Fire and Hazard Detection for Space Vehicles Using LEDs

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Agenda

- Team Members
- Introduction
- Sensor Overview
- Schedule
- Preliminary Results
- Current Work
- Conclusions and Future Work

Team Members

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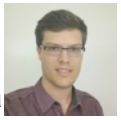

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Collaborators

Dr. Bill Partridge Jr.
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Organizations

- Center for Advanced Turbomachinery and Energy Research (CATER), University of Central Florida
- Fuels, Engines, and Emissions Research Center, Oak Ridge National Laboratory

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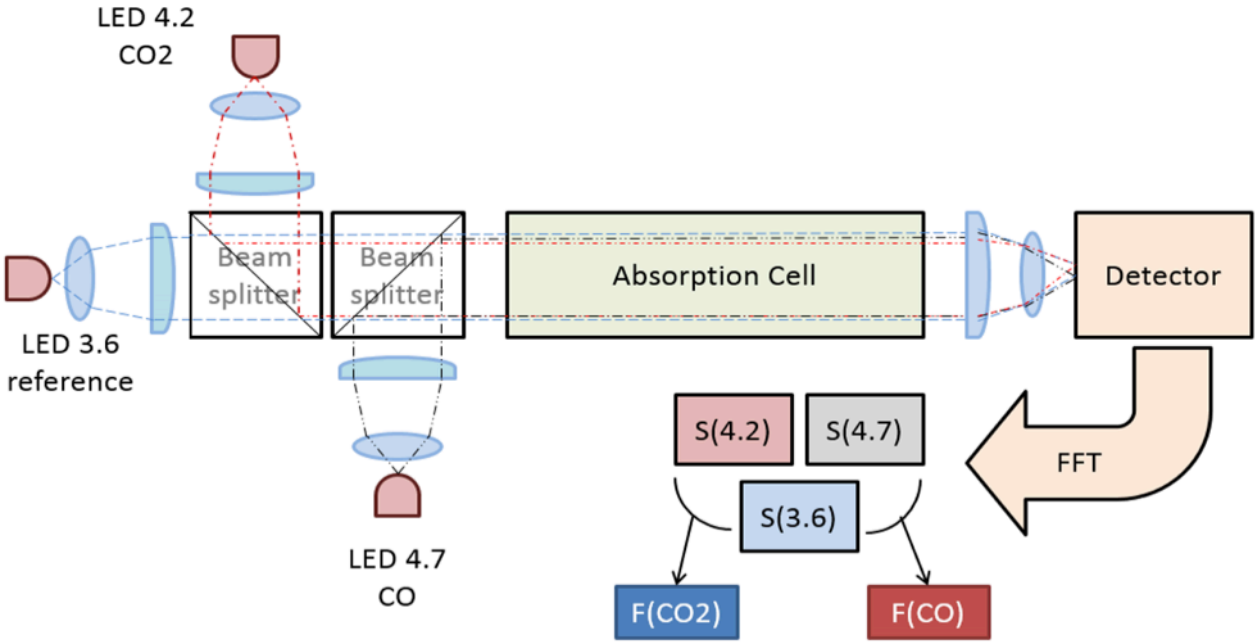
Motivation

Need for a new Sensor

- Current ISS and space shuttle sensors: false alarms and missed events
- Need multiple different sensor types to detect and characterize these events accurately
- Current fire detection sensors are particle based
  - Particle ionization smoke detector
  - NIR laser forward scattering particle detector
- CO_2 concentrations must be monitored in crew cabin for safety
- Time-resolved measurements of CO can be used as early indicator of fires

