**A personal monitor for Environmental Volatile Organic Compounds (VOC)**

# Total VOC Monitoring Device

TF Health

*Personal sensors for better health*

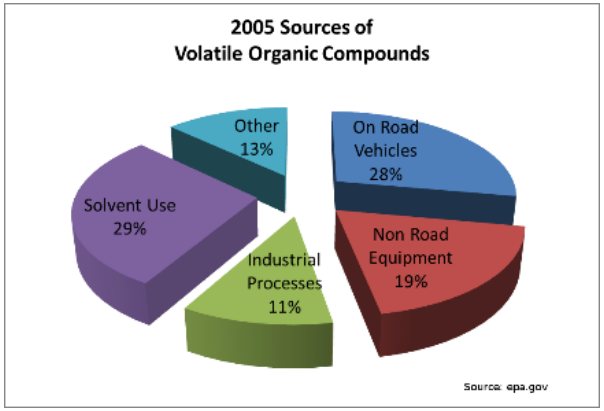
TF Health Co. (d.b.a. Breezing)
1761 W. University Dr., Suite 140,
Tempe, AZ 85281
480-629-5360
www.breezing.com

# *Outline*

- **Introduction to volatile organic compounds (VOCs) and existing sensing technologies.**
- **A chemical sensor for VOCs monitoring.**
- **Sensor & device specifications.**
- **Comparison with current methods and use.**
- **Market analysis.**
- **Summary.**

# Volatile Organic Compounds

- **What are VOCs?**
  - ✓ Volatile organic compound is a broad category of chemical compounds that contain carbon and hydrogen, and are characterized by their volatility.
  - ✓ Majority of VOCs are man-made.
  - ✓ A few examples: benzene, toluene, ethyl benzene, xylenes (BTEX)
- **Why VOCs?**
  - ✓ Dangerous to human health.
  - ✓ Forms ozone.
  - ✓ Destroying the natural processes of plants.
  - ✓ Can form an explosive mixture in air.
  - ✓ EPA estimates 2.2E-4 to 7.8E-4 percent of increased chance of getting cancer if exposed to 0.3 ppb benzene in the air over lifetime.
- **No standards for VOCs in non-industrial setting nor personal level.**



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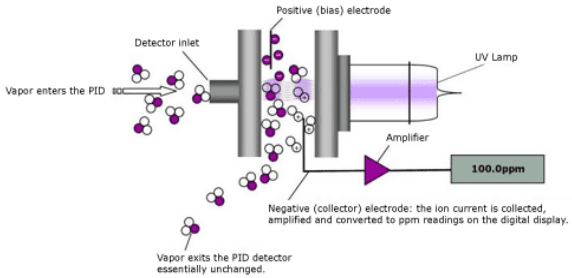
# Existing technologies

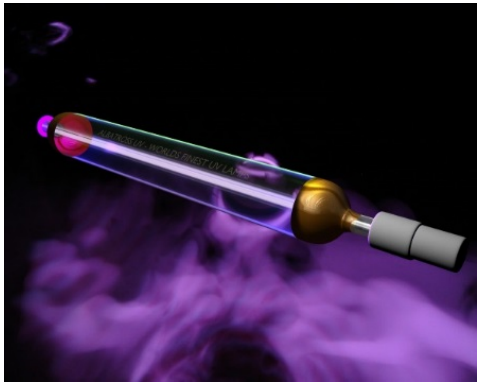
GC-MS:

- Accurate
- Bulky
- Expensive
- Not real time

PID:

- Real-time
- Low selectivity
- Expensive



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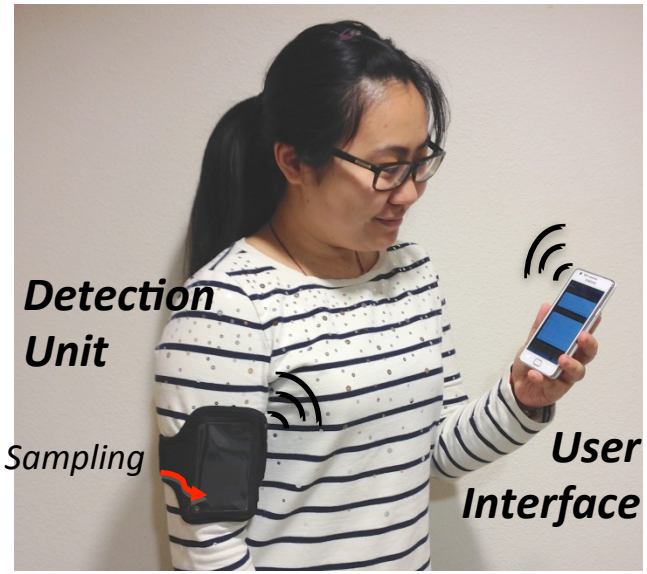
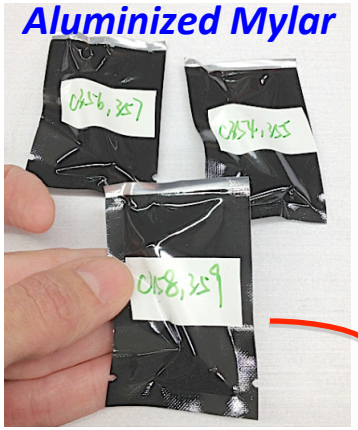
# Personal Environmental Exposure Devices

