DOE ARM Aerial Instrumentation Workshop Report

Discovery Hall @ PNNL, Richland, WA · March 2 & 3, 2020

Conveners: Beat Schmid, Fan Mei, Darielle Dexheimer

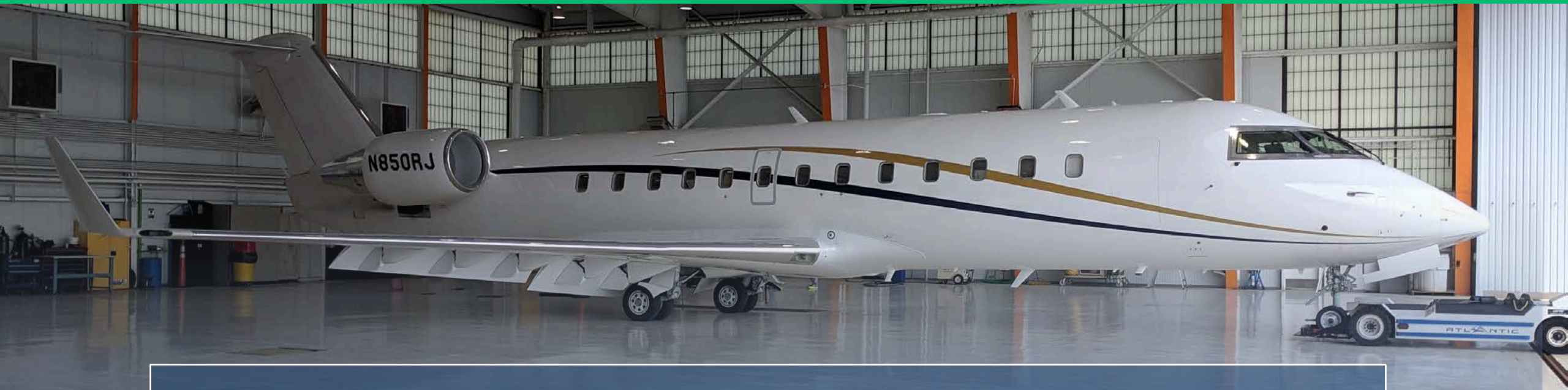
Instruments for Challenger 850 Aircraft

Highlights from Aircraft Participated Field Campaign

Airborne measurements taken during winter and summer as part of a year-long campaign on the coast of Massachusetts provide comprehensive information about fundamental properties of atmospheric aerosols. Photo credit: Courtesy of the U.S. Department of Energy Atmospheric Radiation Measurement user facility on Flickr.

Using airborne data from the GoAmazon 2014/15 field campaign, scientists analyzed measurements of aerosol chemical composition, sources, and evolution in the urban plume from Manaus, Brazil, as it moved into the Amazon rainforest. Image courtesy: ARM Research Facility.

New ARM Research Aircraft



Challenger 850 jet purchased in June 2019.

The Challenger aircraft continues the sampling capabilities of the G-1 for “low and slow” flight while providing enhanced performance:

- Increased payload and capacity
- Higher ceiling
- Larger geographical range
- Improved endurance

Proposed capability for AAF – Session Highlights

- In March, 2020, **59 atmospheric scientists** gathered at Pacific Northwest National Laboratory (PNNL)
- **Forty-five talks** that largely focused on instrumentation and potential capabilities for enhancing airborne measurements

- Implementation criteria for the Challenger 850
  - Short term implementation options (< 3 years)
    - Commercially available
    - Have reliable deployment history
    - Potential facility instruments
  - Mid/Long term implementation options
    - Concept with a strong science driver
    - Require significant funding to support
    - Commercially available, but require major aircraft modification

Proposed capability for AAF – Mid/Long term options

- Aircraft and Atmospheric State Measurements
  - **Microwave Sounding**
- Aerosol Measurements
  - **The next-generation airborne Aerosol Chemical composition through Mass Spectrometer (MS)**
  - **Airborne Lidar**
- Trace-gas Measurements
  - **The next-generation airborne in situ Trace-gas instruments**
- Radiation Measurements
  - **Updated Broadband Solar and IR Radiation**
  - **Spectral and Hyperspectral Solar Radiation**
- Cloud Measurements
  - **The next-generation airborne in situ Cloud Probes**
  - **Ice Nuclei Measurement**
  - **Advanced Radar**

AAF will closely monitor the development of the new technologies and implement the potential capability based on the community needs.

