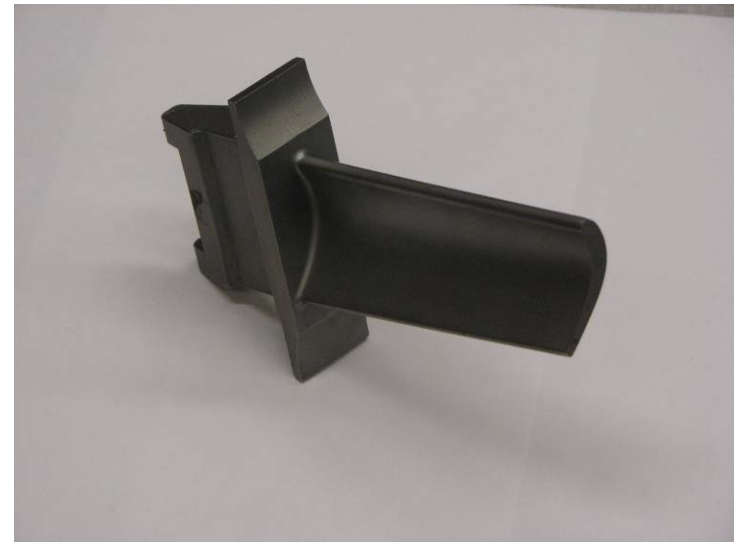
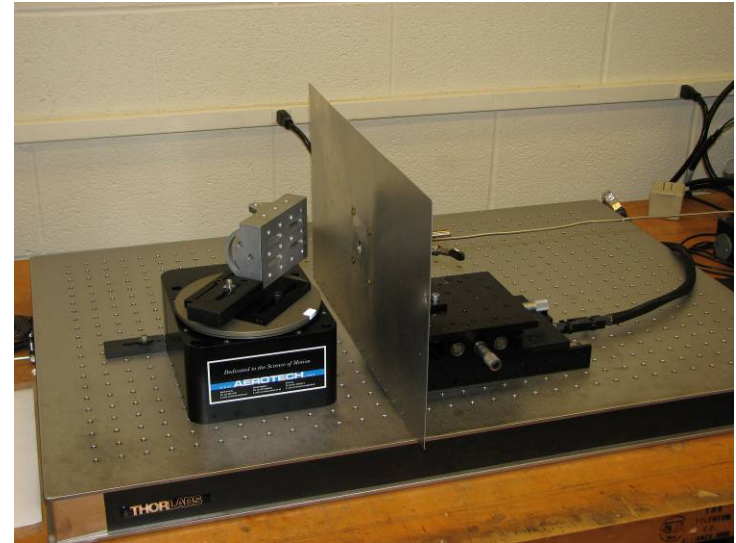
Calibration – Thin Blade

Probe #1 - SNE0611, Clearance Correction, Parallel to Thin Blade, 3 Blades Per Average, 1/22/08



Sensor Calibration

- Calibration Verification
 - With current set up observed calibration accuracy of $\pm 0.12\text{mm}$ (~ 5 mils)
 - Very repeatable for large blade
 - More sensitive for small blade
- Observed installation effects
 - Electric field orientation to blade
 - Thin Blade, parallel orientation
 - Thick Blade, perpendicular orientation
 - Backplane
 - Needs to be greater than a few wavelengths
 - Installation depth
 - Wave guide effects if too deep



Axial Vane Fan Test

- Goal was to gain experience with the microwave sensor and assess its use on an actual rotating hardware
- Axial Vane Fan
 - 72" (~1.8M) Diameter Fan
 - 16 Blades, 1" (~25mm) thick
 - Two probes installed 90 deg apart
 - Operates at 1200RPM
- Acquired data for several configurations
 - Probes electric field aligned parallel & perpendicular to blade
 - Acquired both raw & corrected data
 - Synchronous & Asynchronous data acquisition modes



