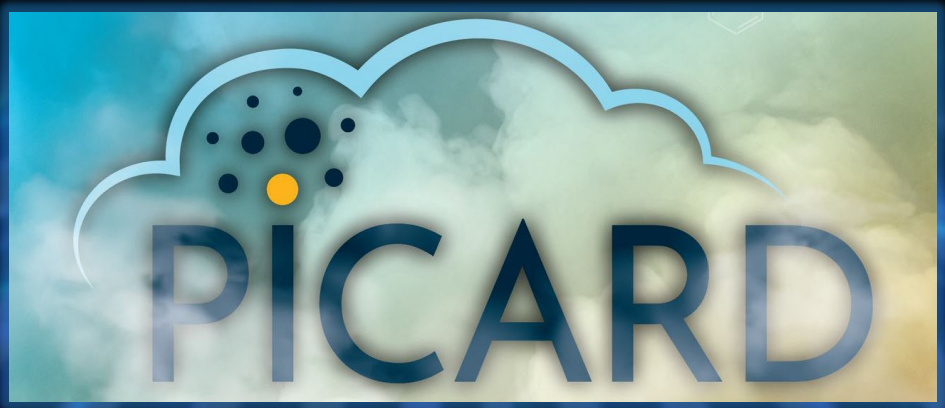
Lightning Talks

26 SEPT 2022

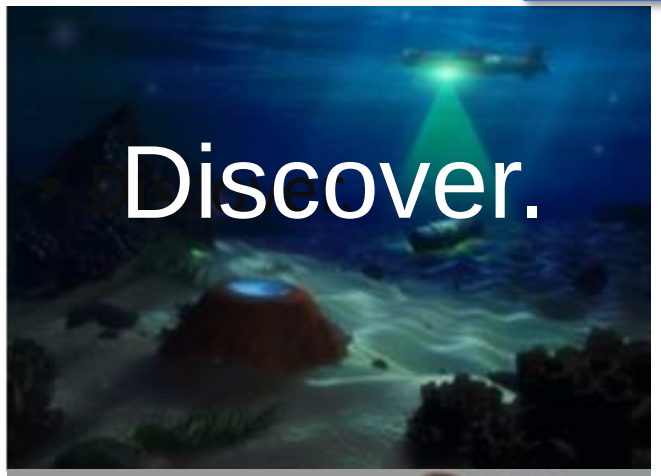
Intelligence Advanced Research Projects Activity

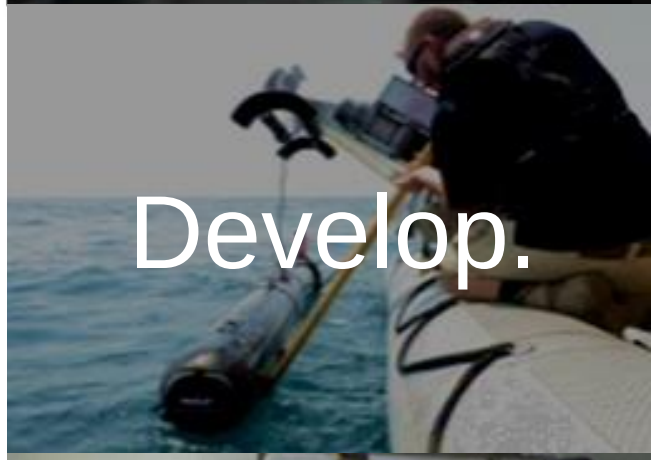
IARPA

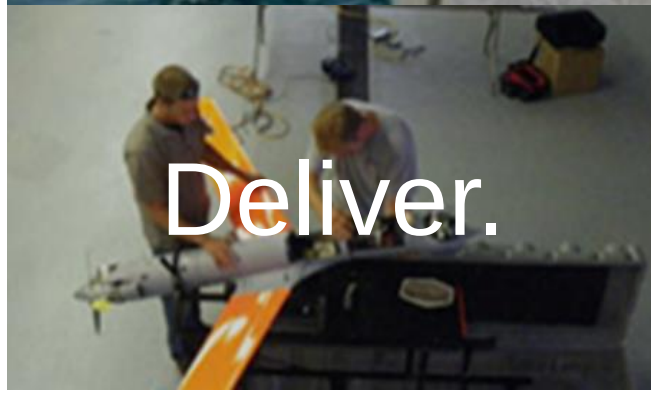
Creating Advantage through Research and Technology



IARPA PICARD Proposers Day; September 26, 2022







ARETE VISION: **Leading-edge science and engineering protecting the nation and the world from seafloor to space.**

DESCRIPTION

- **Employee-owned Small Business**
- **350 employees**
- **Eight U.S. Locations: AL, AZ, CA, CO, FL, VA (2 offices)**
- **> 45 years of government experience**

APPROACH

Rapid, creative, end-to-end development

- **Discover: A science and technology engine advancing state-of-the-art sensing: over 50 patents in force**
- **Develop: A responsive collaborator rapidly maturing prototype system solutions for new and existing sensors**
- **Deliver: Reliable producer of high-performance systems; typically low-SWaP**

CORE COMPETENCIES

- **Detecting weak signals in heavy clutter with low false alarms**
- **Low-SWaP sensors with real-time fusion**
- **Extracting maximum performance from systems**
- **Applying interdisciplinary expertise across domains**
- **Rapid prototyping and production**

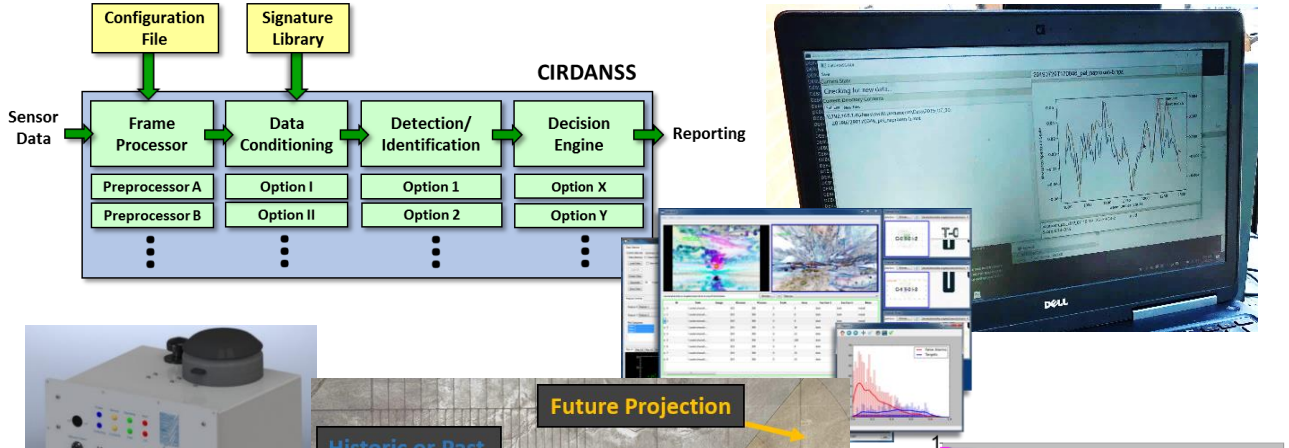
Areté Technical Capabilities Aligned to PICARD (1 of 2)

- **Robust, real-time, modular spectral detection & identification framework, CIRDANSS**
  - Initially funded under IARPA SILMARILS* for standoff IR detection of 100's of trace chemicals
  - Expanded for multiple spectroscopies, use cases
  - Transitioned into operation for low SNR application

- **Practical experience developing and deploying fieldable, low SWaP aerosol detection point sensors**
  - 24/7 monitoring of threats within plumes
  - Outdoor environments, subways, etc.
  - Used alone or in sensor network – next bullet

- **Proven Multi-Node Analytics software for sensor networks**
  - Enhanced P_D vs P_{FA} & plume characterization
  - Transitioned into operation and rigorously tested at Dugway Proving Ground and elsewhere

- **Remote sensing augmentation: 360° Wide Area Threat Detection (WATD) via Low SWaP LIDAR****
  - Detects aerosol plumes or variations in background backscattering properties



*Standoff Illuminator For Measuring Absorbance And Reflectance Infrared Light Signatures

**US Patent 10,473,786; US Patent 11,237,267; US Patent Application 16/833,867

Areté Technical Capabilities Aligned to PICARD (2 of 2)

Layer 0: Phenomenology & Algorithms

- Foundational for all subsequent layers

Layer 1: Point Sensors, Field Portable, Mobile

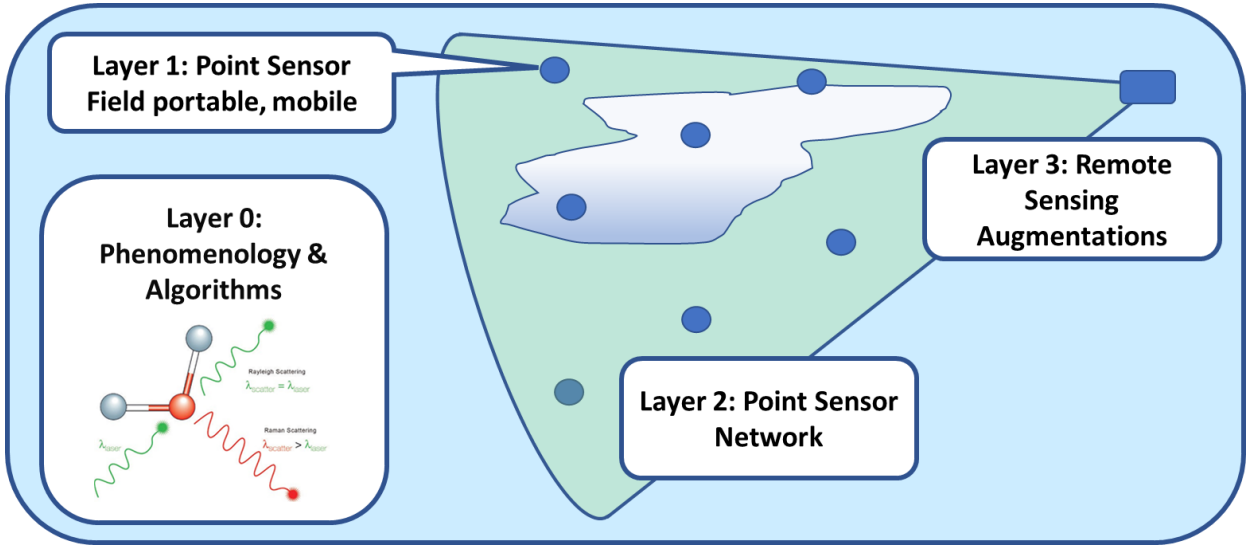
- Non-contact measurements with specific algorithmic configuration governed by Layers 0, 2 considerations

Layer 2: Point Sensor Network

- System-level enhanced identification performance and ability to track/characterize plumes

Layer 3: Remote Sensing Augmentations

- Wide area monitoring to enable (autonomous mobile) point-sensor deployment



Open to collaborators with experience in, but not limited to,

- Independent T&E with chemical aerosols
- Aerosol science subject matter expertise
- Additional relevant sensor capabilities.

Please contact: Dr. Karyn Apfeldorf
kapfeldorf@arete.com
www.arete.com

PICARD
Proposer's Day Lightning Talk

September 26, 2022

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Detect-Ion LLC ("Detection")

Mission: Next Generation Sensor Development For Enhanced CBRNE Sensing

- Small business technology startup (October 2021)
- Technical team hails from SRI International
  - Performers on IARPA MAEGLIN and DARPA SIGMA+ CWMD programs
- Inducted into the Tampa Bay Technology Incubator (TBTI) and housed on USF Tampa campus
  - Dedicated Laboratory space
    - ➢ Onsite rapid prototyping
  - Access to shared high-value lab resources through the TBTI program
  - Florida Hi-Tech Corridor Matching Funds

Proud partners with TBTI TAMPA BAY TECHNOLOGY INCUBATOR USF UNIVERSITY OF SOUTH FLORIDA

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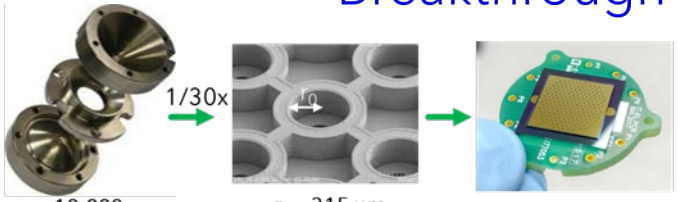
Fieldable Long Endurance Trace Chemical Sensing

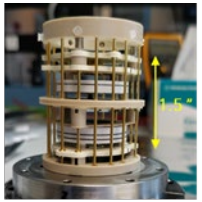
MAEGLIN
REVEALING THE UNSEEN

Breakthrough low-SWaP Mass Spectrometer Design



- ✓ Near 1-amu resolution
- ✓ <2 W power
- ✓ Low ppb LODs

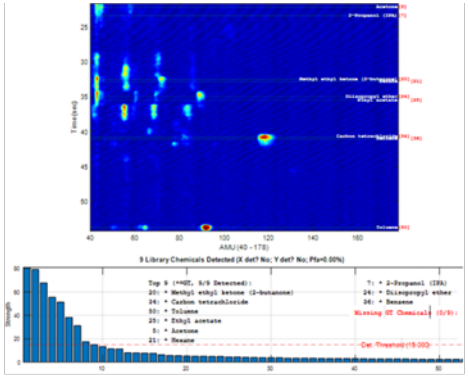
Chip-scale Mass Spectrometry



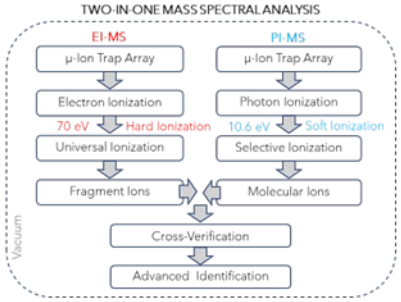
- ✓ Solder-less
- ✓ Wireless
- ✓ Epoxy less
- ✓ >10,000 miles road trip

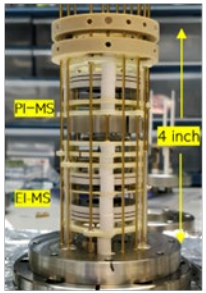
Ruggedized Vacuum Package

ACHILLES (Precon-TD-GC-MS)



Identification Algorithm (2D GC-MS data)





Dual Complementary Ionization

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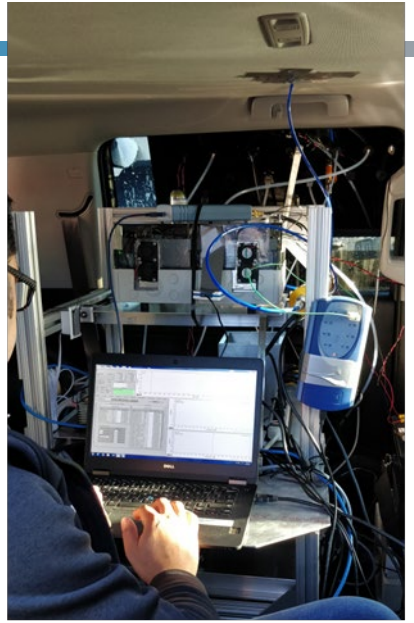
Deployment/Use-Case