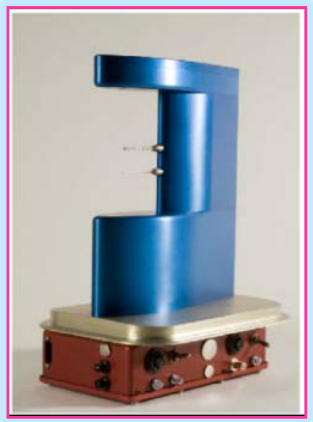
Proposed capability for AAF – Short term implementation

- Aircraft and Atmospheric State Measurements
  - **Vertical Cavity Surface Emitting Laser (VCSEL) hygrometer**
- Radiation Measurements
  - **Hyperspectral imaging**
- Trace-gas Measurements
  - **Fast Ozone**
  - **Ammonia**
- Aerosol Measurements
  - **Scanning mode Dual-column CCN**
  - **Fast Integrated Mobility Spectrometer (FIMS)**
  - **Cavity Attenuated Phase Shift – single scattering albedo (SSA) monitor**
  - **Wideband Integrated Bioaerosol Sensor**
- Cloud Measurements
  - **Wing pylon Radar (PMS canister)**
  - **Water Isotope measurement**

VCSEL hygrometer for water vapor/humidity

- **Vertical Cavity Surface Emitting Laser (VCSEL) hygrometer**
  - Open-path; Near infrared; 25 Hz; Analyses use 1 Hz;
  - Accuracy ≤ 6%; Precision ≤ 1% *(Zondlo et al., 2010)*

Challenges	Solutions of VCSEL hygrometer
Broad dynamic range from 1 to 40,000 ppmv	1854.03 nm (strong absorption line) 1853.37 nm (weak absorption line)
High affinity to surfaces	Open Path



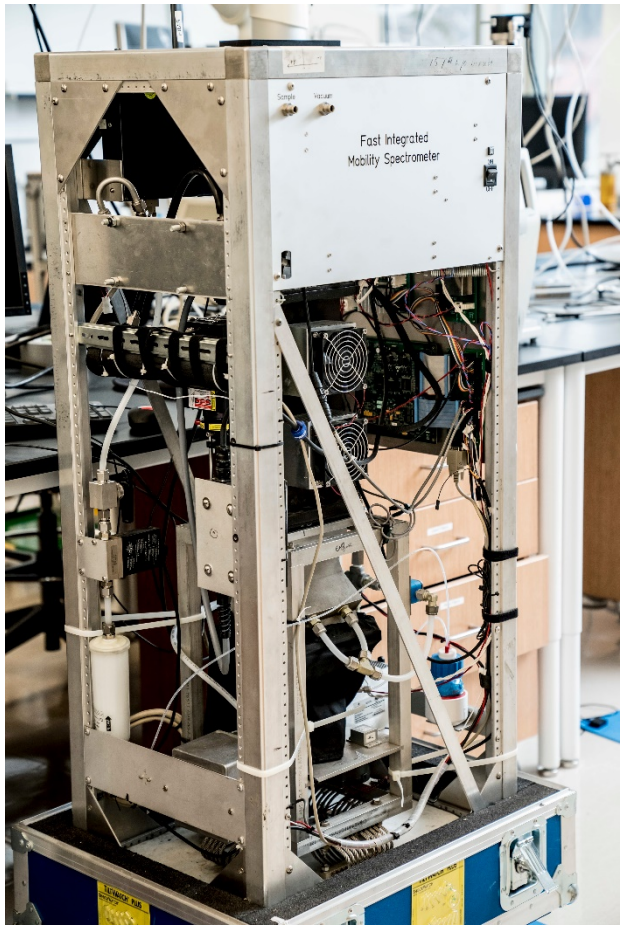
Combine with ±0.3 K temperature uncertainties, **RH_{ice} and RH_{liq}** uncertainties are **7.5%–6.5%** and **10.4%–6.4%** for -69°–0°C, respectively.

