Exploration Systems Mission Directorate

Advanced Environmental Monitoring & Control Strategies for Space Exploration

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14 February 2006

Monitoring & Controlling the environment

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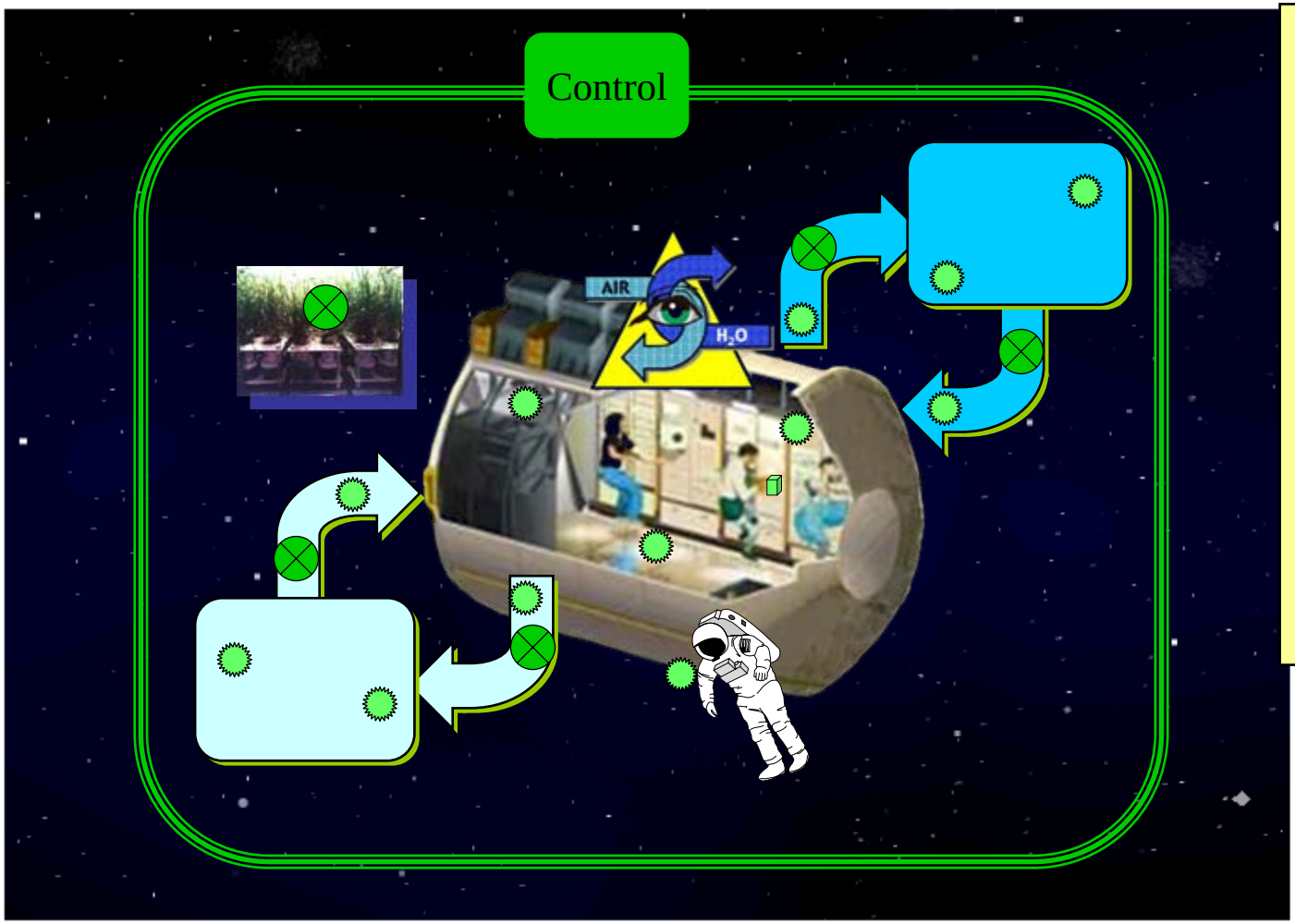

