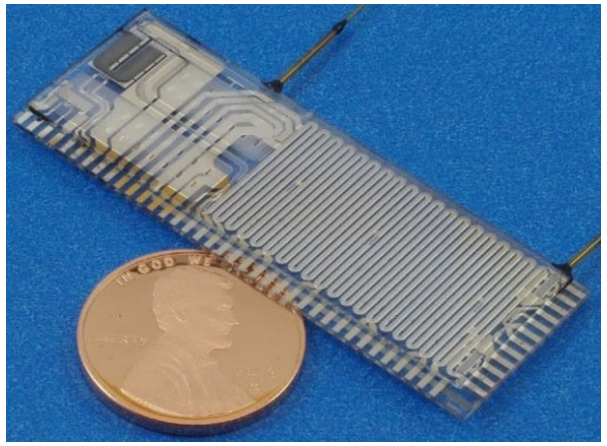
IoT VOC Monitoring with a Fully Autonomous MEMS-based micro-GC

Presented by:

Nabil Saad, Ph.D.

Omniscent Platform



Analytic MEMS Sensor

- Simultaneous multi-gas detection
- LoD < 1ppb
- Dual detectors
- Ambient air as carrier gas
- Low power consumption

OMNI-2200

- Autonomous, Remote Management
- BTX speciation
- WiFi / LTE connection
- Edge computing
- Lightweight 10.4 lb

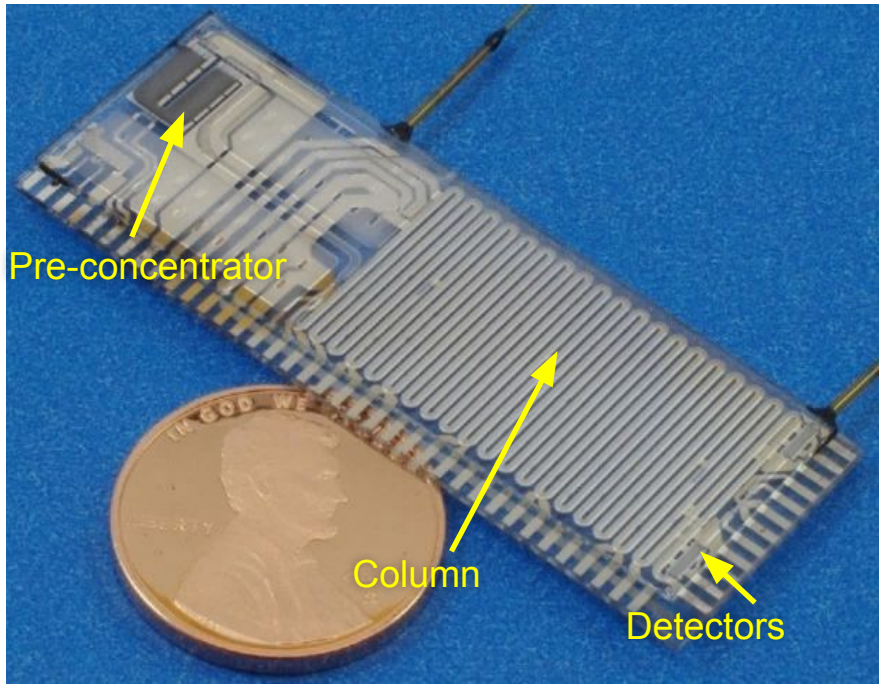
Analytics (OMAP)

- Cloud Analytics
- Remote management via Internet
- Data Visualization on portal
- End-to-end data encryption
- User-defined alerts & notifications

Micro-GC MEMS Chip Architecture

MEMS Chip Components

- Pre-concentrator
  - ✔ Two sorbent beds in series: (Carbopack X™ & Carbopack B™)
- Separation column
  - ✔ 0.6m long with an OV-1 equivalent stationary phase
- Two complementary capacitive detectors
- Flow rate sensor
- Four temperature sensors
  - ✔ One for the Pre-concentrator
  - ✔ Three for the serpentine GC column



Monolithic MEMS µGC Chip

Proprietary MEMS µGC Benefits

A monolithic µGC chip based on Micro-ElectroMechanical Systems Technology

- Benefits of MEMS
  - ✔ Small, light weight
  - ✔ Integrated, repeatable, rapid, and low-power temperature control
  - ✔ High throughput batch production
- Benefits of monolithic integration
  - ✔ Simplifies assembly post-fabrication
  - ✔ Reliable fluidic interconnect between µGC components