Technical Background

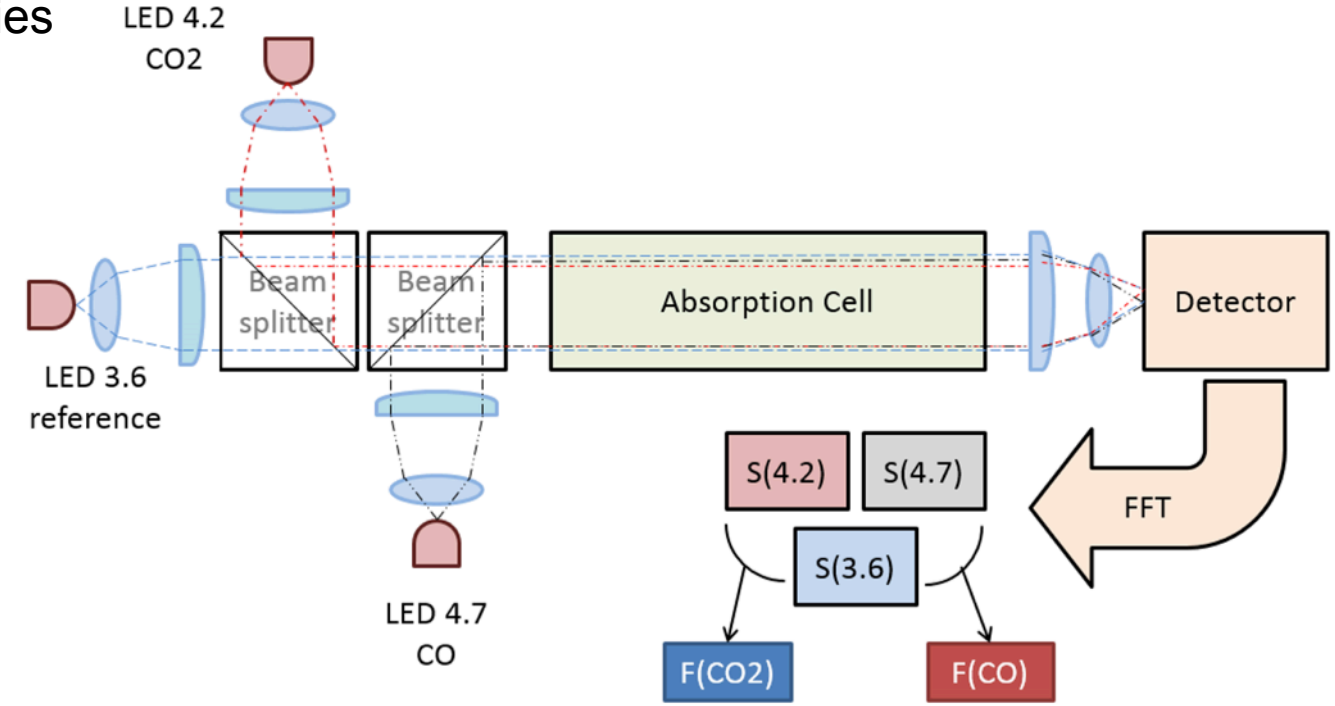
- Non-Dispersive Infrared (NDIR) absorption sensor using LEDs.
- Detects carbon monoxide (CO) and carbon dioxide (CO_2).
  - CO_2 center wavelength around 4.2μm
  - CO center wavelength around 4.7μm
- Implement as an early fire hazard detector for space vehicles



Sensor Design Using LEDs

- Three MIR LEDs centered at
  - 3.6μm (for reference)
  - 4.2μm (CO_2)
  - 4.7μm (CO)
- LEDs amplitude modulated at different frequencies

- Band pass filters
- Collimating lenses
- Pellicle beam splitters
- Thermo-electrically cooled photovoltaic detector