- Air
- Water
- Plant chambers
- Food and Food Preparation surfaces
- Gradual buildup of toxic species
- Hazardous events
- Chemical
- Biological

sensors

actuators

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AEMC Objectives

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- Closed environments, including all space habitats, are sensitive to contaminants
- A system of technologies is needed to monitor the environment with
  - Reliability
  - Accuracy and Range
  - Efficiency
- Monitoring needed to report
  - status of ECLSS;
  - External threats such as dust entry, leaks
- Control approaches needed to assure reliable operation of complex closed loop life support

AEMC History

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- Started in 1995 with emphasis in low to mid Technology Readiness Level activities
- Examples:
  - BioLuminescent Bioreporter Air Monitoring Circuits (Sayor, University of Tennessee)
  - Deep UltraViolet detection of biologicals and propellant (Conrad, JPL)
  - Lateral Flow Quantum Dot Assay for microbials (Lambert, JPL)

Bioluminescent Bioreporters

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McDUVE Fluorescence Detector

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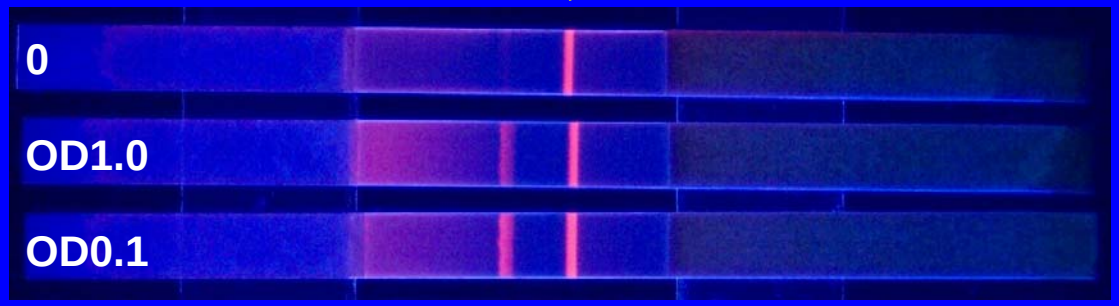
Excitation = 224.3 nm
Detection = photomultiplier tubes with selectable band pass filters
Sensitivity = 1000 molecules of tyrosine at 3 cm with a single 100 μs laser pulse.
Average sensitivity = 20 - 50 pp trillion for solid mixtures; even better for solutions

Single Agent LFAs for Model Pathogenic Bacteria

Lambert, Fisher

E.coli

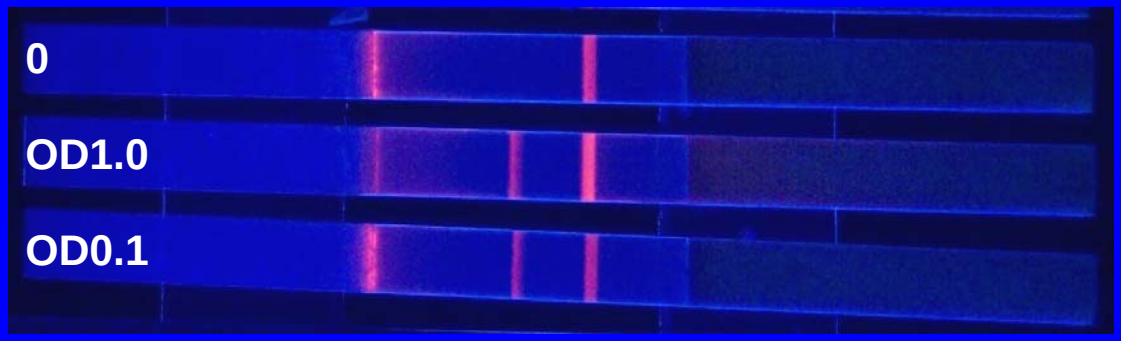
(EC, gm-, bacilli)