Outdoor Sampling (NRL)

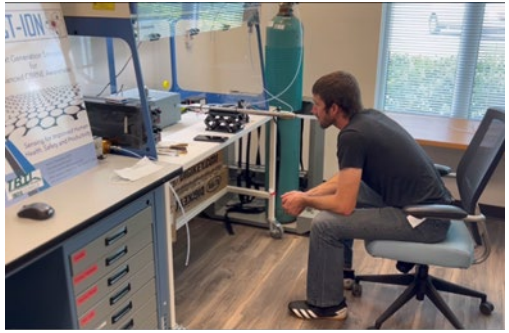
Tropical Bay (NRL)



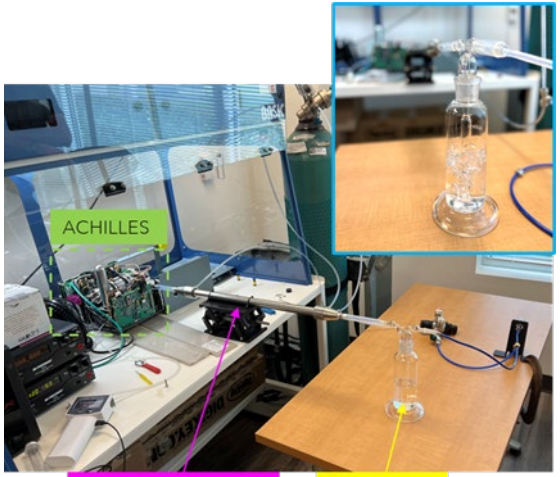
Mobile Deployment (Boston)

Grand Central Station (NYC)

USAF/AFRL Flight Testing



Breath Diagnostics



ACHILLES as Water Sensor

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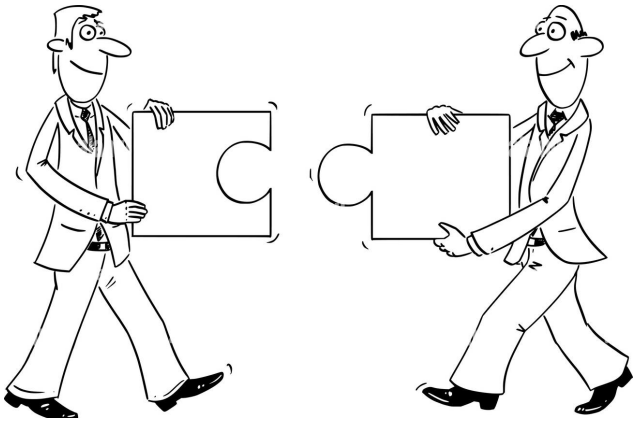
Critical Themes for PICARD



- Aerosol collection
  - Collector design
  - Material
- Low-SWaP sensing approach
  - Point sensing
  - Standoff sensing
- Systems engineering
  - Extreme component engineering
- Environmental processes to understand aerosol behavior
- Data science: AI/ML for detection of events/activities (not just chemicals)
- Operational knowledge: Need a “bad” actor on the team!
- And a wicked T&E plan! ☺

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Thank you!

Ashish.chaudhary@detect-ion.com

Tel: 727.251.0889

https://detect-ion.com

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DWT Standoff Aerosol and Gas detection

PICARD Proposers' Day

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SYSTEM INTEGRATION

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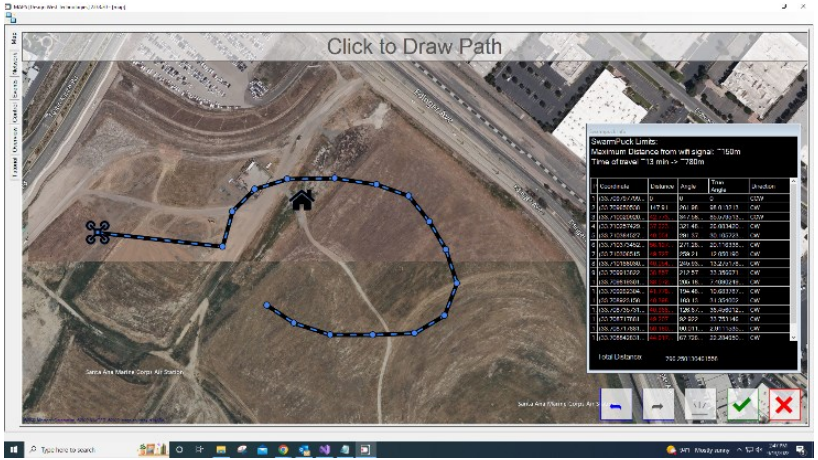
Swarm based threat mapping

- Drone with swarm control and standardized sensor interface – choose between DWT's chem/RN or other manufacturer's sensors
- Obstacle avoidance and visual inertial odometry
- No RF communication between drone and base station → jam proof, no RF signature
- Intuitive user interface, minimal training required
- Download data in docking station after rapid 15min areal swarm scan, machine learning based data analysis



Software interface – control center of swarm

Drone prototype – GPS denied environment and obstacle avoidance

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DESIGN WEST TECHNOLOGIES INC

ON FLIGHT SENSING TECHNOLOGY

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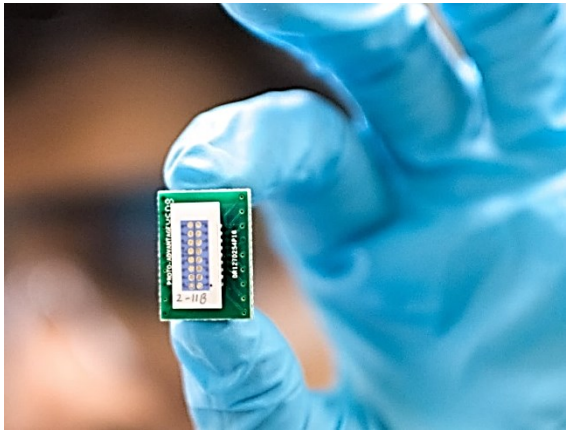
DWT Sensor Technology

- Over the past 12 years DWT has developed Single Walled Carbon Nanotube (CNT) based sensor array technology
- CNT are coated with semi-selective formulations and a machine learning based pattern recognition algorithm identifies the threat
- Extensive previous testing and development for CWA and TIC gas detection: DHS SBIR ‘17, CWMMD OTA ‘18, SOFWERX AIM ‘19, ROSETTA II TRE ‘20, third party tests ’21
- More recently – successful application for aerosols: DHS SBIR ’22



DWT gas sensors: handheld, wearable, throwable/droppable

DWT wearable aerosol detector (liquids & solids)

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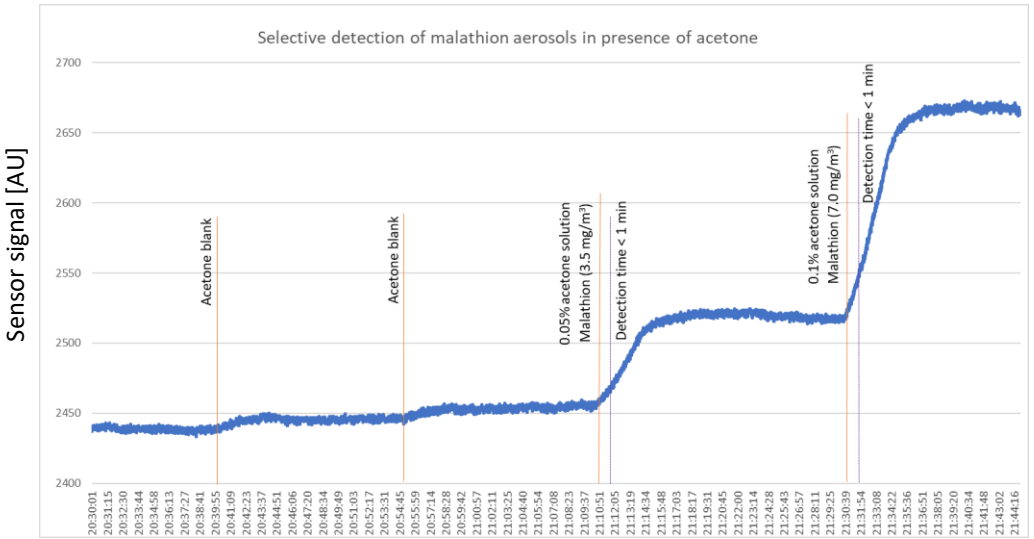
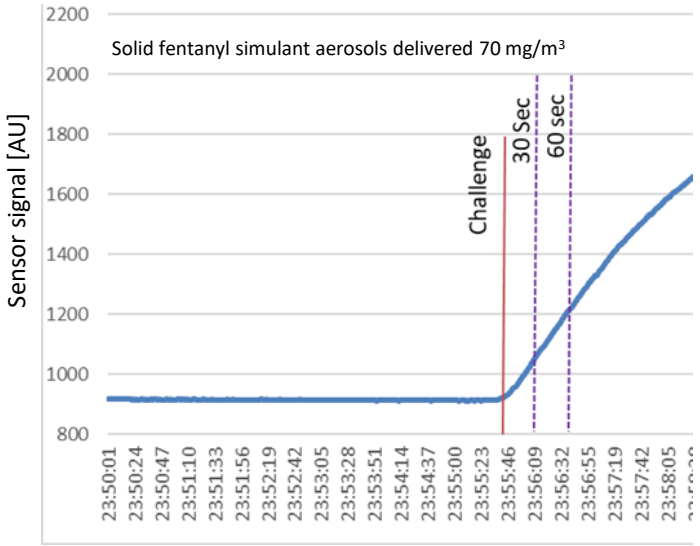
CNT sensor for aerosol detection

- During recent DHS SBIR 22.1 (Topic Code: 10) DWT designed an integrated aerosol collector/detector and demonstrated detection of solid/liquid aerosols within a minute
- Simulants tested and detected for GD, VX, Fentanyl



Malathion aerosols were selective detected over acetone vapor



Supported by DHS SBIR Contract #70RWMD22C00000007

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REMOTE SAMPLE COLLECTION

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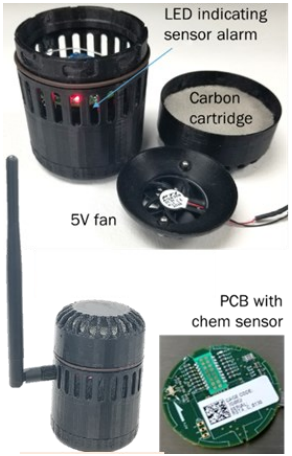
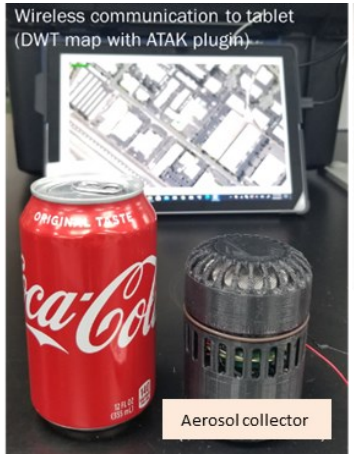
Standoff Sample collection

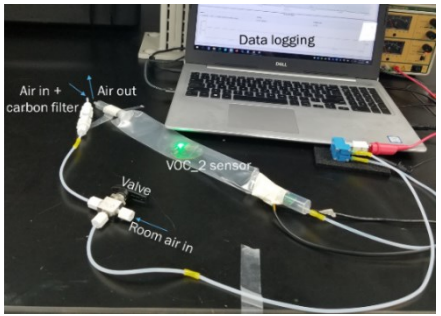
- Drones capable of deploying and retrieving a payload
- Inconspicuous sample collector collects gas and aerosol
- Nonspecific alert via DWT sensor once sample was collected (no time lost with evaluating “empty” collectors)
- Analysis of collected sample in a mobile or central lab via PCR/GC etc.

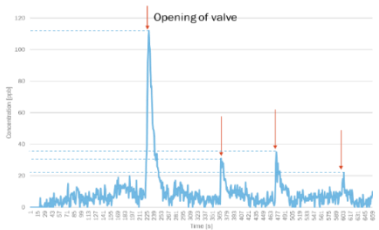
Sample collector





Lab analysis of the collected sample





Left; Experiment setup with VOC_2 sensor, and Right: opening valve to room air, background air is filtered through carbon cartridge

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RELATED TECHNOLOGY TRL 7

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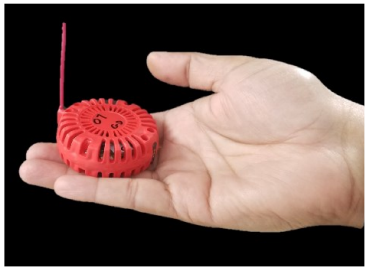
Related Technology – DropPuck System

- Software, algorithms, firmware and hardware integration leveraged for Swarm based aerosol sensing
- Standoff detection system deploys SWAP-C chem or RN sensors via UAV
- Sensor nodes establish mesh network and base station software displays threats on map and forwards to ATAK
- Previous system assessment: Thunderstorm 20-02, CBOA‘21, CBOA‘22
- Upcoming demos: AEWE’23, MSSPIX’23



DropPuck

Drone agnostic release mechanism

Base Station and ATAK

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MINIATURIZED SYSTEMS FOR CHEMICAL ANALYSIS

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Civil and Environmental Engineering

Expertise

MEMS and Microfluidics

Embedded Systems and Power-Aware Computing

Surface Enhanced Raman Spectroscopy

Microscale Gas Chromatography

Data Analytics

Aerosol and Gas Sampling

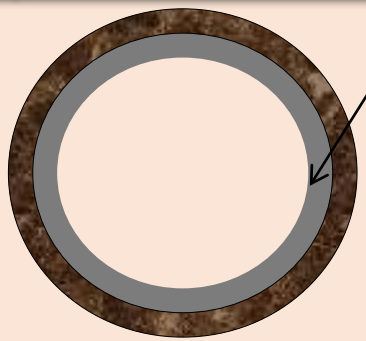
Field measurements of Particle-Phase Organics

Chip-Scale Gas Analyzer

Microfabricated Columns

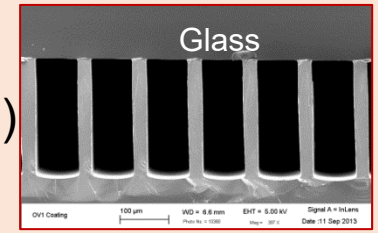
Open tubular Columns

(a)



