# PORGRESS TOWARDS THE DEVELOPMENT AND QUALIFICATION OF AN ALL OPTICAL, TEMPERATURE AND PRESSURE COMPENSATED, FIBER OPTIC OXYGEN SENSOR FOR MONITORING OXYGEN ENVIRONMENT IN AIRCRAFT FUEL TANKS

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# All Optical Multi-Parameter Fiber Optic Sensor System Including Oxygen, Temperature, and Pressure

# Project Goal

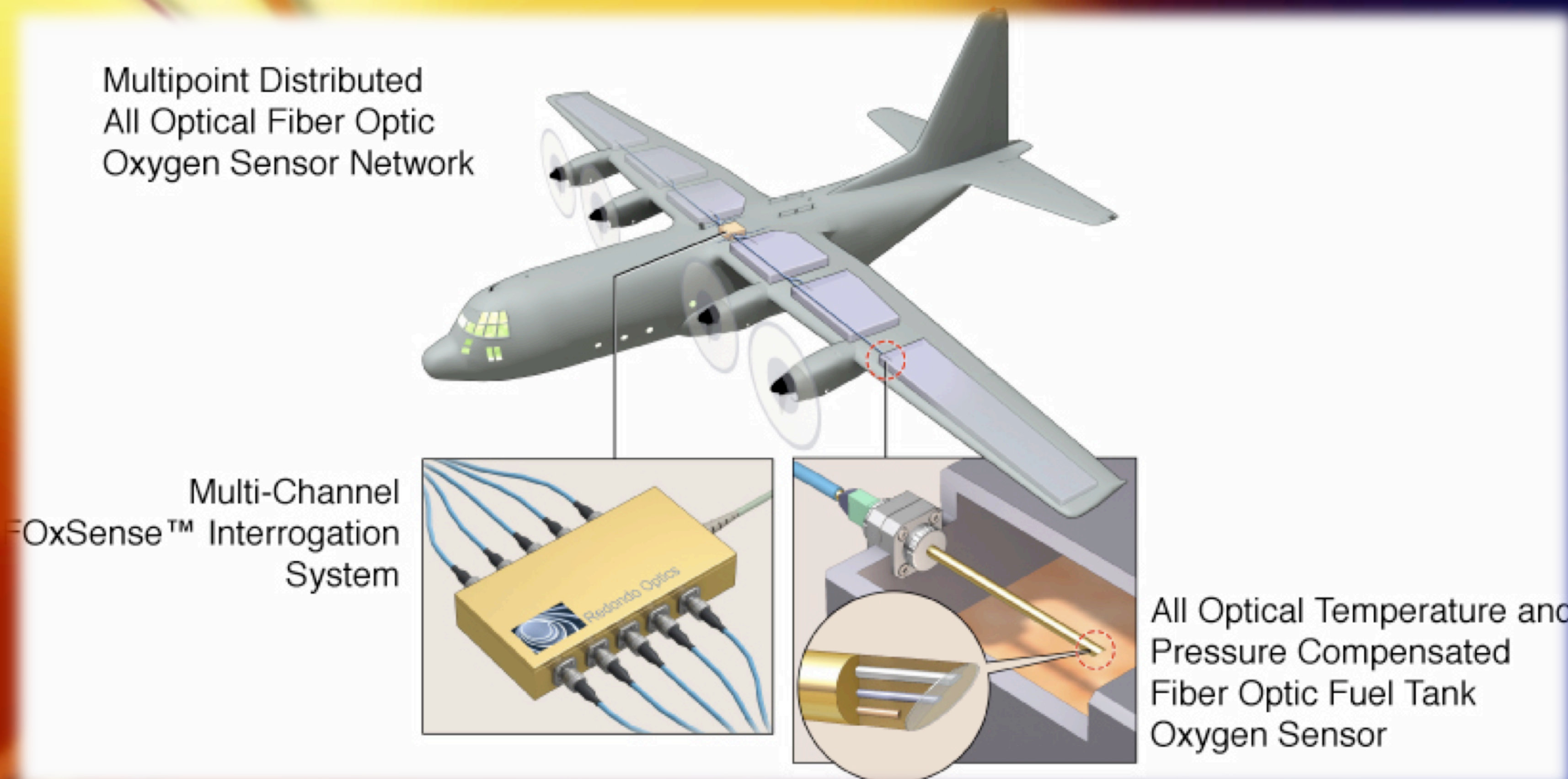
- ***The goal of this project is to demonstrated an all optical fiber optic oxygen sensor network system for the in-situ monitoring and control of fuel tank environment.***

# All Optical Multiparameter Fiber Optic Sensor System

- The sensor system uses a multiparameter all optical temperature and pressure compensated fiber optic sensor network for the "in-situ" monitoring of  oxygen environment in fuel tanks of aircraft.

- All optical, passive, and intrinsically safe.
- No electrical connections
- No sampling required
- Uses a distributed array of multipoint sensors along a single fiber network
- Distributed sensing enables access to each fuel tank
- Remote multi-channel optoelectronic unit monitors in real time O2 fuel tank environment

# All Optical Fiber Optic Oxygen Sensor System




**ROI's system monitors the oxygen environment inside the fuel tanks of aircraft using fluorescence lifetime based optical sensors for the measurement of temperature, pressure, and oxygen gas.**