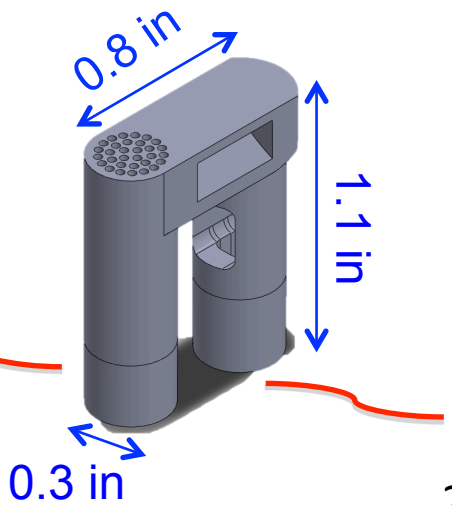
***VOC monitoring device***



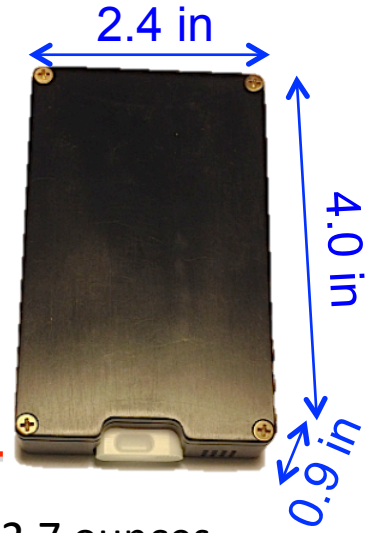

***Sensor Cartridge Package***




***Sensor Cartridge***




***Detection Unit***

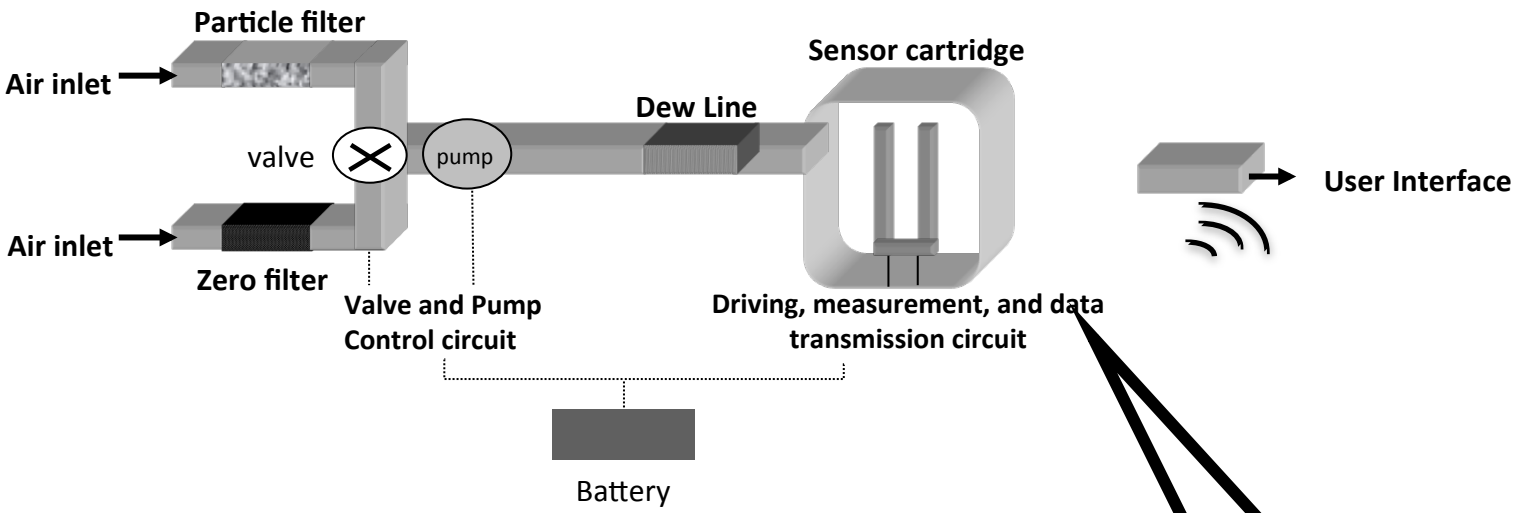



2.7 ounces

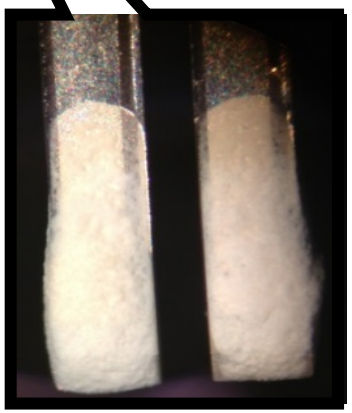
***<u>Detection of VOCs:</u> total toxicant hydrocarbons from petroleum derivatives and acids resulting from burning products ($H_2S$, HCl, HCN)***

# Intellectual Property Status

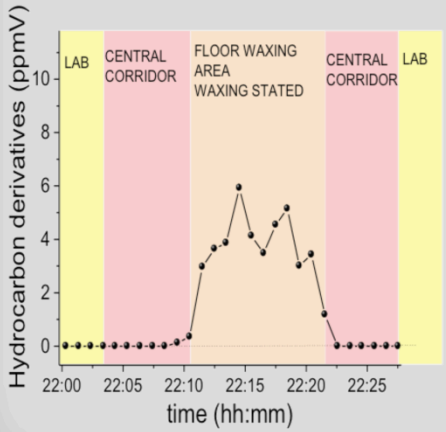
**Sensing materials for selective and sensitive detection of hydrocarbons and acids.**
**United States Patent Number: 13/695,883**

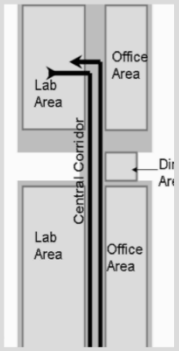



**A quartz tuning fork oscillator**

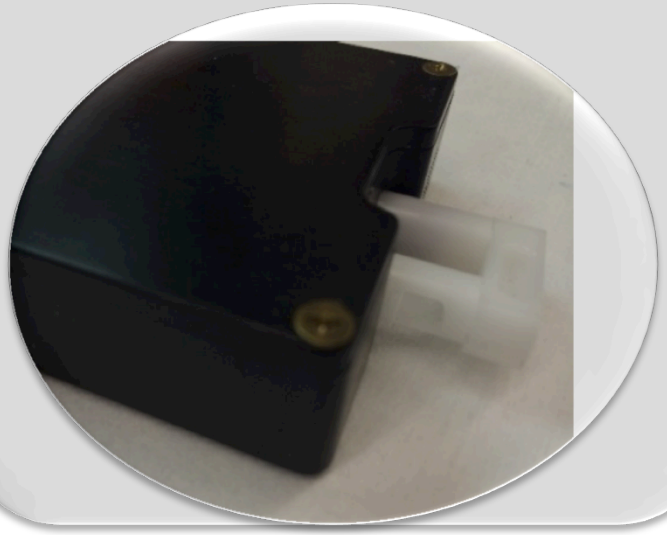


- **Accurate**



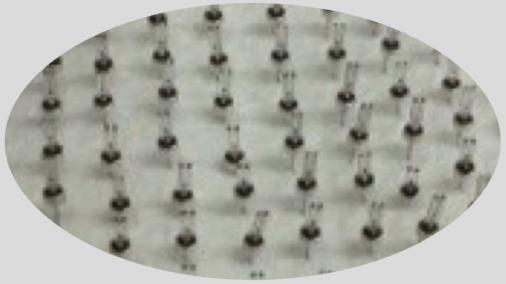

- **Replaceable sensor**



# Design Approach

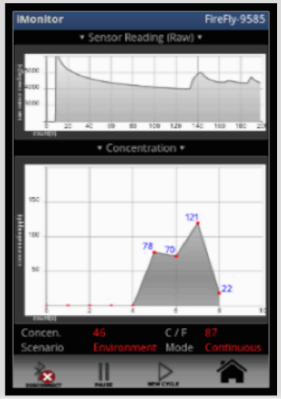
- **Calibration free**

  **Pre-calibrated sensor array**



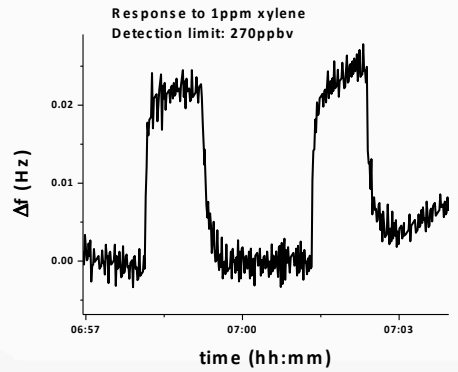
- **Mobile application**

  **User-friendly interface**

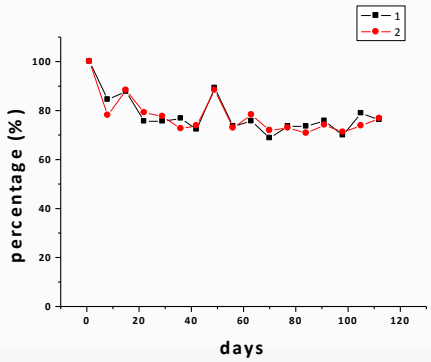


# Major Test Results

- **Precision**




- **Stability**




**Precision**

- Detection limit: 270 ppb
- Display resolution: 1 ppb
- Reversible and reproducible response

**Stability**

- Storage: sealed and stored in freezer(4°C)
- Stable response in 5 months

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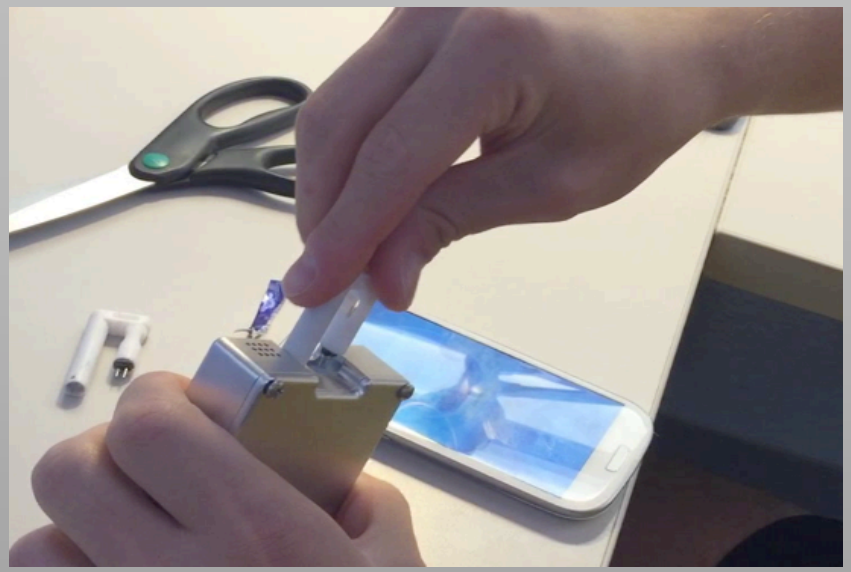
# Device Specifications

| Operation Conditions | |
|---|---|
| Temperature | 25°F to 113°F (-4°C to 45°C) |
| Atmospheric pressure | 11 to 14 psi |
| Humidity range | 0 to 95% RH (non-condensing) |
| **Performance Data** | |
| VOCs Measurement range | 270 ppb to 320 ppm (at least) |
| VOCs fitting regression | $r^2$>0.996 |
| VOCs accuracy | ±4% of measured value or better |
| Response time | Raw Data: 1 second per measurement<br>Calibrated concentration: 3 minutes per data point(adjustable) |
| Warm up time | <5 mins |
| Display Resolution | Auto scale (minimum 1 ppb) |
| Repeatability | 3% of signal |
| Shock Resistance | ±20 $m/s^2$ (approximately ±2 G's) in x, y, and z axis |
| Life time | 464 ppm·h |
| Shelf time | 70%-75% of initial sensitivity after 4 months |