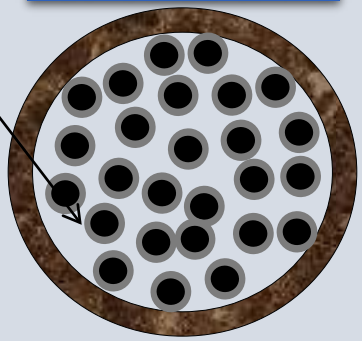
Stationary Phase

(d)

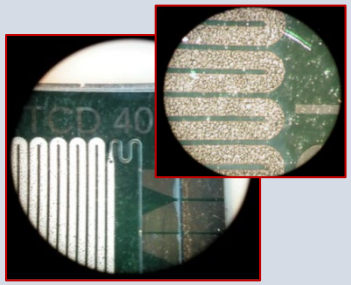


Packed Columns

(b)



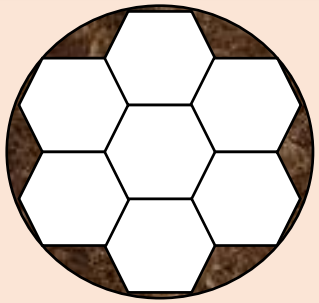
(e)



B. C Kaanta et al., *J. Micromech. Microeng. 2010*

Multicapillary Columns

(c)



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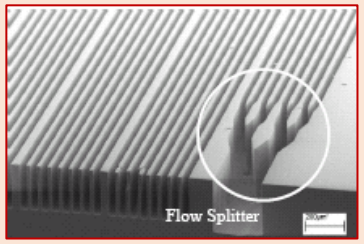
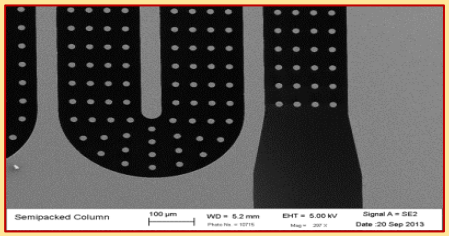


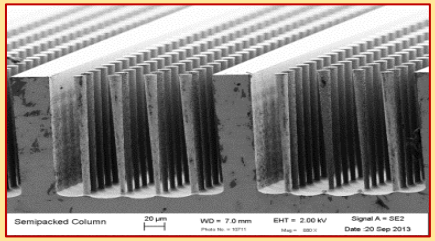
M. Zareian-Jahromi, et al., JMEMS 2009

VTMEMS Lab

Semipacked Columns

(g)

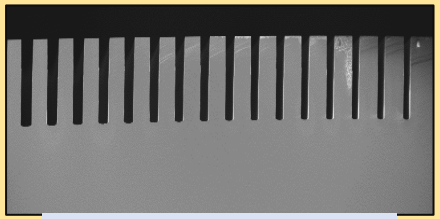




VTMEMS Lab

Modulated Columns

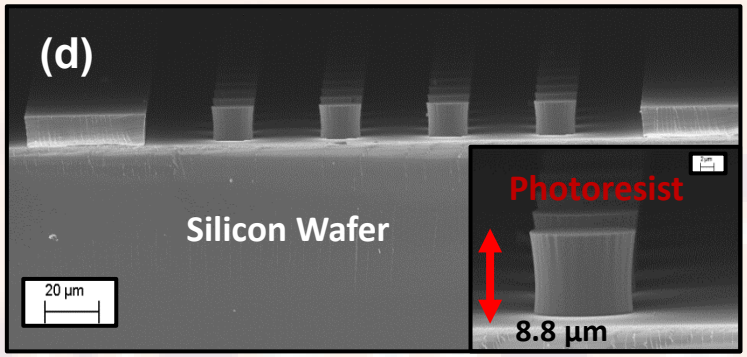
(f)

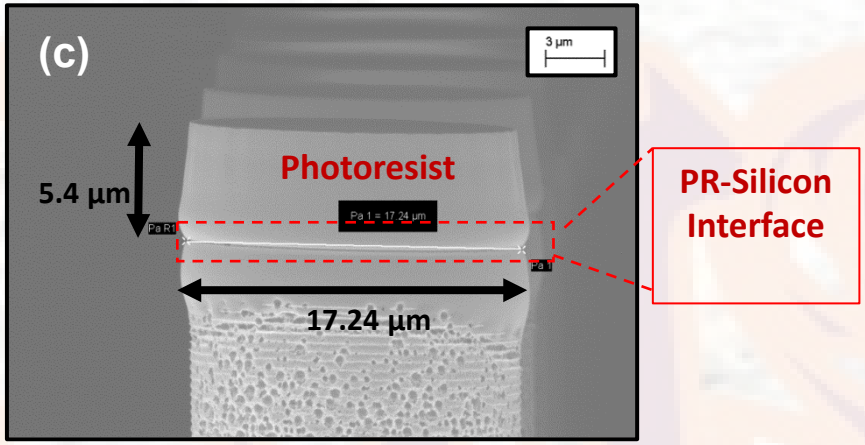


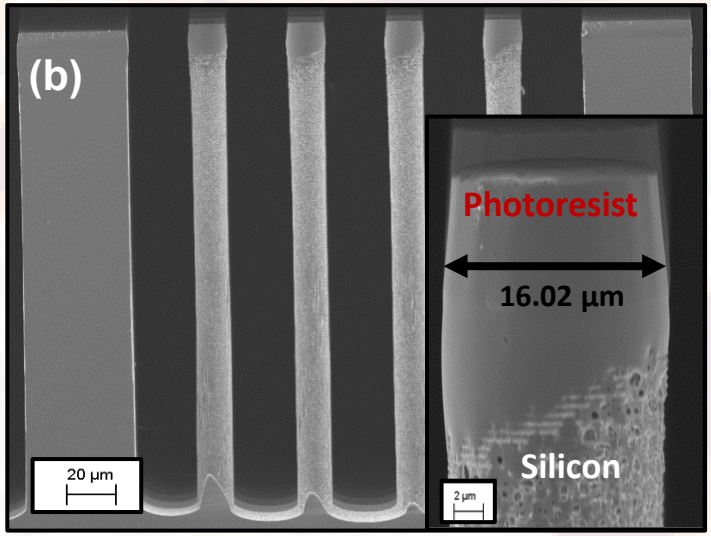
VTMEMS Lab

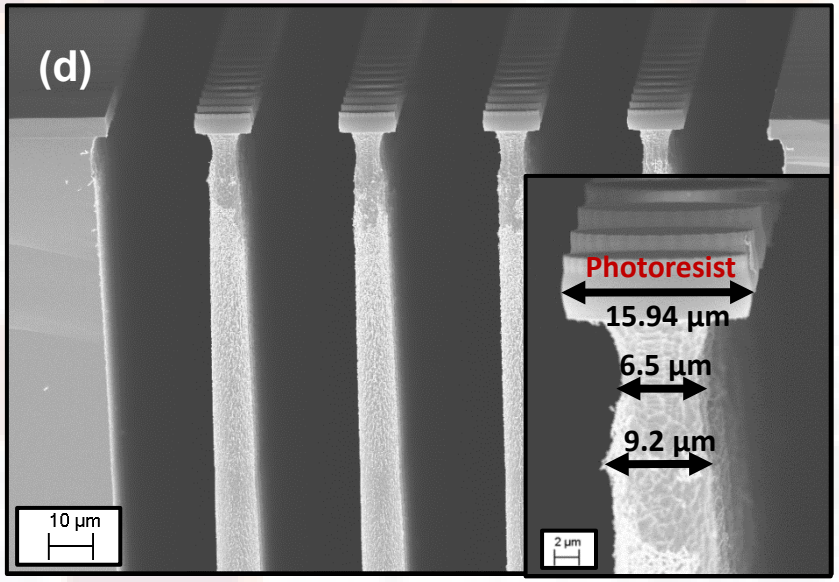
MEMS

Semi-Packed Columns

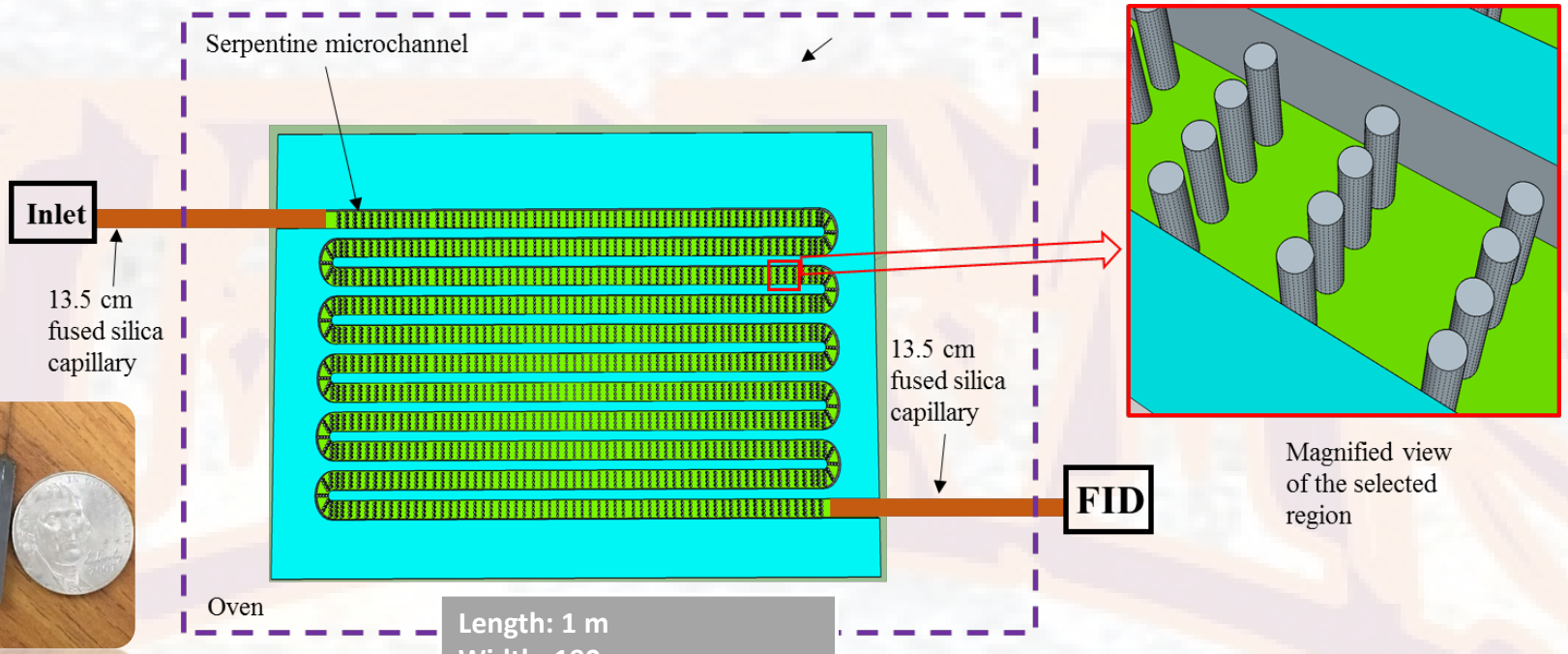




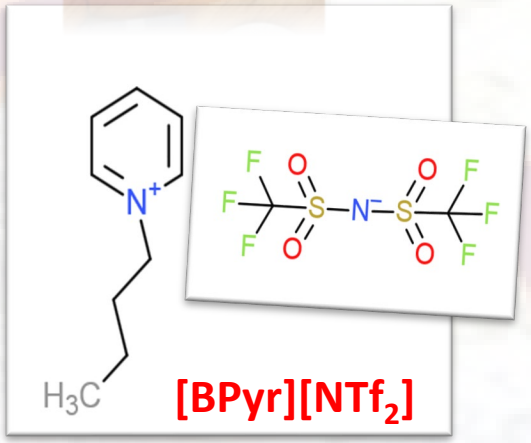


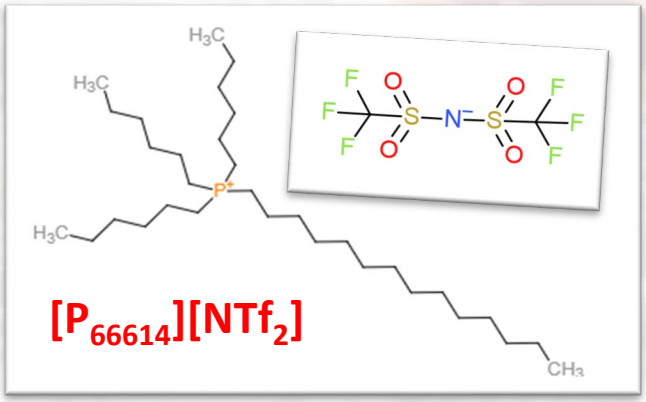


Ionic Liquid as Stationary Phases



Length: 1 m
Width: 190 µm
Depth: 240 µm
Pillar diameter: 20 µm
Interpillar distance: 40 µm





Regmi et al. *Journal of Chromatography A* 1510 (**2017**): 66-72.

