Current and Proposed Miniaturized Instruments for TBS and UAS

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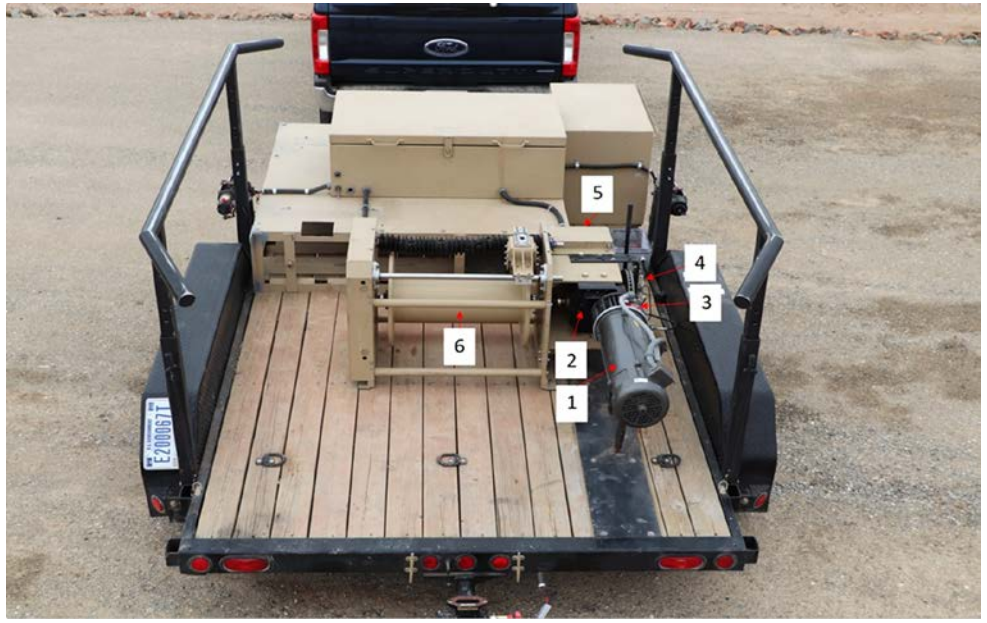
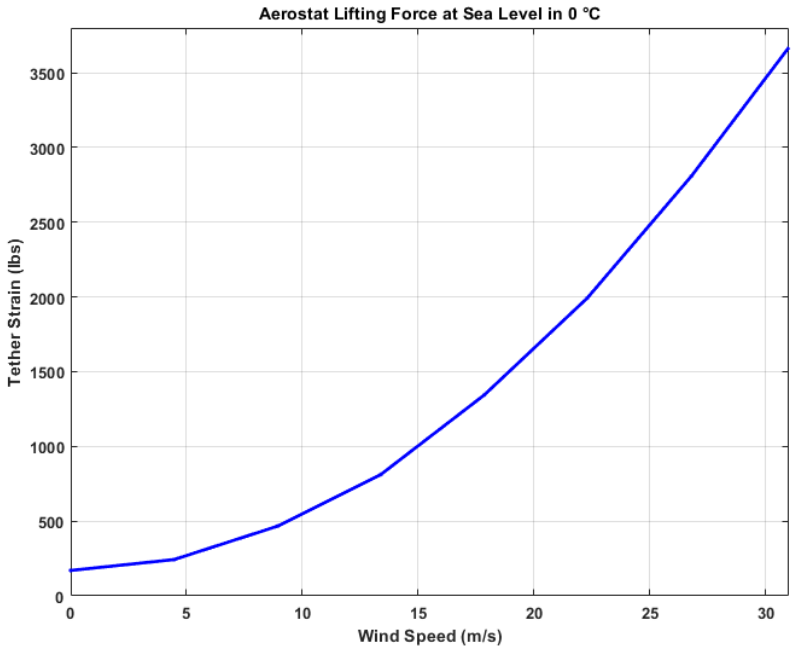
ARM Aerial Instrumentation Update and Discussion, June 24, 2020

