

A Multipollutant Smoke Emissions Sensing and Sampling Instrument Package for Unmanned Aircraft Systems: Development and Testing

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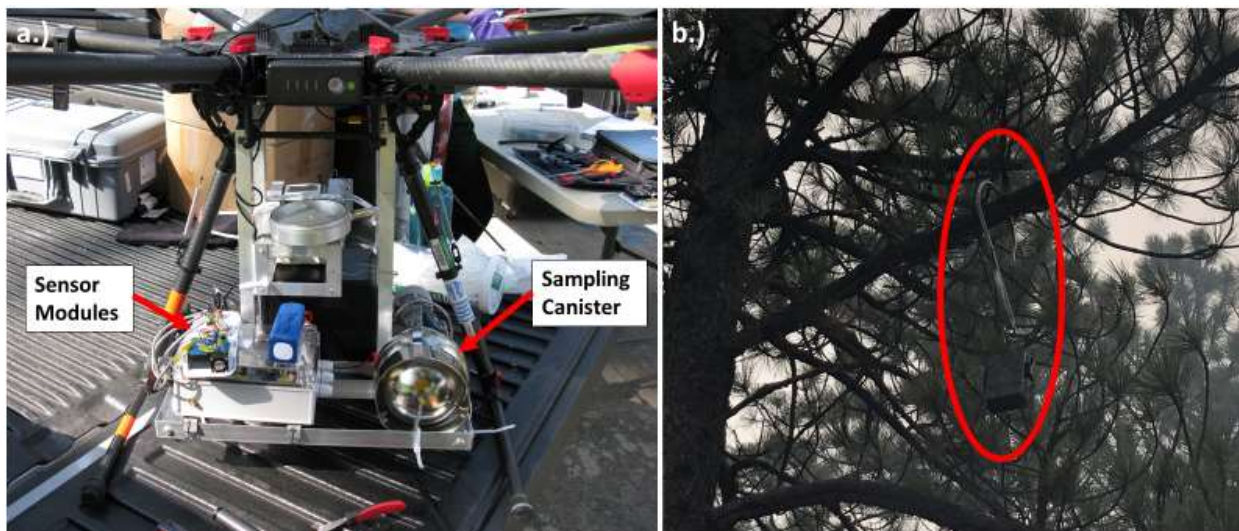


Figure 1. Instrument configuration in Tall Timbers, FL (left) and Sycan Marsh, OR (right). (a) A prototype of the sensing module and one sample canister mounted below a DJI Matrice 600 Pro hexacopter on a custom aluminum rack. At this time, the instrument was in the early stages of development and as such, only data from the canisters were analyzed. Instrumentation not related to this article is also included in the image. (b) The sensing module as shown in Figure 1 and described in this article was hung in a tree approximately 8 m above the ground level and collected emissions measurements as the fire passed underneath.

Table 1. Specifications for CO, CO₂, and PM sensors.

	DGS-CO 968-034 CO	K-30 CO₂	PMS 5003 PM
Resolution	0.1 ppm	1 ppm	1 µg/m ³
Accuracy	± 15 % ¹	± 30 ppm or ± 3% ²	± 10 µg/m ³ (within 0~100 µg/m ³) ⁴
Measurement range	0 to 1000 ppm	0 to 10,000 ppm ³	0 to ~1000 ppm (PM _{2.5}) ⁵
Response time	< 30 s (15 s typical) (T ₉₀)	20 s diffusion time (T _{1/e})	< 1 s
Power or current consumption	12 mW (continuous sampling)	40 mA average	≤ 100 mA (active sampling)
Weight or dimensions	< 2 ounces	57 mm x 51 mm x 14 mm	50 mm x 38 mm x 21 mm

¹ 15% of measured value within specifications, zero accuracy ± 1 ppm.

² ± 3% of measured value when concentrations are > 1000 ppm and within specifications.

³ 0 – 5,000 ppm within specifications.

⁴ ± 10% at 100~500 µg/m³.

⁵ 0 – 500 ppm effective range (PM_{2.5}).

Table 2. Volatile Organic Compound (VOC) concentrations and analytical measurement uncertainty (MU) observed at Tall Timber Research Station, FL, USA in April 2018.