Ionic Liquid as Stationary Phases

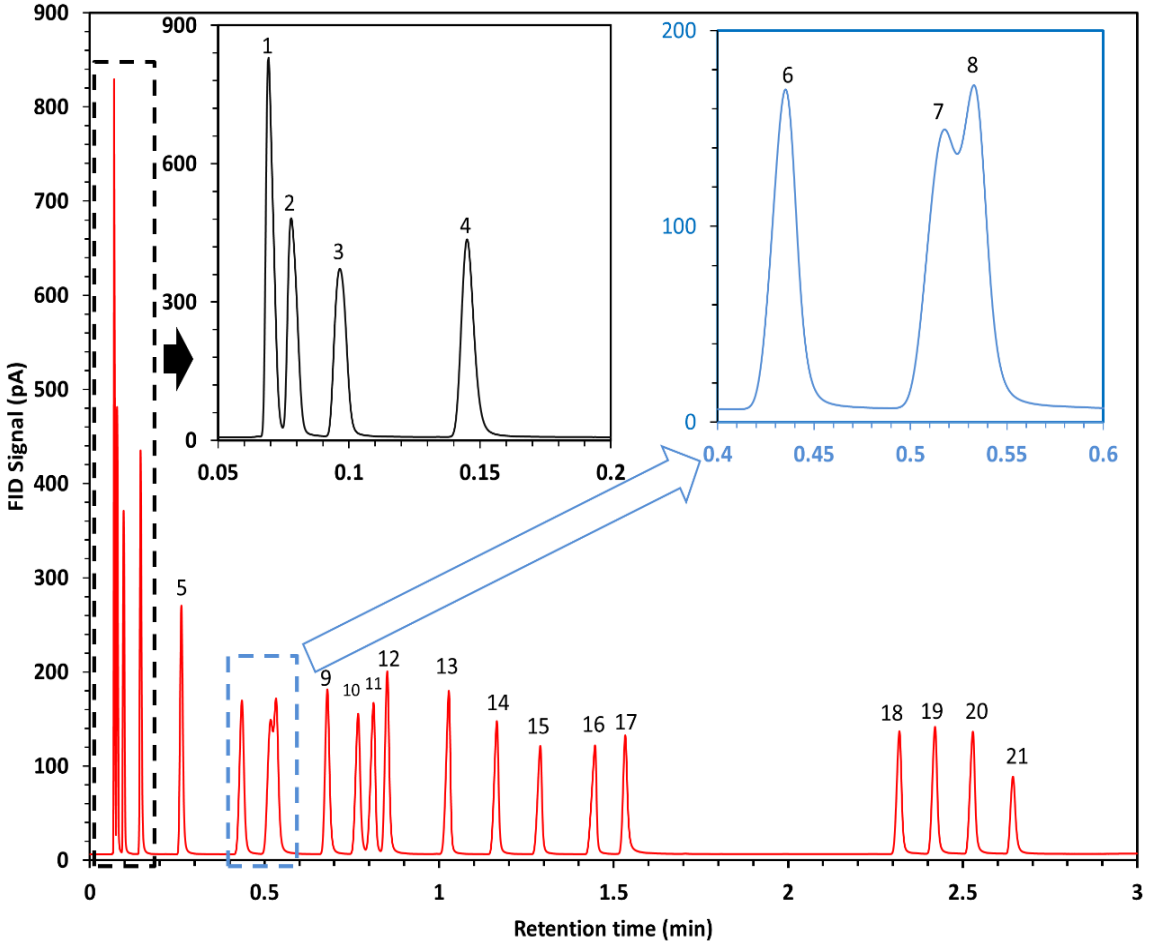
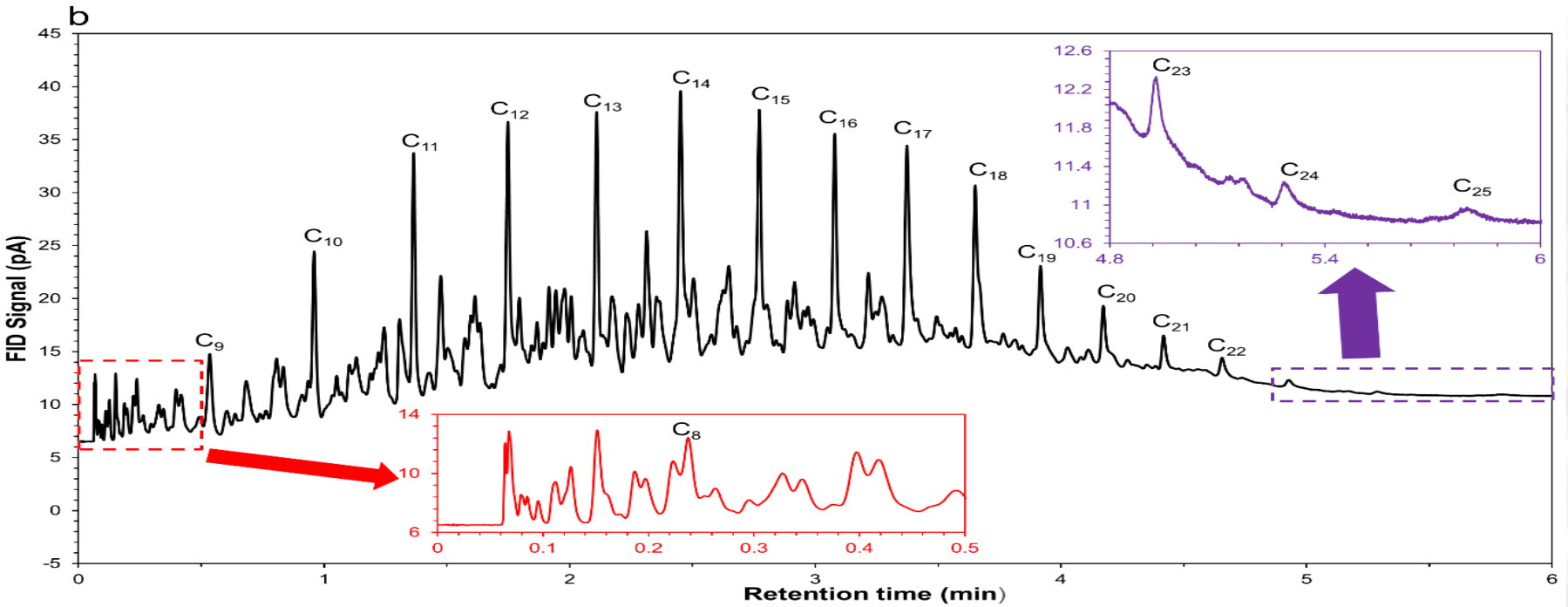


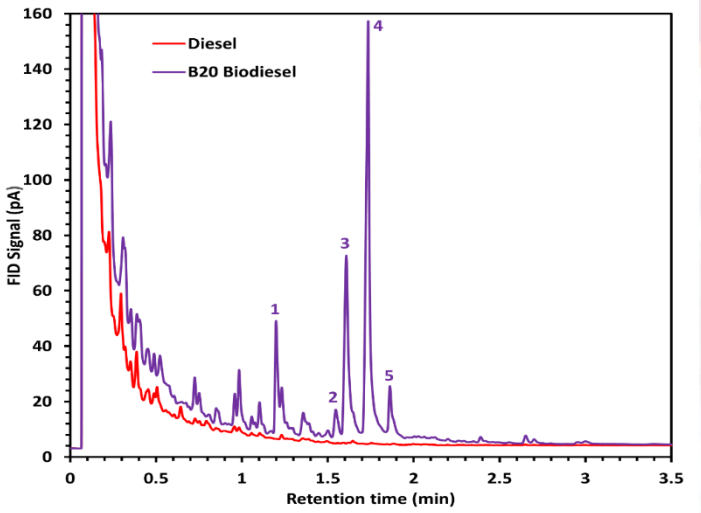
Table 1. Components of the Test Mixture		
Peak	Compounds	Boiling Point (°C)
1	Heptane	98
2	Octane	126
3	Nonane	150
4	Benzene	80
5	Toluene	111
6	Ethylbenzene	136
7	p-Xylene	138
8	m-Xylene	139
9	o-Xylene	144
10	2-Chlorotoluene	159
11	Isobutylbenzene	170
12	Styrene	145
13	Butylbenzene	183
14	1,2-Dichlorobenzene	180
15	2,5-Dichlorotoluene	197
16	1,2,4-Trichlorobenzene	213
17	Benzyl chloride	177
18	Naphthalene	218
19	2-Ntrotoluene	222
20	3-Nitrotoluene	232
21	4-Nitrotoluene	238

Chromatogram showing the separation of a 21-component mixture of organic compounds using a column prepared by depositing [BPyr][NTf_2] on alumina surface. Chromatographic conditions: injection volume 0.1 µL, split ratio 400: 1, inlet pressure 25 psi for 0.5 min and then ramped to 35 psi at the rate of 60 psi/min, oven temperature 30 °C for 0.5 min and then ramped at the rate of 40 °C/min to 130 °C.

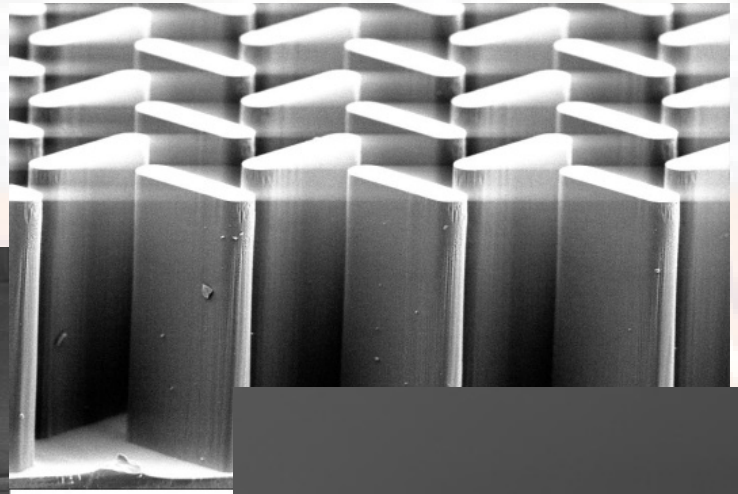
Separation of Diesel Components

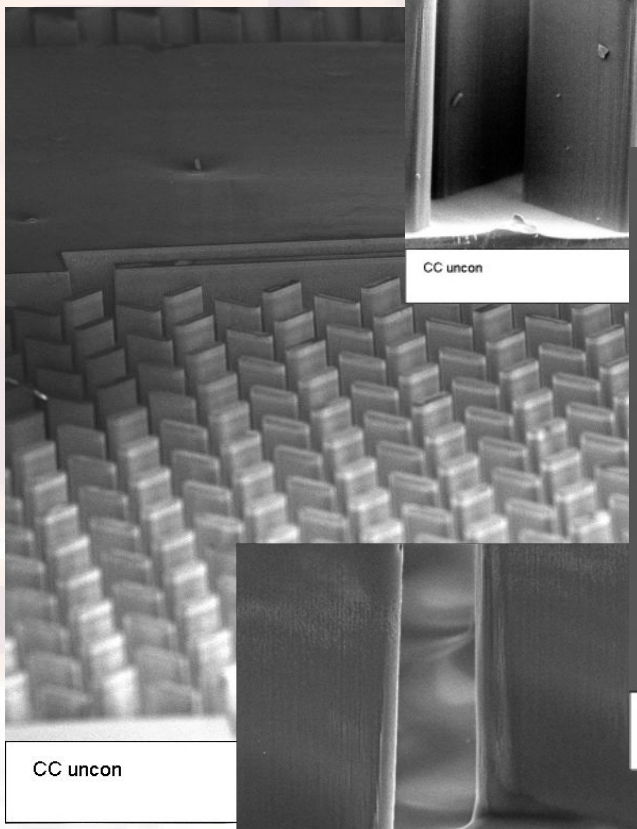


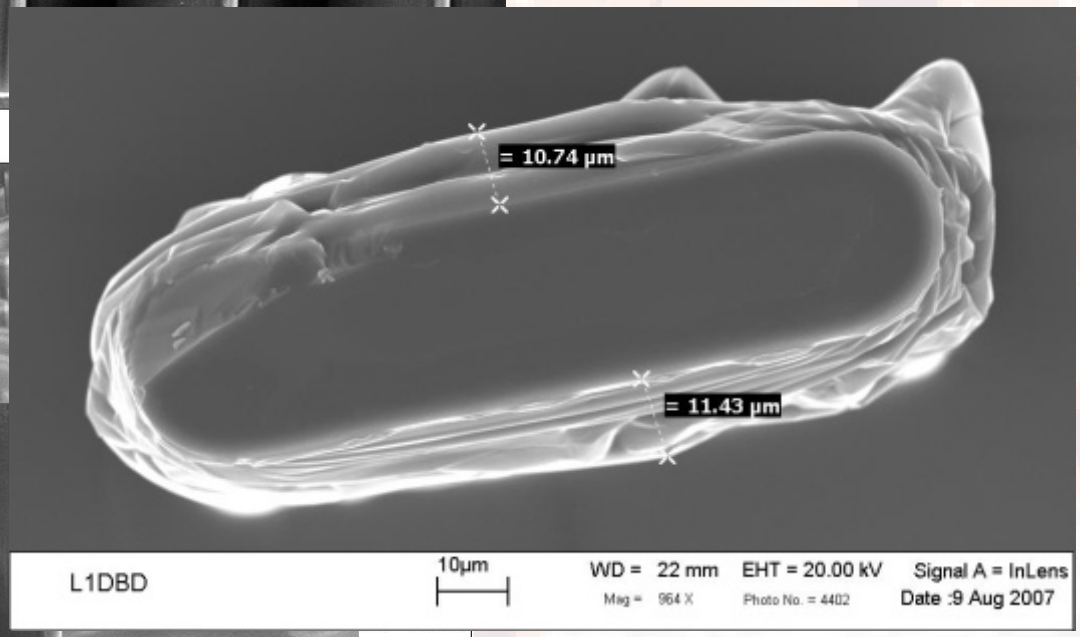
Overlay of the chromatograms of the separation of diesel (red) and B20 soy biodiesel (purple) using the alumina-[BPyr][NTf2] column. Diesel:Biodisel (80:20) blend at a concentration of 5 mg per ml in dichloromethane was obtained from Restek Corporation. A 5 mg per ml solution of diesel in dichloromethane was prepared in the lab. Chromatographic conditions: injection volume 1 µL, split ratio 20: 1, inlet pressure 35 psig, oven temperature ramped from 100 °C at the rate of 40 °C/min to 200 °C and held for 1 minute. The fatty acid methyl esters peaks were identified by comparing the retention time of the peaks to a standard mixture of fatty acid methyl esters (FAME #1 from Restek Corporation). The peak numbers correspond to: (1) methyl palmitate (C16:00), (2) methyl stearate (C18:00), (3) methyl oleate (18:01), (4) methyl linoleate (C18:02), and (5) methyl linolenate (18:03).