NSF G-V research plane in HIPPO Global Campaigns

2nd Dual-column Cloud Condensation Nuclei Counter (CCNc)

- **Advantages with two dual-column CCNc**
  - Simultaneously 1 Hz data from four supersaturations
  - Implementation of a scanning mode operation

Fast Integrated Mobility Spectrometer (FIMS) for Aerosol concentration and size distribution (<60 nm, 1 hz)



Current version:

- Size: 22”×17”×50” (56 cm×43cm× 127cm, W×D×H)
- Power: 110 VAC, 4 A (operation), 6 A (max, startup)
- 150 lbs

Previous deployments:

- BBOP (2013, AAF G-1)
- GoAmazon 2014/5 (2014, AAF G-1)
- HI-SCALE (2016, AAF G-1)
- ACE-ENA (2017 & 2018, AAF G-1)
- CAMP^{2}Ex (2019, NASA P-3B)

Next version:

- Reduced size (22”x17”x~40”), weight (~120 lbs)
- More robust.

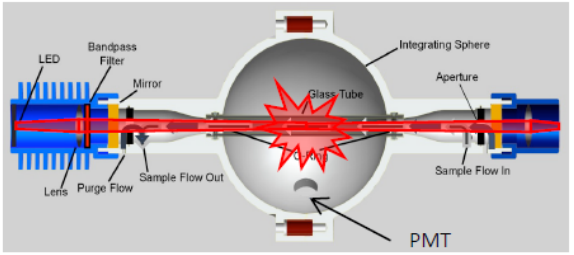
Cavity Attenuated Phase Shift – Single Scattering Albedo (SSA) Monitor (CAPS PM_{SSA})

Data/Measurements/Retrievals:

- Direct measurements of extinction through CAPS technique (Mm^{-1}), Scattering through inverse integrating nephelometer (Mm^{-1}). Derive SSA (Scat/Ext) and absorption (Ext-Scat).

Principle of Operation:

- Measure the phase shift from a modulated LED source. Wavelengths = 405, 450, 530, 630, 660, or 780 nm



Aerosol Sci. and Technol. 49:267-272 (2015)

Science Drivers:

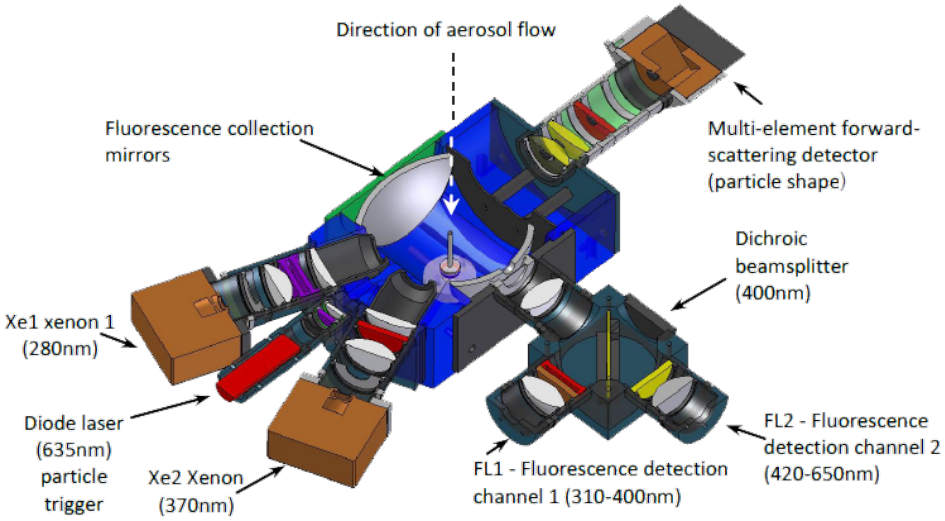
- Extinction, scattering, and SSA are critical parameters required for radiation models.
- The CAPS-based SSA and derived absorption can serve as a reference and measurement constraint for Neph/PSAP-derived SSA.
- CAPS PM_{SSA}, wavelength-matched with a direct absorption measurement (e.g., PAS, PTI), will provide optical closure and a real-time SSA measurement.
- CAPS PM_{SSA} wavelength matched with a filter-based absorption measurement will an important check on potential absorption-measurement, filter-based biases.