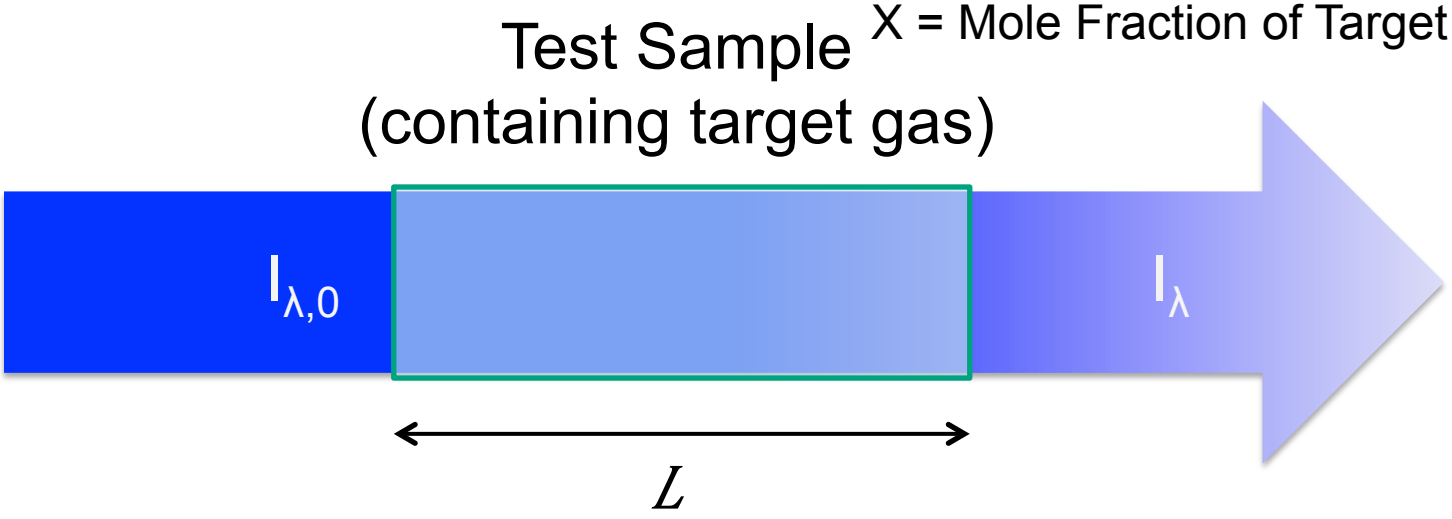


Absorption Spectroscopy and Beer's Law

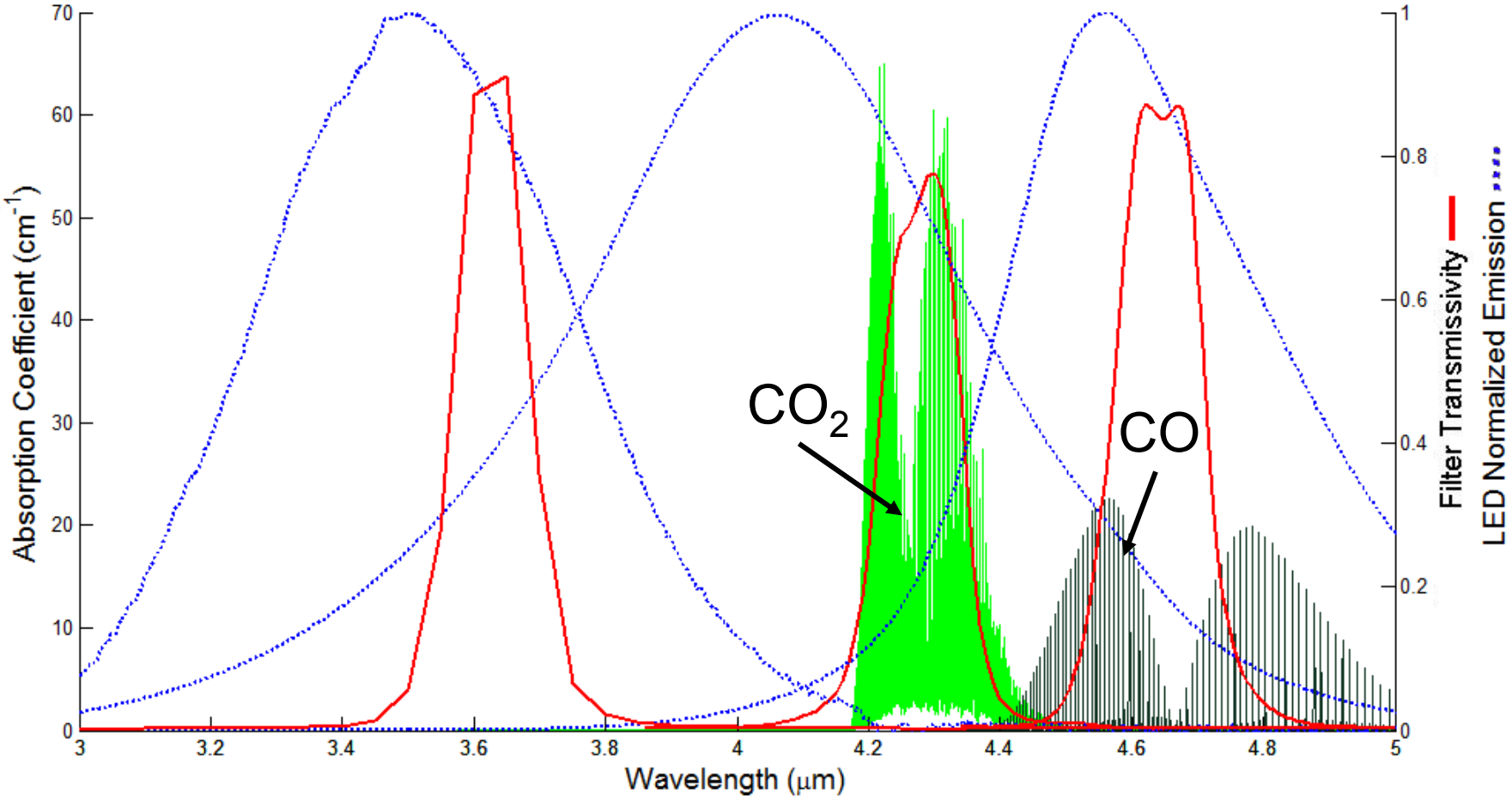
Beer-Lambert Law of Absorption

$$A_\lambda = ln(I_\lambda/I_{\lambda,0}) = k_\lambda LX$$

A_λ = Spectral Absorbance (Typically 0-1)
I_λ = Transmitted Radiation at λ
$I_{\lambda,0}$ = Incident Radiation at λ
k_λ = Spectral Absorbance Coefficient (Intrinsic Property at λ)
L = Path Length of Gas Cell
X = Mole Fraction of Target Gas



