



ISA Standards for Turbine Engine Test Cell Instrumentation



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Agenda

- The Need for improved Test Cell Instrumentation
- Current efforts to Develop and Standardize Instrumentation (ISA 107.1 through ISA 107.5)

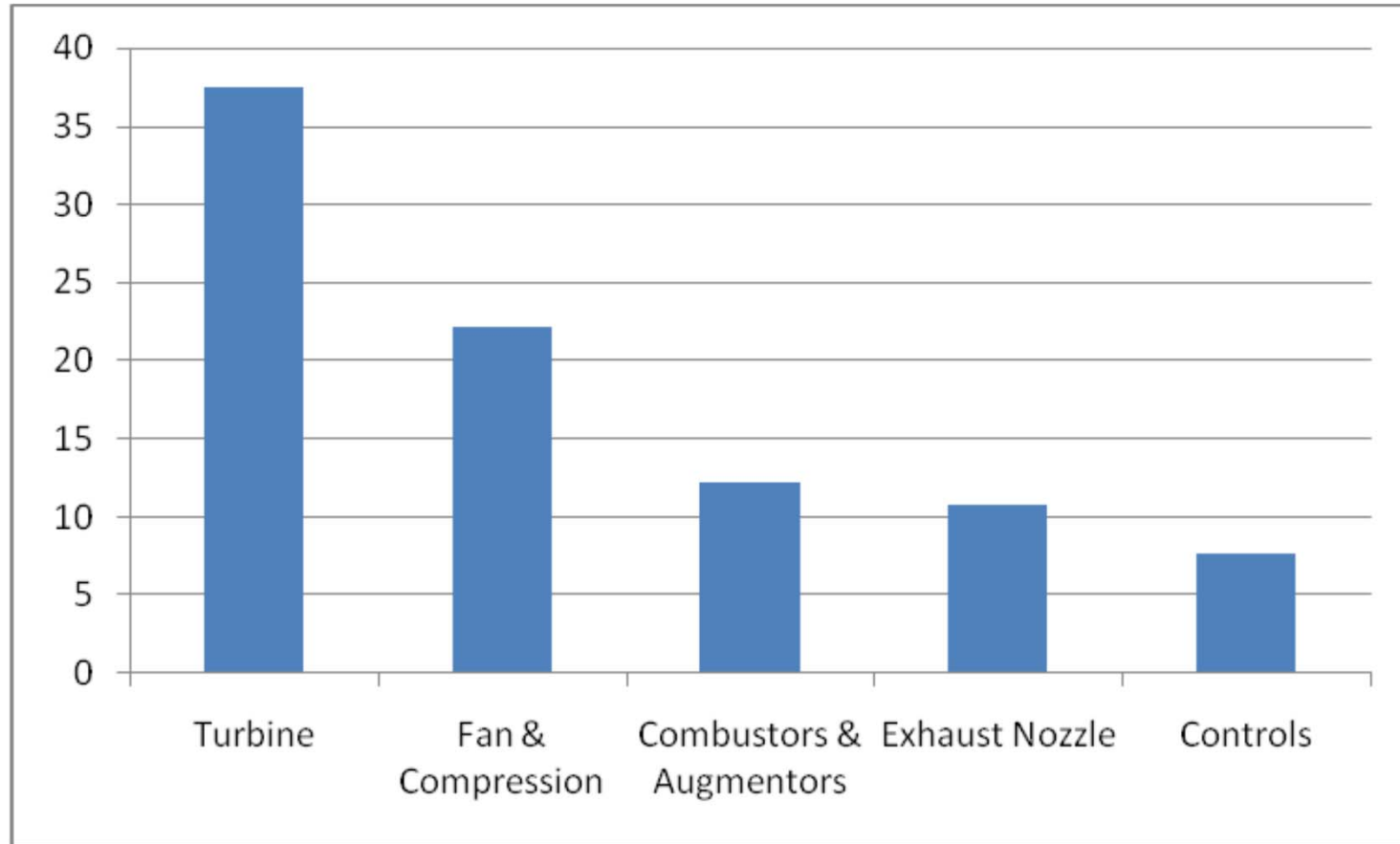


Challenge

- Accurately Measuring the Environment in the Hot Section of a Turbine Engine is a Major Challenge
 - Learning of a design problem early in the engine design phase allows changes to be made which will save significant future maintenance costs



Relative Depot Maintenance Cost by Component Area



Average % depot maintenance cost by component of three prevalent USAF Turbine Engines