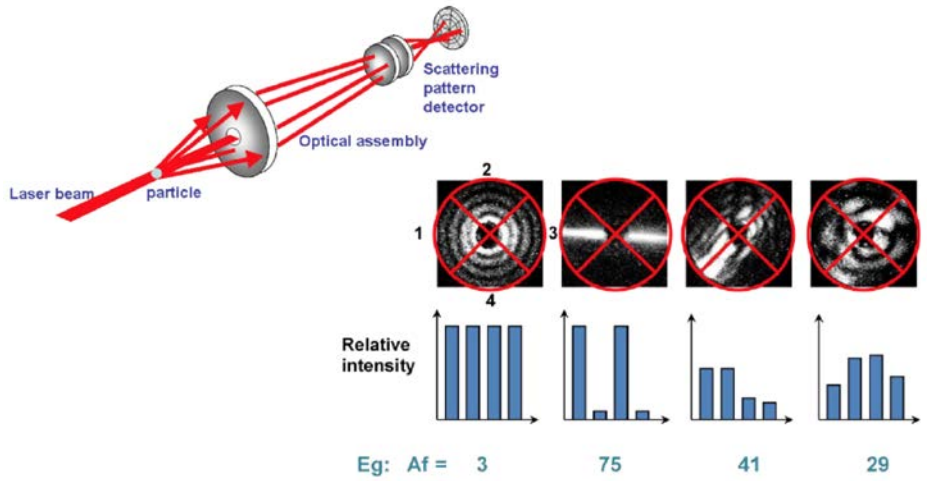
Instrument Specifications:

Weight: 16 kg
Dimensions (LWH): 61 cm x 43 cm x 23 cm
Power: 50 W
Recommended Platform: Challenger 850

Wideband Integrated Bioaerosol Sensor

Detection by Laser Induced Fluorescence





Final Data Products

- **Fluorescent and Non-Fluorescent Size distributions**
- **Fluorescent Fractions**
- **ABC Classification to discriminate particle types**

Fast Ozone Analyzer

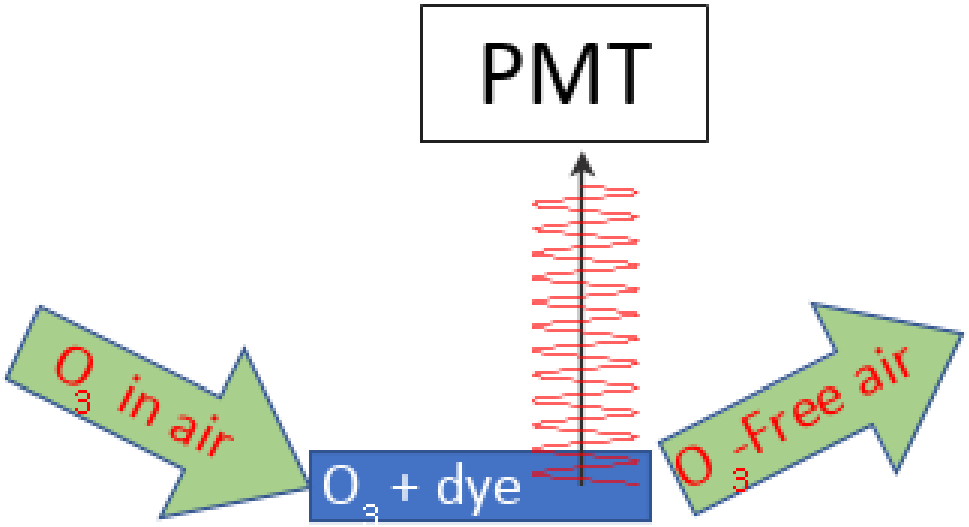
Data/Measurements/Retrievals:

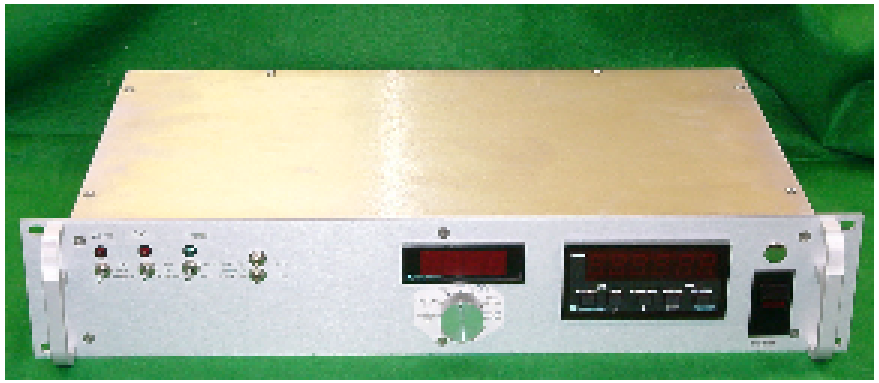
- Ozone mixing ratio at 5-10 Hz.

Speed comes from mass sensitivity of technique AND low volume. Linear dynamic range from 0 - >200 ppbv.

Principle of Operation:

- Chemiluminescence resulting from reaction of ambient ozone with a dye adsorbed on a silica substrate.