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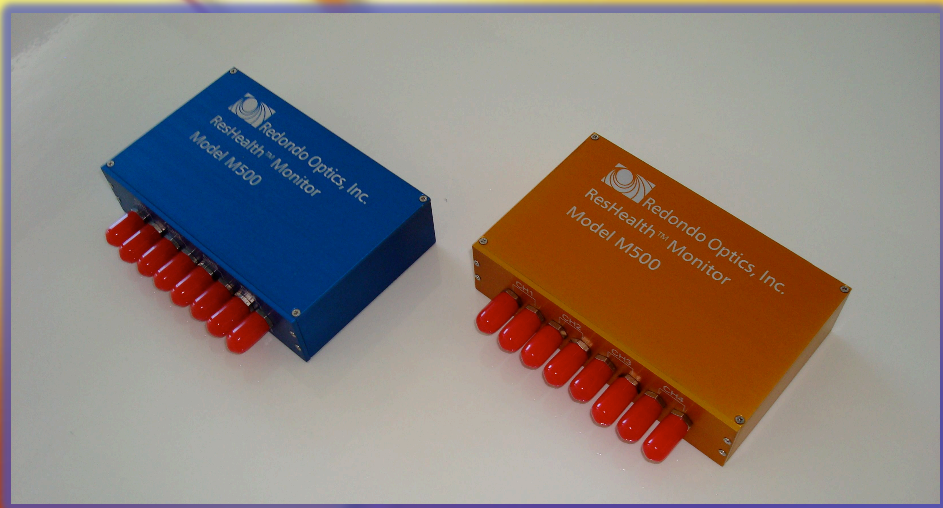
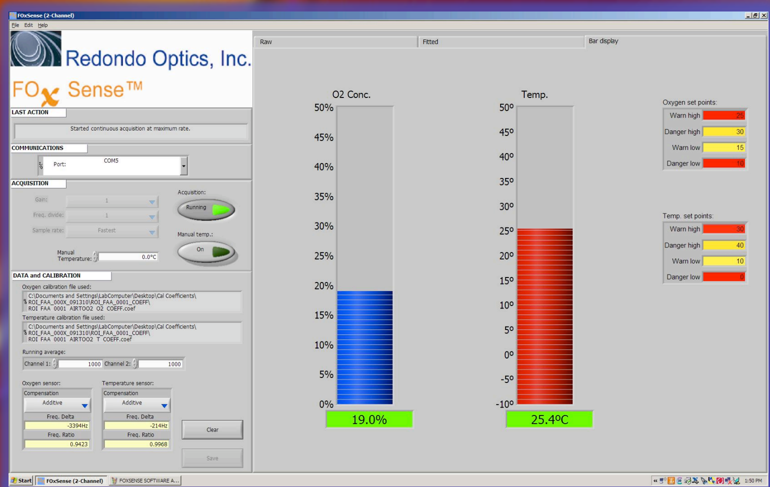
# Multi-Channel Fiber Optic Sensor Read-Out Controller




- Real time status interrogation of all installed sensors
- Multi-channel fiber-optic network system.
- Frequency domain “fluorescence-Lifetime,” detection.
- User friendly three-level alarm status display.

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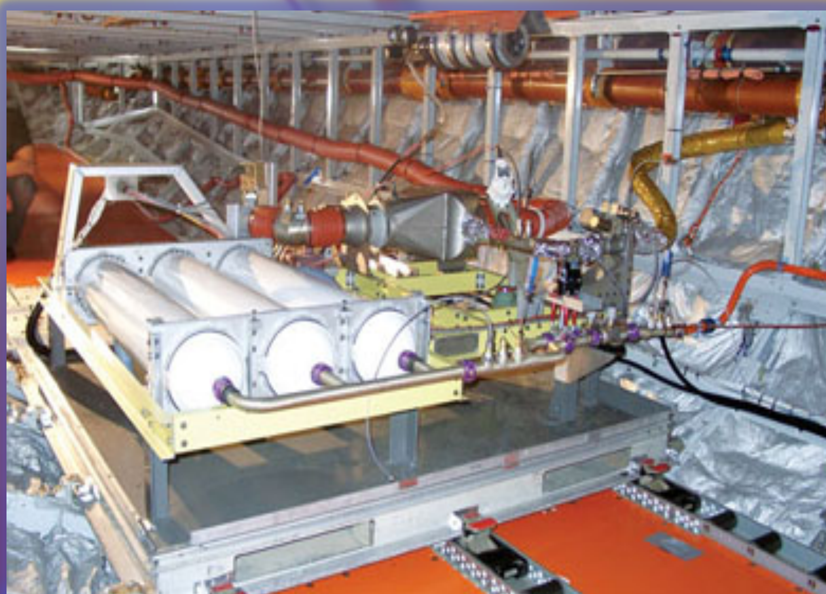
# Motivation

- On July 17, 1996, Paris-bound TWA Flight 800, a Boeing 747-131, broke up in flight shortly after departure from New York Kennedy (JFK) Airport, and all 230 people onboard were killed.

- ***Investigators determined that the breakup was probably caused by the explosion of flammable vapors in the center wing fuel tank.***