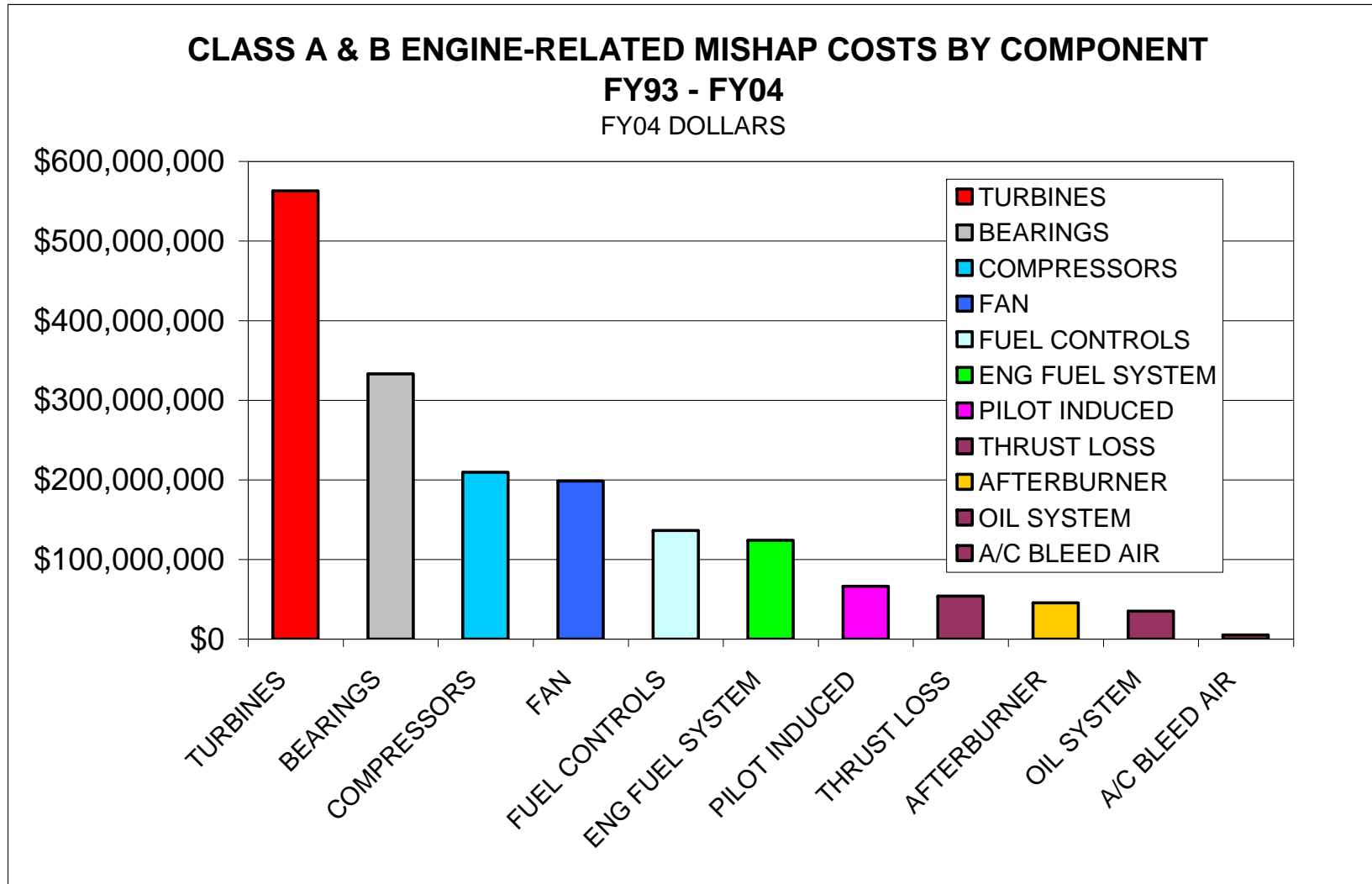
What are Class A and B Mishaps?

A mishap resulting in one or more of the following

- Class A
 - Damage of \$1,000,000 or more (Changed to \$2,000,000 starting in FY10)
 - A fatality or permanent total disability
- Class B
 - Property damage of \$200,000 to \$1,000,000 (Changed to \$500,000 to \$2,000,000 starting in FY10)
 - A permanent partial disability
 - Inpatient hospitalization of 5 or more personnel