Using LEDs in Absorption Spectroscopy



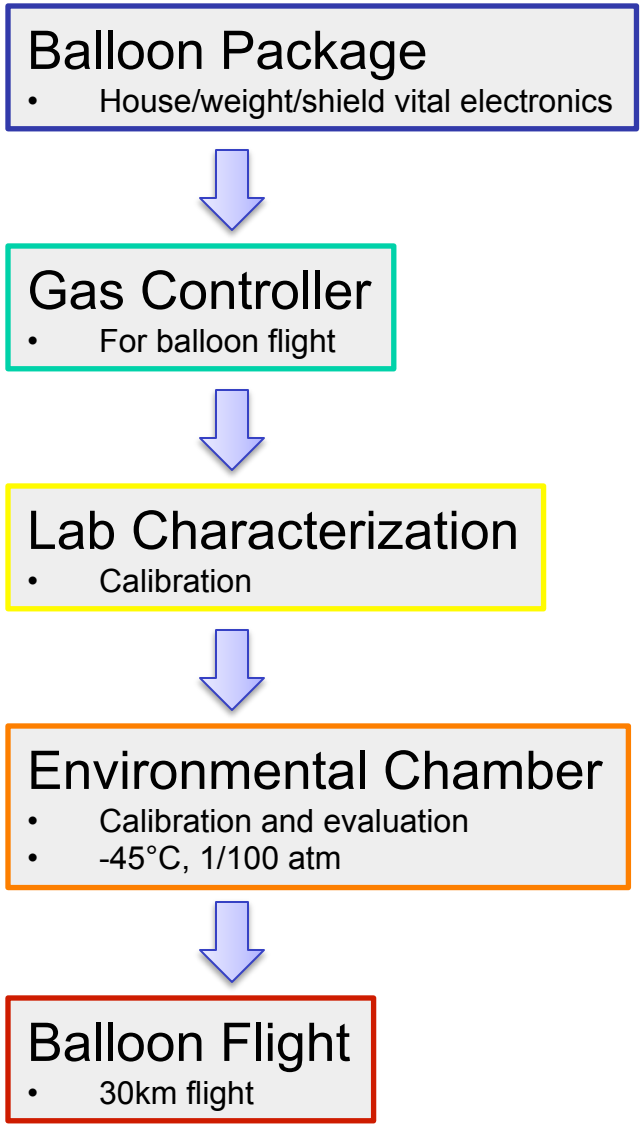
Schedule

Major Milestones

Achieved
- System integration of sensor components
- Sensor housing design for balloon test
- Convert system to run on cRIO DAQ

Ongoing
- Design gas delivery system
- Fabricate gas delivery system
- Integrate systems into final module
- Environmental Chamber Test Fall 2015
  - Preliminary run 10-12/2015
  - Full system diagnostic run 12/2015-4/2016

