# Measuring Oxygen Concentration in a Fuel Tank Ullage

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# Outline

- Background
- FAA Method
- Light Absorption Gas Sample
- Optical Fluorescence In Situ
- Status

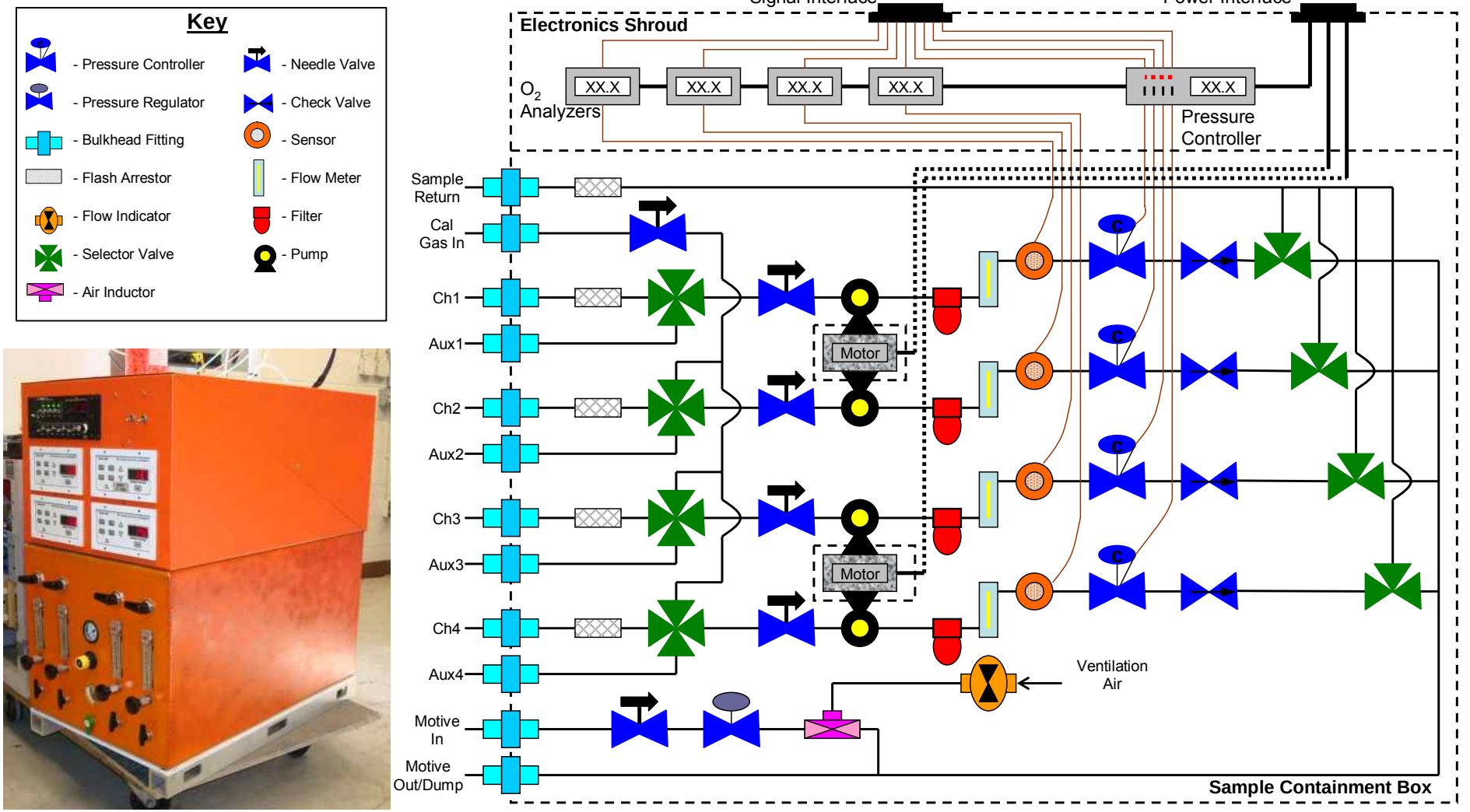
# Background

- FAA has been seeking to improve fuel tank safety in the wake of TWA Flight 800 in July of 1996
  - Rule published requiring extensive flammability reduction on both future built and existing aircraft on present types
- The measurement of ullage oxygen concentration is important to the fuel tank inerting community when researching methods, validating models, and certifying systems
  - FAA method for measuring ullage oxygen concentration at reduced ullage pressures has been successful but can be cumbersome
  - Emerging products have the potential to simplify and improve upon R&D / Certification work for fuel tank inerting