# On-Board Inert Gas Generation System (OBIGGS)

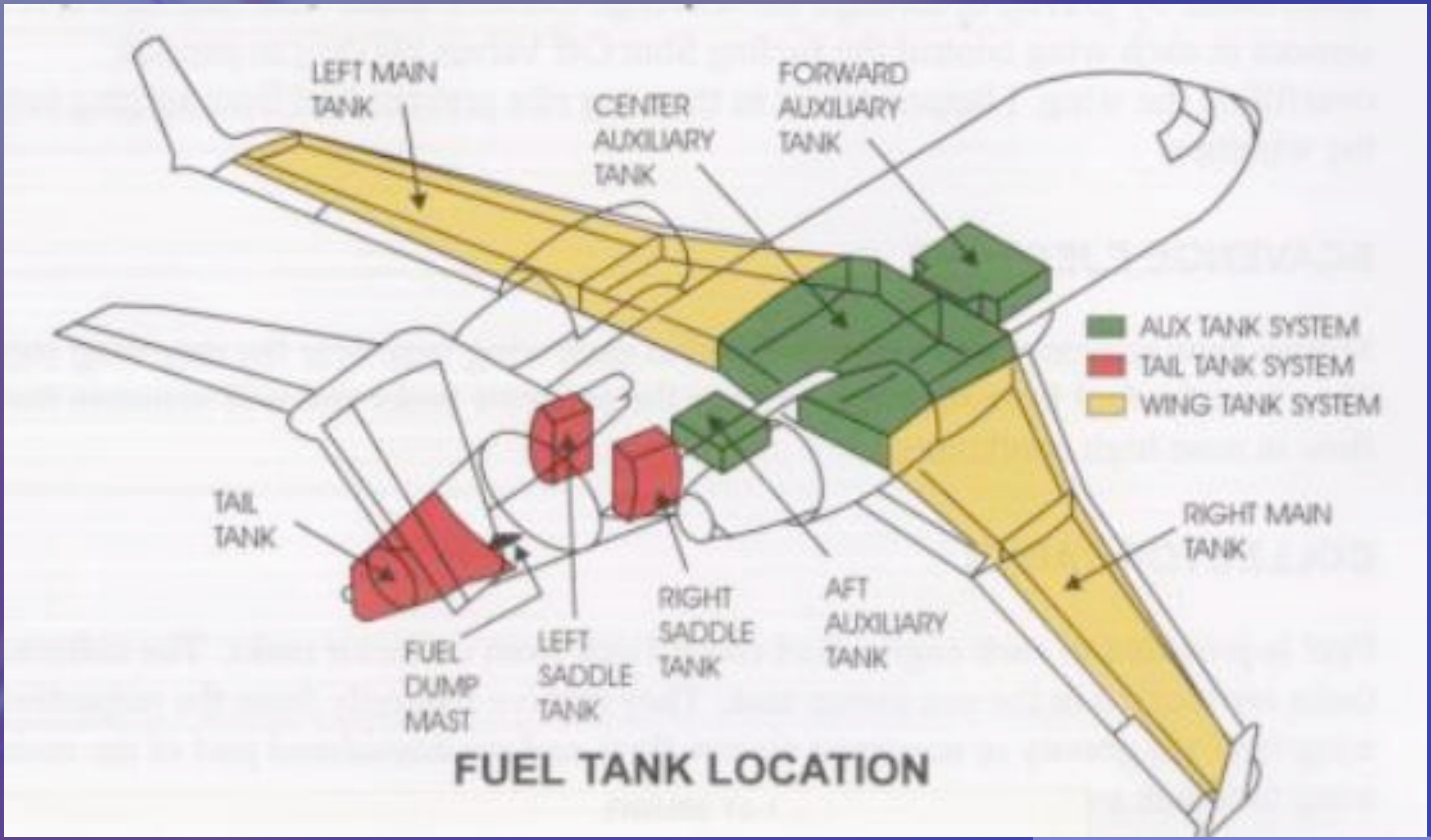


- The OBIGGS is a fuel tank inerting system that generates a dry nitrogen -enriched air "blanket" to cover the interior of the fuel tank and displace the flammable fuel-air mixture.
- And other possible usages such as nitrogen water mist suppression systems

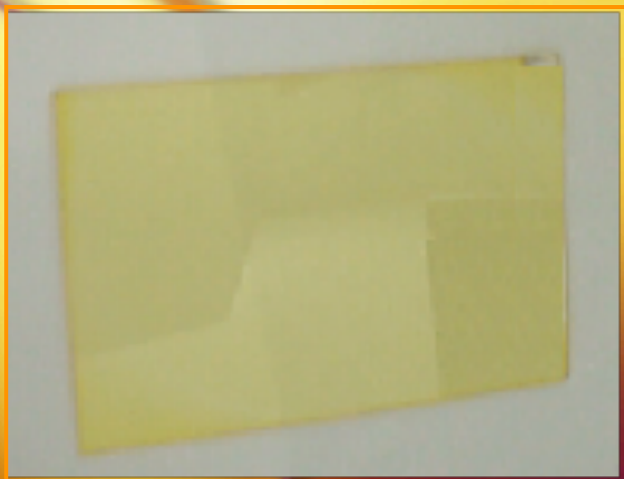
# Requirements

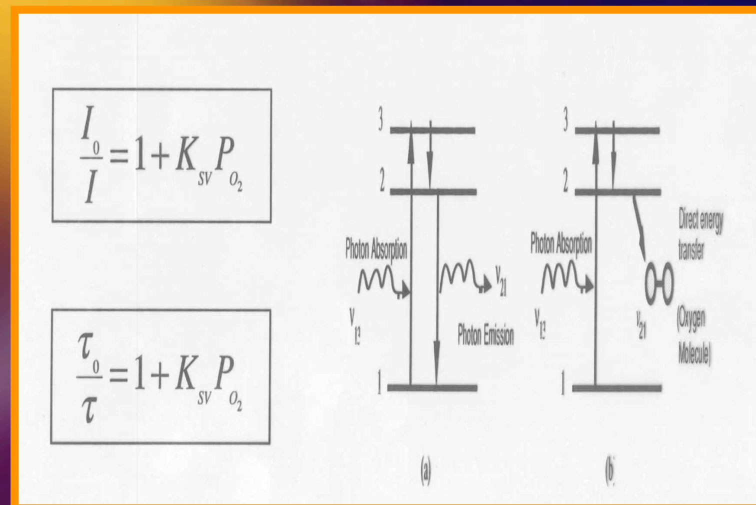
- To enhance the secure and optimum performance of the OBIGGS system a closed-loop oxygen sensing monitoring system is needed to confirm the inert state of the fuel tanks
- Current OBIGGS systems do not have a closed-loop feedback control, in part, <u>due to the lack of suitable process sensors</u> that can reliably measure $O_2$ and at the same time, does not constitute an inherent source of ignition.
- Thus, current OBIGGS operate with a high factor-of-safety dictated by process protocol to ensure adequate fuel-tank inerting.
- This approach is inherently inefficient as it consumes more engine bleed air than is necessary compared to a closed-loop controlled approach.
- The reduction of bleed air usage is important as it reduces fuel consumption, which translates to both increased flight range and lower operational costs.