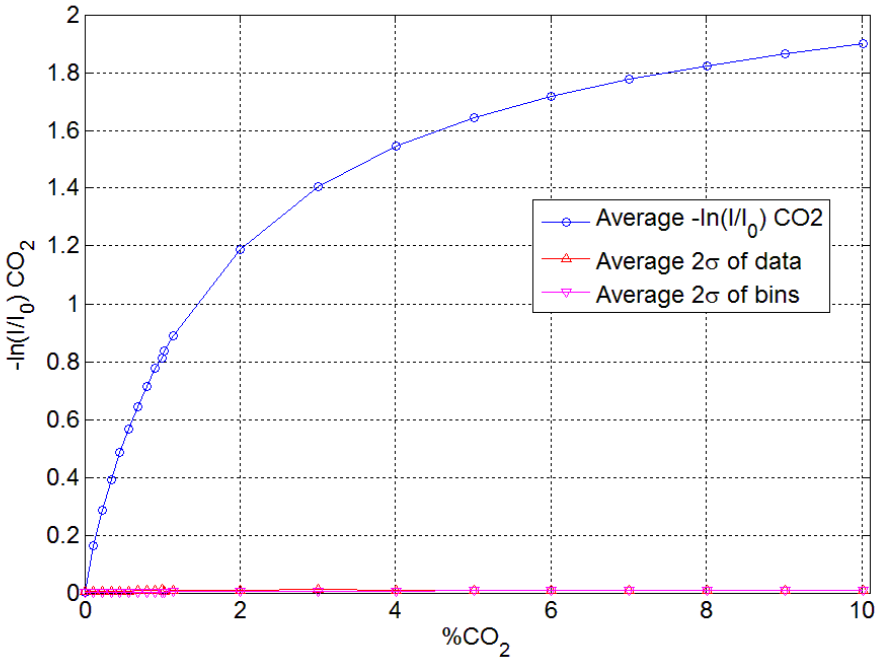
Planned
- Flight Test Summer/Fall 2016



Neat Gas Results Early Proof of Concept

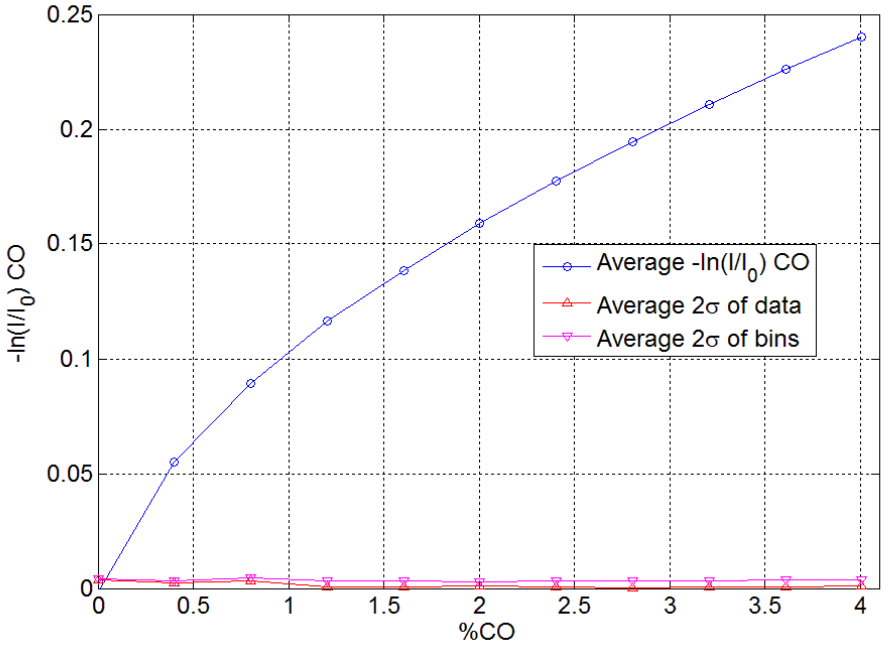
$$-ln(I/I_0) = kLX$$

Neat CO_2 Results



Detection Limit: 30ppm

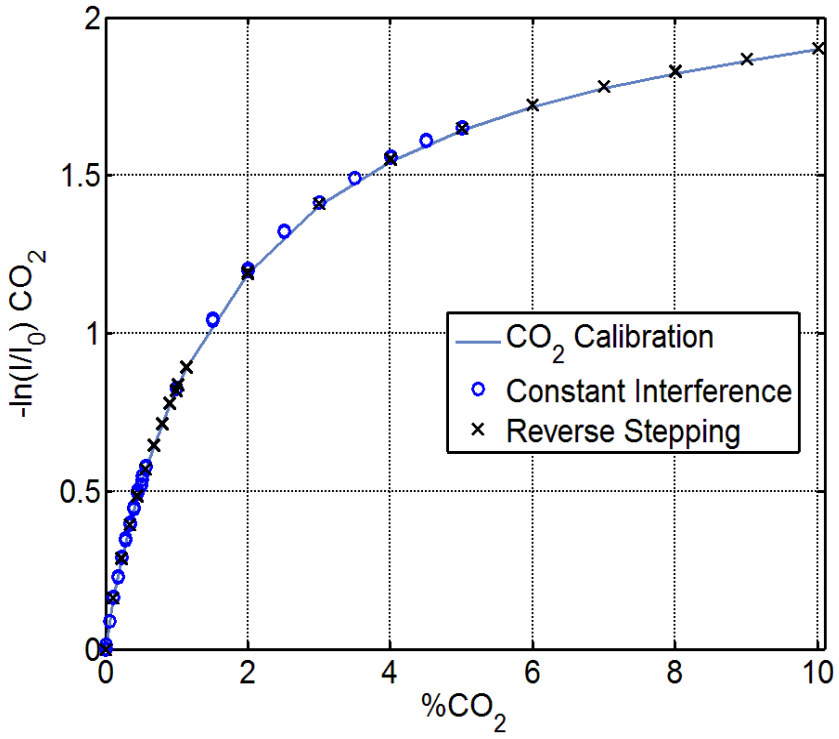