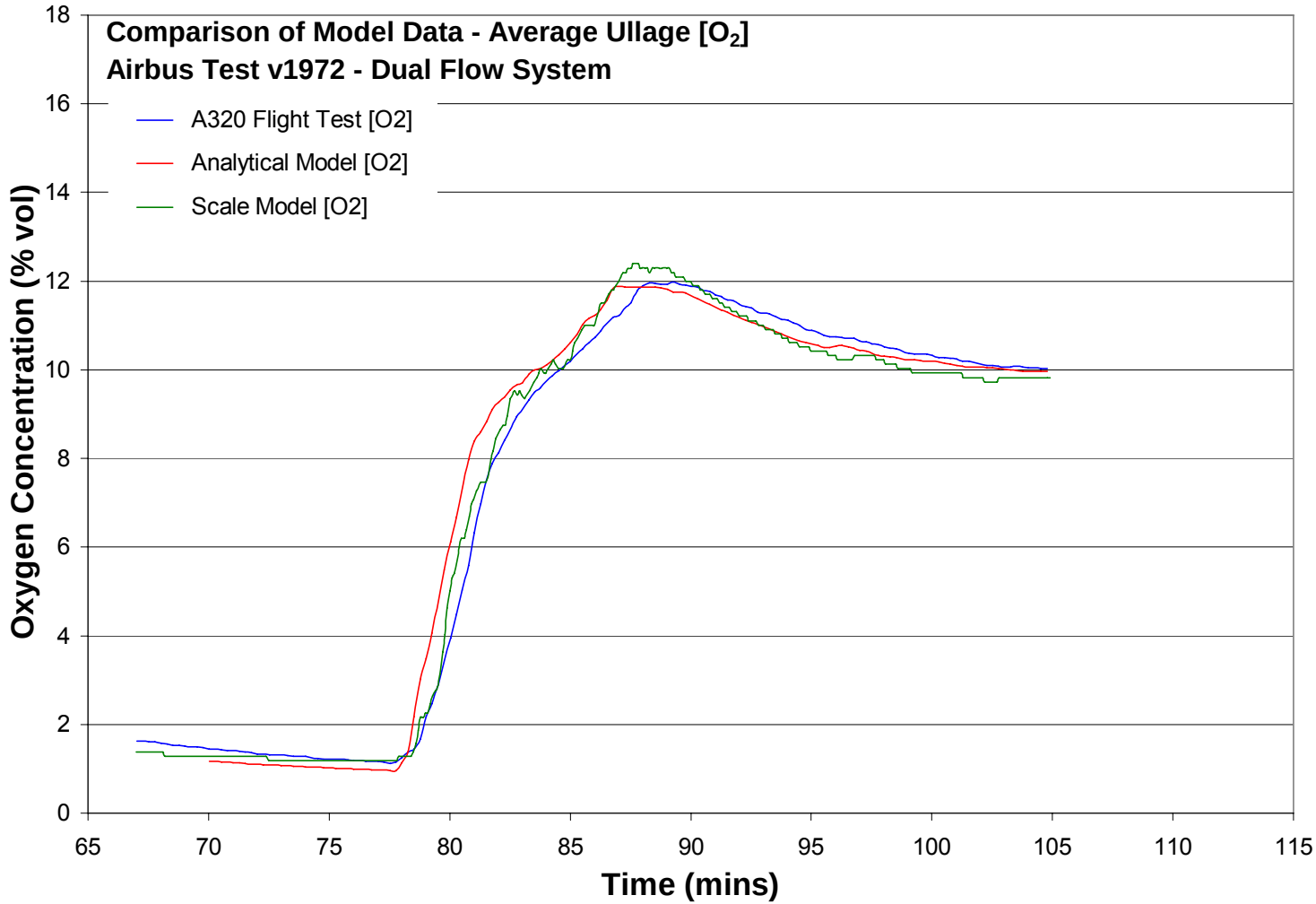
# FAA Method

- FAA method involves an extensive controlled gas sample system using lab based galvanic cell oxygen sensors
  - Method used extensively in the lab and on several flight tests with great success
  - Consistently duplicates calibrations gases up to 40K feet within +/- 0.1% oxygen
- Improved FAA gas sampling method