Current Gas Library

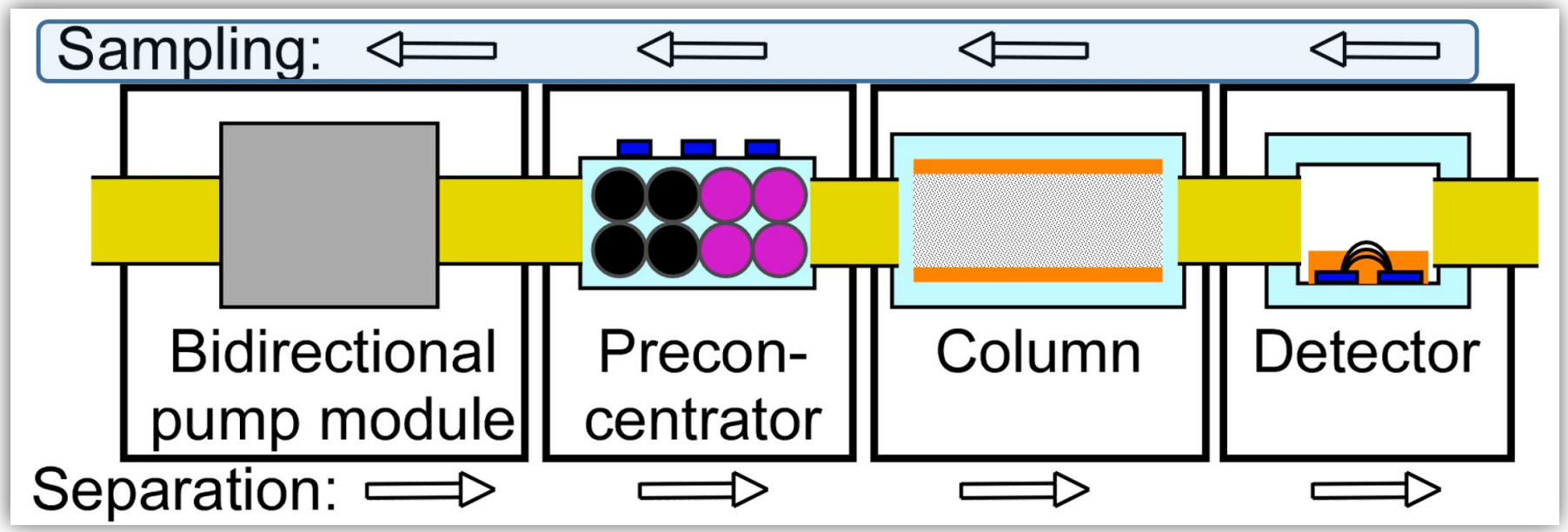
- Current Library
  - Benzene
  - Toluene
  - Ethyl Benzene
  - m-Xylene
  - o- Xylene
- Next Library
  - Styrene
  - Methylal

- Gases detected by Current MEMS Column:

		#	Chemicals
non-polar	Alkanes	*a1*	*n*-pentane
		a2	*n*-hexane
		a3	*n*-heptane
		a4	*n*-octane
		a5	*n*-nonane
		a6	*n*-decane
non-polar	Aromatic hydrocarbons	*b1*	benzene
		b2	toluene
		b3	*m*-xylene
		b4	*o*-xylene
		b5	mesitylene
mildly-polar	Halogenated hydrocarbons & aldehydes	*c1*	hexanal
		c2	chlorobenzene
		c3	chlorohexane
		c4	4-chlorotoluene
		c5	1,3-dichlorobenzene
		c6	Tetrachloroethene
non-polar	Terpenes & other	*d1*	cycloheptane
		d2	α-pinene
		d3	3-carene

Proprietary MEMS µGC Workflow

*Scrubbed ambient air used as the carrier gas during separation



MEMS Micro-GC Operation

Vapor sampling

User-programmable sampling time
(Sampling flow ≈17 sccm)