# Typical Aircraft Fuel Tanks Installations

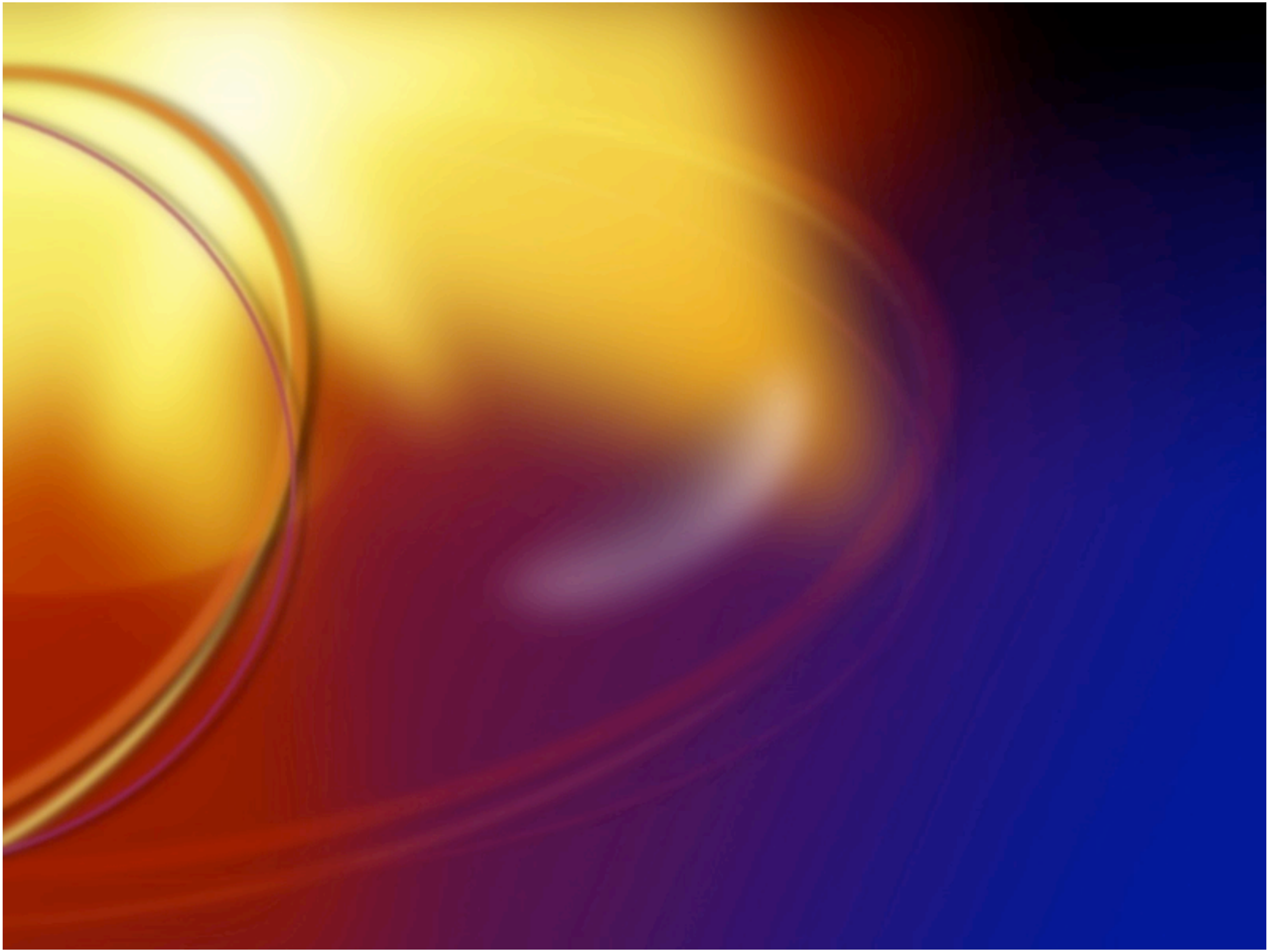


# Fluorescence Based Oxygen Sensing



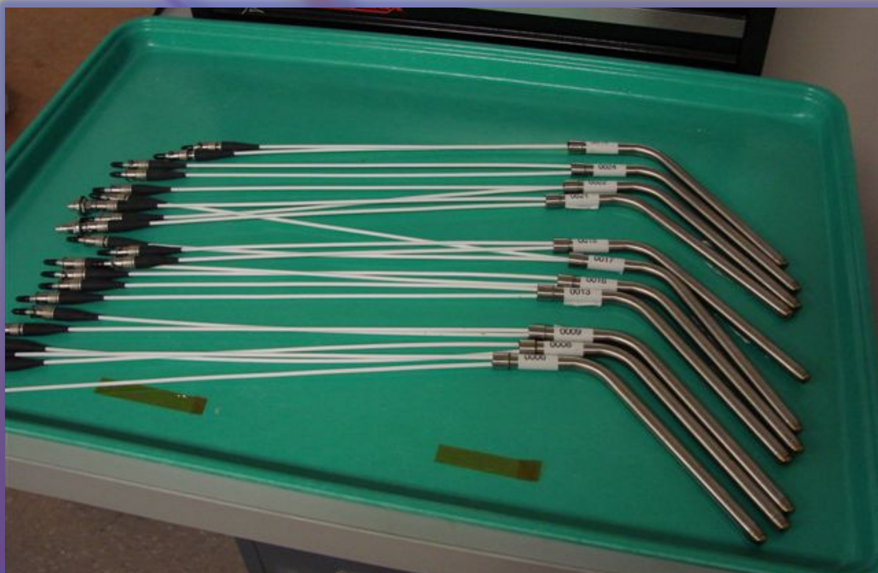



**Based on Stern-Volmer Fluorescence Oxygen Quenching Mechanism**



# Quick-Connect Fiber Optic Sensor Probes

# Aircraft Qualified Fiber Optic Sensor Probes



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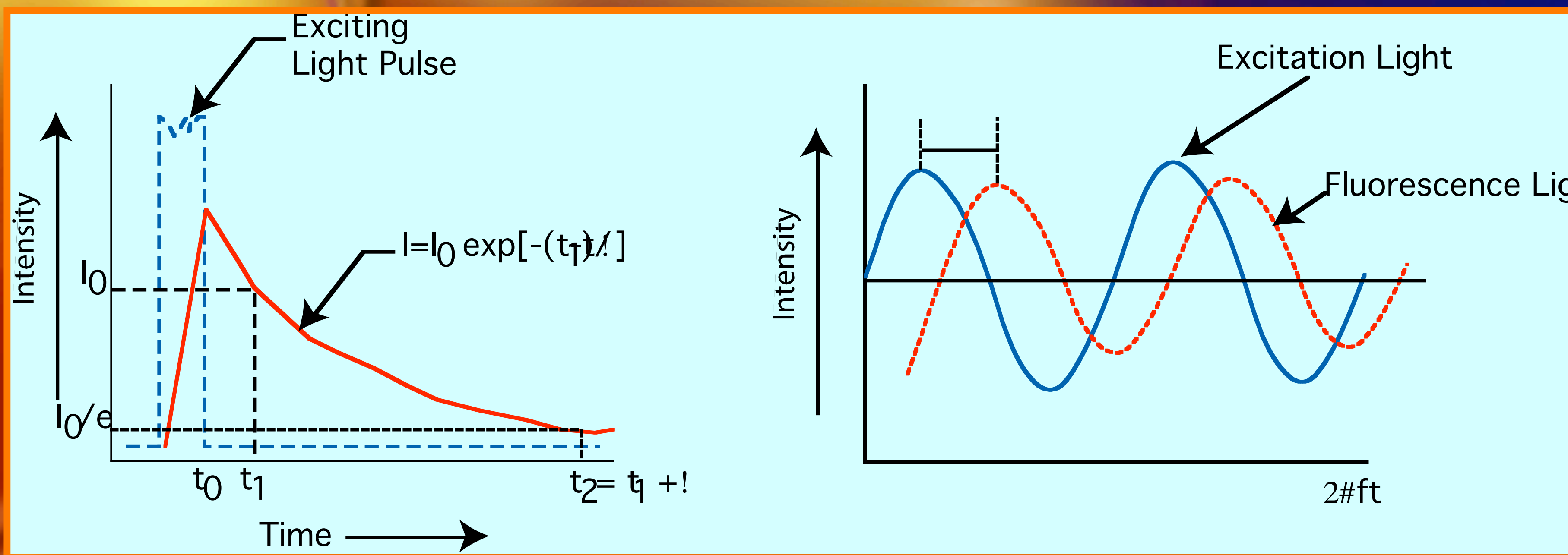
# Fluorescence Lifetime Detection Techniques