Neat CO Results

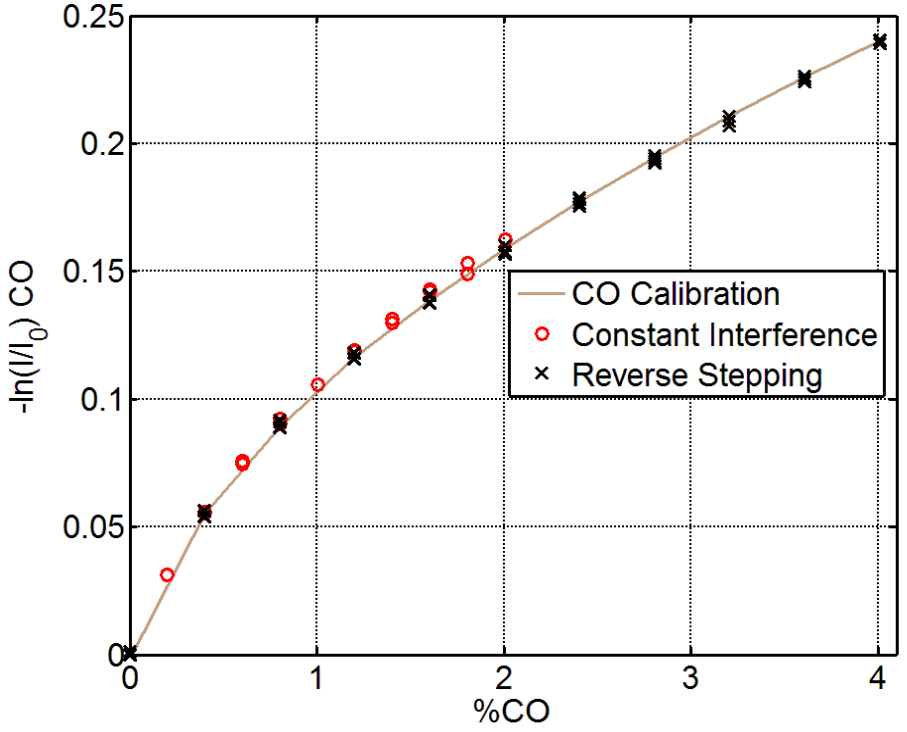


Detection Limit: 400ppm

Cross-Interference Study for CO and CO_2

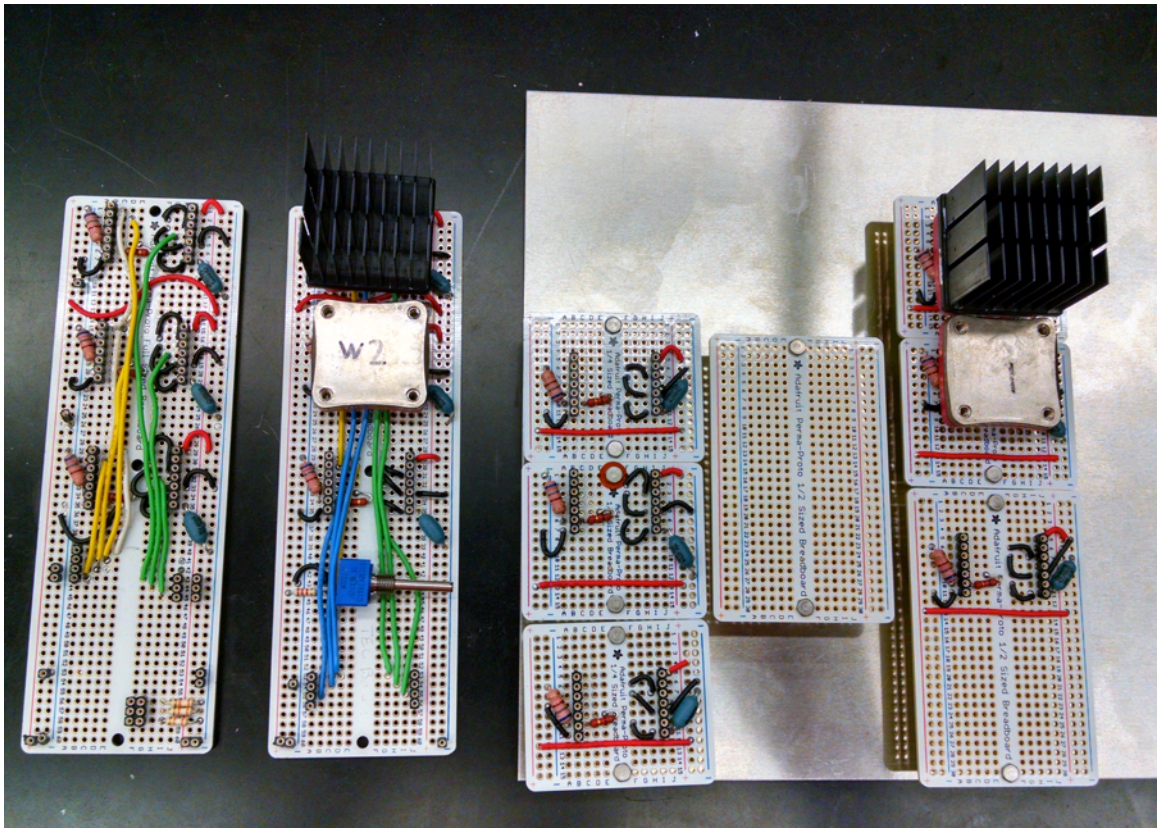
Simultaneous measurements of CO and CO_2 showed no cross-interference.