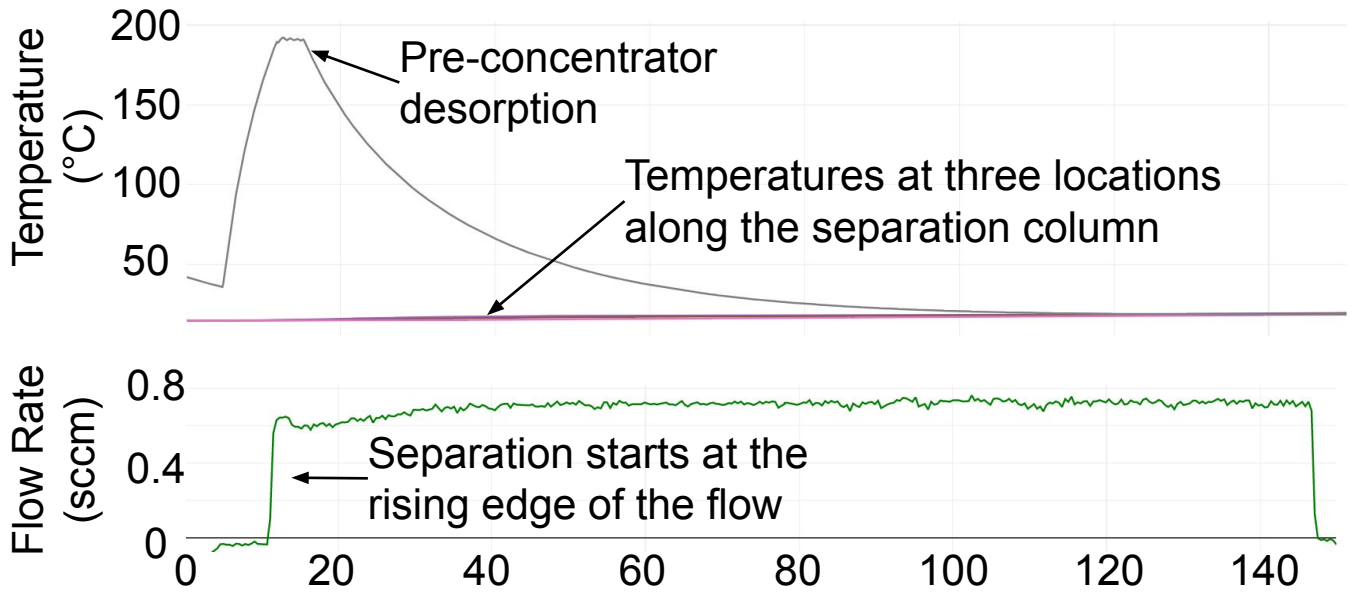
- **2 minutes** for high concentration levels (≥200 ppb)
- **10 minutes** for low concentration levels (≥10 ppb)
- **40 minutes** for ultra-low concentration levels (≤1ppb)

Other steps

- Purging steps for regenerating the analytical path for the next run
- Temperature stabilization
- Data processing and upload