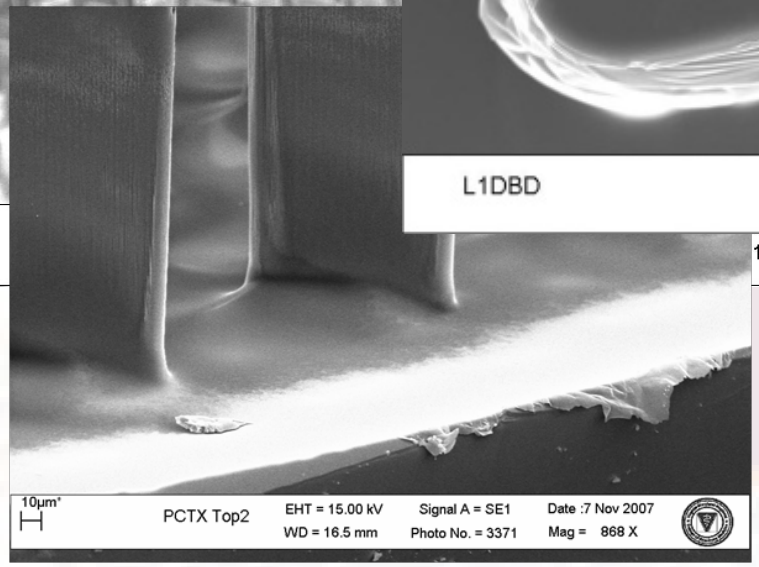


Alfeeli, Sensors and Actuators





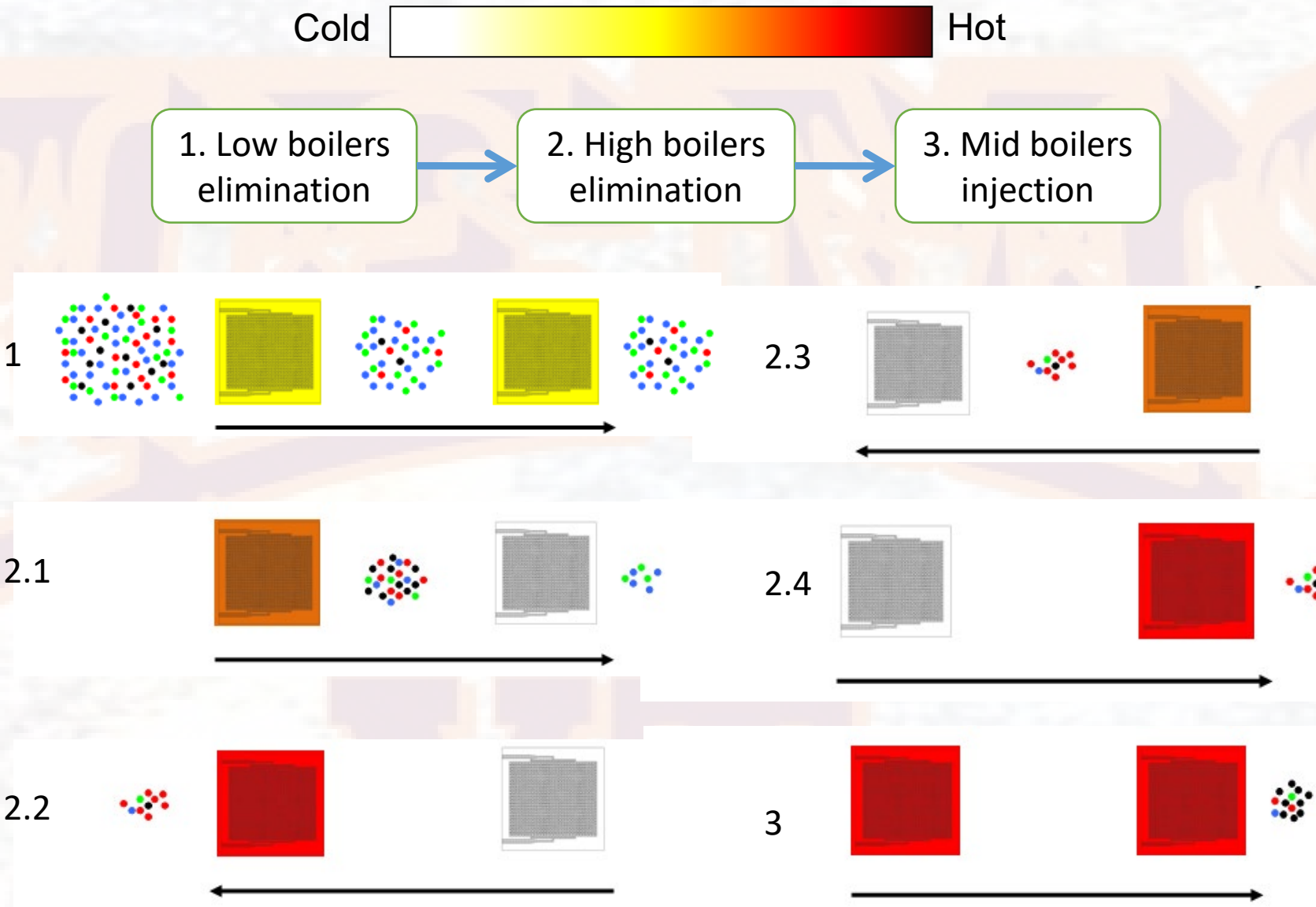




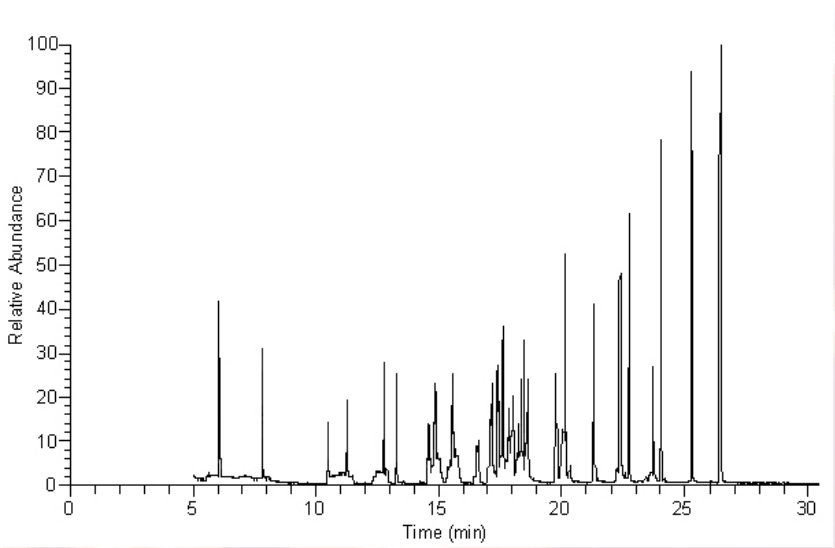
Significant Contribution: Integrating MEMS and Polymer (Tenax TA) Inkjet Printing

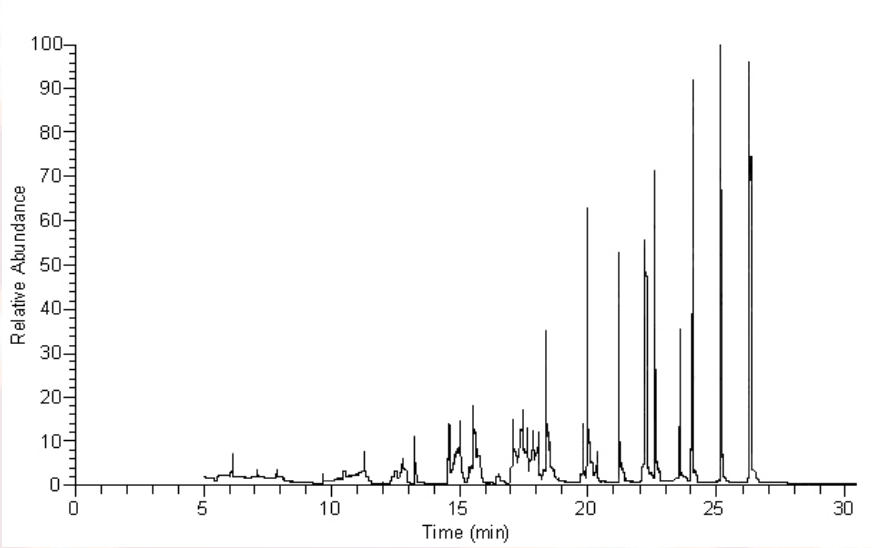
Providing Full-Coverage Coating of Tenax TA in Film-Form on 3D High-Aspect-Ratio Structures

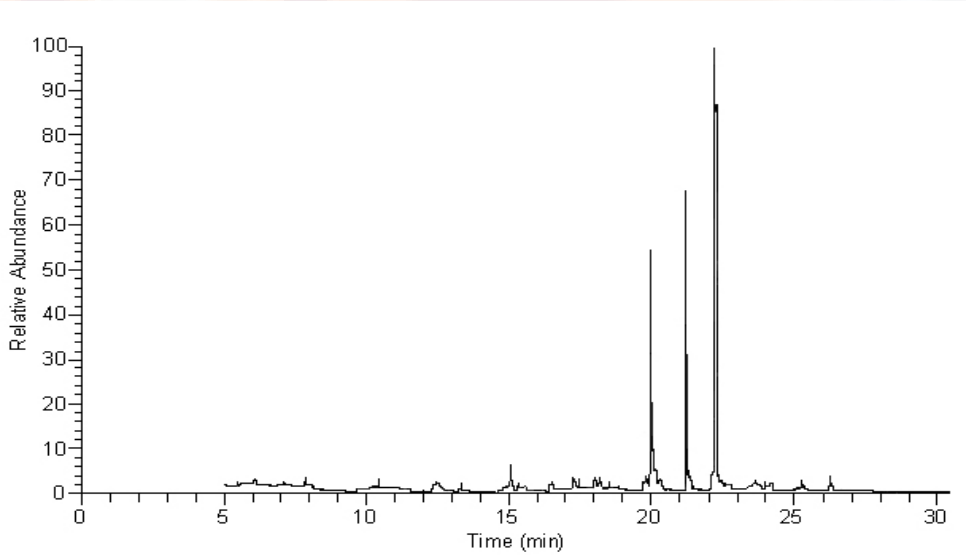
Cascaded Preconcentrators



Cascaded Preconcentrators



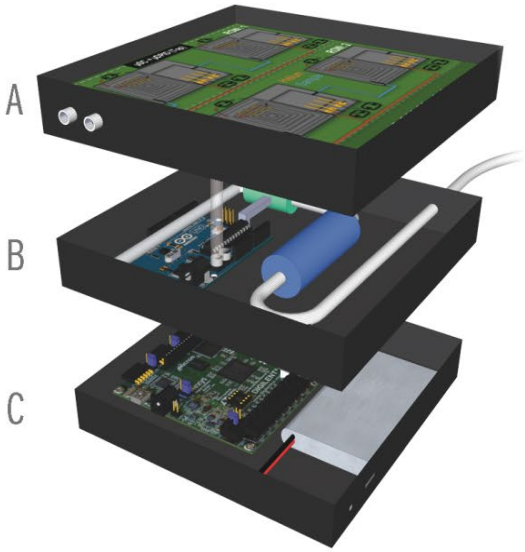




GC-MS analysis of collected indoor air test mixture. (left) a single μPC @T1=35˚C, (center) a single μPC @ T1=60˚C, and (right) cascaded μPCs @T1=60˚C, T2=150˚C, and T3=250˚C resulting in selective preconcentration.

iWAVE (A Revolutionary Concept)

iWAVE Modules



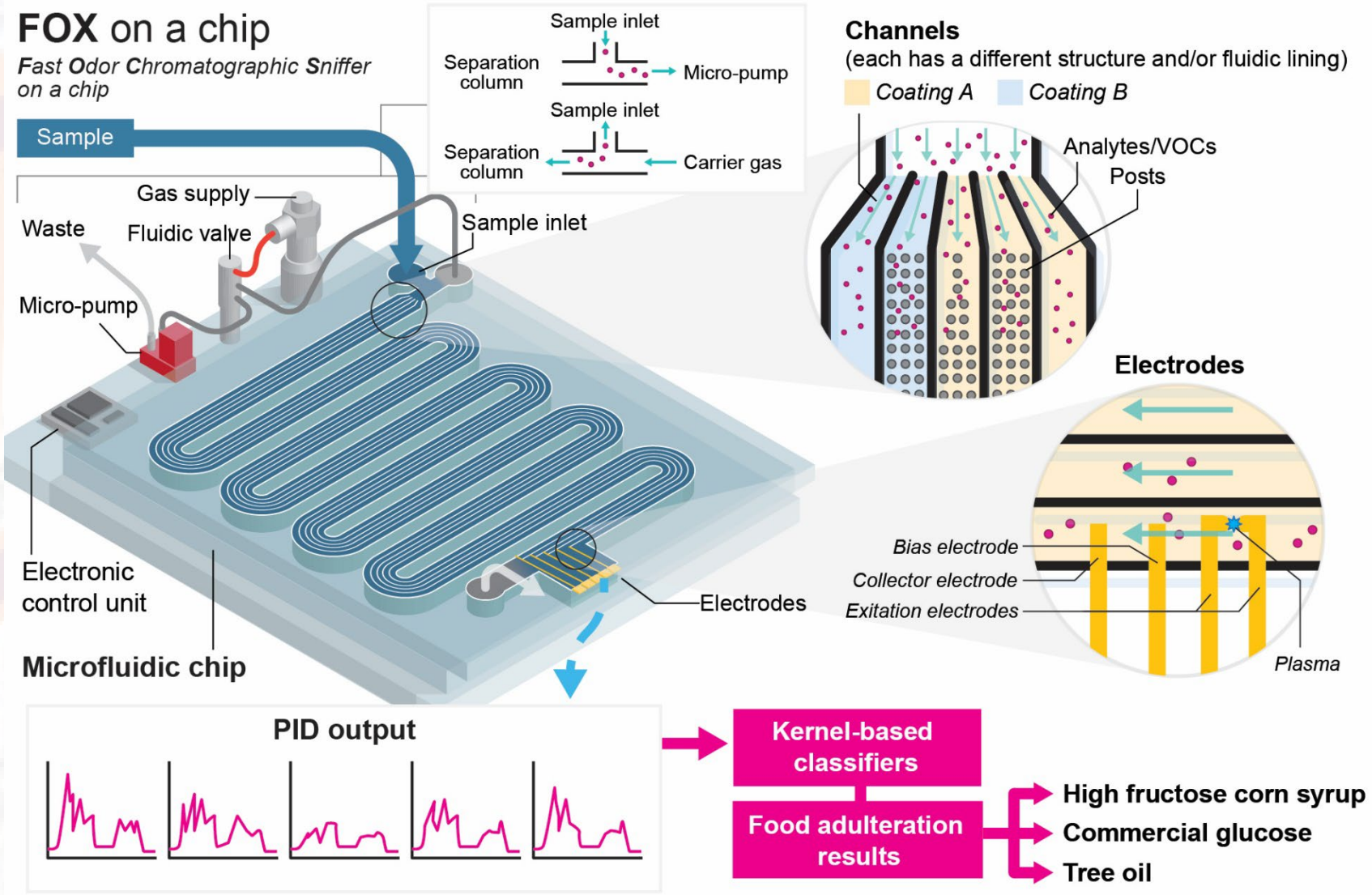
A - Separation and Detection (GCM)

B - Air Sampling, Preconcentration, and Injection (ASPI)

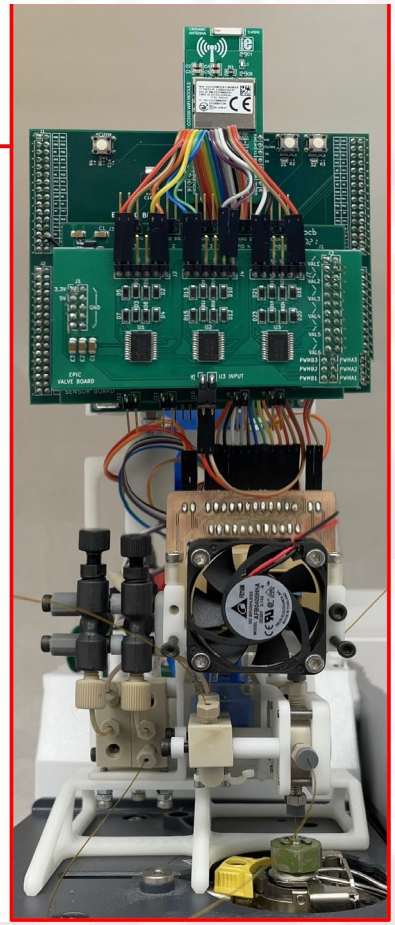
C - Electronic Control and Data Acquisition (ECDA)

intelligent Wearable Analyzer for Vapor Exposure

FOX-on-a-Chip (Chemical Detection-Patent Pending)