System Redesign

- Rebuilt circuitry to reduce feedback
  - Signal leakage caused error in drivers
  - New multi +/- current lines eliminate unwanted cross feed of LED and TEC signals



Why Environmental Chamber Tests?

- Validation of autonomous control systems
- Verification of system in low temperature/pressure environment
  - Lower pressure and temperature over an hour, maintain for two hours
- Troubleshoot prior to balloon test
  - Environmental analog to test system tolerance in extreme atmospheric conditions

Environmental Chamber Test

- UCF environmental chamber
- Test will verify system capabilities at 1/100 atm and -45°C
- Autonomous operation on ground will be achieved

NASA Flight Opportunities (Balloon Test): Proposal Pending

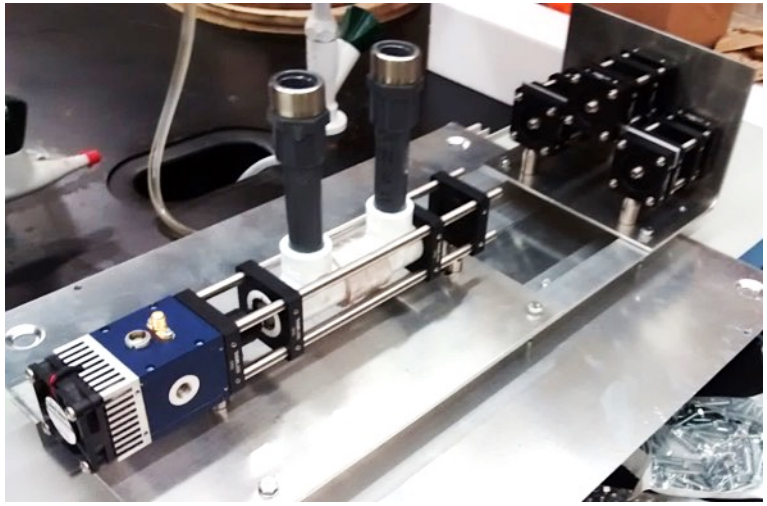
- Opportunity to test system in potential working conditions