Separation

Parameters optimized by Omniscent staff

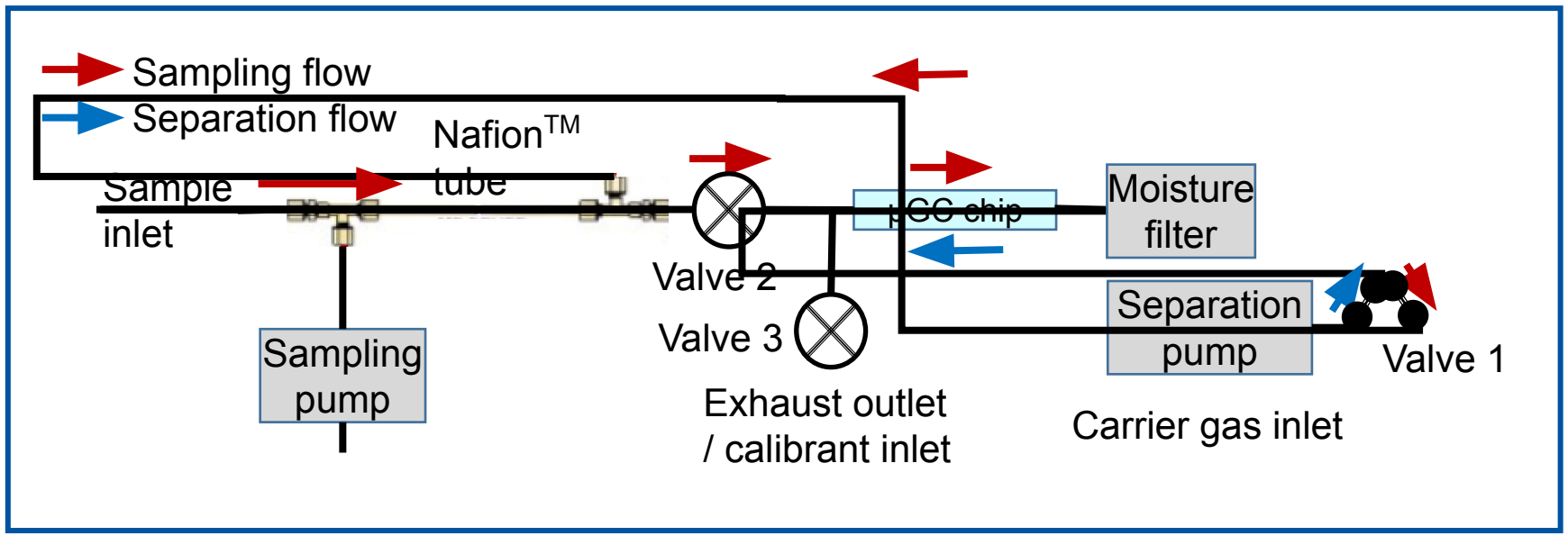


Tolerance to Environmental Stressors

- Humidity
  - ✔ Nafion® tube used in the *sampling* flow path to remove sample moisture
  - ✔ Moisture filter used in the *separation* flow path to remove carrier gas moisture
  - ✔ Both Nafion® & the Moisture Filter are self-regenerated *in situ*

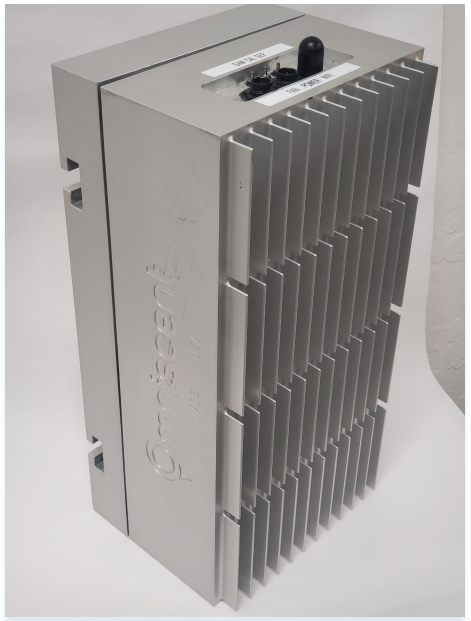
- Temperature Stability
  - ✔ The µGC chip has a temperature-controlled enclosure

- Dust Removal
  - ✔ Dust Filters installed at sample inlet & carrier gas inlet



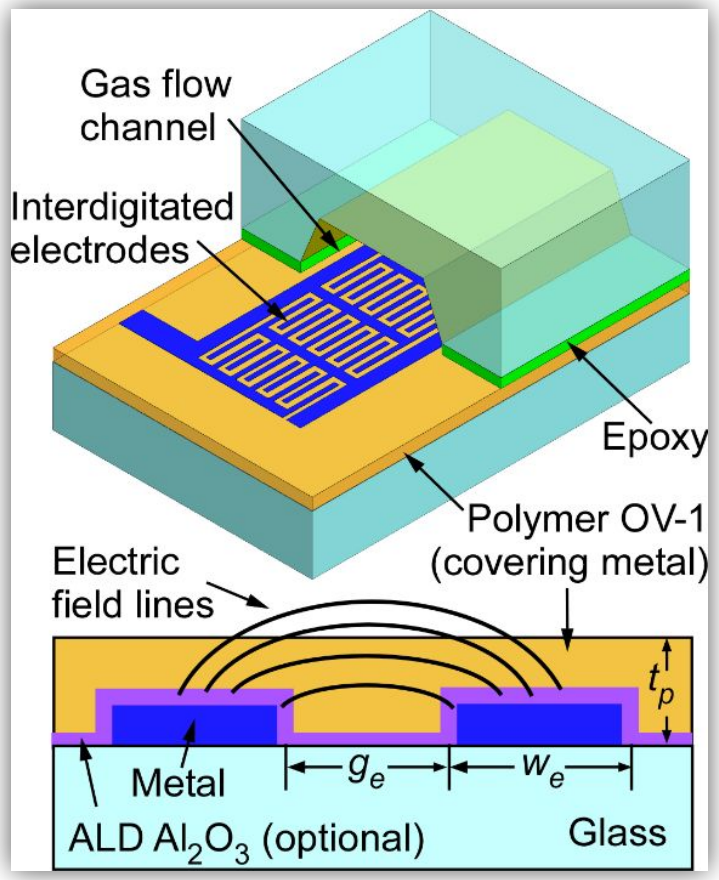
Design Enhancements

- Hermetically sealed enclosure with O-ring:
  - Hermetically sealed enclosure design for high RH tolerance
  - All connectors are tight-sealed to unit enclosure
  - Equipped w/ Internal Heater for < 5°C ambient temp
  - All units tested in environmental chamber for:
    - ✔ RH ≥95%
    - ✔ Temperature range (0°C - 60°C)
- False-Positive VOC Flagging (based on Det1/Det2).
- Continuous Operation mode (endless # of cycles).
- Weather sensor config & link to the full meteorological data page
- Coating of all electronic board with water resistant film.