Cost of Class A & B Mishaps by Component Area

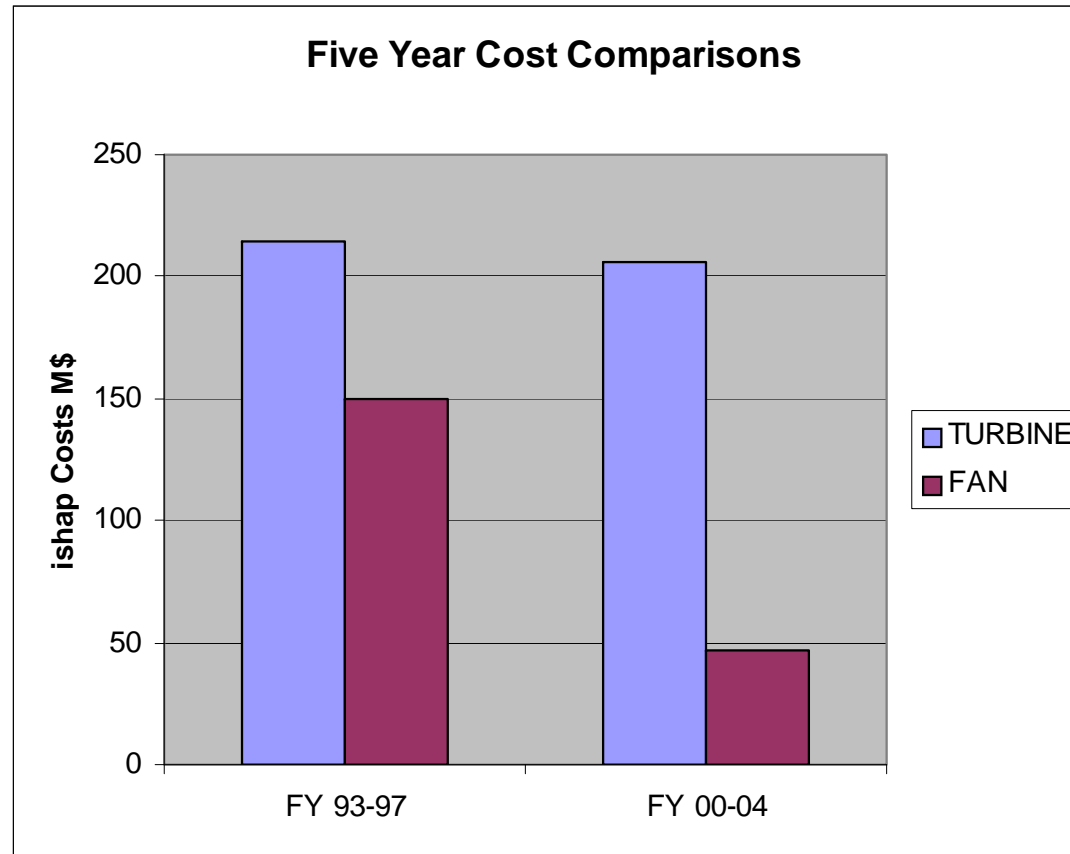


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Five Year Comparison

Fan vs Turbine Mishap Costs



- Fan Mishap Costs Reduced
 - Success of HCF Technology Development Program
 - Improved Inspections
- Now need to apply Resources to Turbine Section Durability

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How do we address this problem?

- Need to Develop and Fund Long Range Plans
 - Technology Development Plans
 - Technology Transition Plans
- Improved Hot Section Measurement Capabilities are Needed
 - TBC Health
 - Component Temperature Measurement
 - Hot Section NSMS / BTT
 - New Hot Section Sensors for Gas Temp, Tip Clearance, and Dynamic Pressure Measurement
- Validating the Accuracy of Test Cell Instrumentation is Vital to Assuring Engine Health



ISA107 Standards Committee Formally Approved

Title:

Advanced Measurement Techniques for Gas Turbine Engines

Purpose:

To develop standards, recommended practices, and technical reports on measurement techniques that are vital in the safe and reliable operation of gas turbine engines.

Scope of Work:

The scope of work of this committee encompasses measurement techniques for gas turbine engines that are developed for and used in aerospace and industrial applications.



Current ISA107 Sub-committees

- 107.1 Nonintrusive Stress Measurement (NSMS) / Blade Tip Timing (BTT)
- 107.2 Temperature Measurement using Thermographic Phosphors
- 107.3 Blade Tip Clearance Measurement
- 107.4 Wireless Data Transmission in the Test Cell Environment
- 107.5 Dynamic Pressure Measurement -(still under development)