  - Made design changes to OBOAS regulated sample train and packaging based on lessons learned during FAA flight testing
  - New system is lighter, smaller, quieter, and takes less power to start and operate
  - Gas sample lag time better but not proven to have equivalent level of safety
  - Questions remains if it is more reliable and maintainable

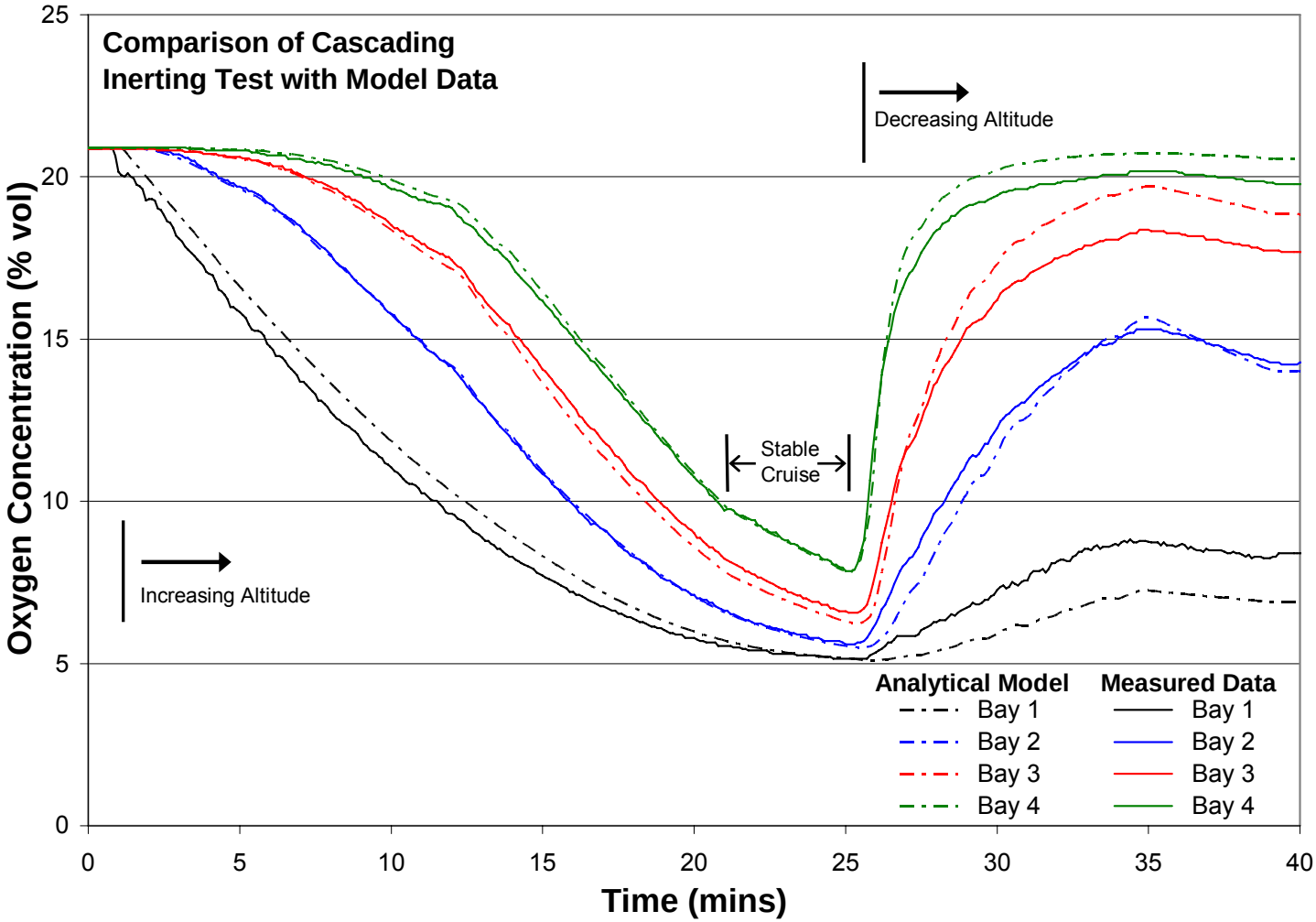
# FAA Oxygen Concentration Measurement Method