ARM TBS Capabilities





1) Baldor 5 HP 180 VDC motor @ 1,276 lbs
2) 75:1 double-reduction gearbox
3) Electronic 24 VDC brake @ 9,400 lbs
4) Secondary hydraulic hand brake
5) 240 VAC reversible regenerative-driven variable speed controller
6) 2.75 km of 3/16” (5 mm) OD 5,500 lb mbs tether

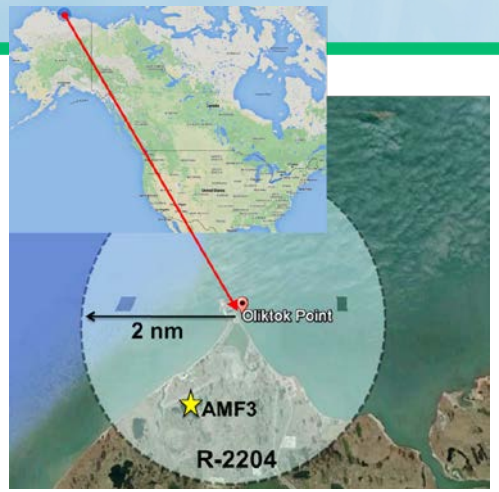
Three TBS trailers in the fleet.

- The TBS employs 3 – 110 m^3 aerostats with a maximum payload capacity of 36 kg depending on the surface altitude.
- The balloon is not launched or retrieved in wind speeds ≥ 10 m/s.
- The balloon may be flown in wind speeds aloft of ≤ 16 m/s.
- The TBS ascends and descends at a maximum rate of 0.4 m/s.
- An instrument size of ≤ 24 inches (61 cm) in any dimension is ideal, although larger shapes can be accommodated.
- An instrument that is longer in the vertical axis than in the horizontal is desirable.

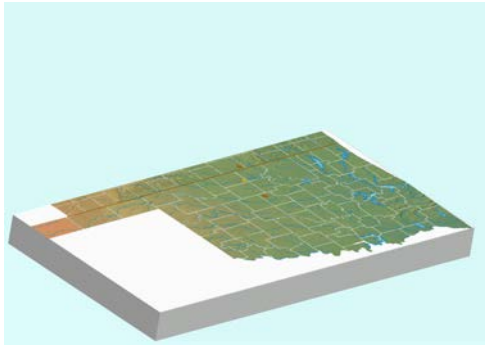
Instrumentation on ARM TBS at AMF3 & SGP

AMF3, Oliktok Point, AK
2015 – 2020
600 TBS flight hours
0 – 7,000’ (2.1 km) MSL
Restricted Airspace flights:

- **In clouds**
- At night
- During low visibility



SGP CF, Billings, OK
2019 – 2020
175 TBS flight hours
0 – 6,000’ (1.5 km) MSL
SGP EF9, Ashton, KS
SGP EF36, Marshall, OK
2020



Cloud Properties

Instrument	Property Measured	Supplier
Supercooled liquid water sondes	Cloud supercooled liquid water content in g/m^3	Anasphere
Video Ice Particle Sampler*	Ice particle maximum dimension, width, area, and aspect ratio from 1 µm – 5 mm	Natural Systems Research
Cloud Droplet Probe*	Droplet ice spectra from 1 µm – 50 µm	DMT, Ismail Gultepe
Backscatter Cloud Probe*	Droplet ice spectra from 5 µm – 75 µm	DMT
Cloud Droplet Measurement System*	Cloud droplet size distribution from 10 µm – 1 mm	Mesa Photonics
*guest instrument		

Aerosol Properties

Instrument	Property Measured	Supplier
Printed Optical Particle Spectrometer (POPS) 4 units by summer 2020	Aerosol size distribution from 140 nm to 3 µm	Handix Scientific
Condensation Particle Counter (CPC) Model 3007 (2 units)	Total aerosol concentration from 0.01 µm to 1 µm	Trust Science Innovation (TSI) Inc.
Cascade impactors (6 units)	Size-resolved chemical composition at four cut-off sizes (0.25, 0.5, 1.0, 2.5 µm)	SKC
ADI MAGIC 200 CPC (3 units)*	Total aerosol number concentration from 1 nm to 1 µm; aerosol size distribution from 1 nm to 3 nm	Aerosol Devices Inc., Chongai Kuang