$$\tan\varphi = 2\pi f\tau$$

$$!_m = \frac{1}{f}\sqrt{\frac{1}{m^2} - 1}$$




**Pulse Excitation**

**Phase Modulation**

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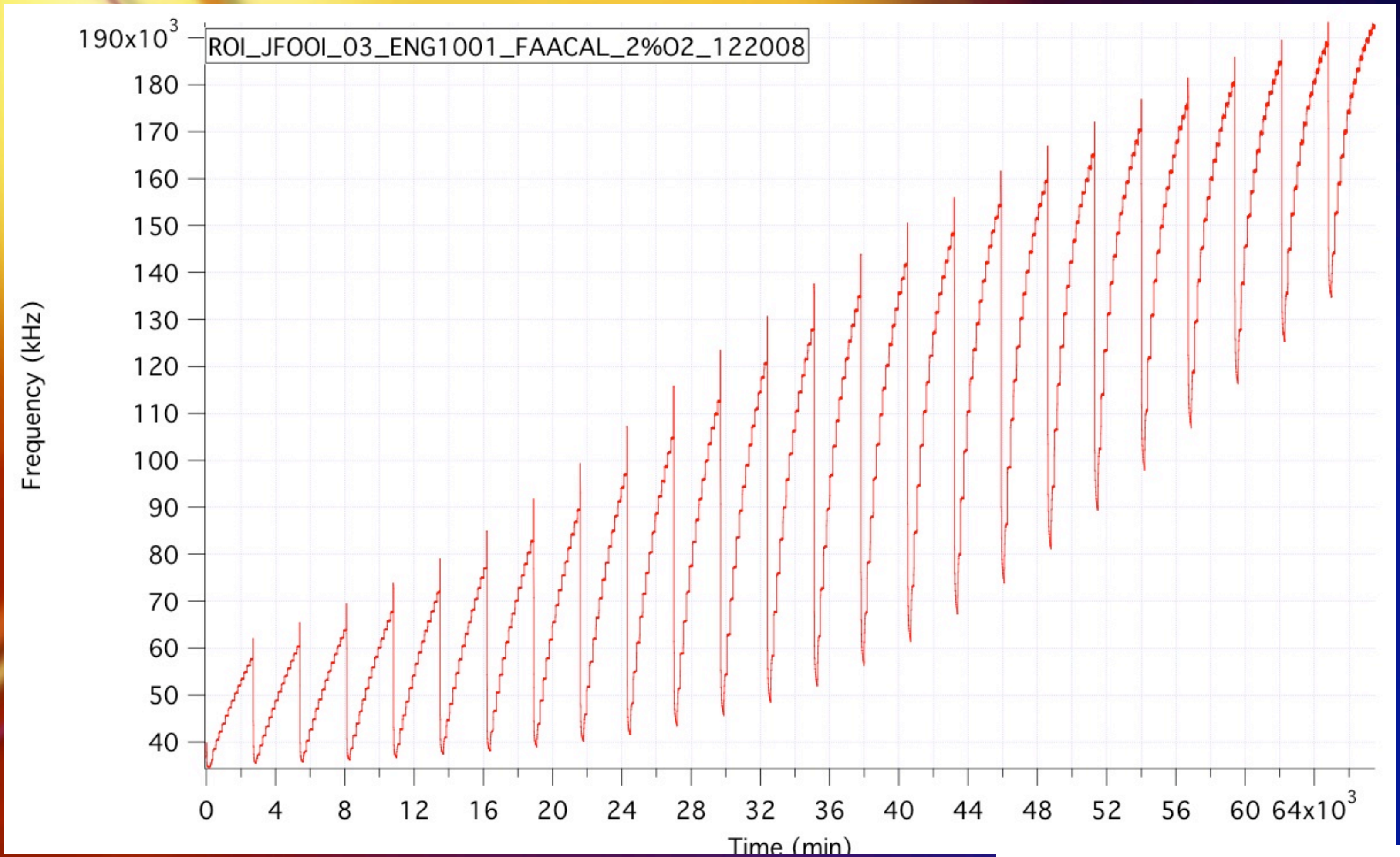
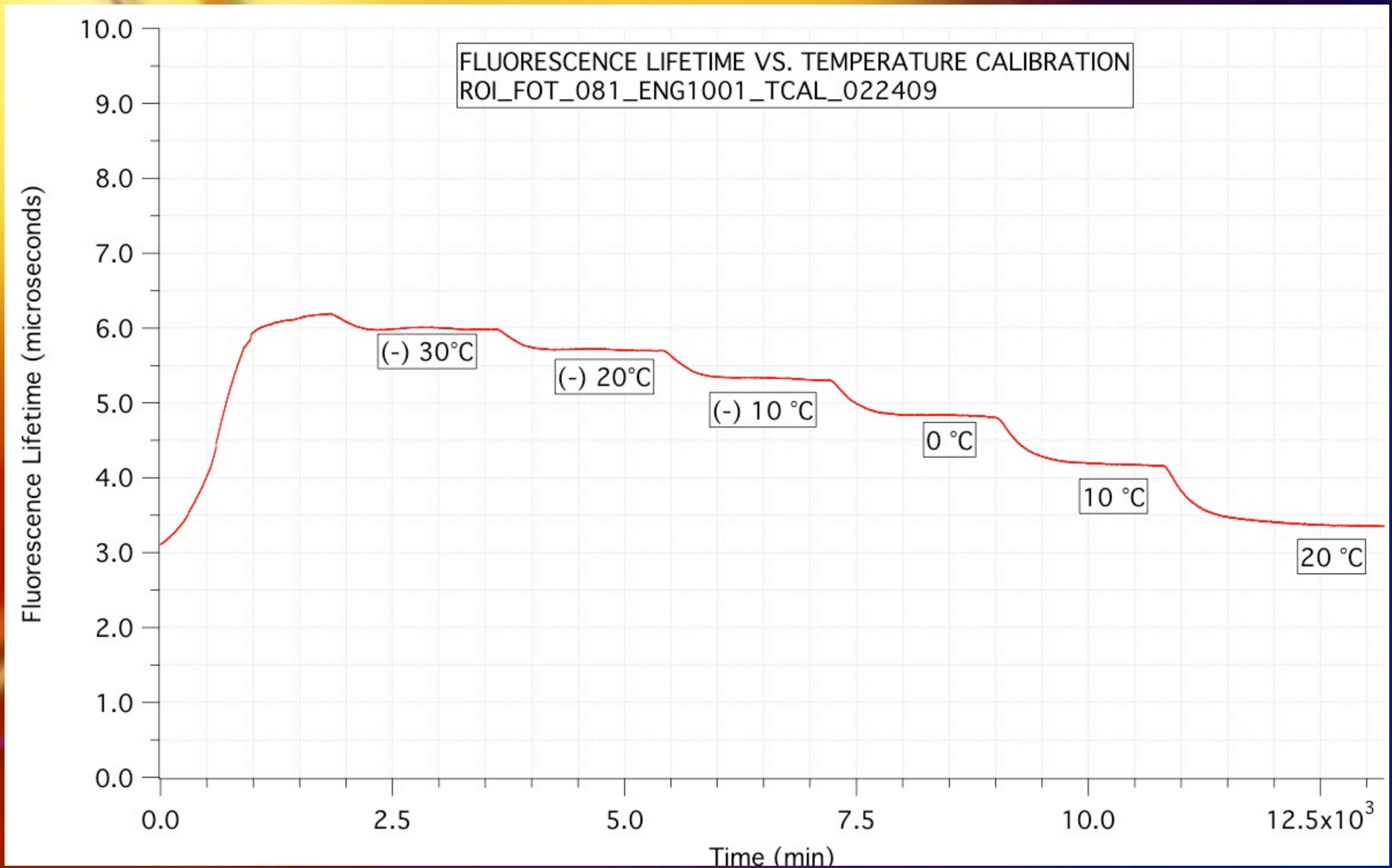
# O2 Sensor Calibration