# FAA Method Flight Test Results Compared with Lab and Analytical Calculation



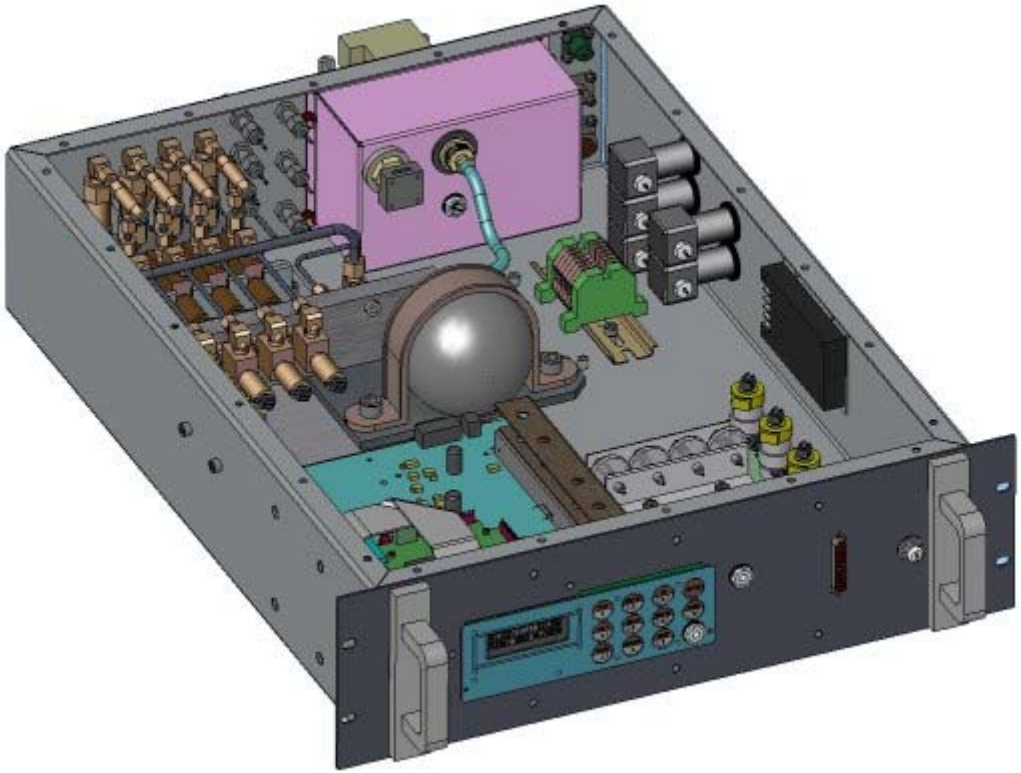
# 4-Bay Cascading Inerting Data Comparison of FAA Method Compared with Analytical Calculation



# Light Absorption Gas Sample

- Oxigraf makes a light absorption sensor which has been applied to an unregulated gas sample train
  - Unregulated sample train uses an integrated sensor board that measures infrared light absorption using a tunable laser diode (TLD technology)
  - Proprietary software used to interpret spectral data
- System has been packaged for flight test
  - System has very fast response time, given short enough gas sample lines and has been shown to duplicate calibration gases as well as FAA method up to 35K feet sample altitude.
  - System packaging has potential to be significantly smaller and lighter than the FAA method and system requires less power.
  - System speed has yet to illustrate usefulness and there are significant limitations to gas sample, and return locations