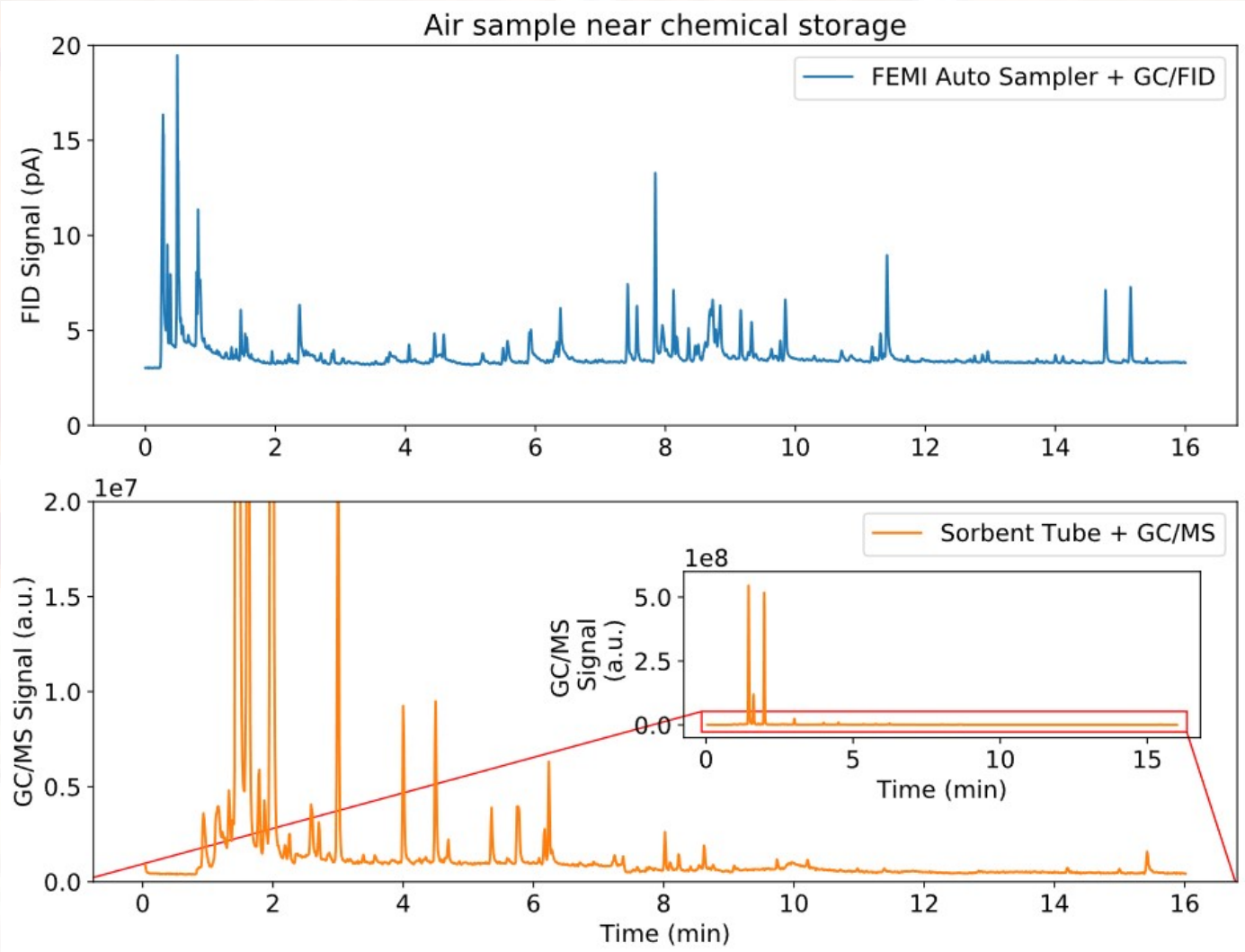


Highly Modular Auto Sampler and iWAVE



Patent Pending

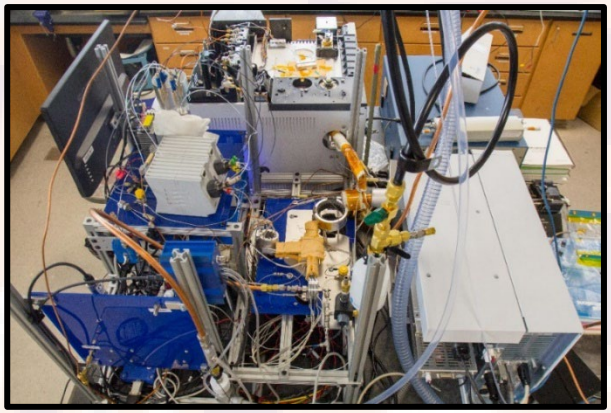
Environmental Sampling



Aerosol/Gas Sampling

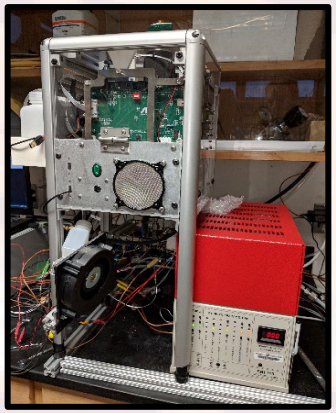
Unprecedented Tools for Aerosol and Gas Sampling

New custom instrumentation developed and built by the Isaacman-VanWertz group:



State-of-the-art tools for highly chemically detailed real-team aerosol collection and analyses

Frazier et al., *Envi. Sci.: Atmospheres*, 2022
Bi et al., *Atmos. Meas. Tech*., 2021a
Bi et al., *Atmos. Meas. Tech*., 2021b
Bi et al., *Atmos. Meas. Tech*., 2021c
Isaacman-VanWertz et al., *Envi. Sci. Tech*., 2016
Isaacman et al., *Atmos. Meas. Tech*., 2014



Autonomous tools for unattended monitoring of aerosol mass and chemical properties

Hurley et al., *Atmos. Meas. Tech*., 2020
Kumar et al., *in prep*

Portable, rugged samplers for multi-site, simultaneous, distributed field sampling

Hurley et al., *in prep*
Onufrevia et al., *in prep*

Lab and Field measurements of Particle-Phase Organics

Some significant contributions to the field by the Isaacman-VanWertz group:

Direct evidence that particle-phase organics do not follow thermodynamic equilibrium partitioning (data from Alabama and Brazil)

Isaacman-VanWertz et al., *Envi. Sci. Tech.*, 2016

First successful effort to comprehensively measure all particle- and gas-phase organic carbon in simulated atmospheric oxidation.

Isaacman-VanWertz et al., *Nature Chemistry*, 2018

New software for analysis of atmospheric chromatographic data that is used by dozens of research groups to analyze particle- and gas-phase organics

Foundation:

Isaacman-VanWertz et al., *J. Chrom. A*, 2017

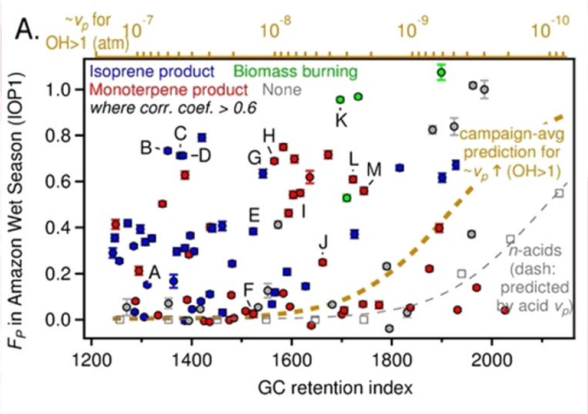
Kim et al., *Atmos. Meas. Tech.*, 2022

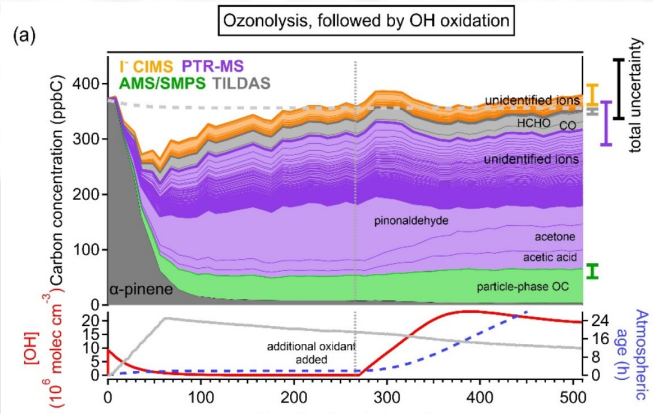
Example high impact uses outside IVW group:

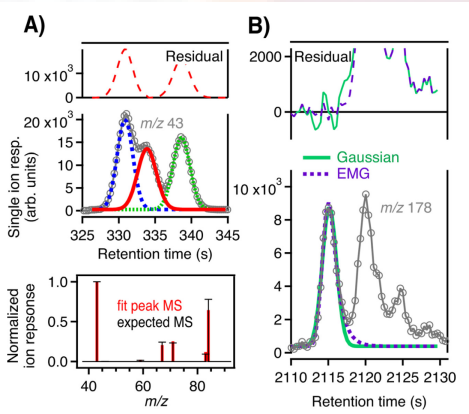
Coggon et al., *PNAS*, 2021

McDonald et al., *Science*, 2018

Zhang et al., *PNAS*, 2018

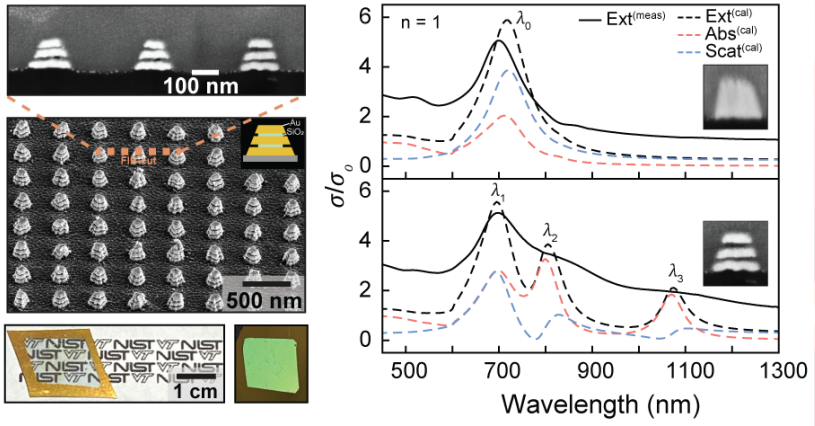


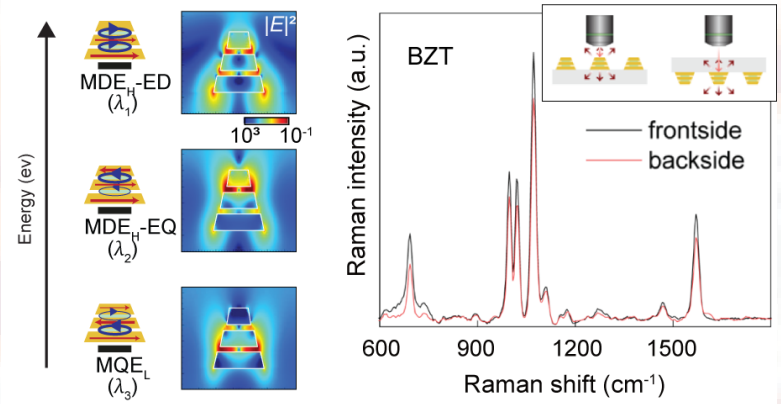


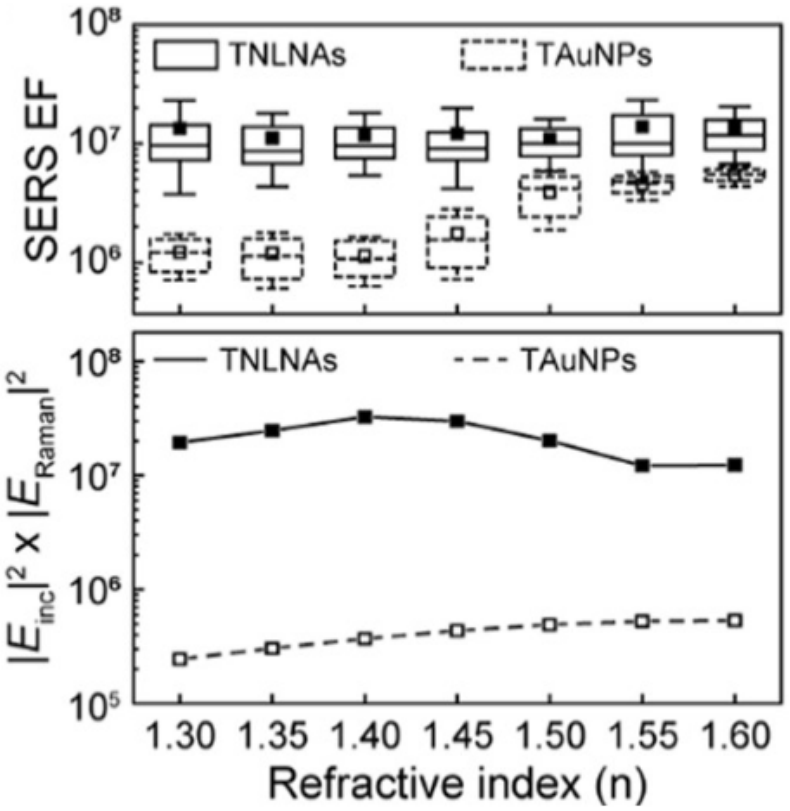


Surface-Enhanced Raman Spectroscopy (SERS)

Broadband Multi-Resonant Plasmonics







- We developed modularized **nanolaminate nanoantennas** supporting multiple hybridized plasmon modes.
  - Broadband multiresonant enhancement of nanoscale light-matter interactions.
  - Refractive-index insensitive **surface-enhanced Raman scattering (SERS)** performance.
  - Transparent SERS devices compatible with frontside and backside laser excitation.