Axial Vane Fan Test – Probe Installation



Probe Installation - Fan Exterior

Probe Installation -Fan Interior

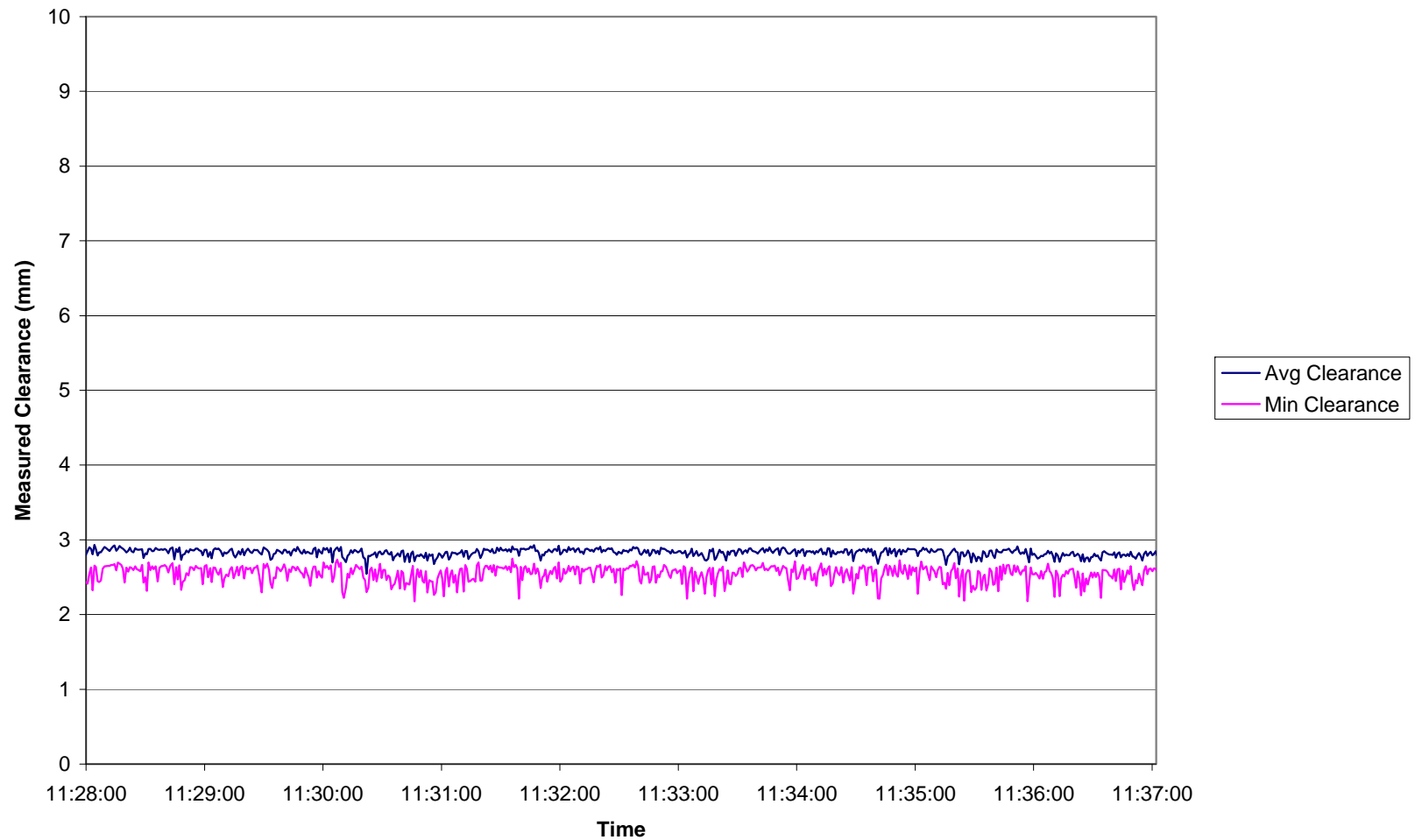


Axial Vane Fan Test - Status

- In process of reducing & analyzing data
- Probes gave reasonable readings over fan's operating range
 - Probe #1 gave best results
 - Clearances were at levels expected during operation (slides 12 & 13)
 - As observed in calibration, perpendicular electric field orientation worked best for large size blade
- Plan is to further analyze
 - Repeatability of individual blade measurements
 - Tip timing
 - Parallel vs. perpendicular electric field orientation results