Gas Phase Properties

Instrument	Property Measured	Supplier
Fielded Remote Organic Sampling Technology (FROST) Sampler*	Identification and concentration of Volatile Organic Compounds on LECO GC-TOFMS > 1 picogram	SNL

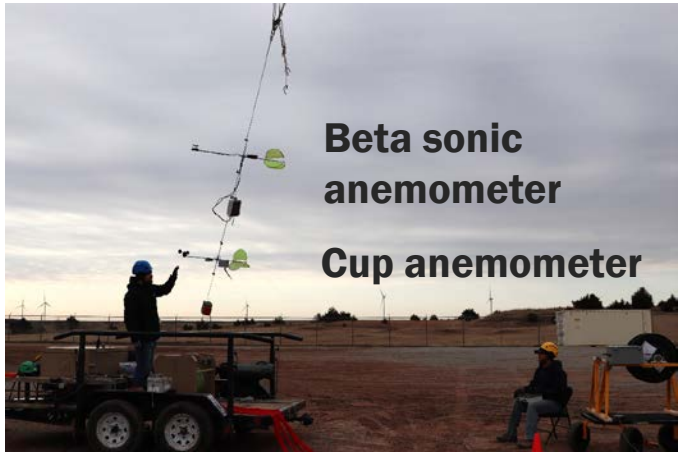
Instrumentation on ARM TBS at AMF3 & SGP

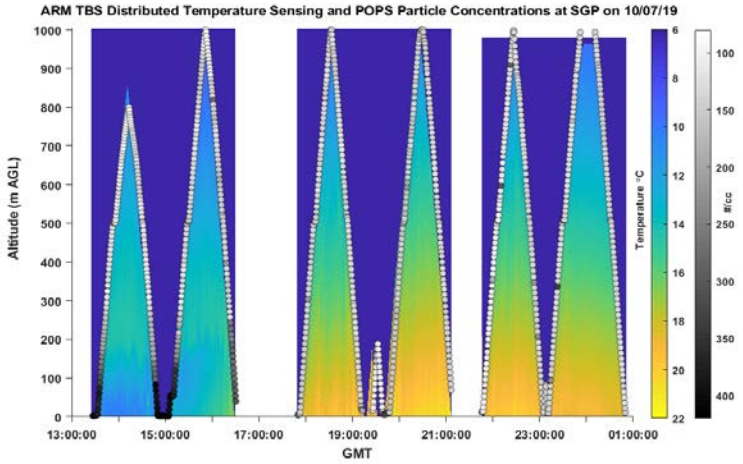
Atmospheric State and Aircraft State

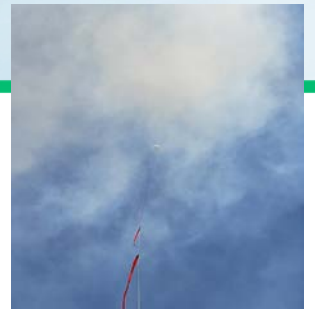
Instrument	Property Measured	Supplier
iMet RSB-1 and RSB-4 radiosondes (multiple)	Pressure, Temperature, RH, 3D GPS	interMet (iMet)
iMet XQ2 UAV Sensor (multiple)	Pressure, Temperature, RH, 3D GPS	interMet (iMet)
Sensornet Oryx DTS*	Distributed temperature sensing at 2 m spatial resolution and 0.08 °C accuracy	Sensornet
Silixa XT DTS*	Distributed temperature sensing at 0.5 m spatial resolution and 0.08 °C accuracy	Silixa
40C cup anemometers (8 units)	1 Hz wind speed	NRG Systems
3-axis sonic anemometer**	Up to 10 Hz u, v, and ω wind speed	Trisonica
3D IMU, barometric pressure altitude, GNSS heading**	Up to 200 Hz x, y, z-axis acceleration and heading (wind direction)	Bosch, U-blox
**in development		