OMNI-2200

Proprietary MEMS µGC Dual Detectors



Capacitive Detector Structure

- Interdigitated thin metal electrodes on glass
- Vapor-sensitive polymer (OV-1 equivalent) covers electrodes
- Capacitance change (ΔC) by polymer swelling and change in dielectric constant (ε) upon vapor absorption

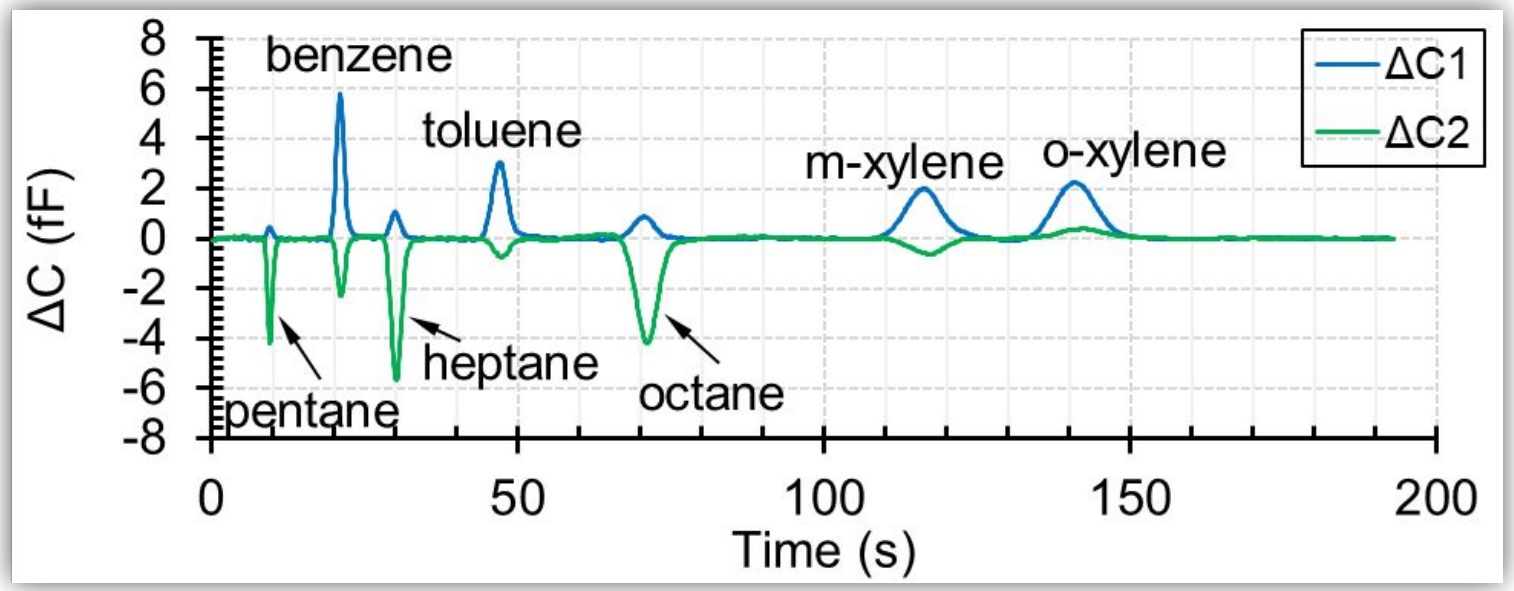
Principle of detection

- CapDet1:**Thin** OV-1 coating; ΔC dominated by swelling; $+\Delta C$ for all chemicals.
- CapDet2:**Thick** OV-1 coating; ΔC dominated by ε-change; + or - ΔC depending on $\varepsilon_{chemical} - \varepsilon_{OV\text{-}1}$