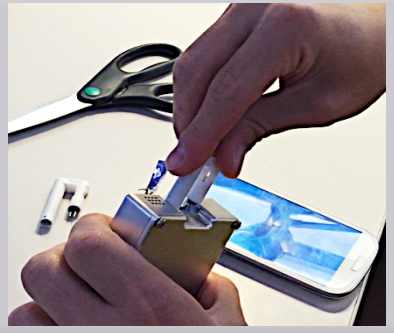
# Measurement Protocol (1,2,3 & 4 steps)



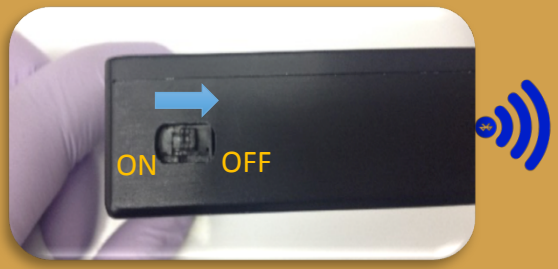
*Tsow, Forzani, et. al., Atmospheric Env., 2012; Sensors & Actuators 2015,*
*Deng, Tsow, Forzani 2016 (in preparation)*

# 1-2-3 Step Measurement Protocol

1- Insert fresh sensor cartridge & scan RQ code of pre-calibrated sensor cartridge



2- Turn on device & connect it to the VOC monitor App

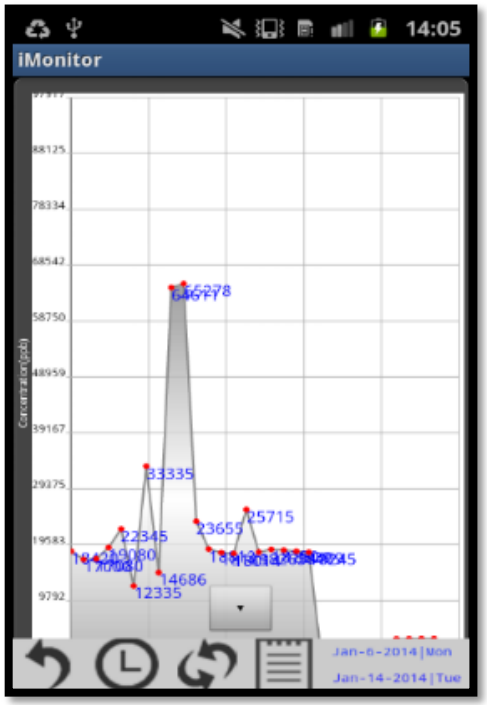


3- Monitor your exposure level!

**Real-time measuring**

# 1-2-3 Step Measurement Protocol

**History data browsing**



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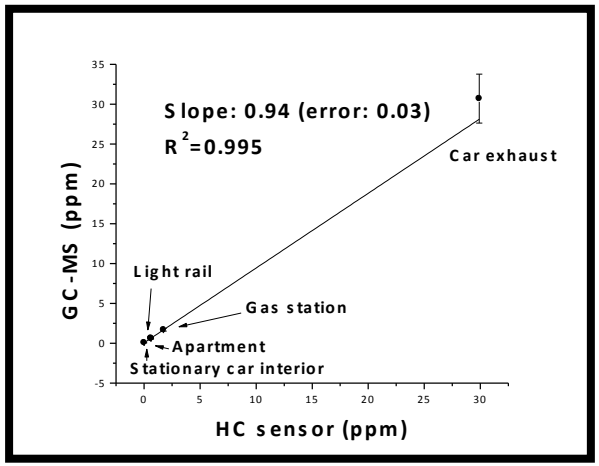
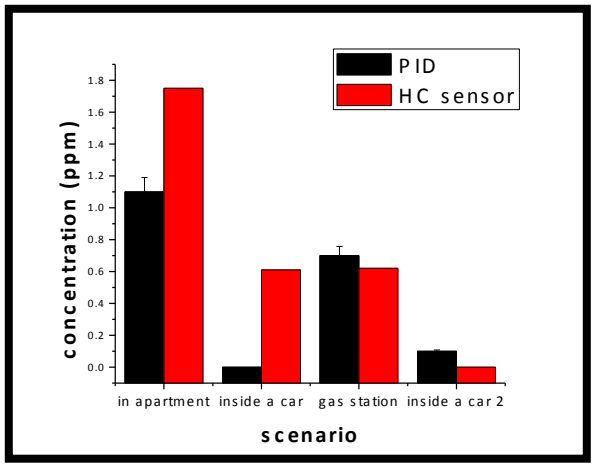
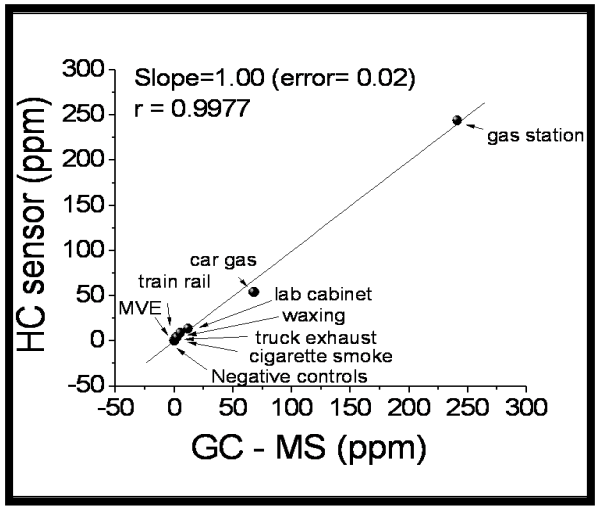
# Correlation with current methods