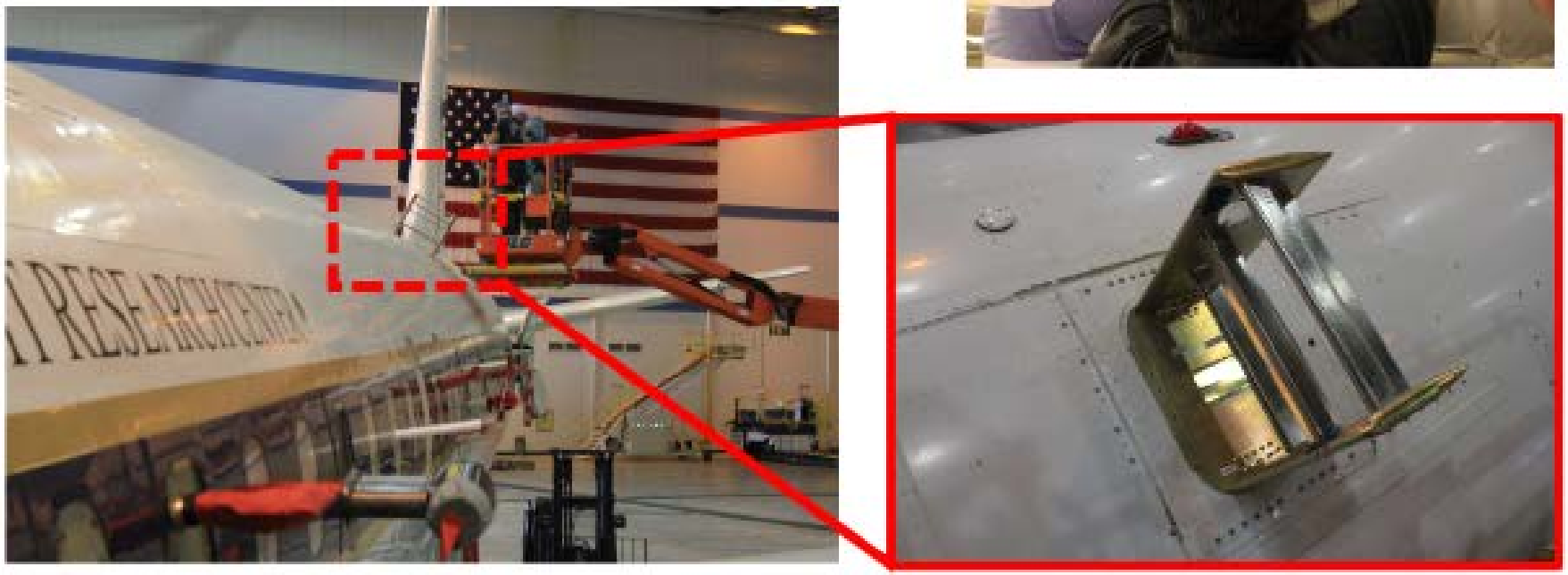


Open-path Ammonia Laser Spectrometer (OPALS)

OPALS on the NASA DC-8 aircraft

OPALS = Open-Path Ammonia Laser Spectrometer

- completely self-contained on window viewport plate



A fast, sensitive, and artifact-free instrument is needed to understand the role of ammonia in aerosol processes.

A multi-phase water isotope measurement approach

Measurements provided:

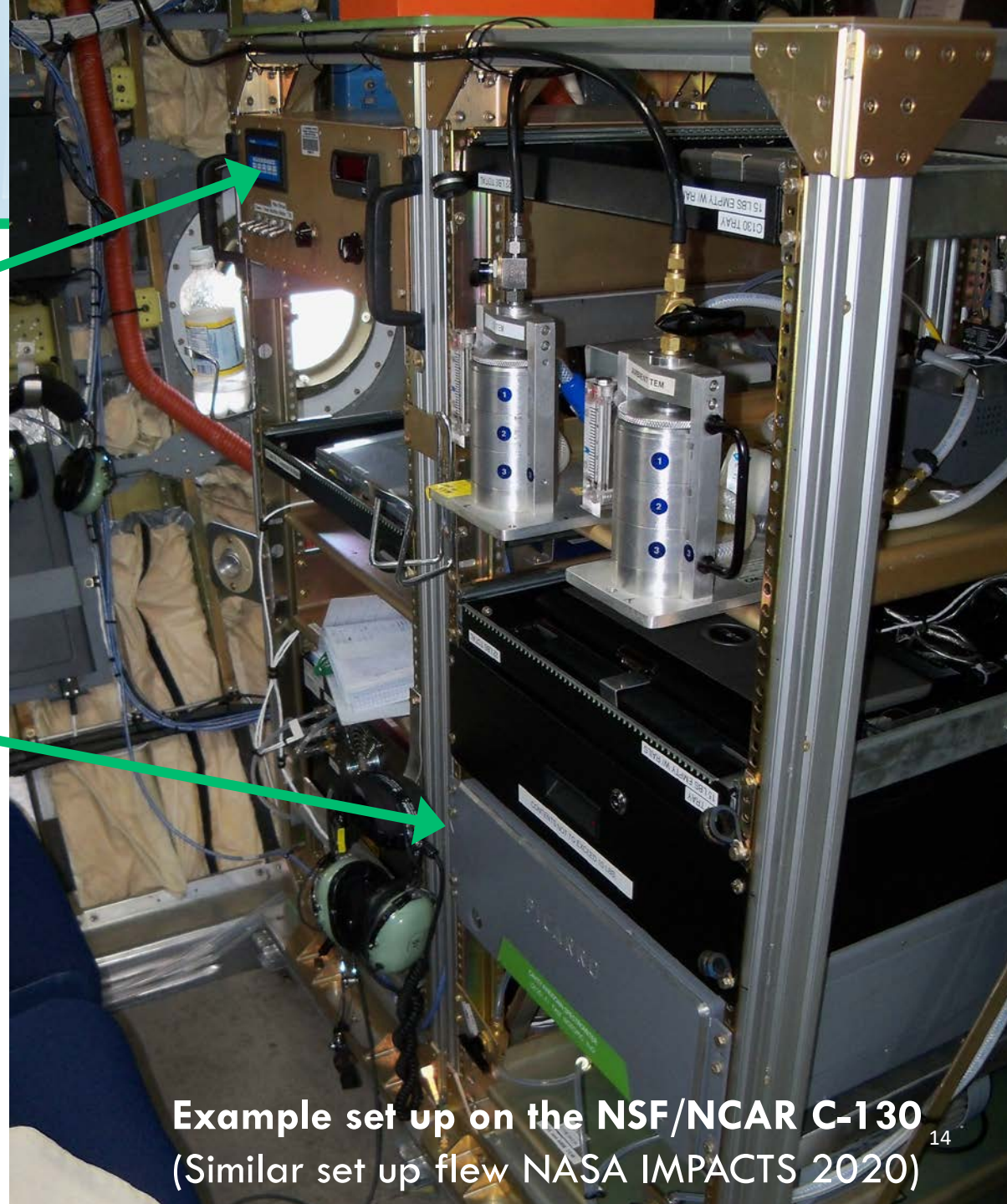
- Total water/vapor, cloud water/ice, and their isotopic compositions