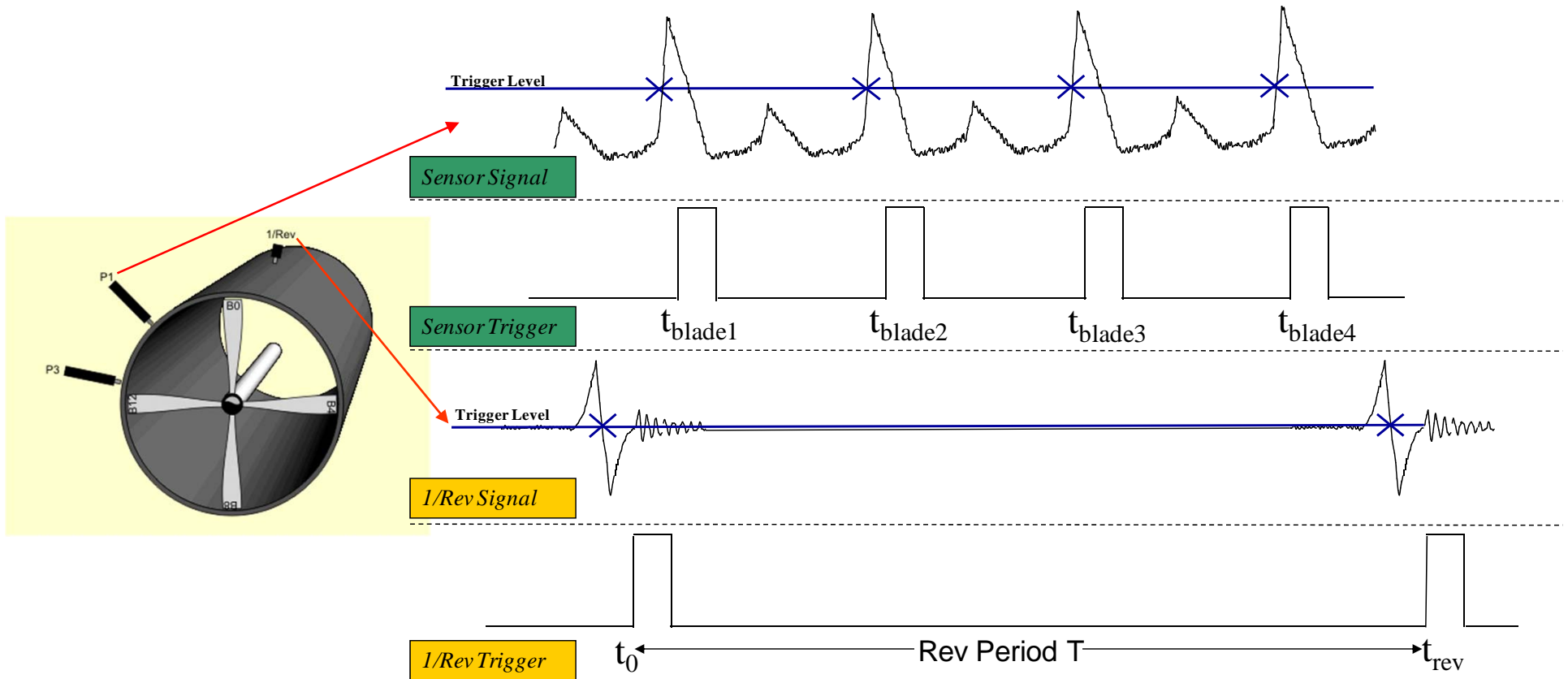


NSMS/BTT Overview

- Measurement is intrusive to the engine case but is non-contact to the blade
- Measures integral (synchronous) and non-integral (non-synchronous) vibrations (NIV) plus static deflections
- Conversion from deflection to stress requires a detailed Finite Element Model (FEM) analysis of the blade