Remote Sensing

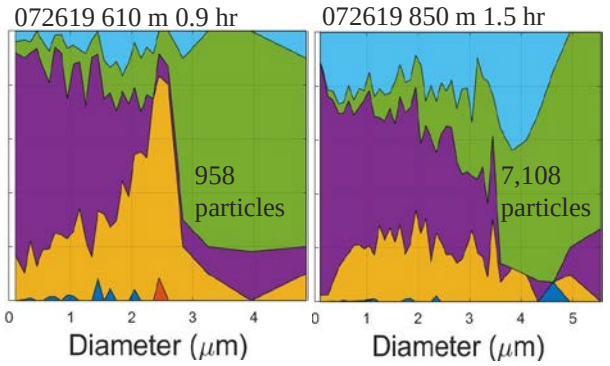
Instrument	Property Measured	Supplier
Mirage 640P*	30 Hz imaging of 1.5 µm – 5.1 µm spectral band, surface temperature	ICI



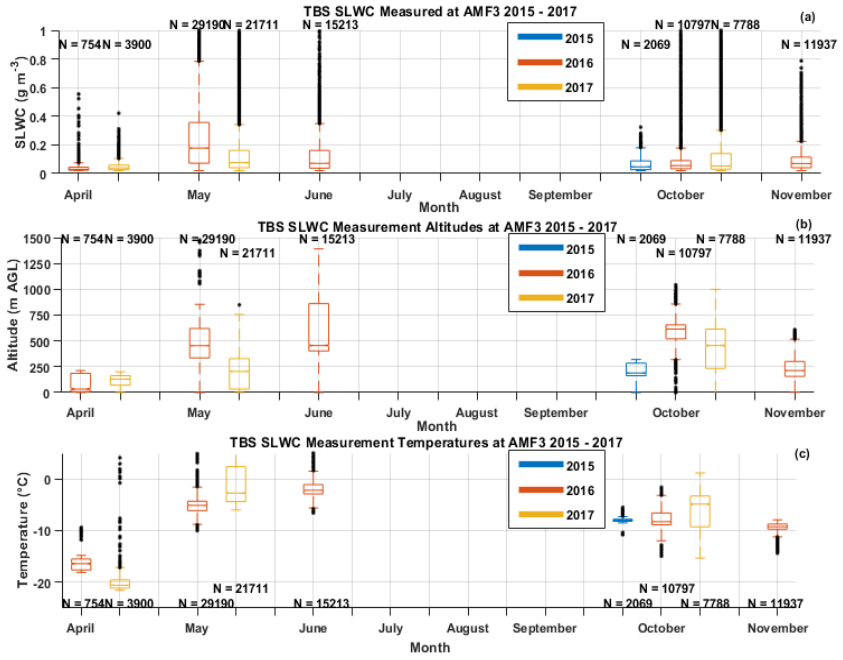




Impactor analysis of 7/26 biomass burning event



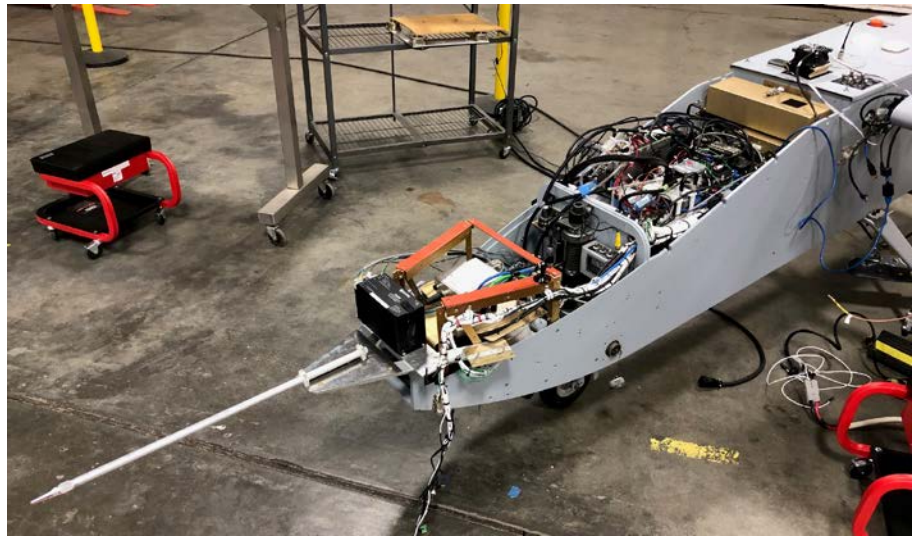
Courtesy of Swarup China and Kuo-Pin Tseng of PNNL/EMSL



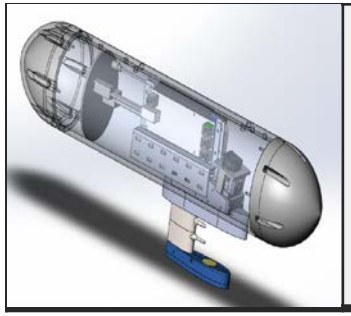
UAS Instrumentation

- Integrated Instruments
  - VectorNav (Position, Attitude)
  - AIMMS-30 (Meteorology)
  - CDP (Cloud Droplet Sizes)
  - MicaSense Camera (multispectral images)
  - IR Thermometer, Heitronics (Surface Temperature)
  - Integrated a POPS into a wing pod (Aerosol Size Distribution)
    - Developed inlet
  - ACCESS (Aerosol composition, number, size, absorption).
    - Developed community inlet
- Not integrated yet
  - Radiation package (SPN1,MFR, and IR20)

HEITRONICS
Infrarot Messtechnik



Proposed Trace Gas Instrumentation for TBS & UAS