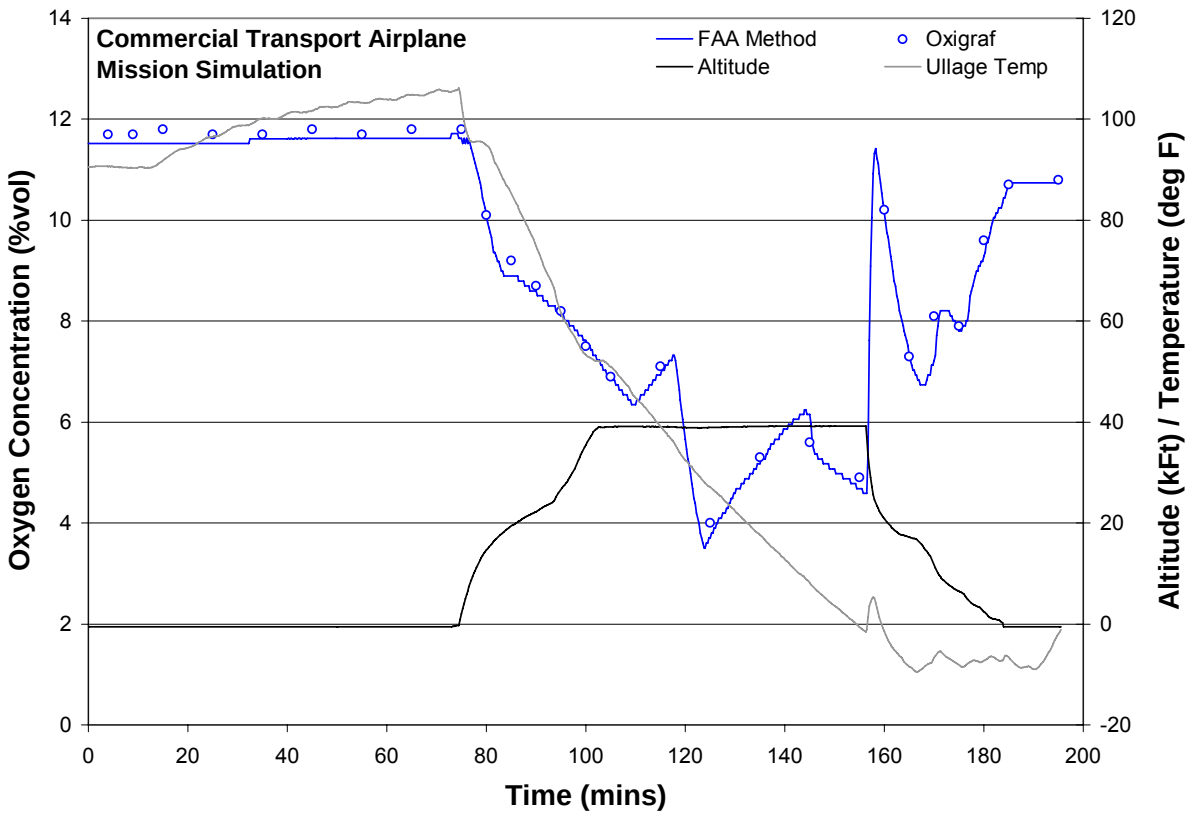
# Light Absorption Method using TLD



**Oxigraf O2N2 Flight Test Oxygen Analyzer**

# Results – Airplane Fuel Tank Simulation

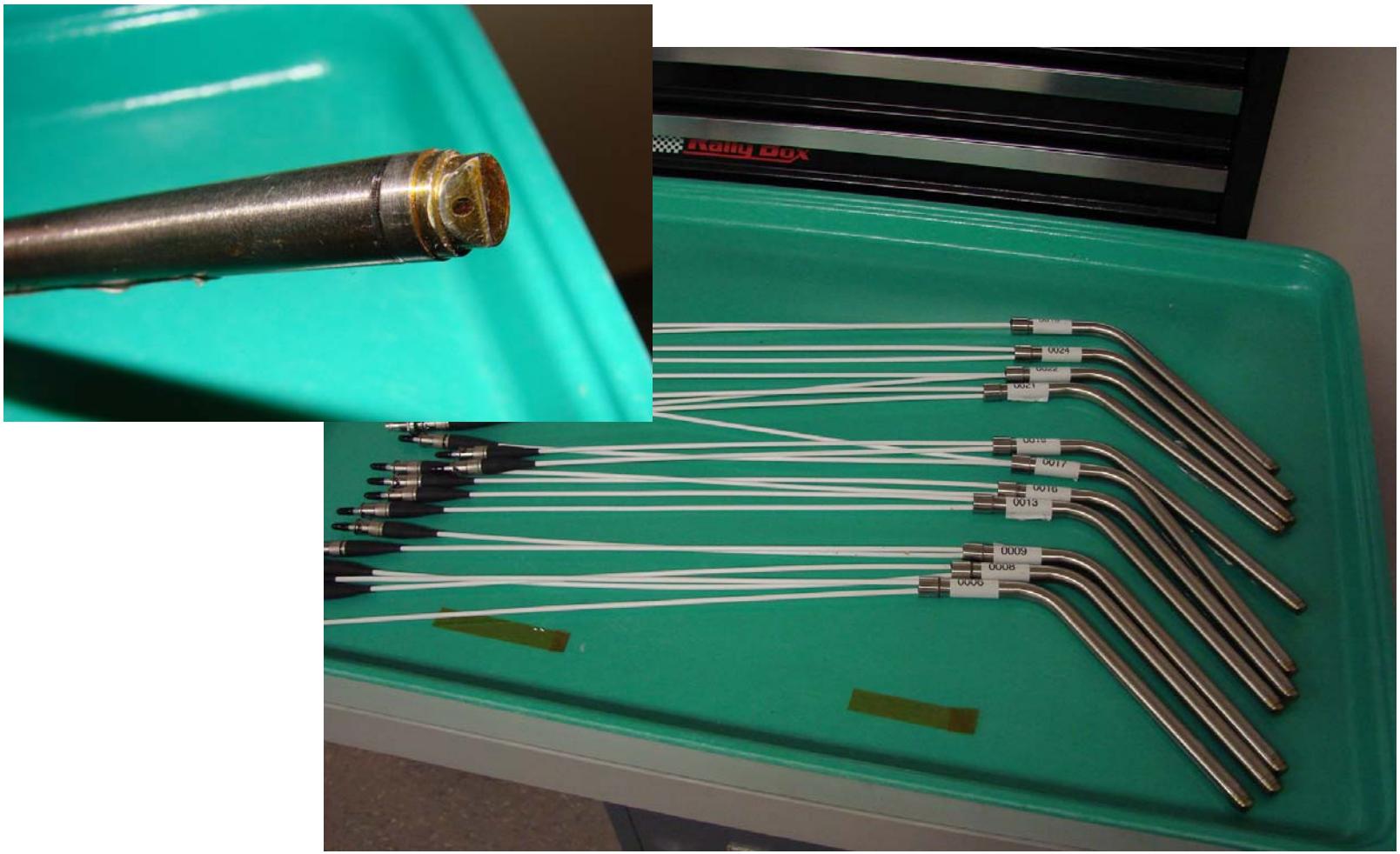
- Measured fuel tank test article ullage [$O_2$] with both the FAA method and the light absorption method (Oxigraf)
  - Results of Oxigraf and FAA method very close
  - The inerting of test tank erratic due to problems, but this illustrates the small advantage of rapid response