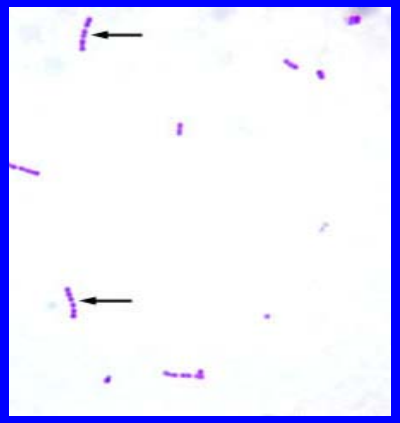


T C

Streptococcus Group A

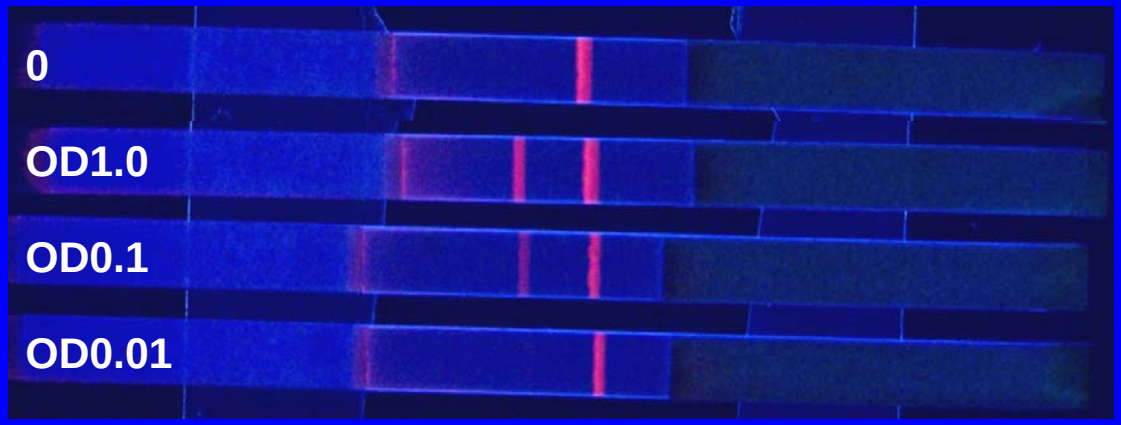
(SGA, gm+, cocci chains)

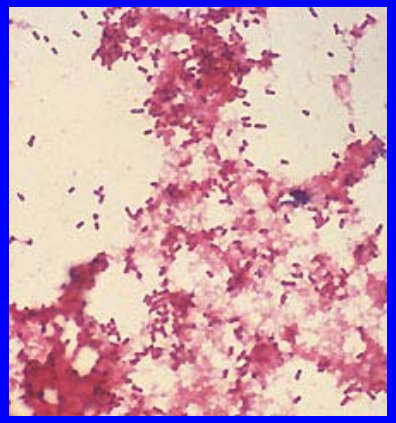




Pseudomonas aeruginosa

(PA, gm-, bacilli)





(OD0.1~5x10^{6} bacteria)

Vision for Space Exploration

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- Announced by the President on January 14, 2004
- AEMC shifted emphasis to higher Technology Readiness Levels

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Monitoring Priorities

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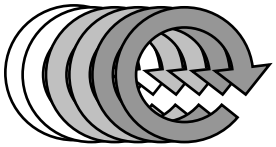

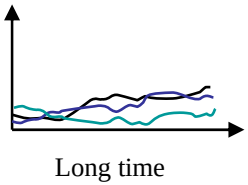

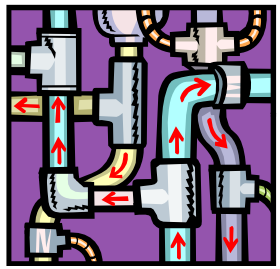

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Gradual increase of:

- Harmful chemical or microbials
- Chem/bio indicators of malfunction

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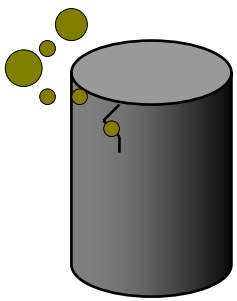

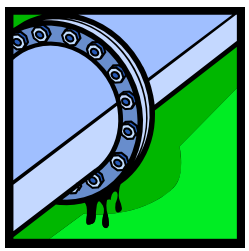

Hazardous event such as fire or leakage

- Harmful release
- Event indicators

http://microgravity.grc.nasa.gov/combustion/cfm/cfm_intro.htm

*"A Review of Monitoring Technologies for Trace Air Contaminants in the International Space Station," John T. James and J. Torin McCoy , NASA, Johns Space Center, SAE 2004-01-2339, International Conference on Environmental Systems, July 2004.