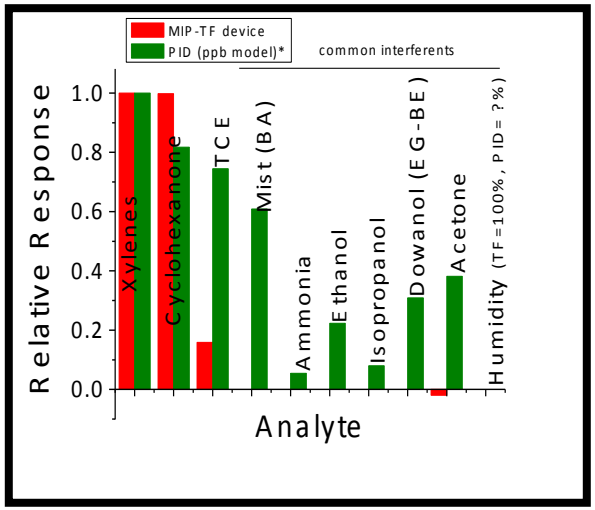
Total VOC Monitor vs GC-MS




Total VOC Monitor vs PID



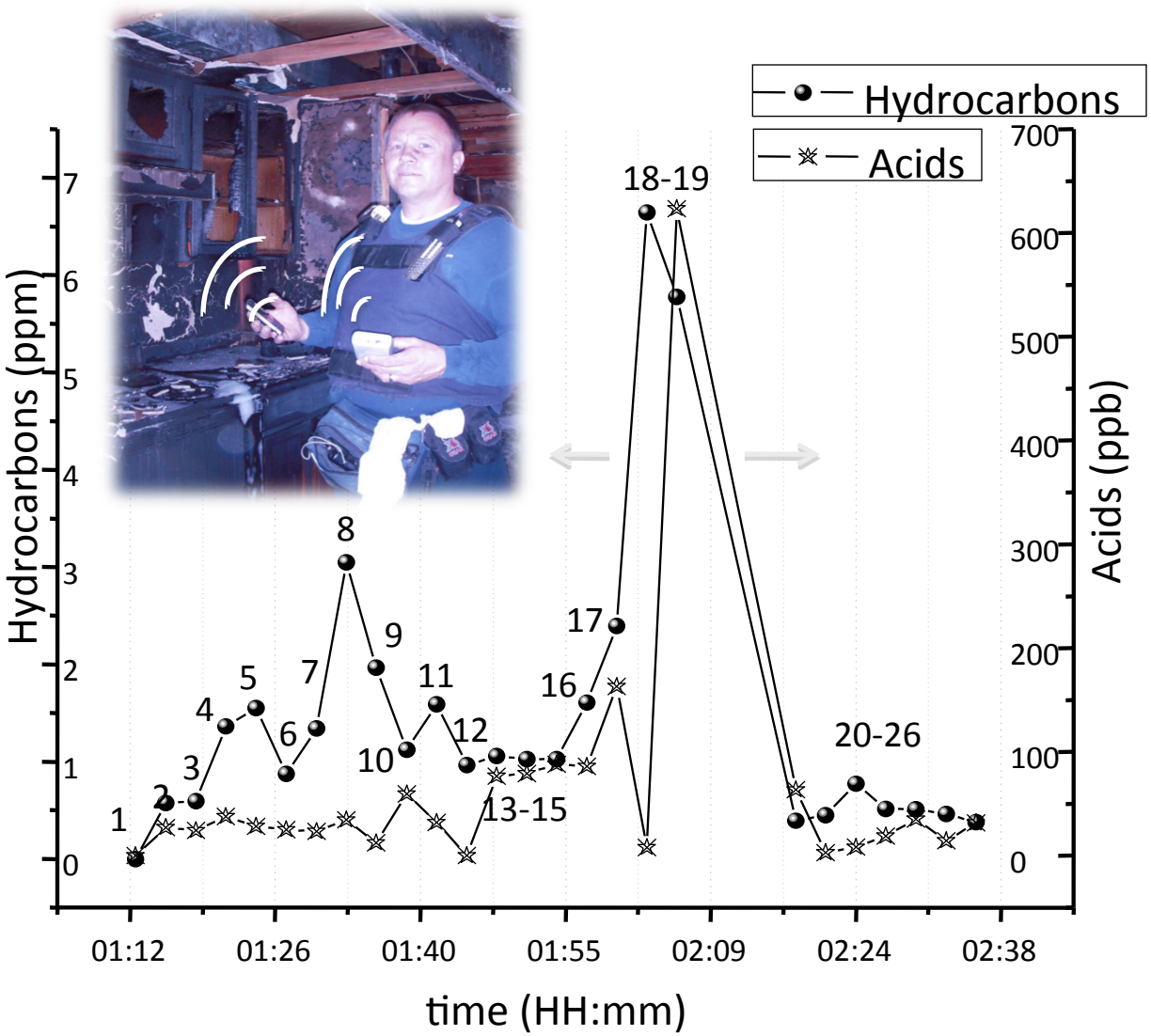



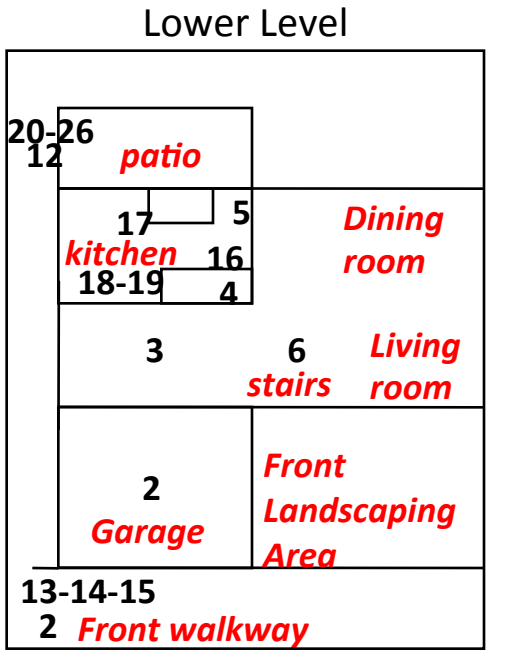
# Device Comparison

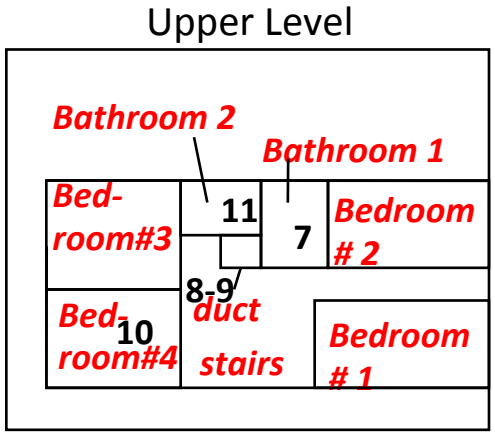
| Name | Total VOCs Monitor | PID (Photo Ionization Detector) |
|---|---|---|
| Measurement method | Mass sensitive detection | Photo ionized detection |
| Measurement range | 270 ppb to 320 ppm | 100 ppb to 5000ppm |
| Resolution | 0.1 ppm | 0.1 ppm |
| Measurement time | 3 mins | 1 s |
| Warm up time | <5 mins | <5 mins |
| Sensor operating life | 1 week | N/A |
| Calibration necessary | No | Need calibrate with standard gas cylinder |
| Continuous operating time | 6 hours | 16 hours |
| Dimensions | 4.0 in × 2.4 in × 0.9 in | 9.3 in × 3.6 in × 2.9 in |
| Weight including sensor | 0.17 lbs | 1.75 lbs |
| Device type | Portable | Hand – held |
| Supported platform | Android, Windows | N/A |
| Cost | ~$ 320 | $ 6515 |