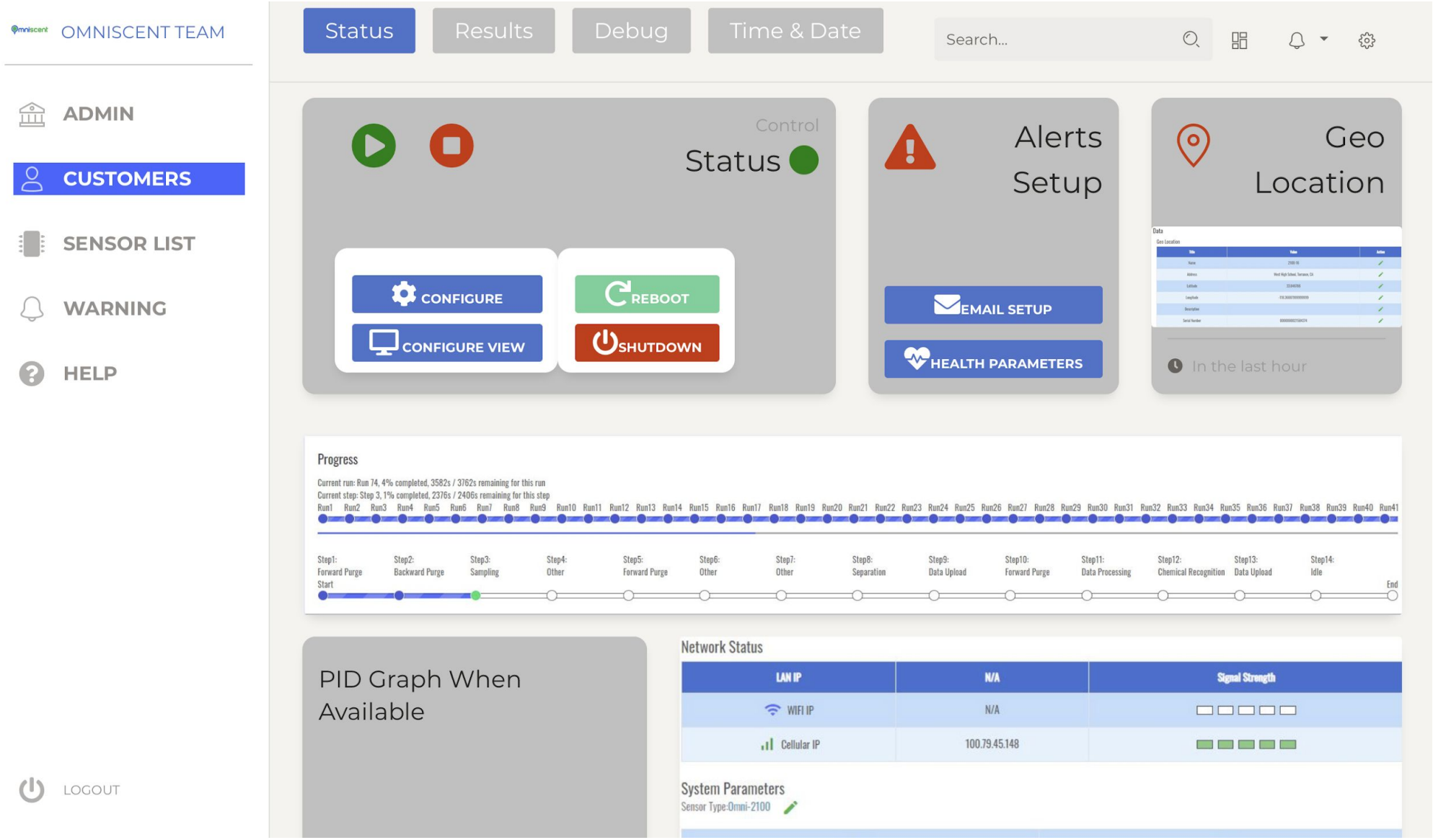
Compound Identification Using Two Detectors

- Peak height ratio of our two detectors (ΔC1/ΔC2):
  - Provides an extra level of chemical identification beyond just the retention time metric

- ΔC1/ΔC2 is:
  - ✔ ≈ -3 for Benzene
  - ✔ Between 0 & -0.5 for alkanes
  - ✔ >0 for polar & mildly-polar chemicals