Priorities: Jitendra Joshi's 4x4+

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- 4 minutes without AIR
  - you DIE
- 4 hours without THERMAL CONTROL
  - you FRY
- 4 days without WATER*
  - you DRY
- ❖ 1 day of Contaminated Water
  - you feel like dying
- 4 weeks without FOOD
  - is not **GOOD**
- 4 months without SOLID WASTE
  - you will leave in HASTE

Monitoring priorities

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	Air, chemical	Water, chemical	Microbial	External
Earth Orbit	x			
to Moon	x	x		
on Moon	x	x	x	x
to/on Mars	x	x	x	x

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Technologies in Development

Monitoring Capability for Atmospheric Constituents

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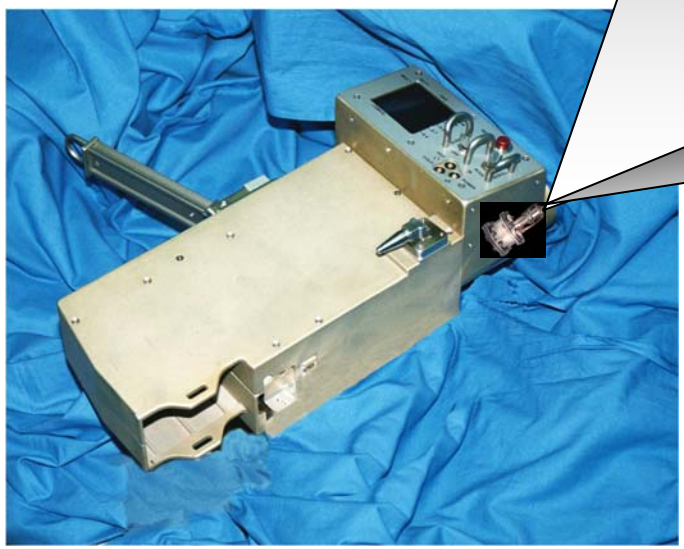
- Flight validated technology being modified and accelerated to increase monitoring versatility and sensitivity.
- Smallest mass spectrometer in space, flown by NASA in 2/01.
- Used by astronauts in Shuttle Mission 5A and beyond to detect ammonia and air leaks outside the International Space Station.
- Currently being modified with a front end- Gas Chromatograph
- Instrument that has built on previously tested versions will build on successive flights to foster improvement in functional capabilities.



The QMSA Packaged as the Astronaut's Trace Gas Analyzer (TGA)

The Quadrupole Mass Spectrometer Array (QMSA)

Will be delivered for ISS testing and validation in FY 08.