0% to 30% O2 at 2% O2 Steps & -50°C to 60°C @ 5°C Steps



# Temperature Sensor Calibration

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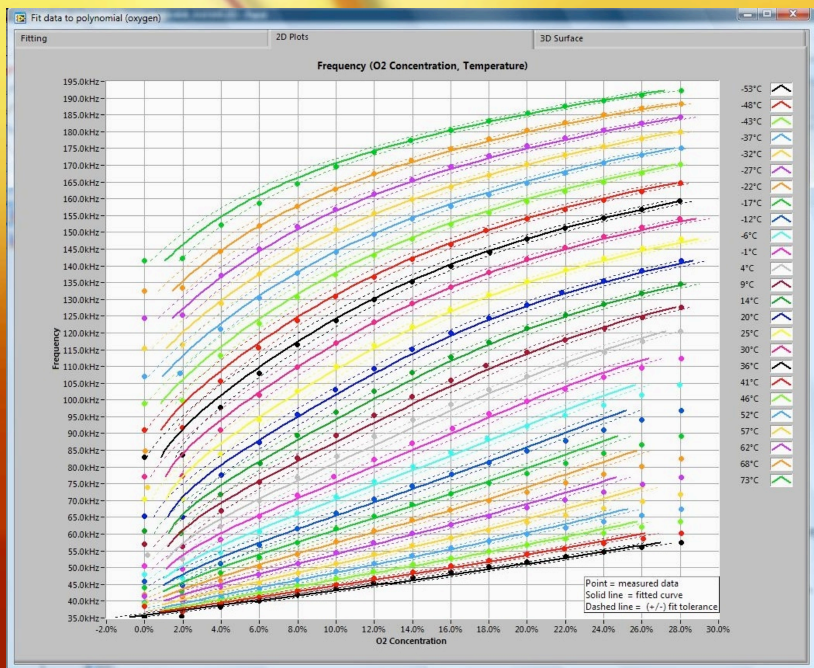
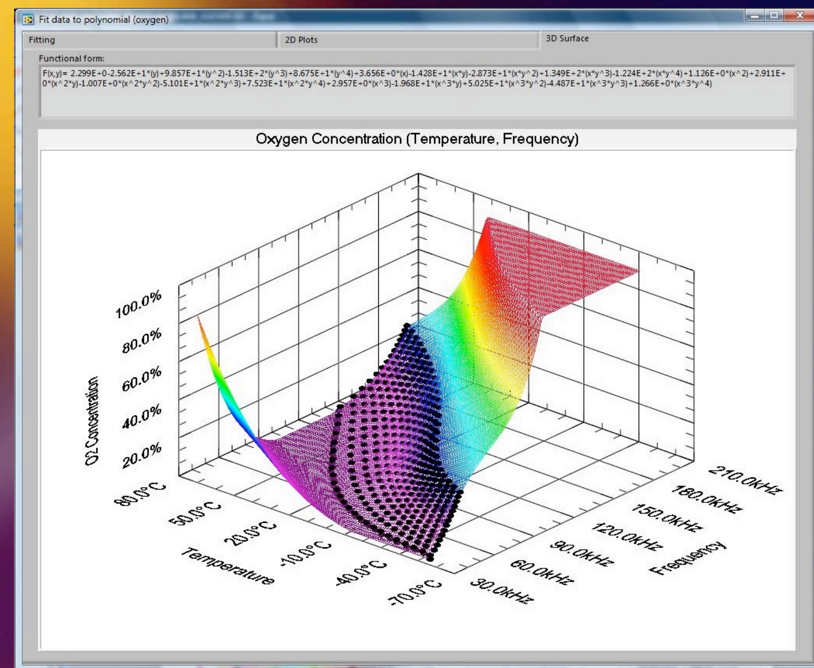
# O2/T Look-Up Calibration Protocol




Base on calibration protocol the accuracy of the algorithm is ± 0.7% O2 from the reading over the entire oxygen and temperature range