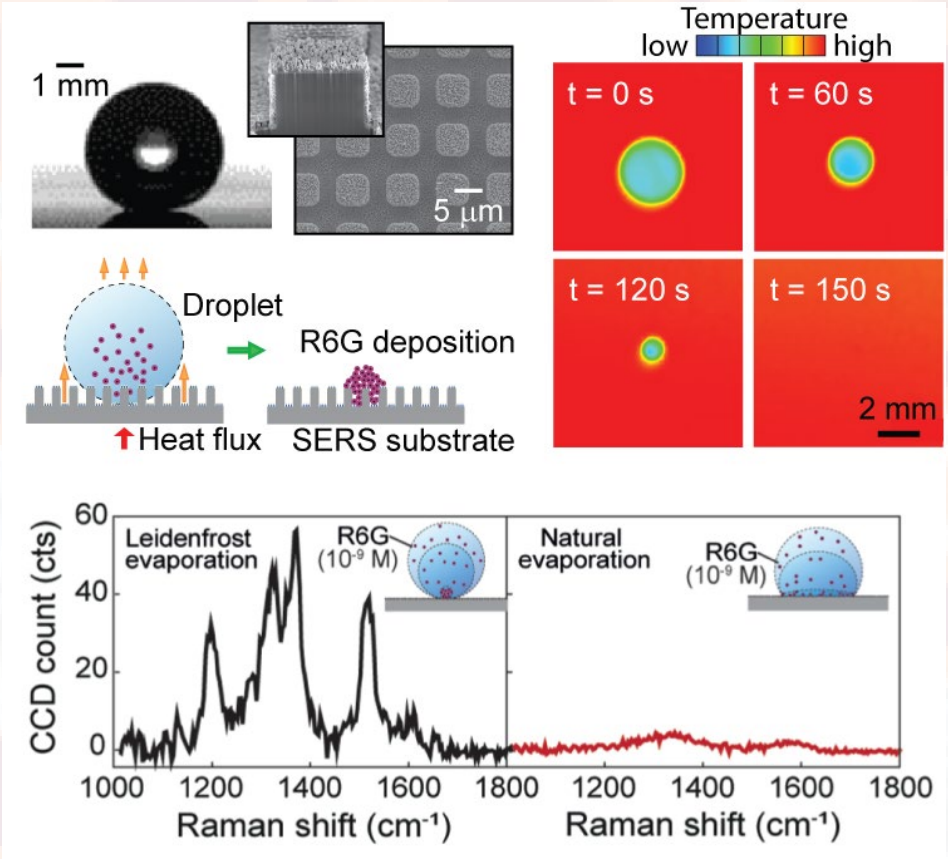
W. Zhou et. al. Nano Letters 18 (2018) 4409

W. Zhou et. al. ACS App. Nano Mat. 4 (2021) 3175

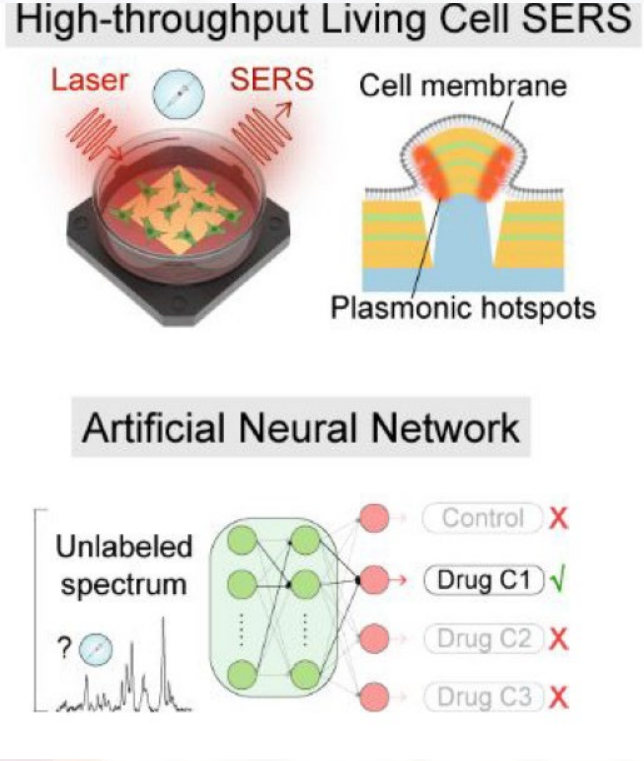
Superhydrophobic SERS Devices for Rapid Biochemical Detection of Microdroplet Samples

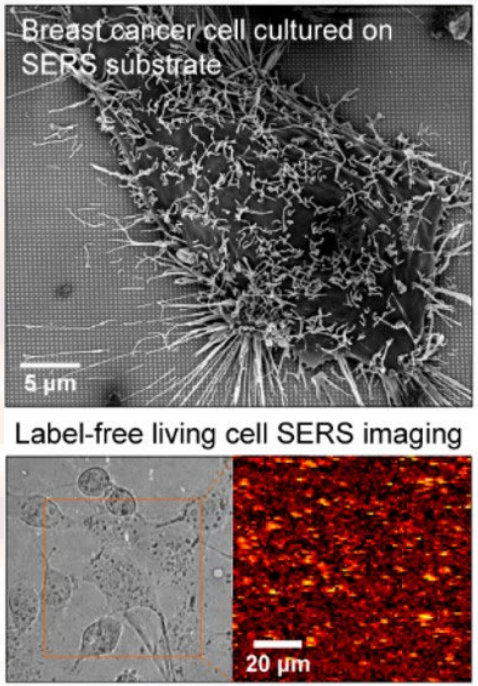
- We have developed novel **superhydrophobic SERS substrates** allowing a <u>partial Leidenfrost evaporation-assisted enrichment</u> approach for **ultrasensitive SERS detection** of ultralow (nM) concentration analytes in minutes.
- **Superhydrophobic SERS substrates** consist of <u>*nanolaminate plasmonic nanoantennas*</u> on <u>*hierarchical micro-nanopillar arrays with a hydrophobic Teflon coating*</u>, which is a **biomimetic lotus structure**.

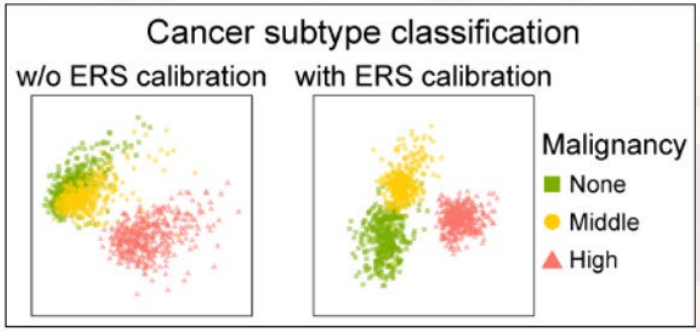
W. Zhou et. al. ACS Nano 14 (2020) 9521

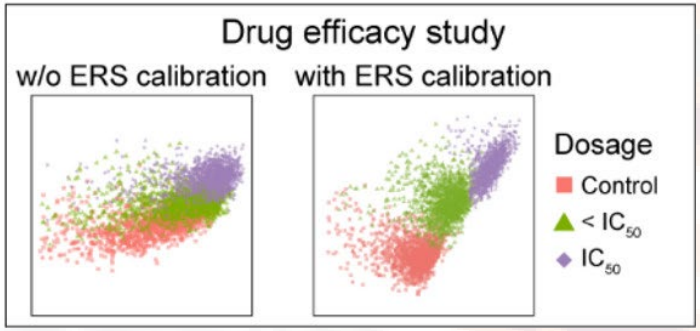


Machine-learning Empowered Real-time SERS Analyses









- We have employed non-supervised and supervised **machine-learning (ML)** methods to analyze and classify SERS spectra of molecular components associated with different cell lines and drug responses.

W. Zhou, M. Agah et. al. Nano Lett. 19 (2019) 7273

W. Zhou, M. Agah, et. al. Anal. Chem. 93 (2021) 4601

W. Zhou, M. Agah et. al. ACS App. Nano Mat. 5 (2022) 10358

Laser-based Airborne Free-Space Optical Rapid Gas Evaluation (LAFORGE) platform

Presented by Stephen Roberson

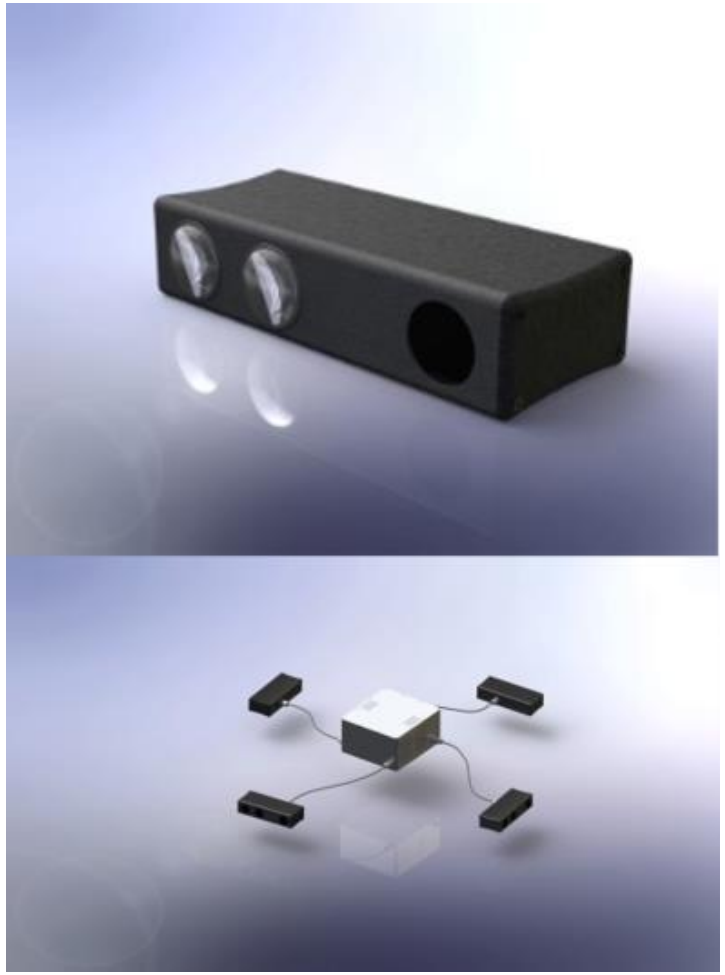
4S-Silversword Software and Services
Stephen Roberson, Lead Physicist
Rob Smith, Senior Scientist
William Ziegler, Program Manager
4s-llc.com

NuMoon Technologies
Gianna Arnold, CEO
Brad Conrad, CSO
numoontech.com

TALOC

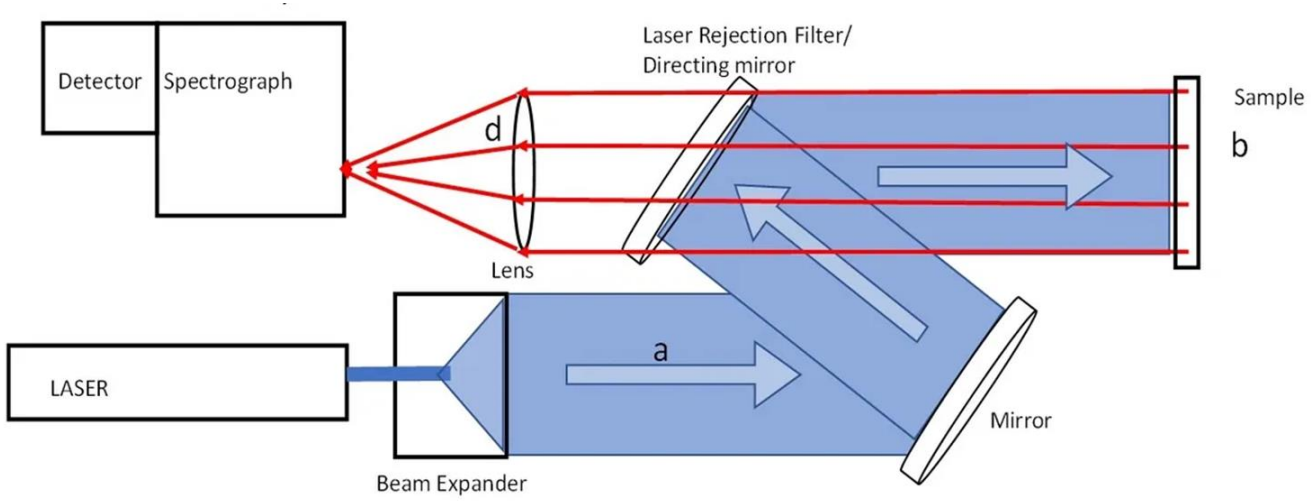
silversword

- **TALOC** – Through the Air Link Optical Component is a free space optical communication technology
- Dual wavelength operation
- Solid state scanning and tracking (no moving parts).
- Optical acquisition and tracking (no GPS or RF required)
- Multiple optical units can be centrally controlled to provide 360-degree coverage.
- Works out to 1 nautical mile.

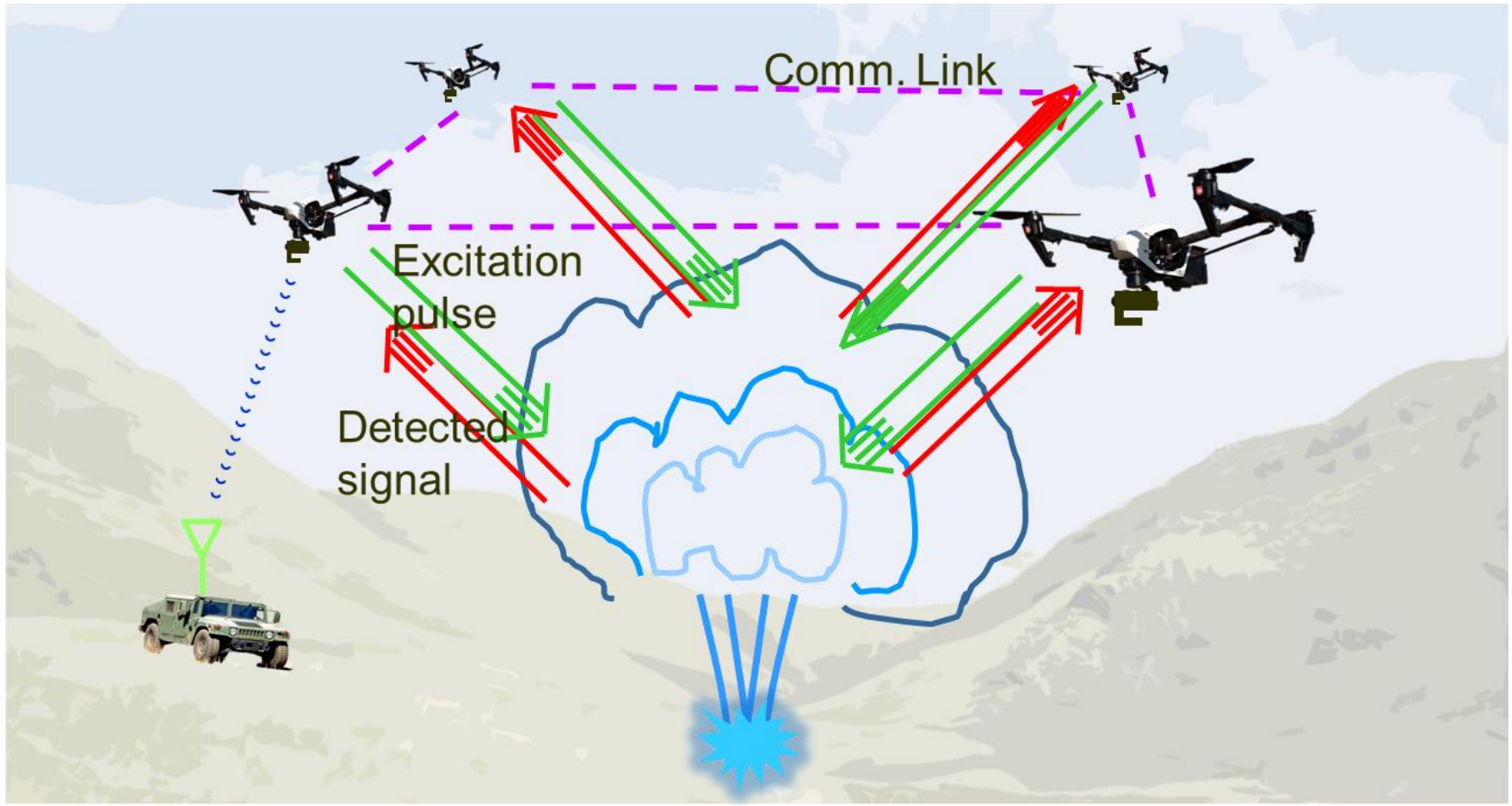


Optical Characterization Setup

- Optical collection configuration allows coupling of Raman scattered light from an unfocussed Nd:YAG excitation source to be efficiently coupled into an optical fiber.
- High power excitation pulses are used while simultaneously avoiding sample degradation, multiphoton effects, and alleviating the need for deep sample penetration depths.
- No need for accurate focal plane adjustments. Light is collected from a large cross-sectional area, not a discreet focal point.
- Currently proven effective out to 100 m