	PSI Laser Hygrometer Payload	▪ Operating wavelength: 2.7 µm DFB Tunable Diode Laser (TDL) ▪ Pathlength: 2 x 5 cm = 10 cm ▪ Precision & Accuracy: 2 ppmv at 240 K ▪ Reporting Rate: 1 Hz ▪ 0.82 kg ▪ 39 W ▪ Water vapor mixing ratio from ScanEagle UAS deployment compared with aircraft measurements
	Princeton Mid-IR CH_4 Sensor	• 4.5 kg • 30 W • Can detect 5 ppbv at 1 Hz • Needs larger vertical gradient than 5-10 ppbv • Adaptable for CO and N_2O with no change of detector/optical cell • UAV CH_4 gradient and absolute amounts consistent with Picarro on tower at 1 and 9 m – in-flight comparison
	University of Houston SO_2 sonde	• New single sonde based on traditional ECC O_3 sonde system using iodine/iodide redox reaction • New SO_2 method able to measure large SO_2 plumes ($[SO_2] >> [O_3]$) in detail (up to 250 ppb) without missing the smaller SO_2 plumes • 3 sigma limit of detection of .47 ppb • 1 kg • Compared with original dual SO_2 sonde on 17’ TBS and BlackHawk UAS

Images courtesy of D. Sonnenfroh/Physical Sciences Inc., Lei Tao/Hongming Yi/Mark Zondlo/Princeton University, James Flynn/University of Houston, Rebecca Sheesly/Baylor University

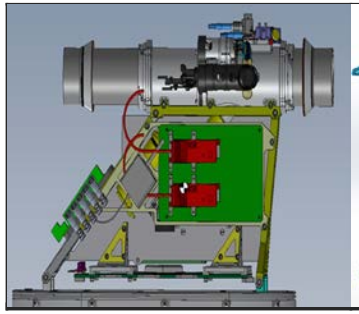
Proposed Aerosol Instrumentation for TBS & UAS