# Field tests

## Study 1: Exposure assessment of fire overhaul activity

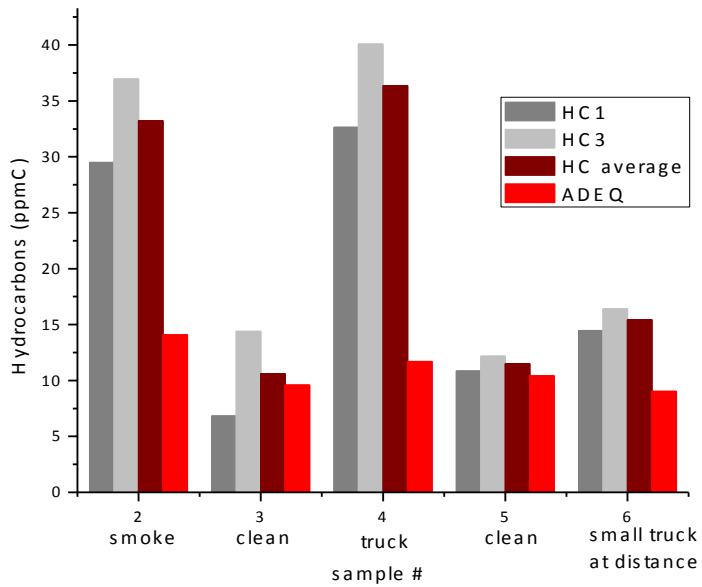


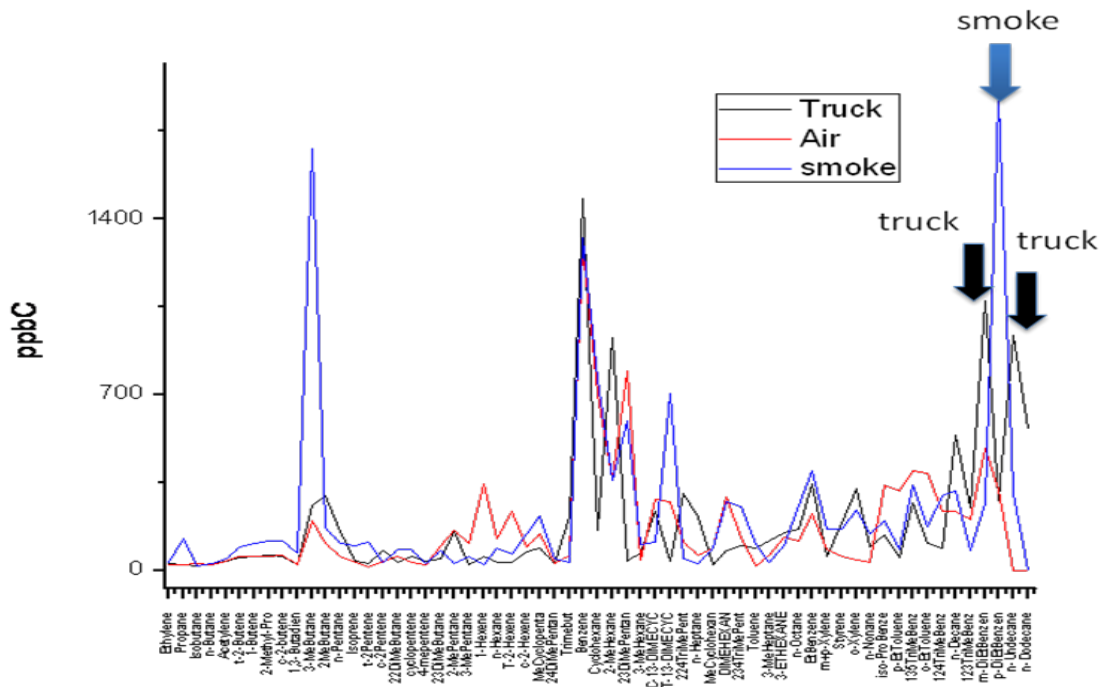



# Field tests

## Study 2: Environment monitoring in Phoenix with ADEQ



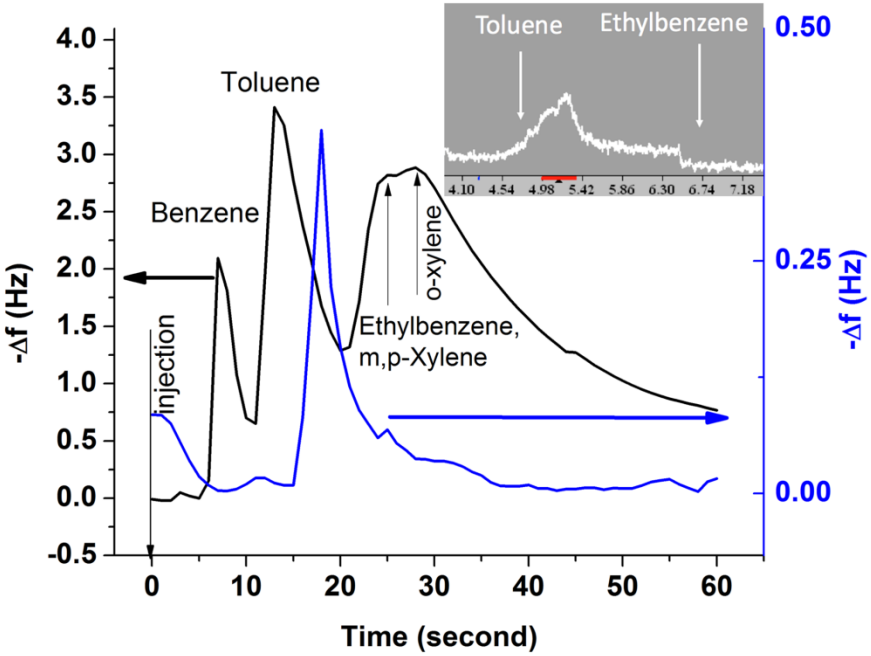

- Hydrocarbon level by ADEQ is around 9.6 ppmC and 10.4 ppmC
- The wearable monitor detected 10.6 ppmC and 11.5 ppmC respectively

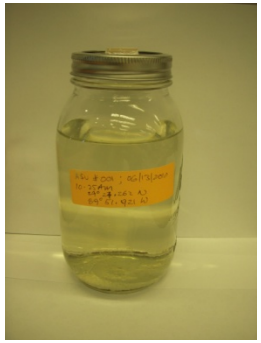
- The hydrocarbon profile for an environment with smoke or with motor vehicle emissions has significant components in the heavy hydrocarbons

# Field tests

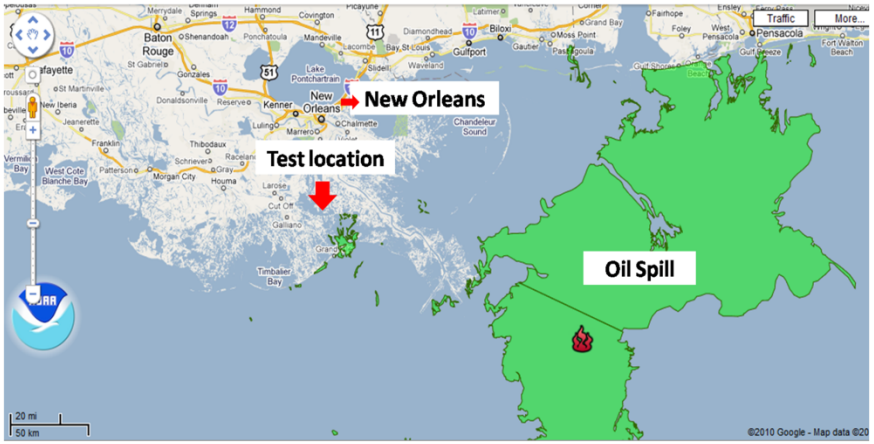
## Study 3: Gulf coast air quality test after oil spill

(a)