Electronic Nose Event Monitoring Capability

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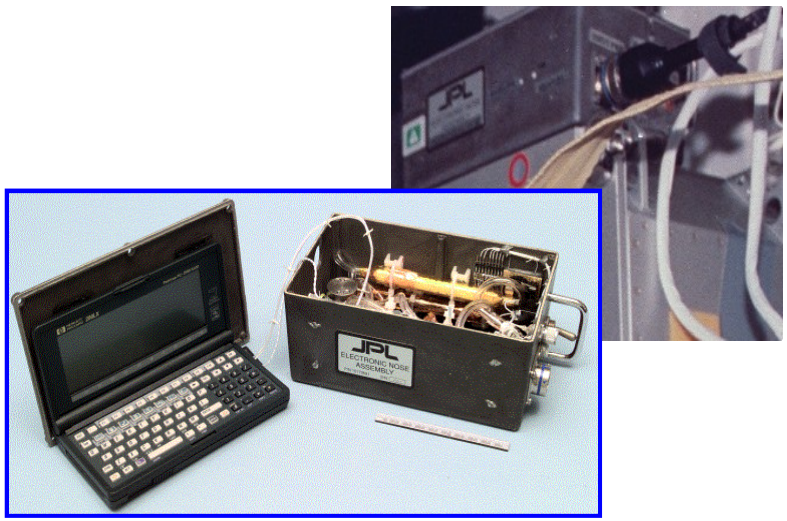
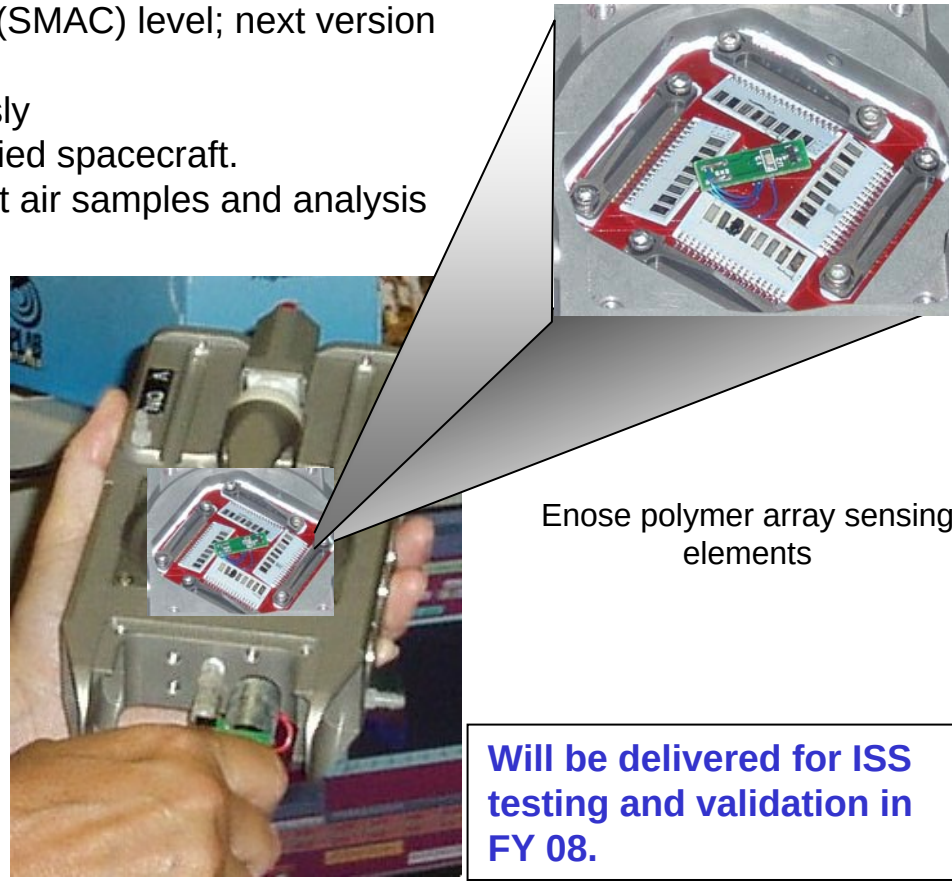
- Flight validated technology being modified and accelerated to increase monitoring versatility and sensitivity.
- Simple, rugged, reliable.
- Smallest, lightest, lowest power Enose known.
- Demonstrated to identify & quantify 10 common contaminants at the Spacecraft Maximum Allowable Concentration (SMAC) level; next version detects 24.
- Enose experiment ran it for 6 days continuously
- First ever continuous monitoring of any occupied spacecraft.
- Results were confirmed by taking independent air samples and analysis



The ENose Experiment flew in the middeck on STS-95 in Oct-Nov 1998.



Mark II Enose in lab testing

Enose polymer array sensing elements

Will be delivered for ISS testing and validation in FY 08.

CSPE Water Biocide Monitor

Porter, Iowa State University

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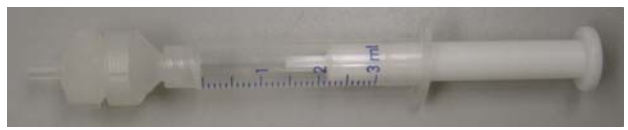
•Biocides can be lost through adsorption, consumption, other mechanisms.
• Low concentrations of biocide to not inhibit microbial growth. Excess poses health risk.
• Monitor uses Colorimetric Solid Phase Extraction (CSPE)
• Colorimetric quantification of iodine, silver. Other targets in development.
• Simple, reliable.
• Rapid, low power, tested in KC-135

Colorimetric effect captured on tiny membrane Filter disks

Handheld reader gives quantitative results.



Syringe used to inject water through Filter disks

Will be delivered for ISS testing and validation in FY 08.