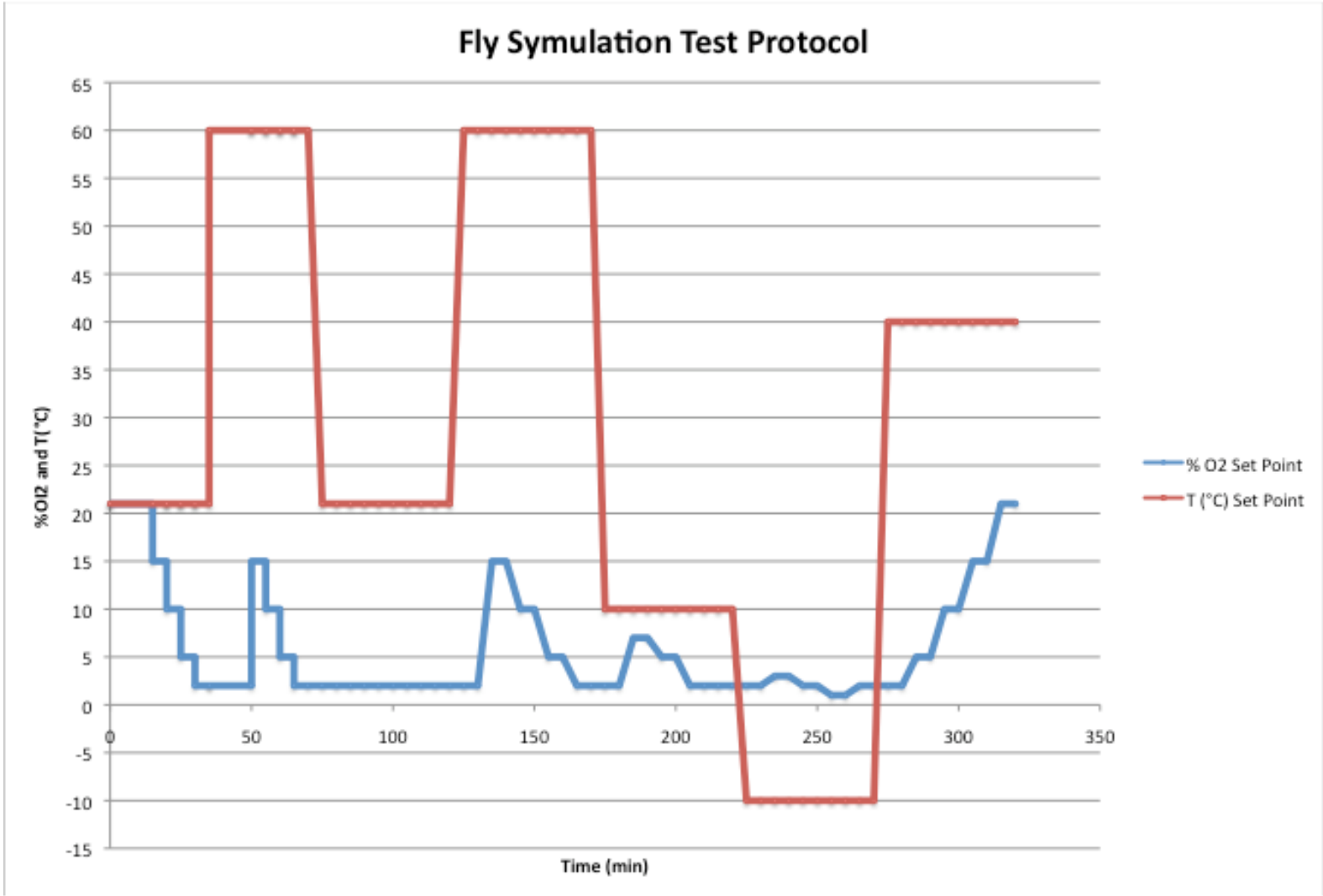
# Optical Fluorescence

- Optical fluorescence using in situ probe (ASF)
  - Small fiber optic probe uses spectrometer to interpret coherent light signal which is highly dependent on temperature/pressure
  - Used in situ (in place) which has many advantages (low power, small size/weight, rapid response) but also has limitations
- Applying an in situ probe has been be very problematic
  - Not practical to calibrate on a daily basis
  - Requires simultaneous/co-located accurate temperature and pressure measurement to compensate signal
  - As applied today, does not have faster response than FAA
- Recent work performed has illustrated marked improvement of the probe to duplicate calibration gases
  - Still struggle with good results at high altitudes
  - Probe has passed rigorous DO-160 E testing

# Latest Optical Fluorescence (ASF) In Situ Probe



# ASF Oxygen Sensor Data with Varying Temperature



# Status

- Both the FAA method and the light absorption (Oxigraf) method duplicate calibration gases well at a variety of conditions and both agree on oxygen concentration measurements made during a simulation of an inert commercial transport airplane fuel tank flight cycle
  - Oxigraf system has faster response time but appears to be of little advantage
  - Oxigraf system already performed some flight testing and is slated for more with several OEMs / Operators
- Optical fluorescence making progress but still working out problems
  - Slated for more chamber examinations in December