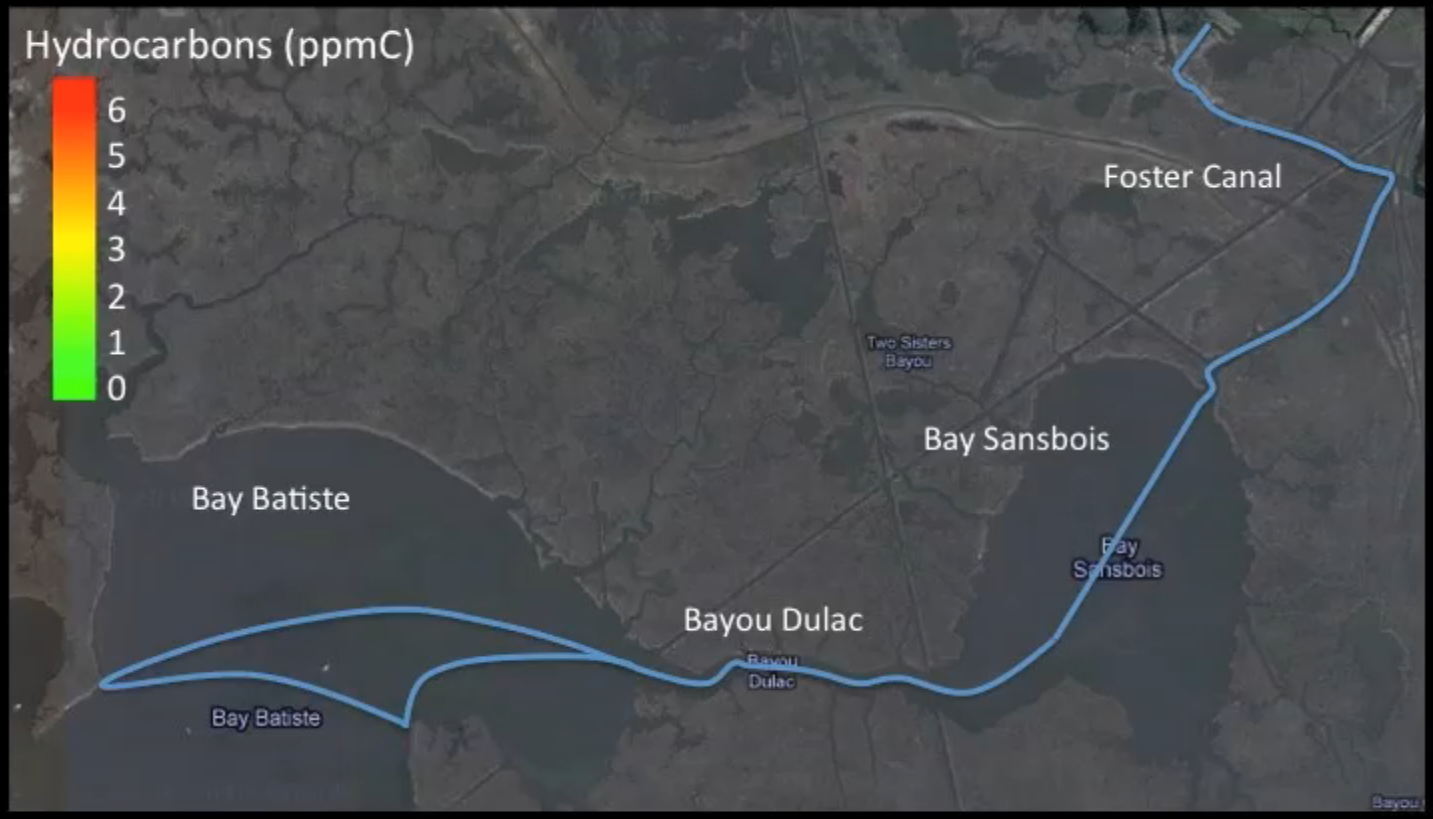



(b)




- BTEX was found to be below the detection level (~1ppb) during the trip.
- A short alkyl hydrocarbon was identified.
- The real-time findings by the ASU hybrid device were confirmed by GC/MS (collected water samples).

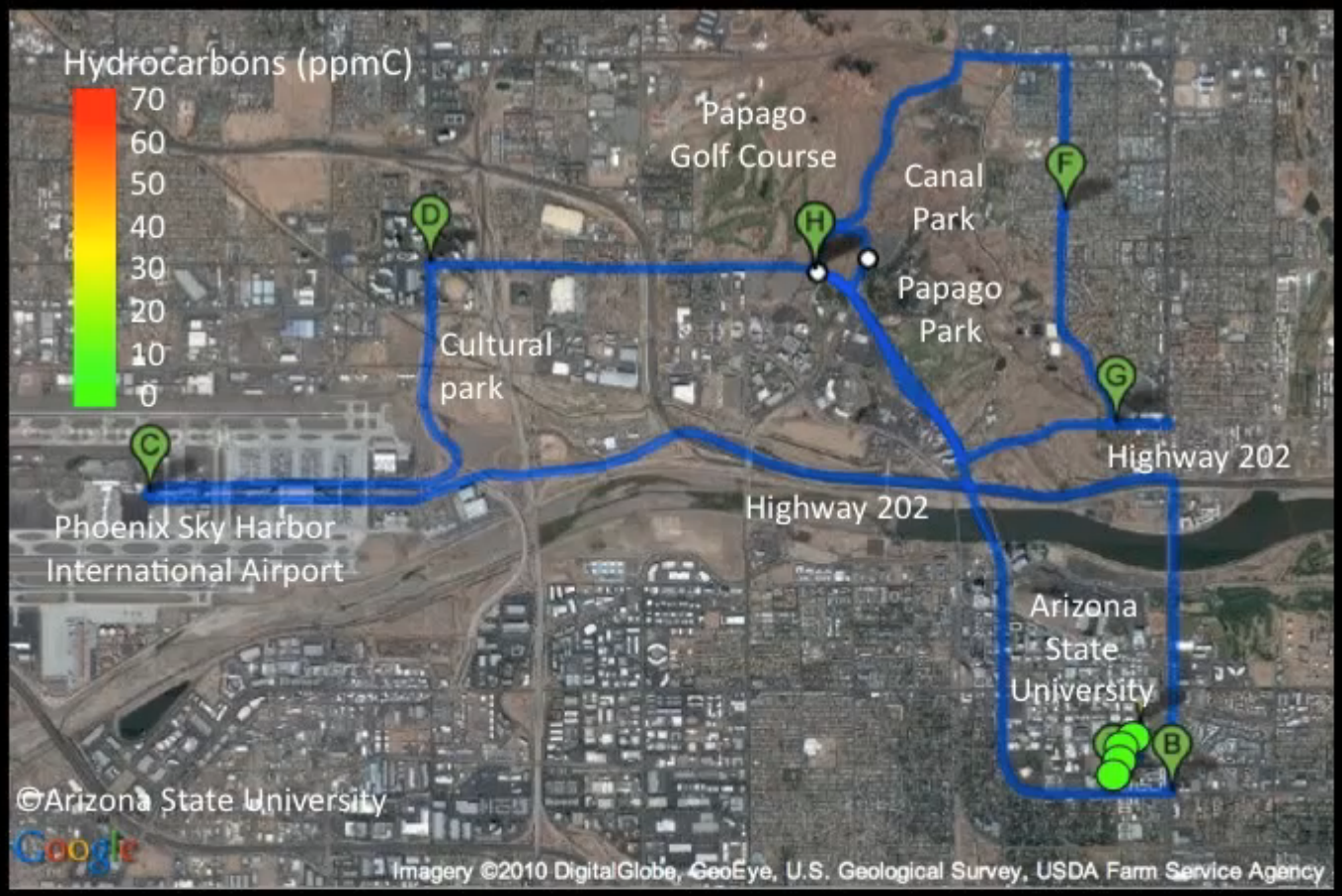
# Personal Exposure Assessment – Wireless Wearable Sensor Device




©Arizona State University

# Field tests

## Study 4: Personal exposure to hydrocarbons



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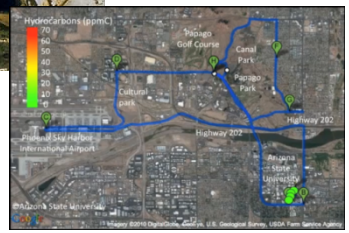
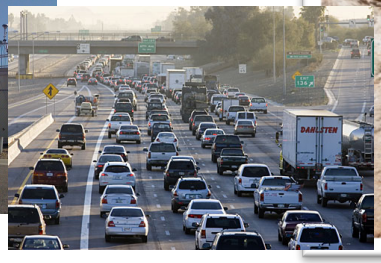
# Market size

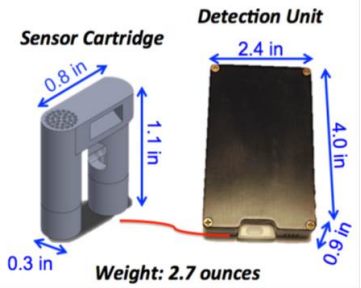
| Market Niche Size | | | |
|---|---|---|---|
| **Market Size in Dollars** | Growth Rate | Base Year | **Detailed Basis for Estimate** |
| **$638.3 million** | 3.9% | 2014 | **Total Gas Sensor US Market. The revenue generated by the sale of gas detection monitors in North America was $488.1 million. This is expected to reach $638.3 million in 2014 at a compound annual growth rate of 3.9 percent according to one source.** |
| **$182 million** | ~6% | 2012 | **Toxic Gas Sensor Demand - Demand to 2017 - $268 million**<br>**For currently available technology - Breakdown**<br>**Electrochemical – 2012 - $38 million 2017 - $49 million**<br>**Optical $92 million $148million**<br>**Other $52 million $ 71 million** |
| **$117 million** | **~6%** | **2012** | **Combustible Gas Sensor Demand – Demand to 2017 - $151 million**<br>**For currently available technology - Breakdown**<br>**Pellistor/Catalytic Beam 2010 - $56 million 2017 - $68 million**<br>**Optical $33 million $49 million**<br>**Other $28 million $34 million** |

