Unmanned Aircraft Systems (UAS) Chromatograph for Atmospheric Trace Species (UCATS)

CIRES (Univ. of Colorado) & NOAA Earth System Research Laboratory
Boulder, Colorado

UCATS was designed and built for autonomous operation aboard the Altair Unmanned Aircraft System in an unpressurized, ambient temperature environment. To date it has amassed >140 operational flight hours, including three flights >20 hours in duration.

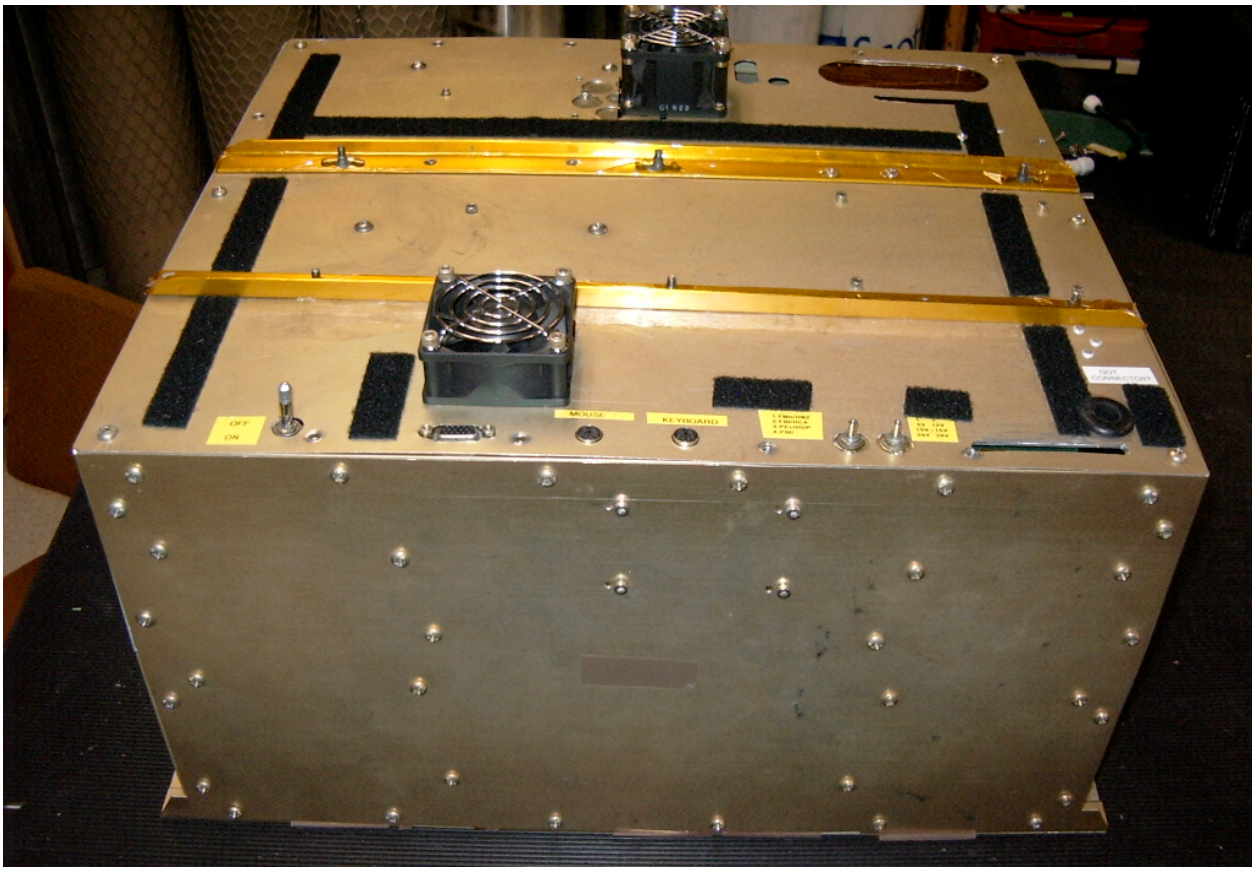
UCATS is three different instruments in one enclosure:

- 2-channel gas chromatograph (GC)
- Dual-beam ozone photometer (OZ)
- Tunable diode laser (TDL) spectrometer for water vapor (WV)

The UCATS enclosure measures 41 x 46 x 25 cm (W x L x H) and weighs 28 kg (62 lbs)
Power consumption is 9 Amps @ 28 VDC (250 W), 16 A (450 W) during warm-up

External to the UCATS enclosure are:

- A Teflon diaphragm pump (KNF) for sampling air through an external inlet
- 2 high-pressure aluminum cylinders: Nitrogen and calibrated whole air
- Keyboard, monitor, and mouse



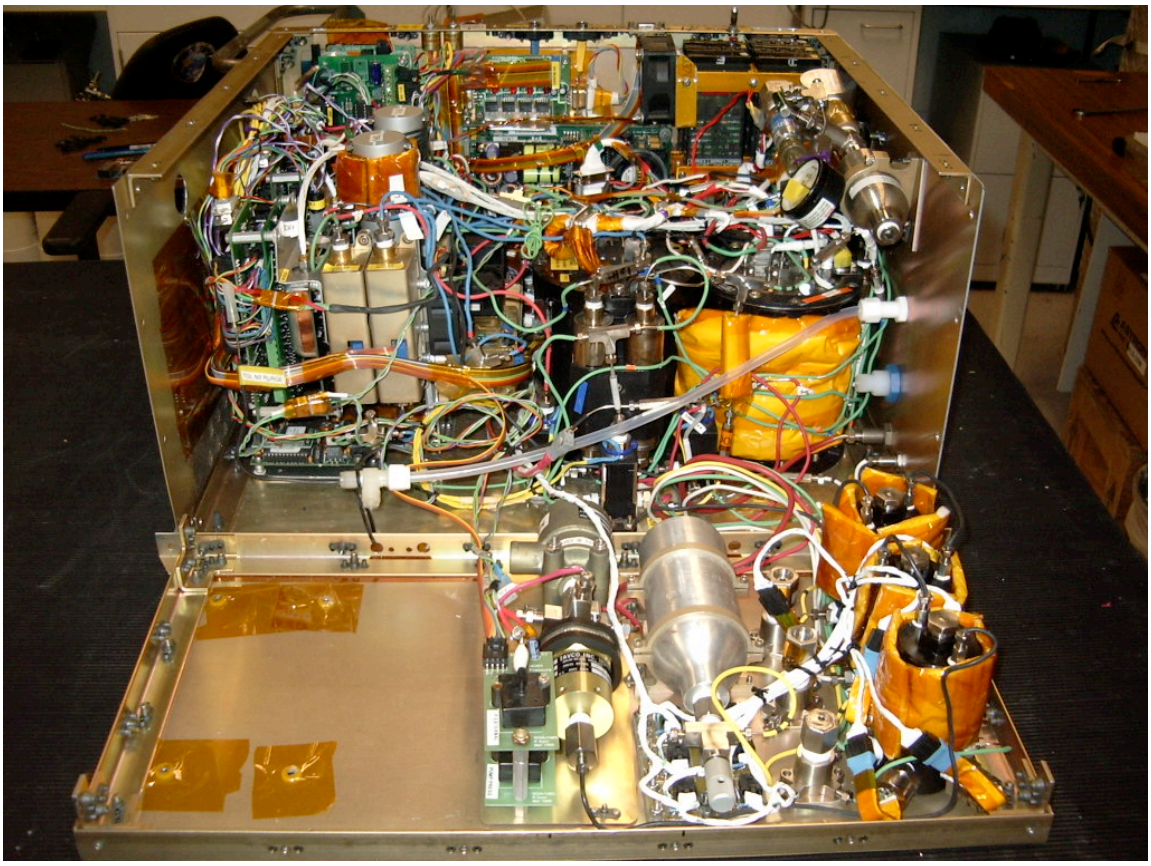
UCATS: a 2-channel GC, an ozone photometer (OZ) and a TDL hygrometer (WV)