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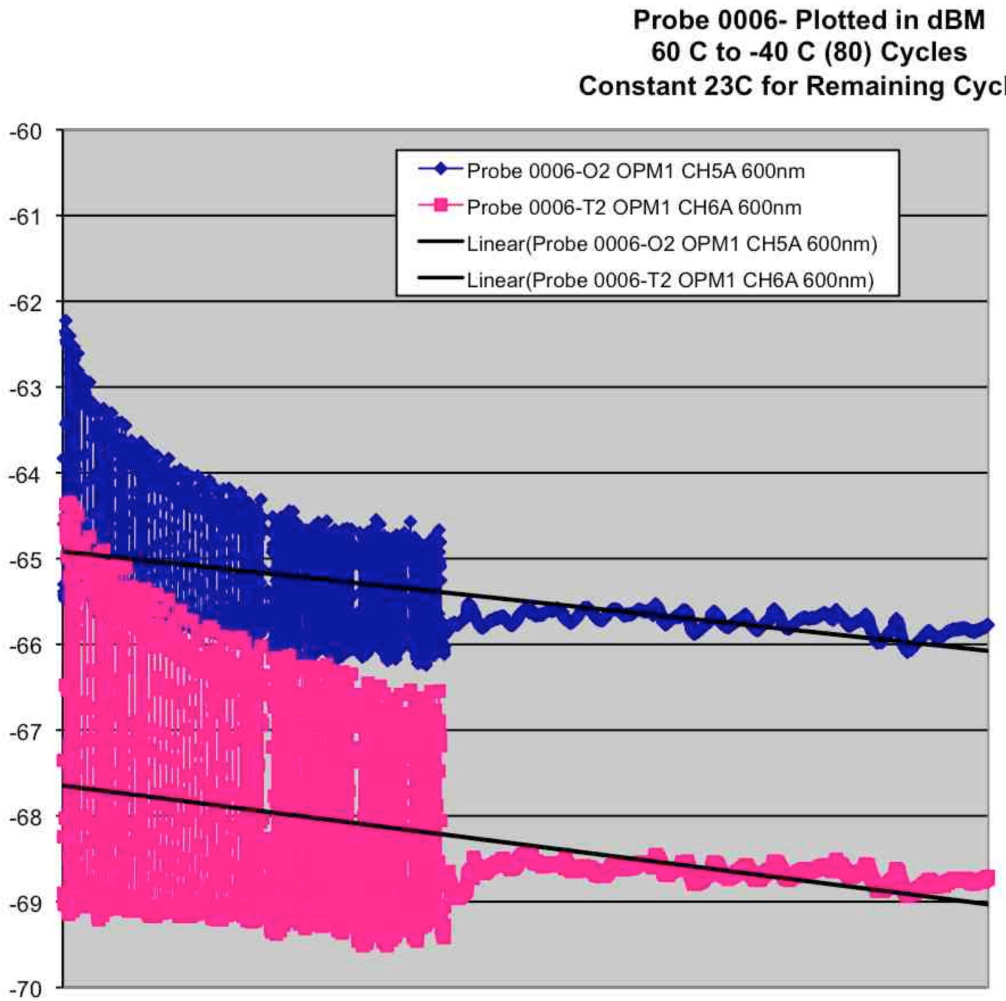
# Long Term Environmental Performance Qualification




**Over Full Test to Date 750 Hours**

Oxygen Change 6.45% dBm
Temperature Change 8.03% dBM
Oxygen Change 60.34% nW
Temperature Change 69.57% nW

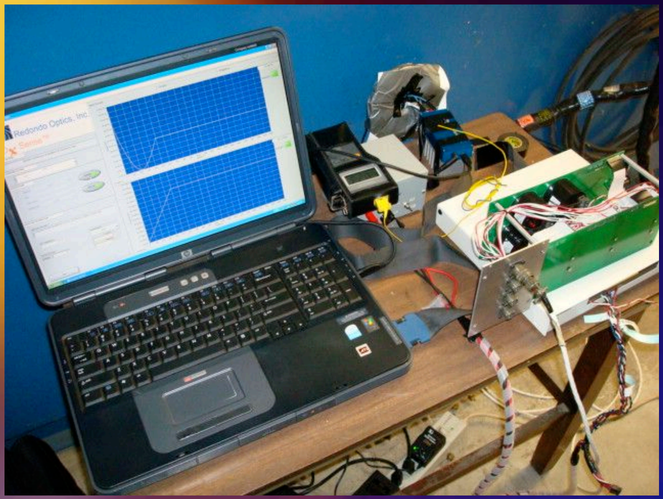
min 0.238nW Oxygen; 0.112nW Temp
max 0.599nW Oxygen; 0.368nW Temp

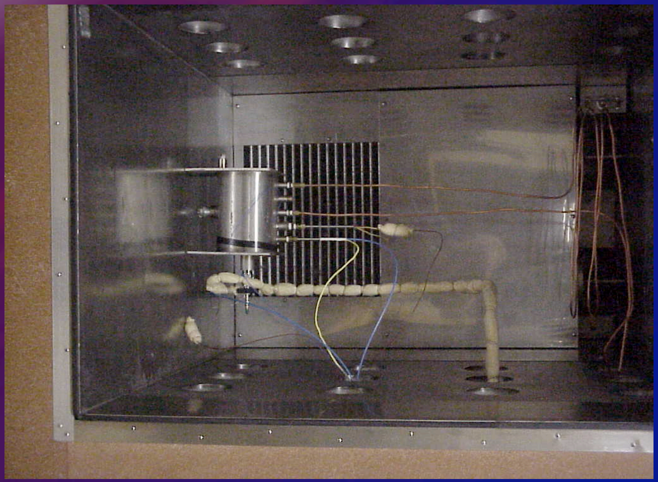
**Over last 12 Hours**

Oxygen Change 0.366% dBm
Temperature Change 0.272% dBM
Oxygen Change 5.41% nW
Temperature Change 4.21% nW