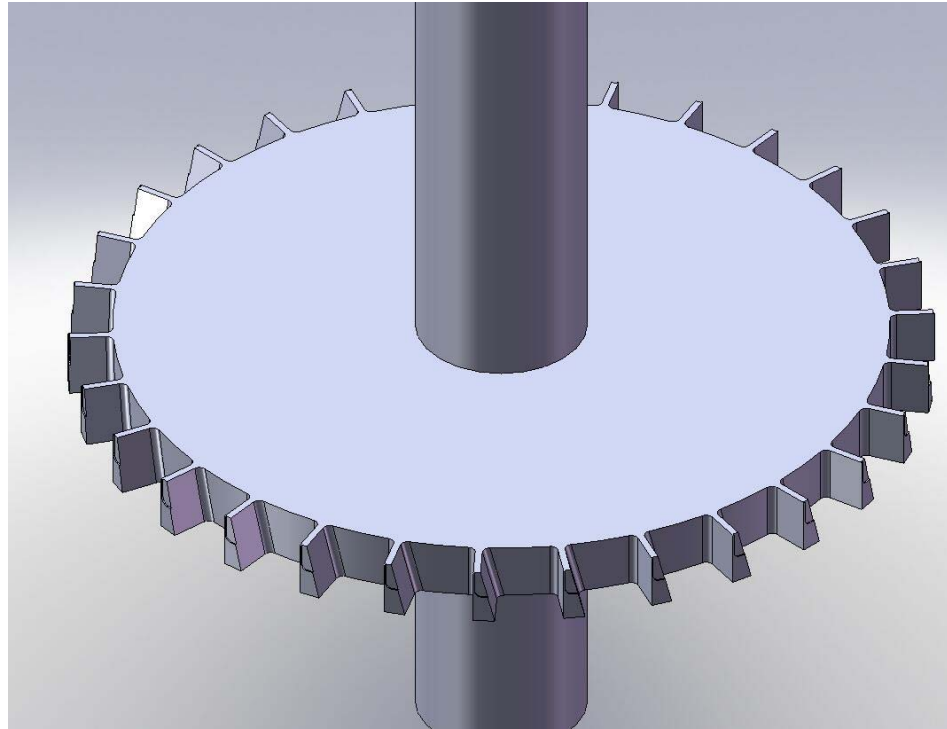


NSMS/BTT Overview





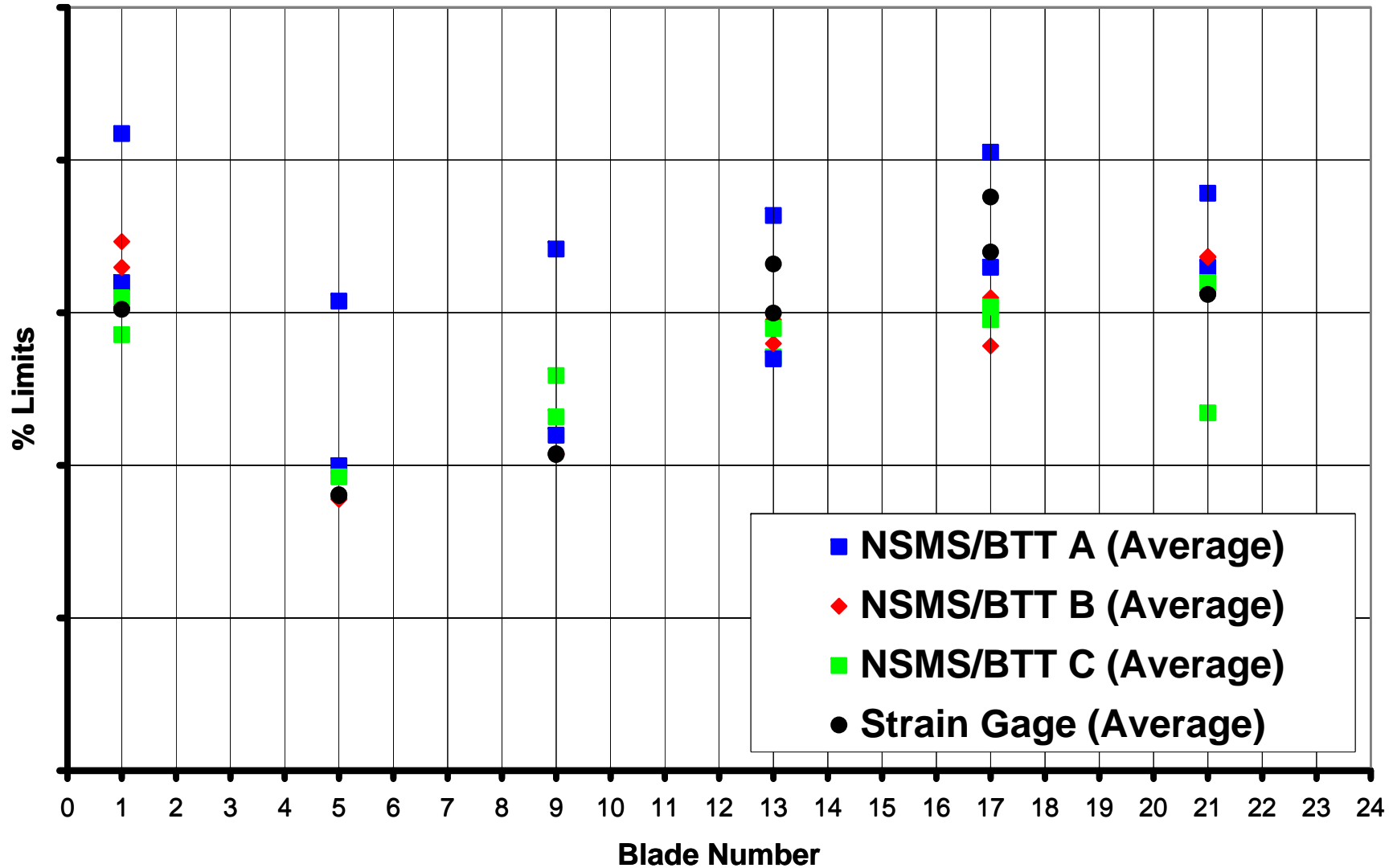
OAI DO #2 Effort - NSMS



Conceptual Design of Pseudo Vibration Calibration Rotor



Why Standardize??