Gas Chromatograph (GC)

The 2-channel UCATS GC utilizes rapid gas chromatography to measure nitrous oxide (N_2O) and sulfur hexafluoride (SF_6) every 70 s, and hydrogen (H_2), methane (CH_4) and carbon monoxide (CO) every 140 s. Each channel is comprised of a 12-port valve for sample injection, a 1.5 cm^3 sample loop, narrow bore (2.2 mm id) packed columns, and an electron capture detector (ECD). The N_2O/SF_6 and $H_2/CH_4/CO$ measurements require doping of the ECDs with miniscule flows of carbon dioxide and nitrous oxide, respectively, from small, high-pressure cylinders inside the instrument. The GC carrier gas (N_2) and calibration gas (whole air) are contained in aircraft-certified high-pressure cylinders external to the instrument box. A Teflon diaphragm pump, also external to the GC, flushes air samples through the GC for their subsequent analysis. For extended low-tropospheric flying, a small amount of dessicant ($Mg(ClO_4)_2$) is required to dry the sample air stream before it enters the GC. Calibration is performed in-flight every 560 s through the analysis of a standardized cylinder of dried whole air. Further calibrations are performed in the laboratory to characterize detector response functions over the full ranges of trace gas mixing ratios measured during flights. An on-board computer provides instrument control while continuously logging chromatographic and engineering data. Data are recorded on removable media (PCMCIA flash disk) during flight, then are archived off-line after landing. In the post-flight phase, chromatograms are processed into mixing ratio data with error estimates for each measurement.

Data Interval: every 70 s (N_2O, SF_6) or every 140 s (H_2, CH_4, CO)

Accuracy: ±1% **Precision**: ±2-3% (H_2) ±0.2-0.5% (N_2O) ±0.4-0.8% (CH_4) ±0.8-1.0% (SF_6) ±3-5% (CO)