Web-based User Interface



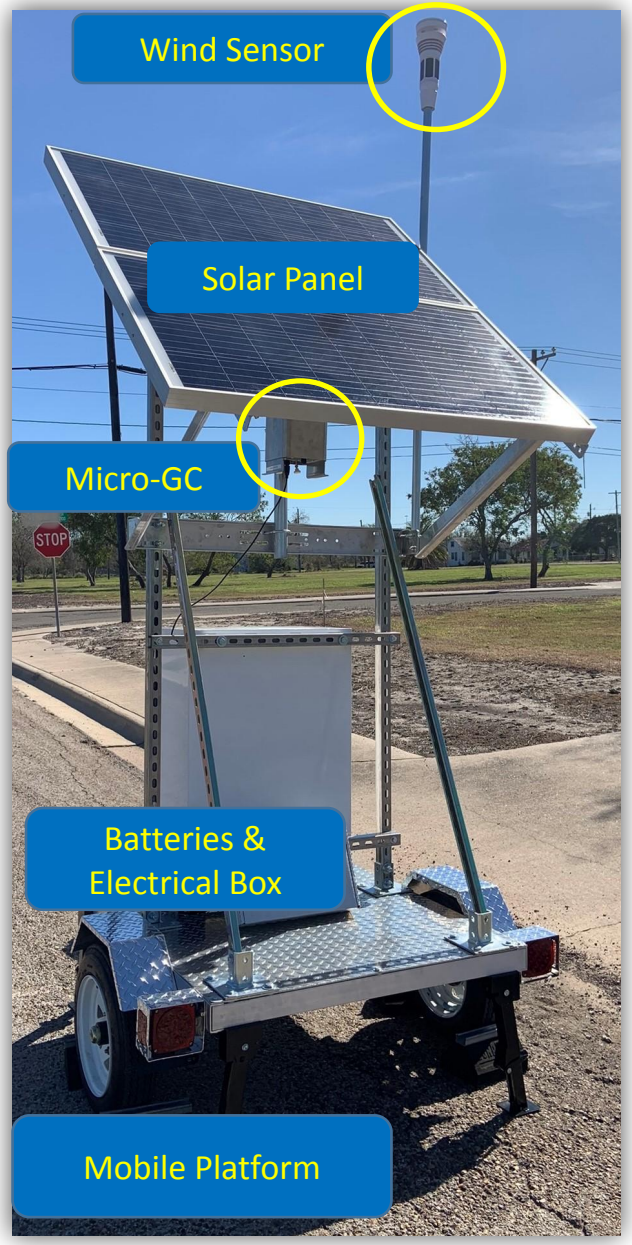
Omniscent BTX Fenceline Monitoring

- Autonomous, portable
- Near real-time
- Speciation
- In-system, onsite analysis
- Low CapX, OpX

Solar-Power Option

- Solar-powered
- Onboard WiFi
- Anemometer
- Mobile platform

- 240 Watt PV system
- Sustains 6.5 days of no-sun
- 265 A-hr Battery



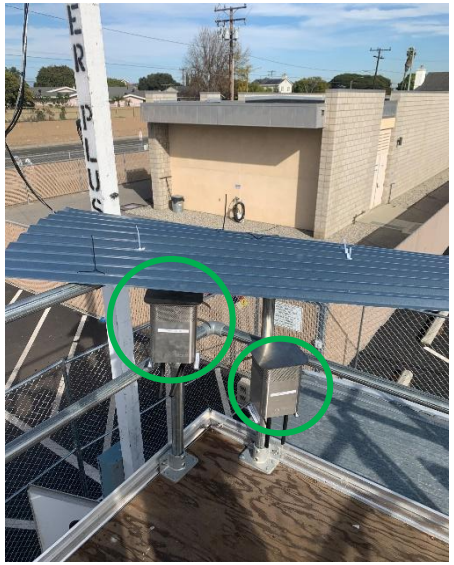
This platform is conducive for emissions monitoring in remote locations

Field Deployment

- Small & simple form factor to deploy in tight spaces.
- Easy access to web interface (portal) for data viewing & retrieval.
- Text alerts for threshold-exceeding user-set VOC values.
- Low detection limits: sub-1ppb.
- Flexible sampling times and intervals.
- Solar power for off-grid operation.
- Wind speed & direction measurements for emissions source attribution.