min 0.246nW Oxygen; 0.128nW Temp
max 0.260nW Oxygen; 0.134nW

# ASF Fuel Tank Test Facilities



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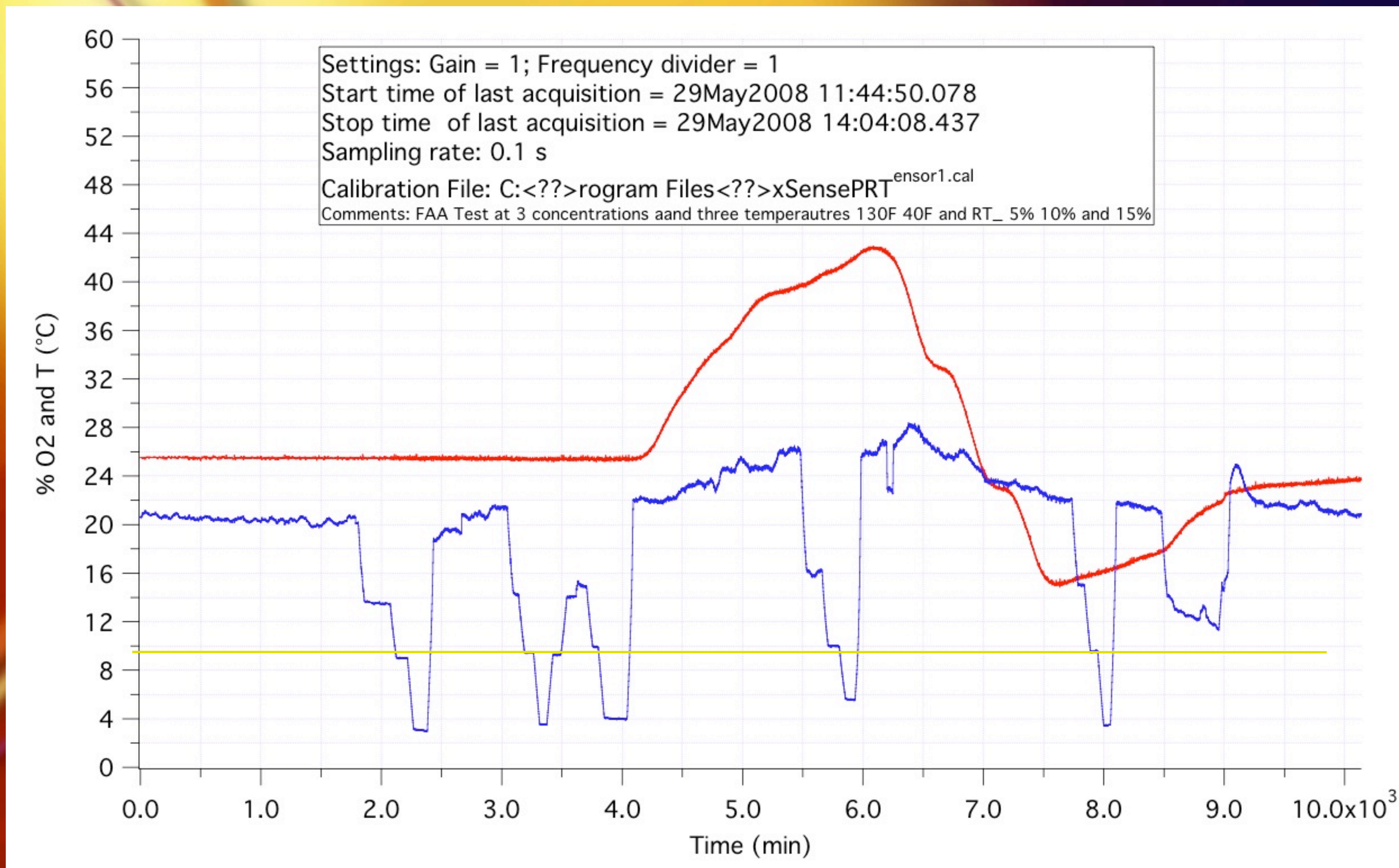
# FAA Fuel Tank Test Facilities


# FAA Calibration Test May 2008

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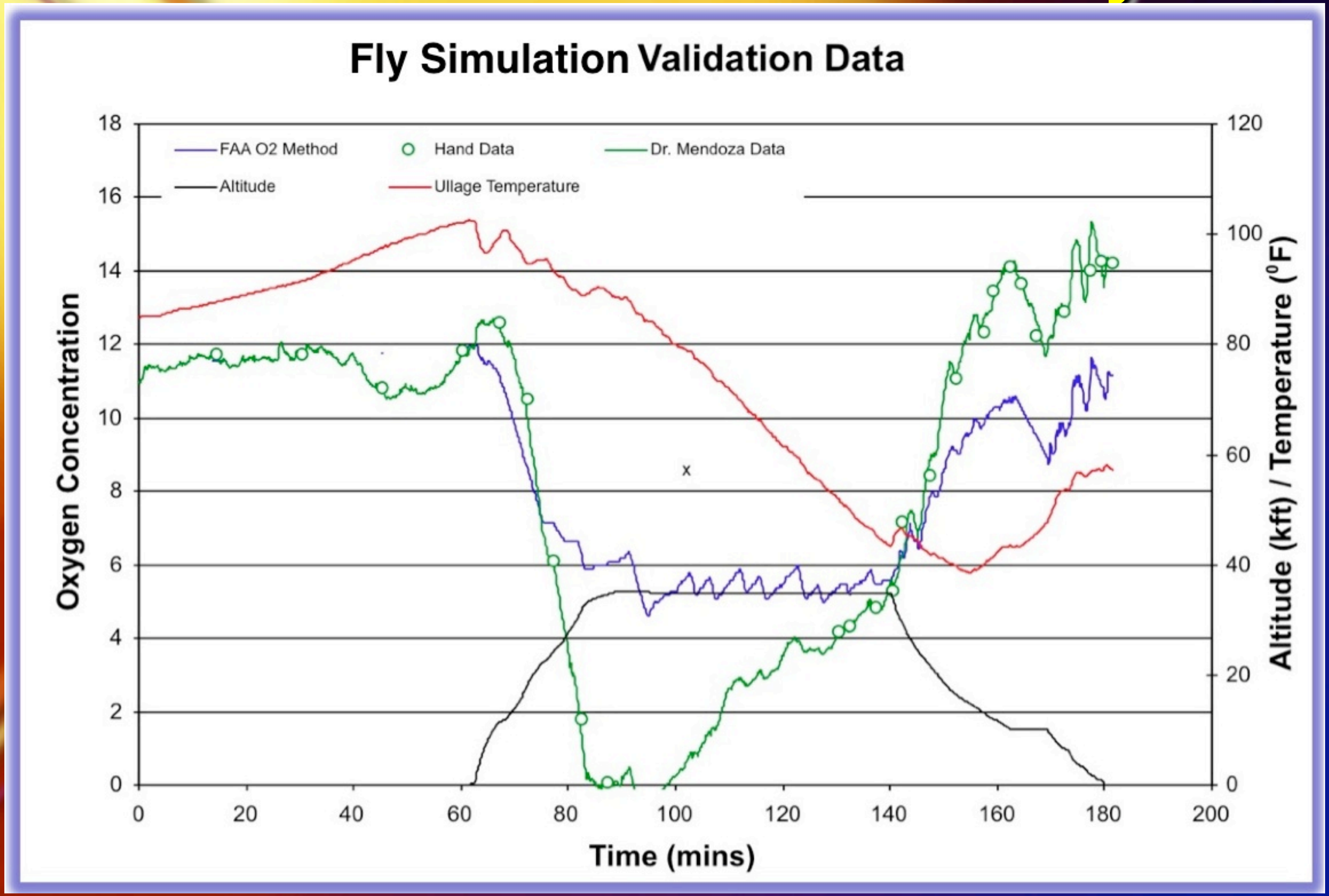
# FAA Fly Simulation Test May 2008

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# Second Generation Results

- **Over all for the second round of testing at the FAA the all optical fiber optic temperature compensated oxygen sensor system was able to monitor the oxygen environment inside a simulated aircraft fuel tank on a low altitude fly simulation test.**

- *The results and observations had given indication of areas were the system can be improve for the third round of development to meet or exceed the target performance specifications.*

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# US Unveils New Fuel Tank Safety Rule