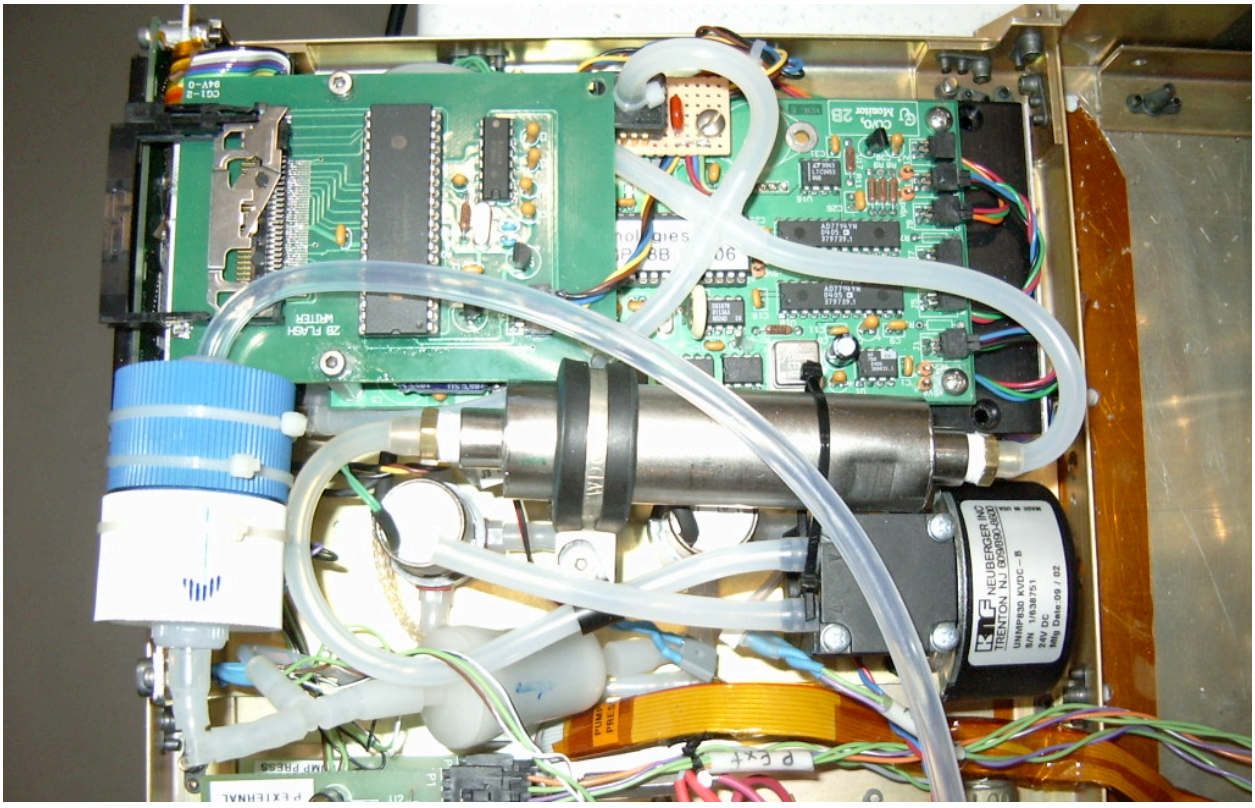


UCATS 2-Channel GC

Dual-Beam Ozone Photometer (OZ)

The OZ photometer is a small, low power, dual beam instrument that measures ozone (O_3) mixing ratios in the air stream every 10 s. The instrument, which resides inside the UCATS GC box, is nearly self-contained, having its own air pump, instrument control software, and data acquisition board, needing only its power from the GC power distribution system. The photometer requires its own Teflon inlet tubing (absolutely void of wetted metal surfaces) to provide an air flow of ~1 L min^{-1} with a downstream diaphragm pump. The ozone measurements are based on the absorption of UV light (254 nm) by ozone present in the air drawn through one of two 15-cm long absorption cells, as measured by a photodiode detector. Ozone-free (scrubbed) air is simultaneously drawn through the other 15-cm long absorption cell to provide a reference signal (I_O) at the other photodiode detector. Solenoid valves regularly switch the whole air and scrubbed air streams to the two cells, minimizing systematic errors in the dual cell, dual detector configuration. The ozone mixing ratio is determined through a simple Beer-Lambert Law calculation of ozone concentration, combined with the measured cell temperature and pressure. Calibration is performed in the laboratory before and after each mission. The instrument is re-zeroed before each flight. Data are recorded on a PCMCIA compact flash card which is removed post-flight for data processing, and are also logged by the GC data acquisition system.

Data Interval: 10-s average
Accuracy: Greater of ±2 ppb or ±3%
Precision: Greater of ±1 ppb or ±2%