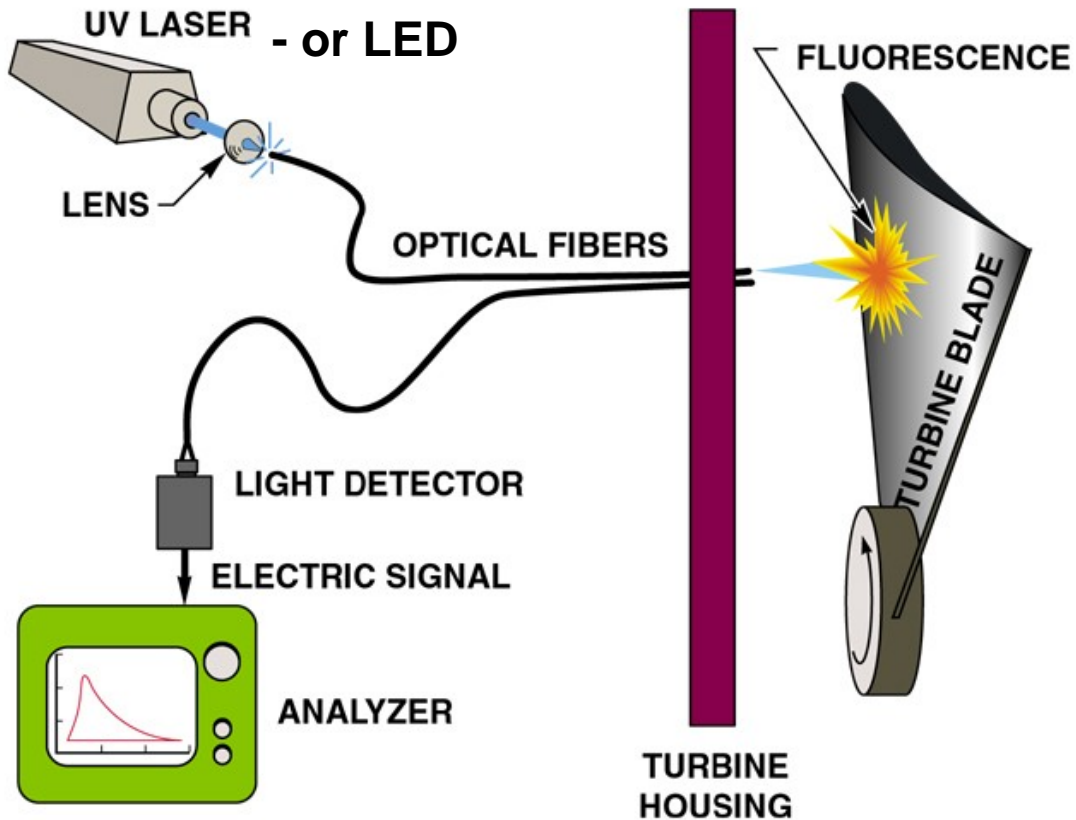


ISA 107.2 Thermographic Phosphors

- Temperatures can be determined from pulsed-illumination-induced fluorescence of thin phosphor coatings applied to turbine engine surfaces of interest.
- Thermographic Phosphors hold significant potential for solving component temperature measurement problems in the engine.
- Standardizing definitions of coating durability, fluorescence efficiency, temperature range and temperature sensitivity as well as defining methods for establishing these characteristics is required.
- Standards for Thermographic Phosphors will benefit both aircraft and power generation engine manufacturers and sensor vendors alike.