# Exposure Detection Markets

- Petrochemical industries – Industrial Hygiene
- Firefighters – first responders
- Epidemiologists and exposure science professionals
- Outdoor air monitoring
- Indoor air quality monitoring and personal tracking

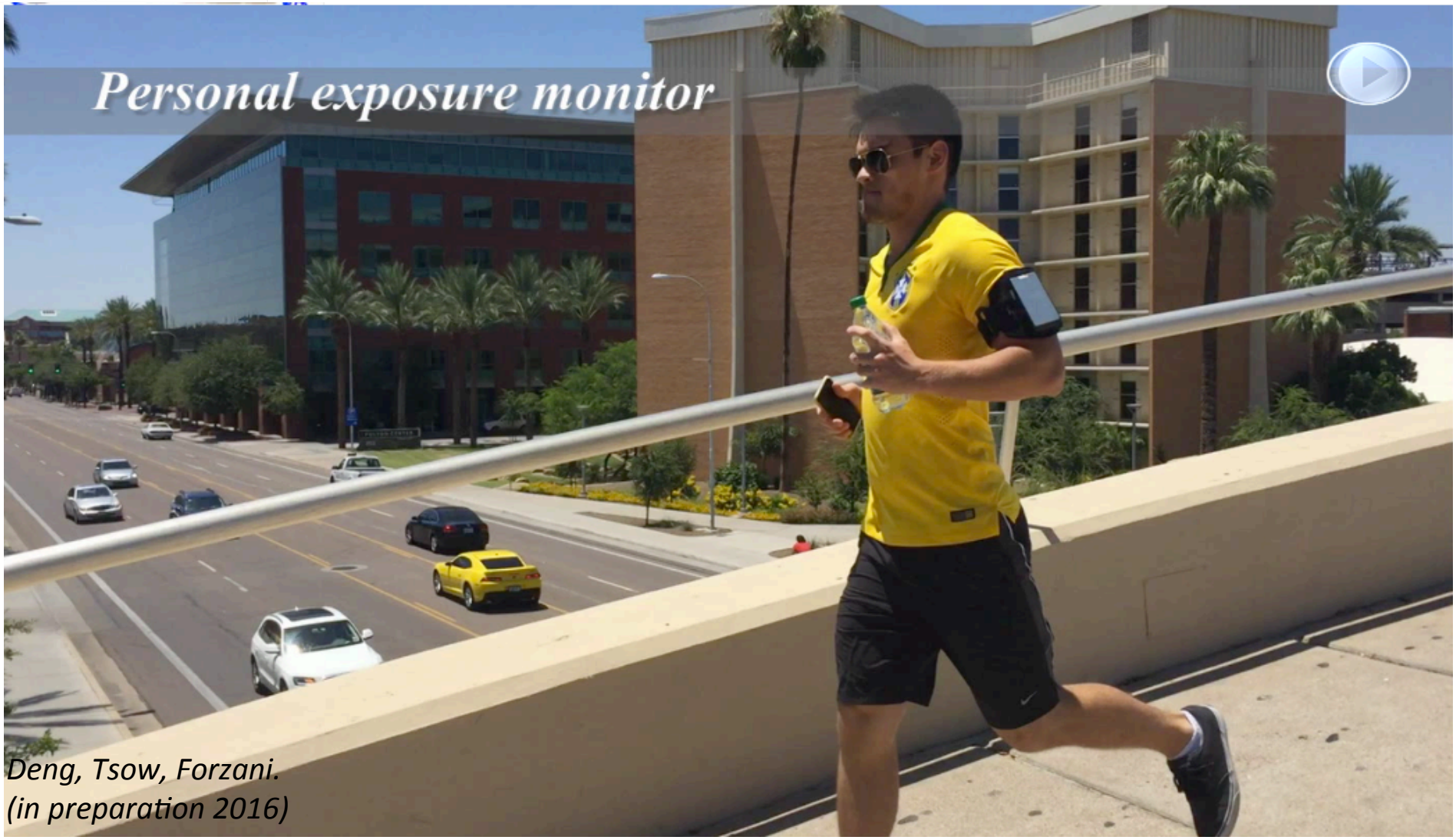







# Market target

## 1. *Personal Exposure Tracking*




*Deng, Tsow, Forzani.*
*(in preparation 2016)*

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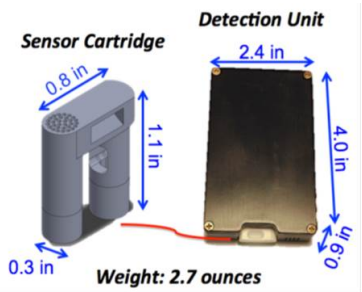
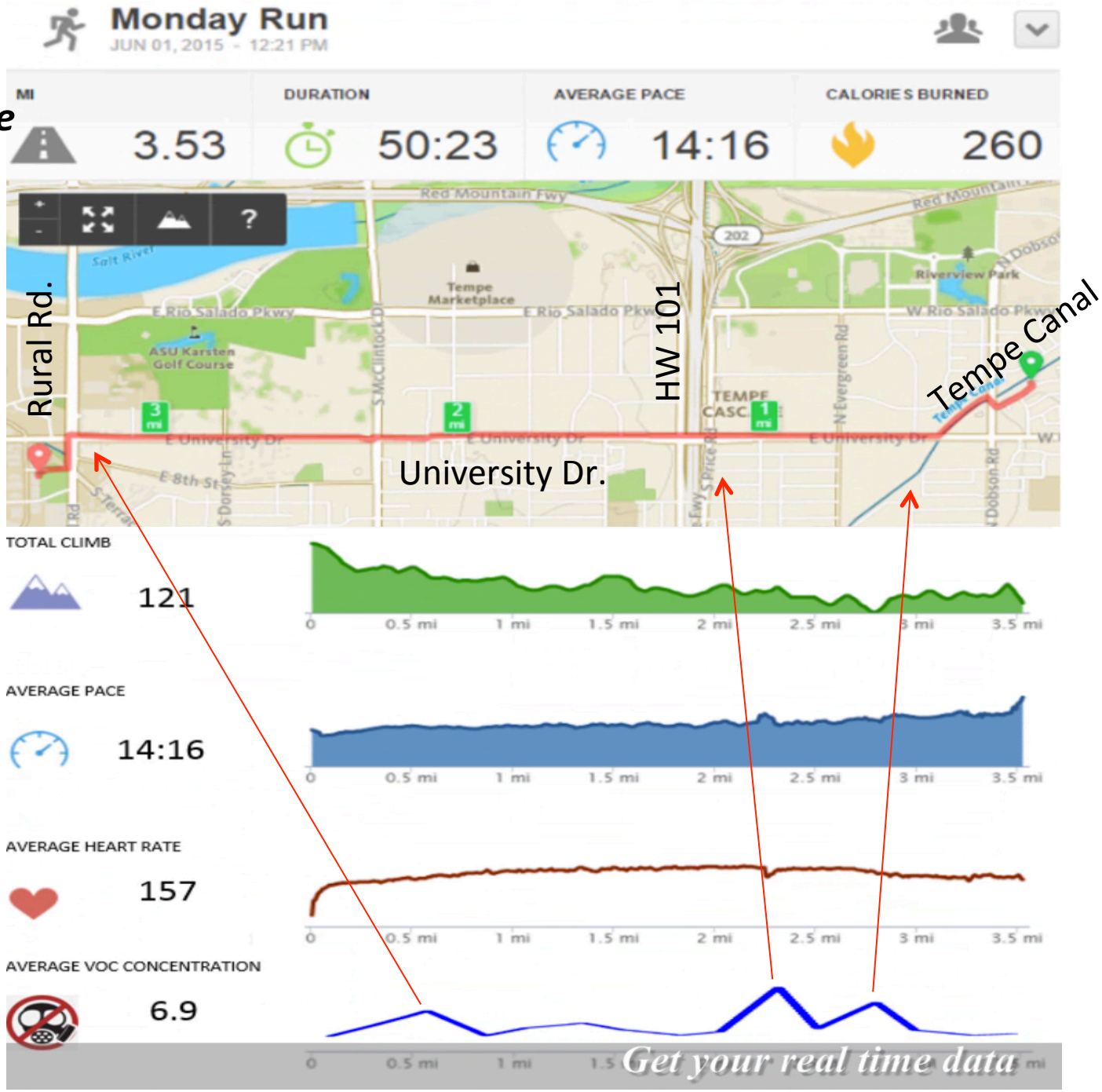



*Deng, Tsow, Forzani. (in preparation 2016)*

# Market target

## 2. *Petrochemical industry*

### Device Designed at ASU Helps Out in Gulf

**Technology determines if air is safe to breathe**

Updated: Thursday, 17 Jun 2010, 9:26 PM MDT
Published : Thursday, 17 Jun 2010, 9:26 PM MDT

TEMPE - The massive oil spill in the Gulf is contaminating the water and possibly the air, for people living or working near it.