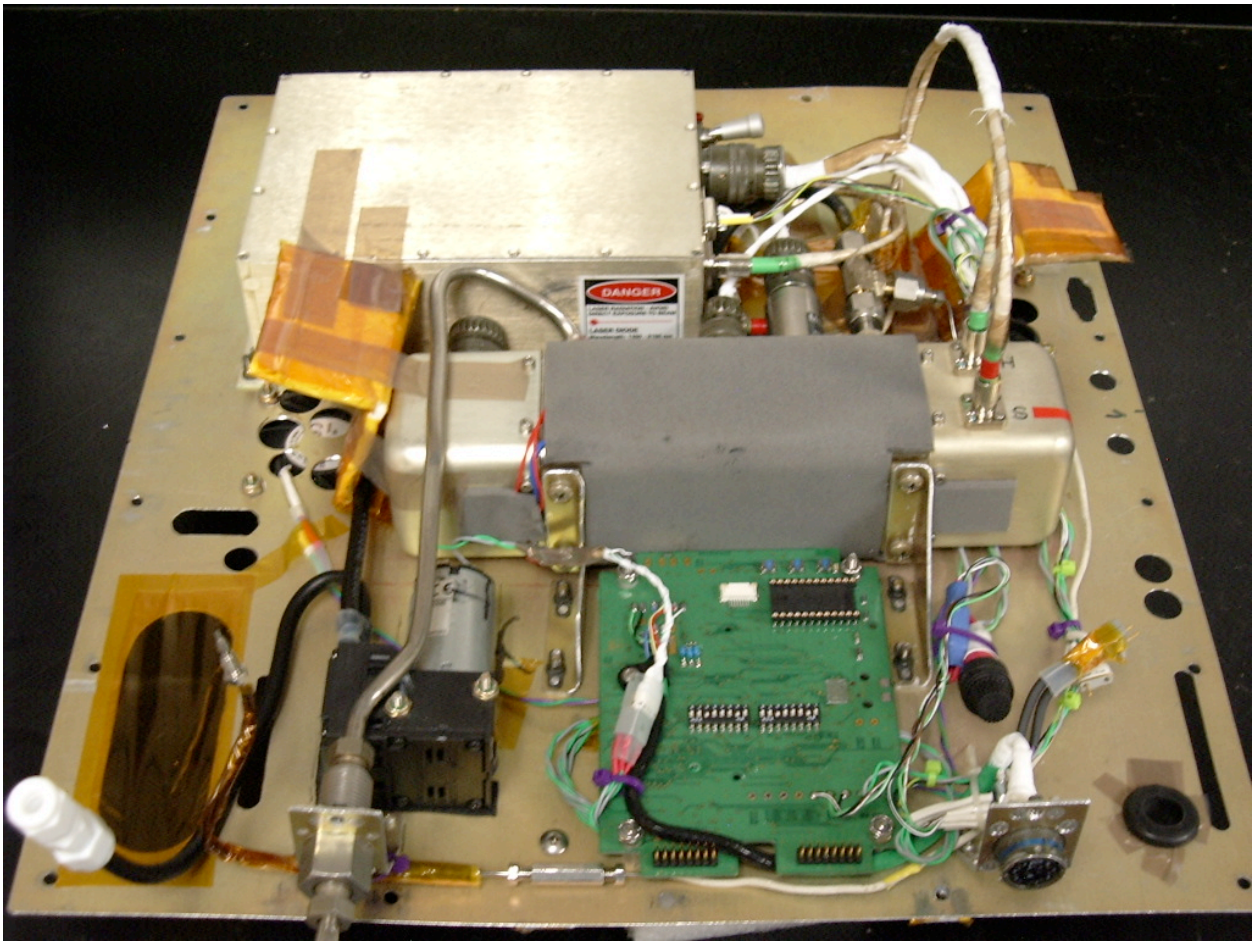


UCATS Dual-Beam Ozone Photometer (OZ)

Tunable Diode Laser Spectrometer for Water Vapor (WV)

The WV TDL spectrometer provides 1 Hz measurements of water vapor using near-infrared (1370 nm) laser absorption spectroscopy with second harmonic detection. Output from the fiber-coupled near-infrared diode laser is split into two optical paths that probe the same temperature-regulated sample cell: a short path (13.4 cm) for H_2O mixing ratios greater than ~700 ppmv, and a long path (389 cm) for H_2O mixing ratios from 1 to ~1000 ppmv. The instrument, mounted on the inside face of the top panel of the UCATS enclosure, utilizes the GC power distribution and data acquisition systems. Air is drawn from a tee in the heated GC inlet tubing, using a small downstream diaphragm pump, to provide sample flows of ~1L min^{-1} to the hygrometer. Water vapor mixing ratios for both optical paths are computed by a microprocessor within the instrument, using vendor-defined calibration parameters and standard pressure and temperature conversions. Mixing ratio values and vital housekeeping data (e.g., cell pressure, cell temperature, laser power, spectral line position) are output via serial port to the GC computer for logging. Calibration is checked in the home laboratory against a cryogenic frost point hygrometer, and in the field using gravimetrically-prepared standards of water vapor in zero air.

Data Interval: 1 s
Accuracy: ±3-5%
Precision: ±2-3%



UCATS Tunable Diode Laser Spectrometer for Water Vapor (WV)