Application of Thermographic Phosphors to Turbine Engine Blades/Vanes



White phosphor coating



Red Fluorescence when illuminated indicates temperature

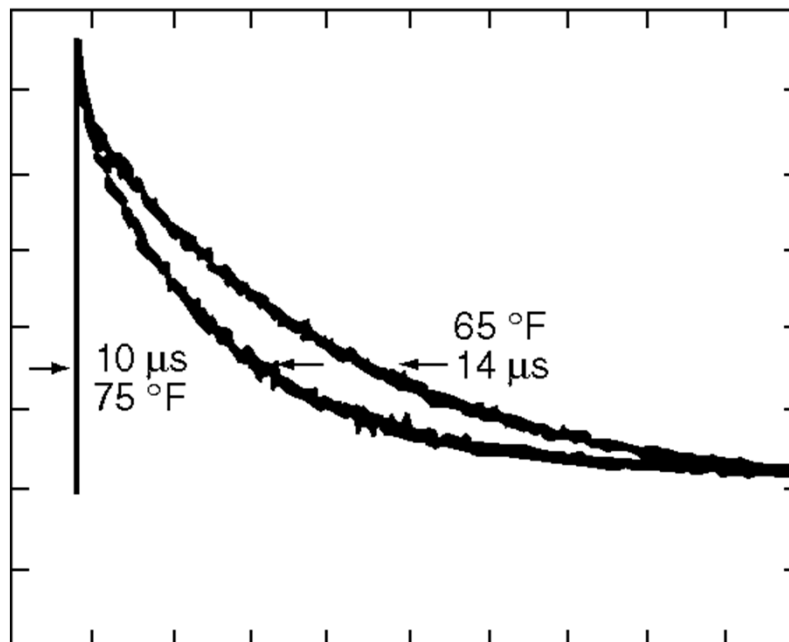
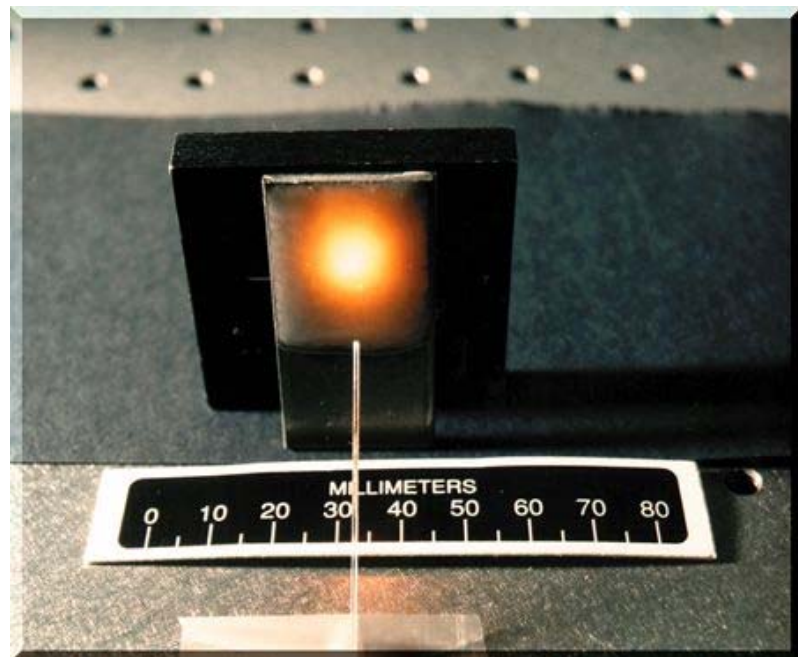
Thermometry Methodology

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Decay time the most sensitive function of temperature

ORNL-DWG 97-1687 EFG





Decay time vs temperature for selected phosphors

DWG. NO. K/G 96-569 GSS
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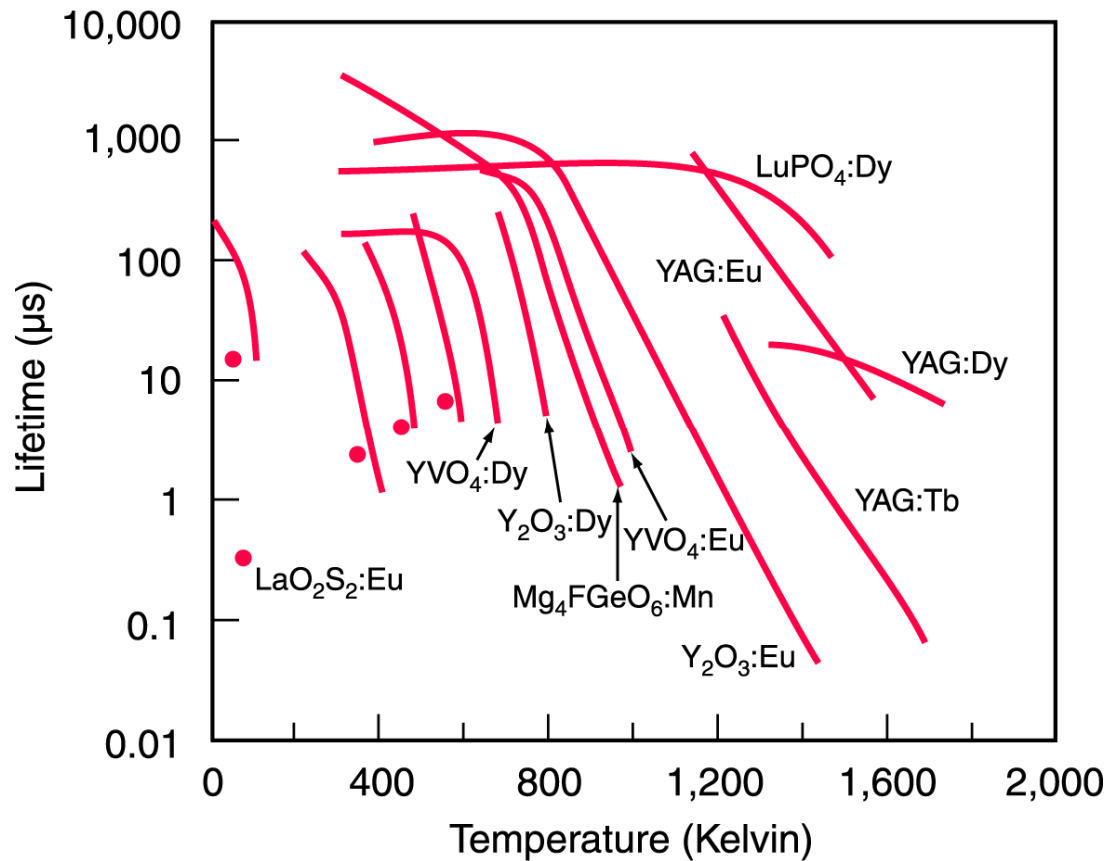


Figure 12. Lifetime versus temperature of selected phosphors.