So students and scientists from ASU are running tests to find out if the air is safe to breathe. Under sponsorship from the National Institute of Health, ASU's Biodesign Institute is working with the University of New Orleans to develop equipment to test the air quality there.

A team from the Biodesign Institute went to the Gulf to conduct experiments and collect data.

June 13th, 2010

# Market target

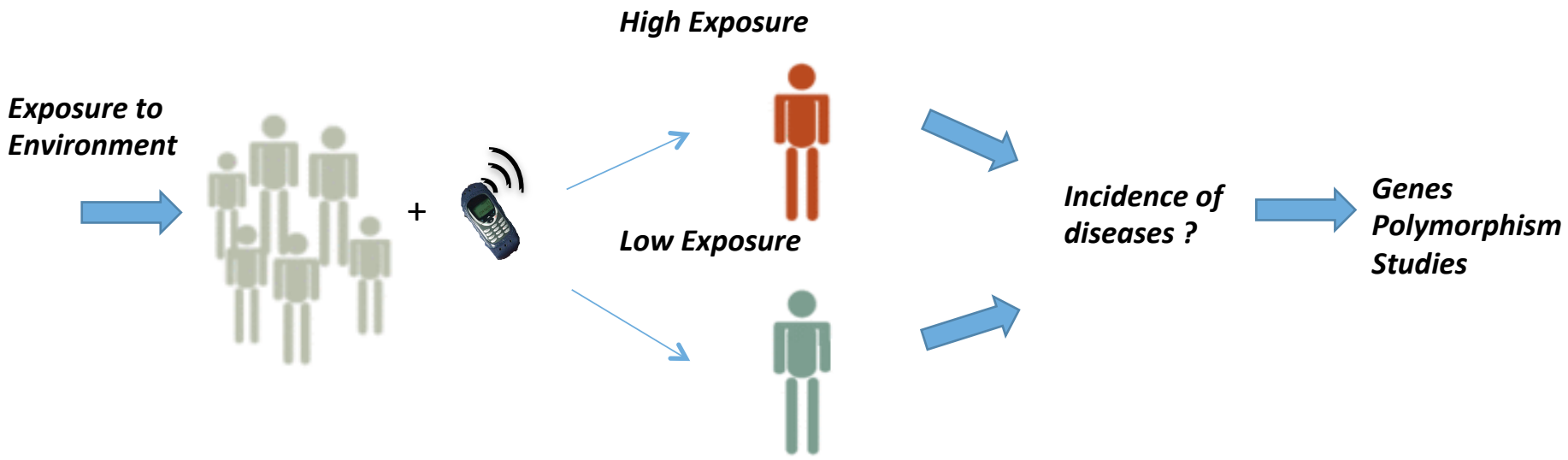
## 3. *Firefighters – first responders*

- Accurate and reliable detection for breathing zone area of first responders and firefighters
- Important gases detected for monitoring of overhaul activities after fire is put down to avoid contact with toxicant chemical released from materials (great product combination with CO sensor)
- Versatile technology to specific applications for leak detection of industrial solvents and gases.

# Market target

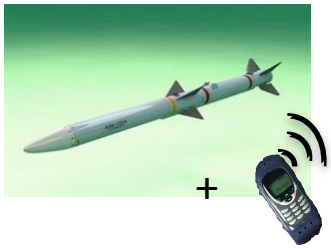
## 4. *Epidemiologists, environmental and exposure scientists*

- Epidemiology studies are mostly based on the research community generally supported by NIH, CDC, and other federal agencies and foundations. They constitute the "early adopters" of many innovative products. Although this community is limited, it is always willing and able to invest in new technologies that can take further their research efforts. Another positive aspect of this community is that they are more insensitive to costs than the industrial monitoring community, and thus does not wait for economies of scale to reduce instruments price. There is a real need for real-time and remote sensing of traffic exposure within the epidemiology community.
- Integrated hybrid sensors from have already gained notice within the community, having been pointed out by NIH Director, Francis Collins to the US Congress, and Epidemiology Community meetings attended by NJ Tao's team members.

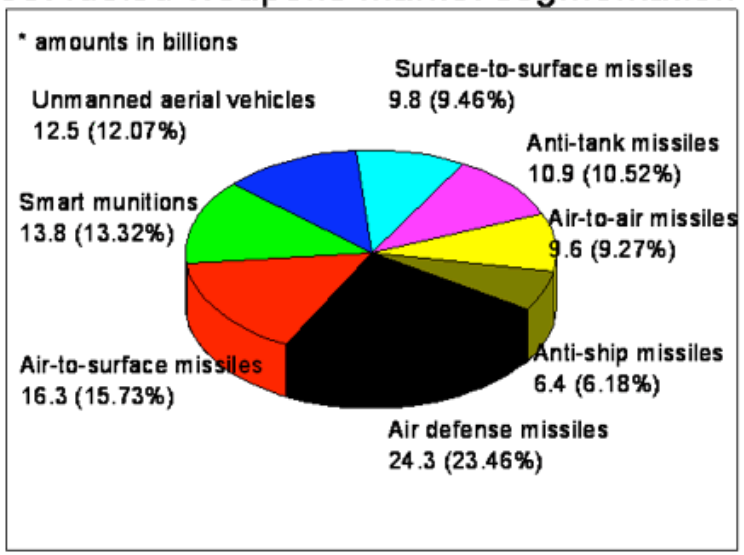


# Market target

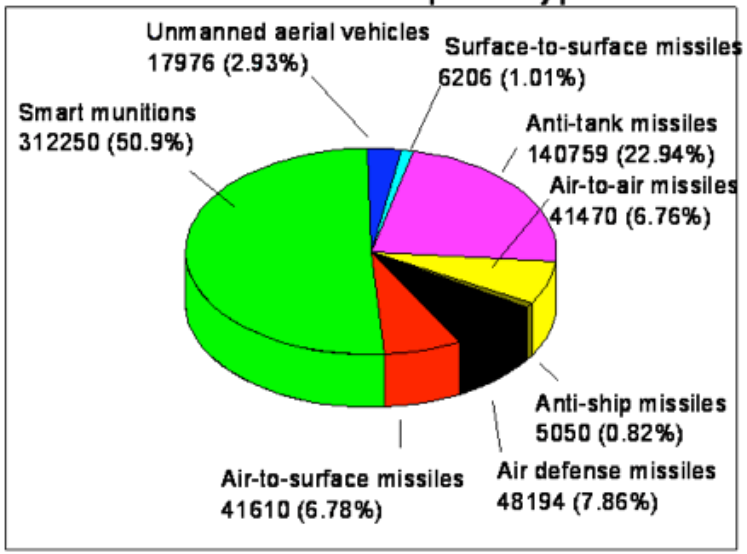
## 5. Jet fuel leak detector for missiles



### Jet fueled weapons market segmentation*




### Jet fueled weapons types



# *Outline*

- Introduction to volatile organic compounds (VOCs) and existing sensing technologies.
- A chemical sensor for VOCs monitoring.
- Sensor & device specifications and use.
- Comparison with current methods.
- Market analysis.
- Summary.

## Summary

- A wearable and wireless sensor that can detect real-time VOCs concentration is presented.
- It is small, robust and can reliably detect VOCs in concentration of ppb levels. It is suitable for both indoor and outdoor VOCs monitoring.
- Gas-calibration free protocol of use.
- Total VOCs device shows good correlation with gold standard method.
- Several field studies under different application scenarios demonstrate the monitor's capabilities and flexibility.

TF Health

*Personal sensors for better health*

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