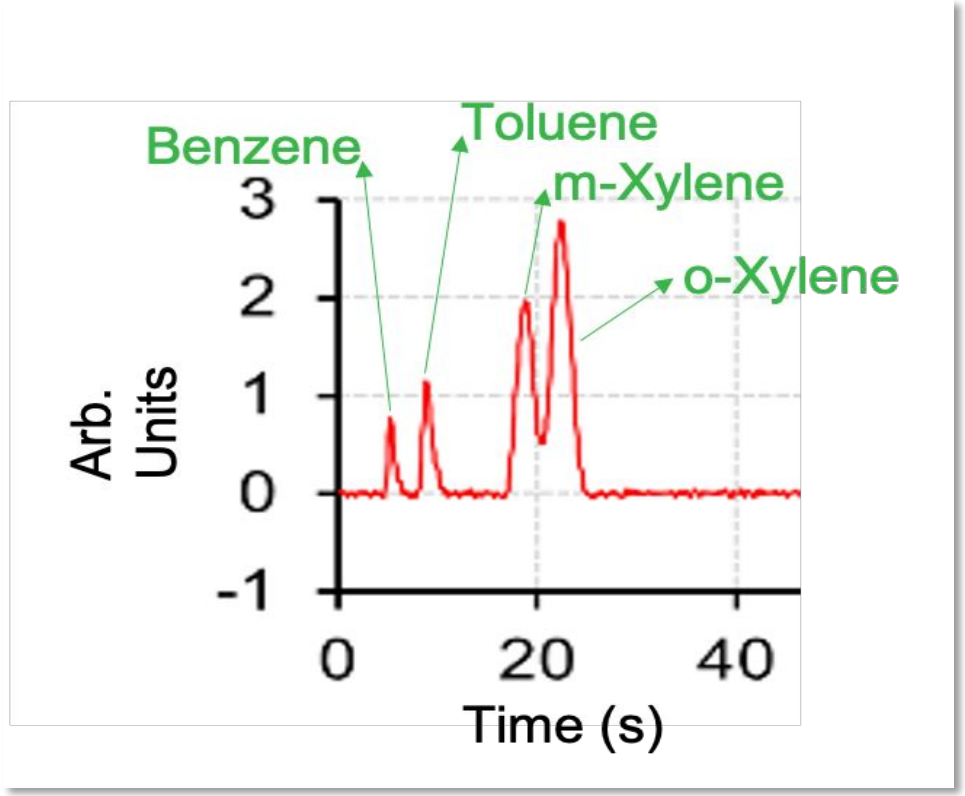
Refinery Deployment in Texas

Deployment in CA



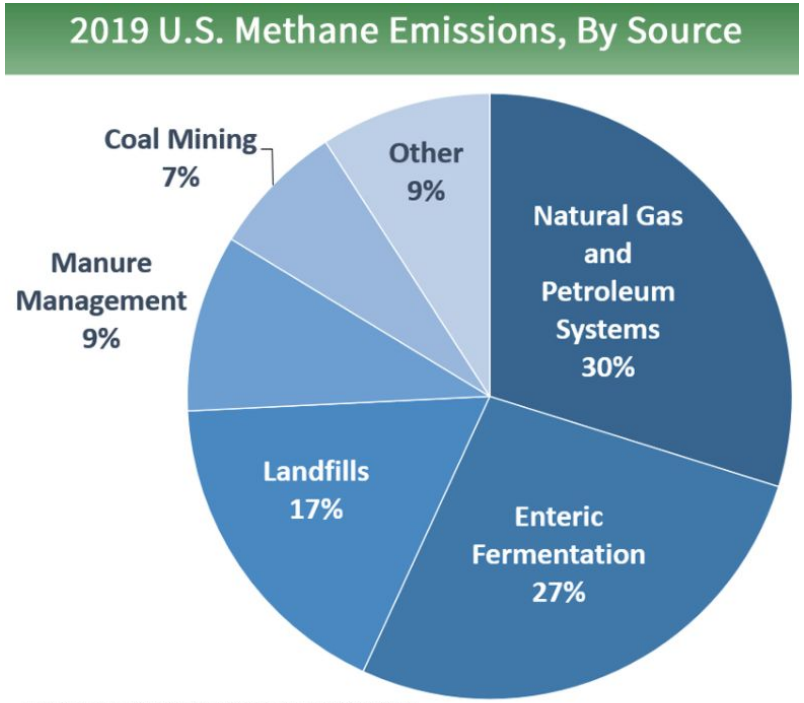
Fast GC Analysis – High Conc. Scenario

OMNI-2100 µGC achieves ultrafast analysis of BTX in less than 40sec cycle



COP26 & Methane Monitoring

- US & EU announced joint pledge to cut Methane emissions.
- Commitment to reduce 30% Methane emissions by 2030.
- **300,000** Oil & Gas well sites <u>to be monitored</u> in the US.



U.S. Environmental Protection Agency (2021). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019

Omniscent Low Cost IoT Methane Sensor

- A new high-performance, low-cost and small-size NDIR sensor module with sub-ppm resolution.
- Measures CH_4 at **0.1ppm** resolution.
- Measures H_2O & reports dry mole fraction.
- Measures Total Hydrocarbons at 1ppm resolution.
- GPS + WiFi/Cell.
- Commercial units available in Q4.