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ISA 107.3 Blade Tip Clearance

- Particular Topics of Interest
 - Hazardous Area Approval Requirements
 - System Bandwidth Measurement
 - Calibration



Hazardous Area Approval

- Was never a requirement however with the move into production environments this focuses the customer's mind on the legal standards which the rest of the equipment have to comply with
- Capacitive based systems can have a significant amount of stored energy especially if high energisation voltages are used.



Bandwidth measurement

- System Bandwidth becoming more important with the need for better response for tip timing measurement
- Not everyone measures their bandwidth the same way
- Need to include whole system into measurement
- Capacitance injection the only valid method for capacitive based systems
 - Need a similar method for other technologies



Calibration

- Test rig
 - Measurement of uncertainty
 - Router motor clamped to a bench v custom rig
- Calibration Disc
 - Design quality
- Measurements
 - Calibrated and maintained test equipment
 - Repeated tests and standard deviation monitoring



ISA107.4 Scope

- The Subcommittee's focus is to define scalable architectures, system components, and protocols that allow secure reliable wireless connectivity for test cell based turbine engine measurements.
- The subcommittee will address technologies including but not restricted to wireless mechanisms for data transmission and passive wireless sensing or technologies required for harsh environments as found in the operating power turbine test environment
- The results of this Subcommittee may serve as a basis for future on-wing engine health monitoring or control systems.



ISA107.4 Purpose

- Identify where shall the wireless interfaces need to be?
 - Define the surrounding environment (inside or outside engine)
 - Identify the radio frequency (RF) environment
- Develop Multi-vendor interoperability support for various applications
 - System integration support for critical and non-critical measurements
 - Common application interfaces
 - Common network management
 - Enhanced security management
- Develop co-existence support
 - With other network standards – possible
 - Other proprietary networks – not addressable



Current Activities

- Prepare a requirements Document
 - What are the critical sense points where wireless can add unique benefit (ex: Turbine bucket & compressor blade strain & temperature)?
 - How many measurement points are needed?
 - How long must the sensor survive?
 - How much can it effect the performance of the surface?
 - What are the security aspects?
 - What size engines will be covered?
 - What are the regions of the world that the system must operate in?
- Prepare a wireless network diagram
 - Illustrate how a wireless instrumentation system would be constructed?



Future Activities

- Prepare a technology assessment and gap analysis.
- Determine where standards and best practices are needed and would be helpful.
- For standards - solicit vendor and user input and proceed with the standards development process.
- Generate best practices documents (informative) as needed.



ISA107.5 Dynamic Pressure Standards

Measuring dynamic pressures within the various harsh environments of gas turbines is extremely complex due to the high-level understanding of the numerous pressure sensor technologies available, fluid dynamics and data acquisition and analysis required in order to collect accurate, reproducible dynamic pressure data

Purpose of Dynamic Pressure Measurement Standards:

To establish a standard to compare gas turbine dynamic pressure instrumentation and a set of best practices for making accurate dynamic pressure measurements within gas turbines



Sensor Technologies

There are numerous dynamic pressure sensor technologies available. A more comprehensive review of the various technologies available to users will enable better selection of the ideal technology for each dynamic pressure measurements

- Piezoelectric
- Optical
- Piezoresistive
- Resonant
- Capacitive
- etc.



Sensor Specifications & Validation Methods

- Standardization of Sensor Specifications
 - Create a standard for sensor specifications for easy comparison of sensor performance, specifically dynamic response and range
- Sensor Validation Methods
 - Determine and evaluate various performance validation test methods
 - Establish set of standard performance validation tests to confirm sensor performance



Dynamic Pressure Measurement Best Practices & Common Problems

- Dynamic Pressure Measurement Best Practices
 - Establish best practices for sensor mounting configurations on engine to reduce mounting related dynamic measurement error
 - Develop best practices for signal conditioning and data acquisition
- Address common dynamic pressure measurement problems on gas turbines



Standard Committee Summary

- Consistency of Measurements is necessary to expanding the use of both new and existing sensing methods as viable measurement tools
- ISA107 “Advanced Measurement Techniques for Gas Turbine Engines” has been established – efforts are underway to develop standards, recommended practices, and technical reports on measurement techniques that are vital in the safe and reliable operation of gas turbine engines
- ISA 107.5 Dynamic Pressure Measurement will hold its initial face to face meeting in conjunction with 58th International Instrumentation Symposium in June