– 30km+ altitude flight

– System designed for unmanned and manned space/ air vehicles

– Balloon test provides potential working environment

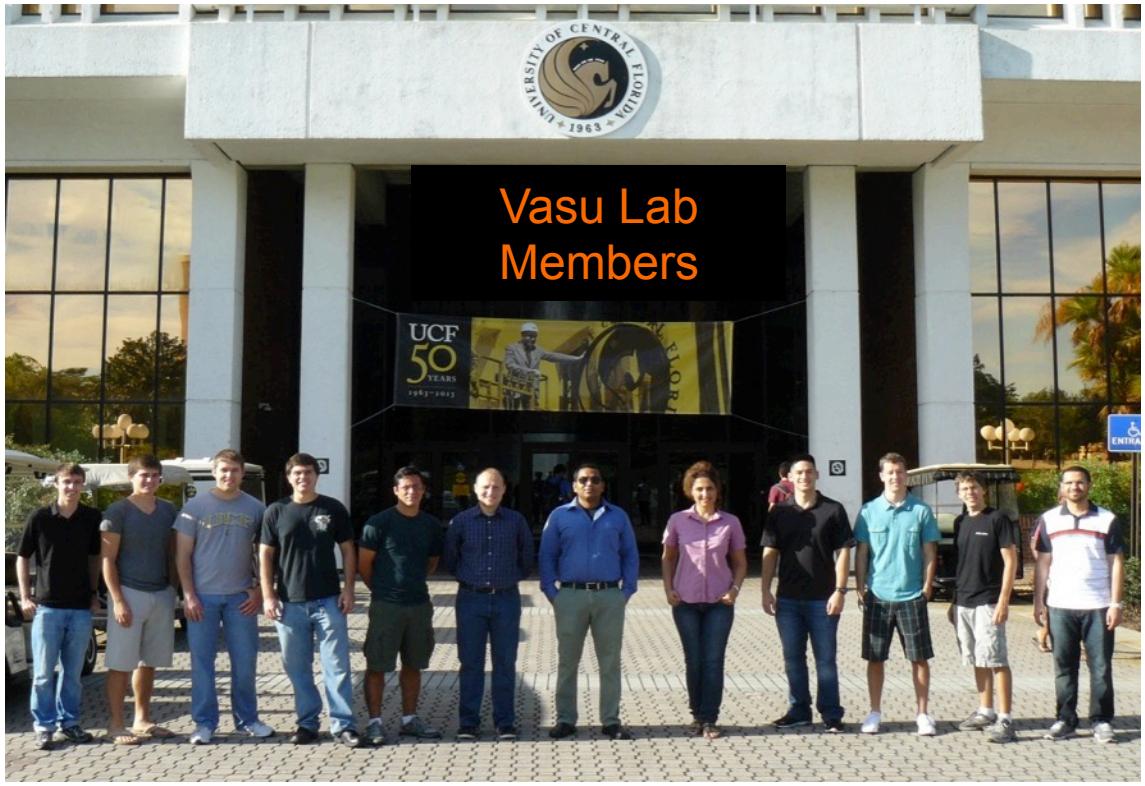
– Autonomous operation in a high altitude environment



Future Work

- Conduct balloon tests
- Characterize smoke of various space material to identify hazardous gases from fire onboard
- Extend range of species that sensor can measure (e.g. hydrocarbon fuels leak (~3.4μm), oxidizer N_2O (~4.5μm), HCN, etc.)
- Develop more accurate quantitative model for broad-spectrum absorption spectroscopy. Currently we rely on calibration models

Acknowledgments



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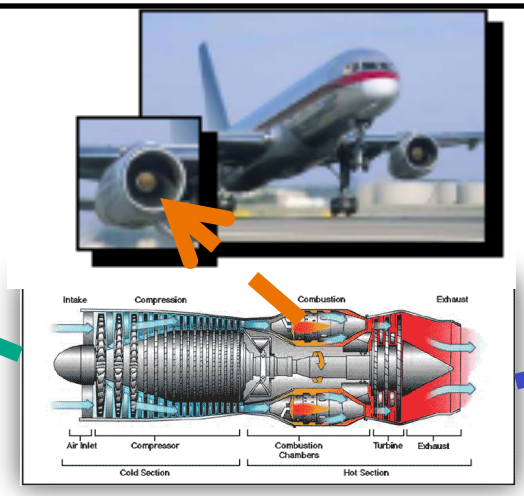
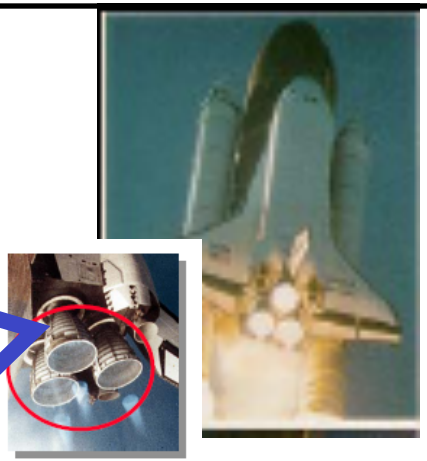
Questions?

Center for Advanced Turbomachinery and Energy Research





Aerodynamics & Heat Transfer

Combustion & Emissions

Alternative Fuels

Cycle Innovation

Extreme Temp Materials

CATER
10 faculty members

Mechanical Integrity

Design & Manufacturing

Polymer/Ceramic Composites

Dynamic Integrity

Plant & Grid Transients

Mid-Infrared Absorption Spectra