Rapid Microbial Monitoring Capability

Monaco (MSFC), Steele, Wainwright

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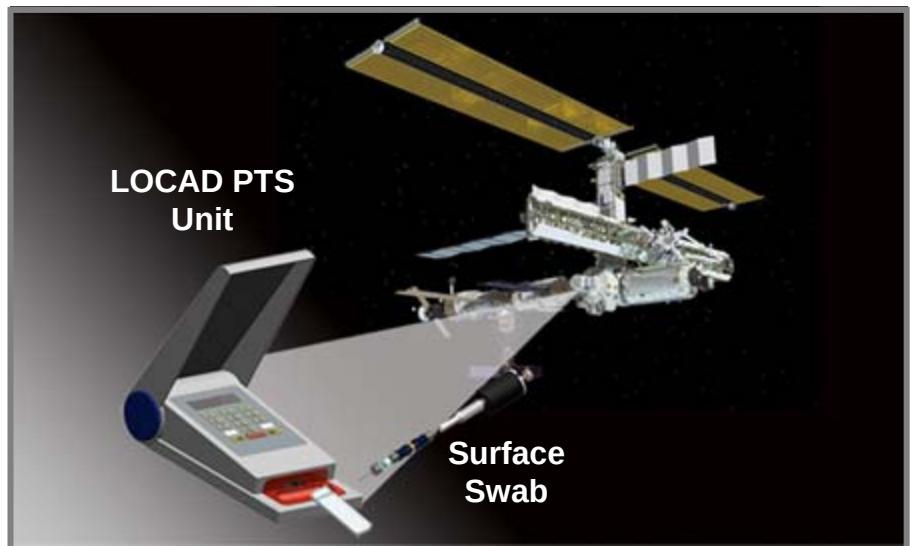
- Validated, commercially available technology from Charles River Laboratories, the Lab-on-a-Chip Application Development - Portable Test System (LOCAD PTS) unit is being modified for use on the ISS for environmental monitoring of microbial bioburden
- Design, fabrication, testing and delivery of a swab unit to accompany the instrument is in progress
- The instrument has been tested in relevant environments: NASA Extreme Environments Mission Operations (NEEMO), KC-135, the Arctic
- Future cartridges to be developed in conjunction with the Marine Biological Laboratory will enable rapid assessments of gram -/+, yeast and mold (FY06), ATP assay (FY07), and specific targets (i.e., Salmonella, Listeria, and E. coli) (FY08)
- An air sampler collection unit will complement the device (FY08)



Will be flown on flight 12A.1 for operation on Increment 14

Tunable Laser Spectroscopy for Gas Phase Detection

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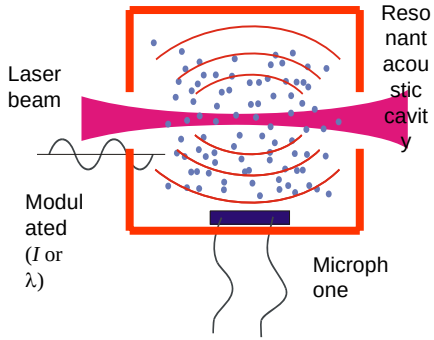

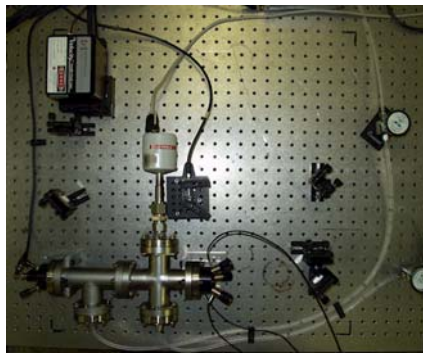

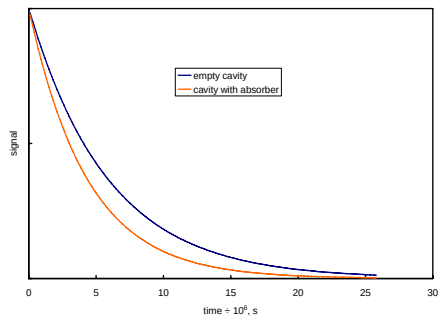

- Team :
  - Rice University:
    - Quartz Enhanced Photoacoustic Spectroscopy--QEPAS
  - George Washington University
    - Cavity Ringdown Spectroscopy--CRDS
  - Jet Propulsion Laboratory
    - Type II Interband cascade lasers
- Explore *two* approaches to optical detection with the same MWIR laser from JPL.
- Goal is the development of mid-infrared laser-based optical sensors for *particular* air constituents for Human use in space.