Site	Pebble Hill - Ambient 1	Pebble Hill - Ambient 1	Pebble Hill - Active Fire 1	Scrub Course - Active Fire 2	Scrub Course - Active Fire 3
units	ppbv ± MU	ppbv ± MU	ppbv ± MU	ppbv ± MU	ppbv ± MU
iso-pentane	0.000±0.001	0.077±0.121	9.534±14.94	0.389±0.61	4.607±7.219
benzene	0.049±0.058	0.136±0.16	3.577±4.209	1.556±1.831	3.376±3.972
1-butene + isobutene	0.126±0.144	0.319±0.338	1.882±1.92	0.982±1.009	1.408±1.441
1,3-butadiene	0.000±0.001	0.000±0.001	1.402±2.008	0.661±0.947	1.281±1.835
toluene	0.000±0.001	0.068±0.108	1.126±1.781	0.457±0.723	0.788±1.246
styrene	0.000±0.001	0.275±0.149	0.750±0.406	0.415±0.225	0.591±0.32
isoprene	0.064±0.094	0.201±0.298	0.769±1.139	0.374±0.554	0.468±0.693
alpha-pinene	0.166±0.244	0.174±0.256	0.686±1.008	0.367±0.539	0.285±0.419
m&p-xylene	0.000±0.001	0.069±0.112	0.539±0.874	0.218±0.353	0.315±0.511
n-decane	0.361±0.313	0.000±0.001	0.215±0.186	0.000±0.001	0.528±0.457
ethylbenzene	0.000±0.001	0.044±0.001	0.424±0.001	0.224±0.001	0.342±0.001
1-pentene	0.000±0.001	0.077±0.001	0.363±0.001	0.190±0.001	0.236±0.001
4-ethyltoluene	0.000±0.001	0.000±0.001	0.224±0.001	0.195±0.001	0.205±0.001
t-2-butene	0.000±0.001	0.000±0.001	0.265±0.001	0.131±0.001	0.201±0.001
o-xylene	0.000±0.001	0.050±0.07	0.221±0.307	0.120±0.167	0.160±0.223
2-methyl-1- pentene	0.000±0.001	0.000±0.001	0.263±0.001	0.118±0.001	0.132±0.001
c-2-butene	0.000±0.001	0.029±0.001	0.221±0.001	0.117±0.001	0.131±0.001

n-nonane	0.000±0.001	0.000±0.001	0.155±0.001	0.127±0.001	0.125±0.001
3-ethyltoluene	0.000±0.001	0.000±0.001	0.163±0.001	0.114±0.001	0.125±0.001
cyclohexane	0.000±0.001	0.052±0.082	0.165±0.26	0.054±0.085	0.084±0.132
2-methyl-1-butene	0.000±0.001	0.000±0.001	0.148±0.001	0.088±0.001	0.109±0.001
n-hexane	0.000±0.001	0.022±0.001	0.148±0.001	0.046±0.001	0.076±0.001
2-methyl-2-butene	0.000±0.001	0.000±0.001	0.117±0.001	0.071±0.001	0.076±0.001
cyclopentene	0.000±0.001	0.000±0.001	0.117±0.001	0.057±0.001	0.058±0.001
n-propylbenzene	0.000±0.001	0.067±0.001	0.092±0.001	0.000±0.001	0.064±0.001
t-2-pentene	0.000±0.001	0.000±0.001	0.083±0.001	0.045±0.001	0.087±0.001
1-heptene	0.000±0.001	0.022±0.001	0.080±0.001	0.035±0.001	0.049±0.001
c-2-pentene	0.000±0.001	0.000±0.001	0.052±0.001	0.024±0.001	0.063±0.001
1,3,5-trimethylbenzene	0.000±0.001	0.000±0.001	0.054±0.001	0.034±0.001	0.037±0.001
n-octane	0.042±0.043	0.076±0.079	0.000±0.001	0.000±0.001	0.000±0.001
o-ethyltoluene	0.000±0.001	0.000±0.001	0.069±0.001	0.000±0.001	0.031±0.001
cyclohexene	0.000±0.001	0.000±0.001	0.042±0.001	0.021±0.001	0.019±0.001
3-methylpentane	0.000±0.001	0.000±0.001	0.040±0.001	0.012±0.001	0.023±0.001
isopropylbenzene	0.000±0.001	0.000±0.001	0.030±0.001	0.019±0.001	0.023±0.001
1,2-butadiene	0.000±0.001	0.000±0.001	0.071±0.001	0.000±0.001	0.000±0.001

1,2,3-trimethylbenzene	0.000±0.001	0.000±0.001	0.050±0.001	0.000±0.001	0.019±0.001
n-heptane	0.000±0.001	0.000±0.001	0.029±0.001	0.017±0.001	0.013±0.001
bz124m_ibubz	0.000±0.001	0.000±0.001	0.026±0.001	0.000±0.001	0.013±0.001
2,2,4-trimethylpentane	0.000±0.001	0.000±0.001	0.019±0.001	0.000±0.001	0.018±0.001
methylcyclopentane	0.000±0.001	0.000±0.001	0.031±0.001	0.000±0.001	0.000±0.001
t-2-hexene	0.000±0.001	0.000±0.001	0.013±0.001	0.000±0.001	0.000±0.001
methylcyclohexane	0.000±0.001	0.000±0.001	0.007±0.001	0.000±0.001	0.003±0.001