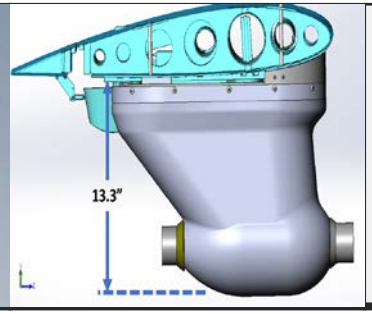
	AethLabs microAeth MA200 Black Carbon monitor	• 715 g • Concentrations of black carbon and ultraviolet particulate matter (indicative of woodsmoke, tobacco, and biomass burning) • 5λ: 375,470,525,628,880 nm • Previous comparison between UAV MA200 and ground based AE-31 • $10,500
	DMT Single Particle Soot Photometer – eXtended Range (SP2-XR)	• 13 kg • 25 W • Refractory black carbon (rBC) number/mass loading, size distributions (50 – 800 nm/1.8 g/cc density), and rBC mixing state • Non-BC size number/mass loading and size distribution (100 – 500 nm) also reported • Used on King Air 300; 2019 POPSICL campaign and in laboratory studies (2019 Paul Scherrer Institute)
	ADI MAGIC 200* CPC	• 2.4 kg • 30 W • May be modified to detect sub 3 nm aerosol • May be adapted to size-resolve sub 3 nm aerosol based on the grown droplet size spectrum • May be used with radio telemetry to inform dynamic operation of TBS to target NPF • Deployment on 3 ARM TBS campaigns thus far with more scheduled

Proposed Instrumentation for TBS & UAS

APRSWorld Wind Sensor

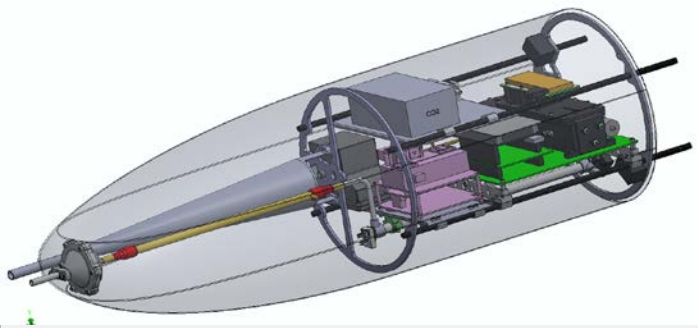
- 10 Hz 3D wind speed
- +/- 5 degree VectorNav wind direction
- 1 Hz p, T, RH
- $6,500
- Prototype undergoing comparisons with existing 2D TBS cup anemometers, DL, and surface-based 3D sonic anemometers





SPEC Sharkeye

Instrument	Measurement Type	Sensor Specs	Target Resolution	Measurement Range	Sampling Speed	Laser Wavelength
µCPI	Camera	1024*1280 8 bit gray scale	1µm per pixel	1µm to 1mm	~30 Hz	905 nm
µ2D-gray	Imaging	128 Photo-Diode Array	5µm per pixel	5-640µm	Continuous	830 nm
µFCDP	Forward Scattering	Signal and Qualifier Photodiode	1µm	1-50 µm	Continuous	785 nm



NOAA NightFOX

- *Instrument package for measurement of modified combustion efficiency (MCE) and aerosol loading:*
- CO_2 (NDIR absorption at ~4 µm), < 1 ppmv precision @ 1 s
- CO (2 x Alphasense CO sensors)
- Aerosol, fine mode (POPS)
- Aerosol, coarse mode (AlphaSense OPC)
- Aerosol filter sampler
- *Remote-sensing package for fire extent (perimeter) and spatially resolved fire radiative power (FRP):*
- Visible and Thermal IR (7.5 – 13.5 µm), FLIR Duo R (44° x 57° FoV)
- SWIR, ~1.6 µm imager and cross-track scanner
- MWIR, ~4 µm cross-track scanner
- ***Remote-sensing package not suitable for use TBS**

Images courtesy of Paul Lawson/SPEC, Troy Thornberry/University of CO