Benefits:

- New tracer of moisture exchange
- Reveals "process" rather than simply describing "state"

Availability:

- Off-the-shelf technology exists for manned aircraft platforms



Example set up on the NSF/NCAR C-130
(Similar set up flew NASA IMPACTS 2020)

Wing Pylon Radar (PMS canister)

A cloud radar provides the ability to see clouds above and below the airplane providing context for in-situ measurements and extending the capabilities of mobile facilities.

Example specifications (ProSensing KPR):

Frequency:	35.6 GHz
Transmitter:	10 W solid state power amplifier
Antennas:	14 cm flat-plate array, 4.5 deg. beam-width
Pulsing:	Interleaved short RF and linear FM pulses
Range Resolution:	30, 75, 100 or 150 m
Delta T:	1 K @ 200 ms integration (5 Hz data rate)
Rec. Noise Temp.:	440 K
Radomes:	Matched Rexolite window
Weight:	25 lb (40 lb with canister)
Power:	50 W AC; 100 W 28 VDC

ProSensing KPR on UW King Air

Hyperspectral Imaging Camera

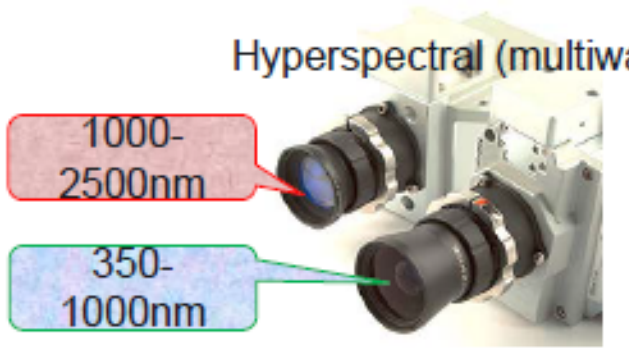
Previous (normal) vs proposed (Hyperspectral) camera

Pacific Northwest NATIONAL LABORATORY

Normal Colored Camera

Camera used at AAF (G-1) : AXIS P1347
Data: True color (RGB) images

Hyperspectral (multiwavelength) Camera



Proposed camera for new AAF (BC-850): Hyperspectral Imager
Data: Image cubes at hundreds of wavelength (350-2500 nm)

The RGB color camera and radiometers mounted on belly of the G-1 aircraft.

A full report of the ARM aerial instrumentation workshop report will be available in July.

- Please choose your top **THREE** of the short term options
  - Vertical Cavity Surface Emitting Laser (VCSEL) hygrometer
  - 2nd Dual-column CCN counter for scanning flow operation
  - FIMS
  - CAPS-PM_{SSA}
  - WIBS
  - Fast Ozone
  - NH_3
  - Water Isotope
  - RADAR (Wing pylon, PMS canister)
  - Hyperspectral imaging

Thank you!