Axial Vane Fan Test – Clearance Data

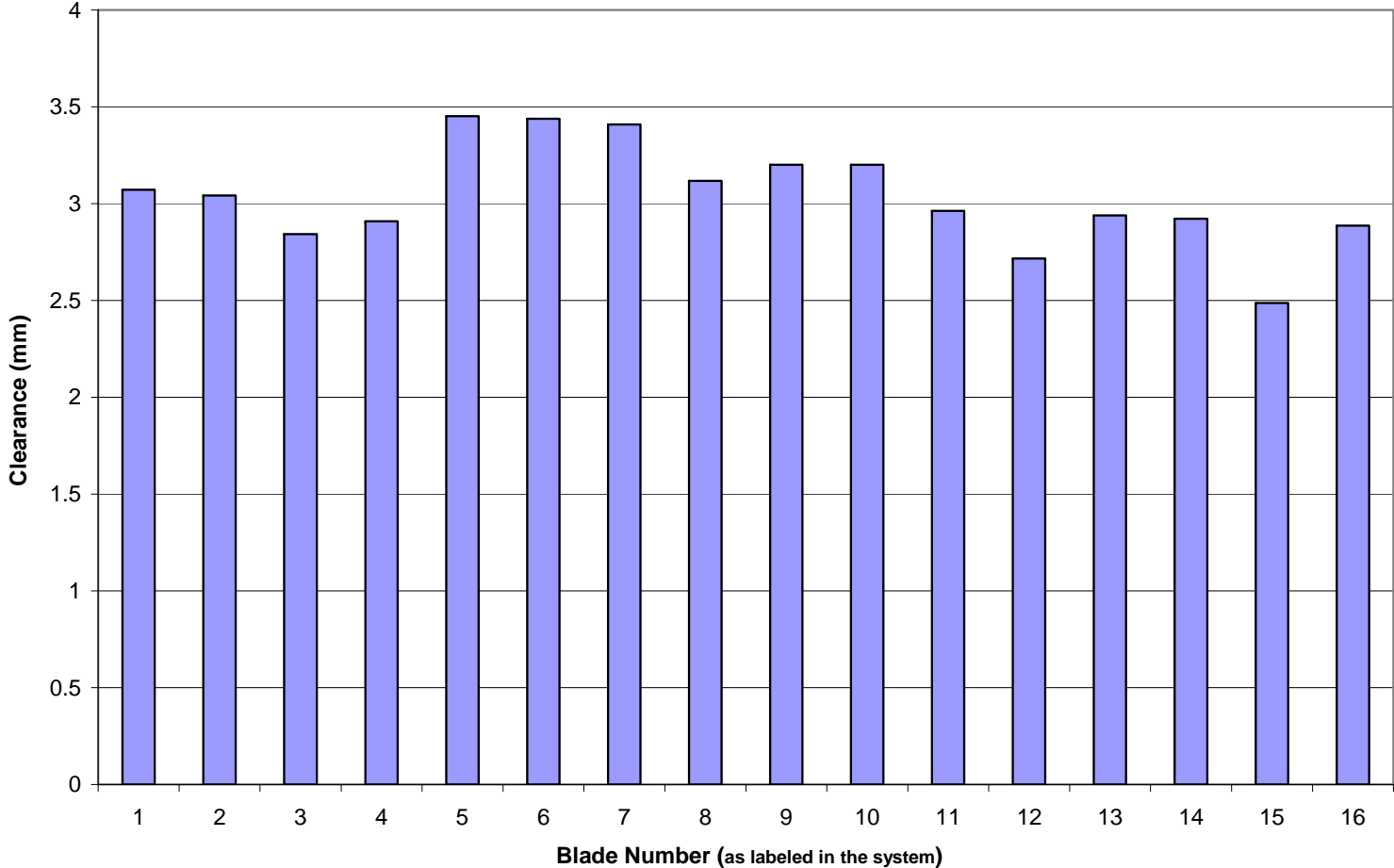
Run #7, Probe #1, Perpendicular Orientation, Corrected, Asynchronous Data Mode



Axial Vane Fan Test – Clearance Data



Tip Clearance Measurements - One Revolution
Run #5, Probe #1 Parallel Orientation, Synchronous Data Mode



Conclusion / Future Plans

- Finish analyzing data from fan test at 10x10
 - Repeatability of individual blade tip clearances
 - Tip timing
 - Comparison of calibrations vs. use on fan
- Accomplish a comparison test between capacitive, optical, and microwave clearance probes
 - Rotor Dynamics Test Rig
 - Axial Vane Fan
- Upgrade system to operate at 24GHZ
 - Acquire 0.25" (~6mm) diameter probes
- Test on an actual aero engine