Proposed LAFORGE Platform Schematic



LAFORGE Platform Summary

- Use several linked UAVs to determine plume spatial characterization, particle concentration, and chemical composition.
- Proposed Modalitites for Characterization with LAFORGE
  - Raman spectroscopy
  - Laser induced fluorescence
  - Laser induced breakdown spectroscopy
  - Calibrated communication laser transmission degradation

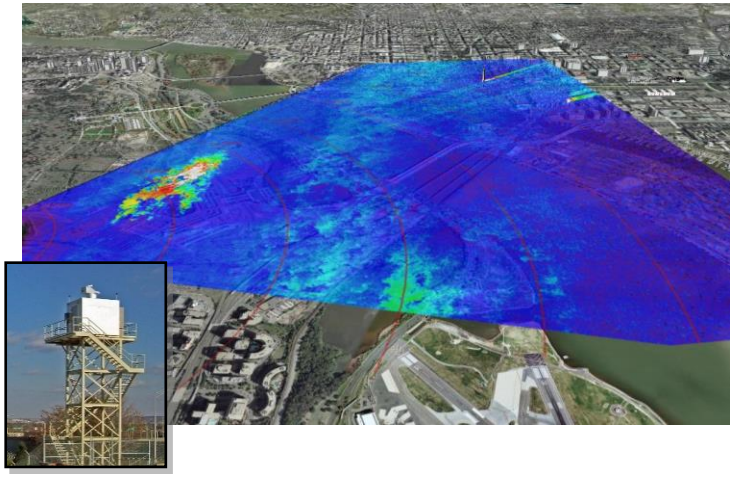
REVEAL-ASI Technology Overview
Enabling Capabilities for PICARD

Presented at:
IARPA PICARD Proposers' Day
September 26, 2022

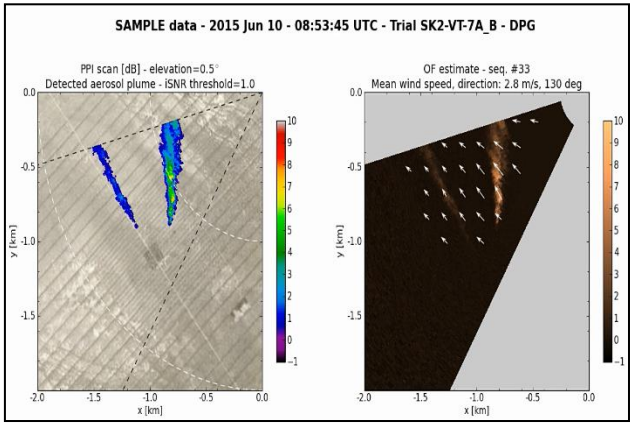
Spectral Sensor Solutions
Email: scott.higdon@S-3LLC.com
Phone: 703-608-2325

Real-time Eyesafe Visualization Evaluation & Analysis Lidar

Backscatter Lidar: Plume Detect/Map/Track

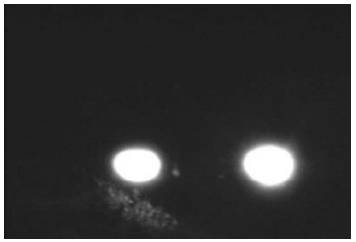


Wind Lidar: 2-D Vector Wind Fields



REVEAL System

Active SWIR Imaging (ASI): Enhanced ISR



Night SWIR Imaging

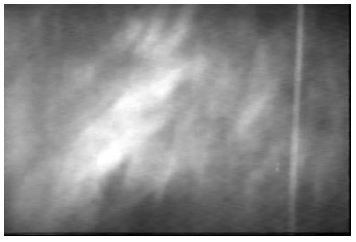
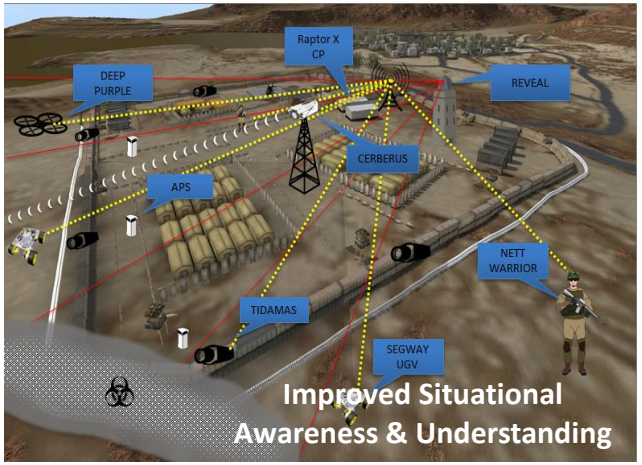


Image Thru Obscurants

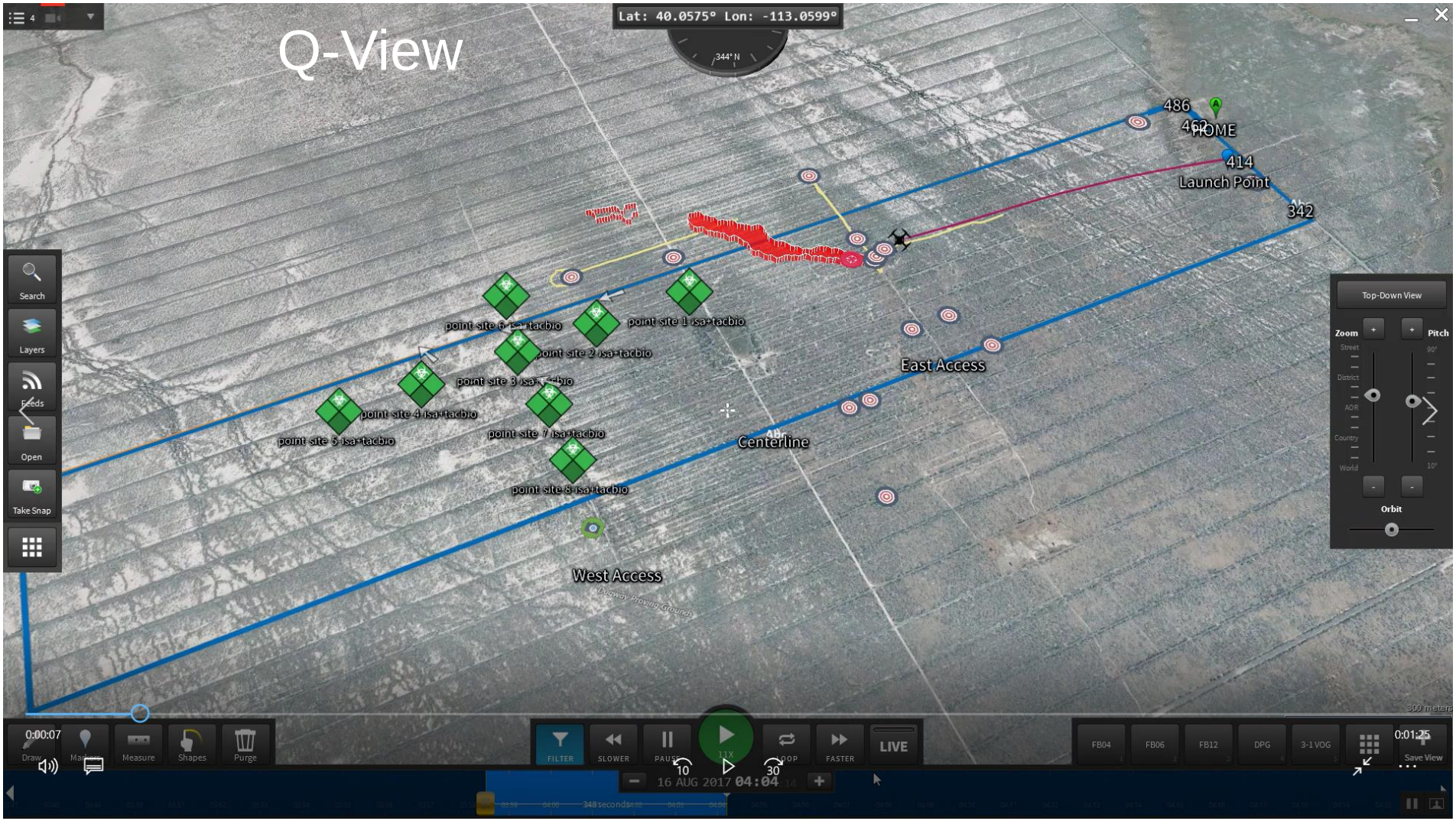
Comprehensive Situational Awareness

Sensor Network: Cueing & Fusion



REVEAL is a Multi-Function/Multi-Mission Lidar Sensor

Lidar Plume Detection, Mapping & Tracking + Effective UAV Cueing = Earlier Warning

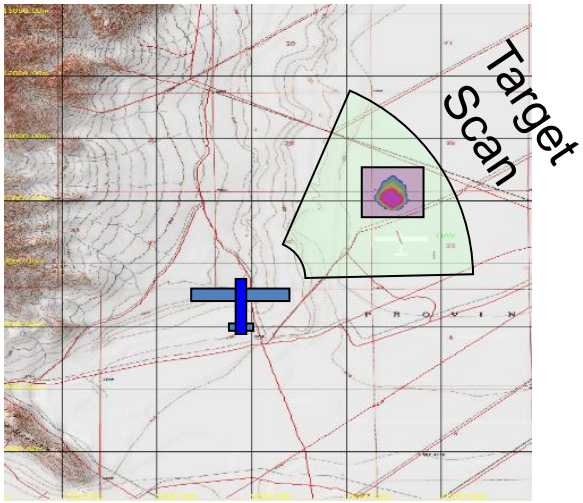


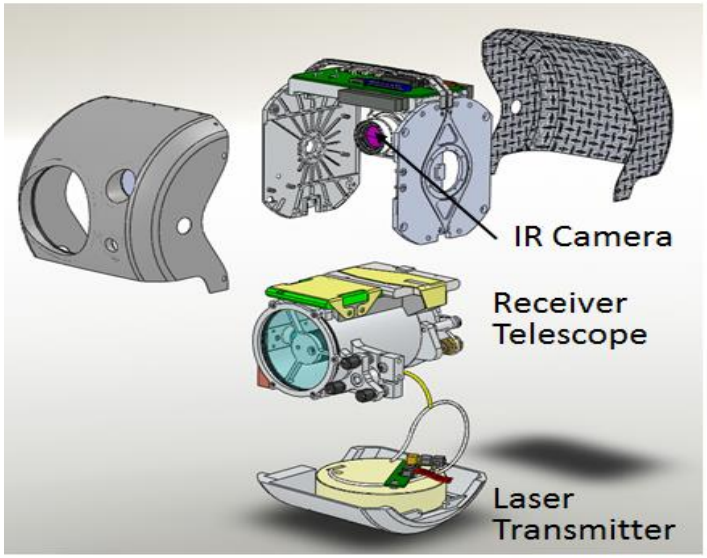
REVEAL provided 5 minutes of additional warning time compared to the TAC-Bio point sensor

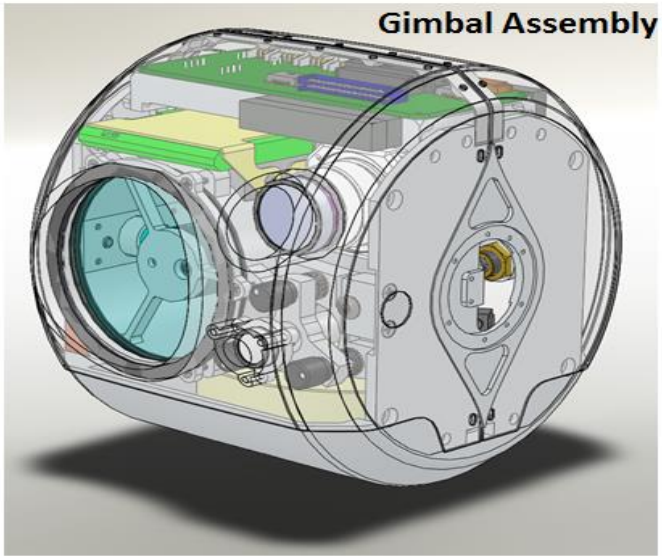
µREVEAL

Key Characteristics

- S3 has a concept design for a miniaturized version of REVEAL for integration onto a Group 2 UAV for long-range, wide-area deployability
- Enables the UAV to find an aerosol plume at a range of 300 – 500 m from the UAV
- Enables effective and efficient cueing of a UAV equipped with a point sensor to provide specificity of the threat
- Increases area coverage rate by orders of magnitude compared to a UAV with point sensor only







µREVEAL has the potential to significantly expand point sensor cueing capabilities

REVEAL-ASI Benefits for PICARD

- Provides long-range high-sensitivity detection, mapping and tracking of chem/bio aerosol plumes over wide areas
- Provides 2D horizontal wind fields which are critical to the transport, dispersion and deposition of the aerosols
- Provides the capability to effectively and efficiently cue mobile platforms with integrated point sensors into the plume
- Provides the capability to cue fixed-site point sensors to the time-of-intercept by a chem/bio aerosol plume
- ASI mode can provide 3D maps of obstacles for ingress/egress routing of mobile platforms and additional situational awareness and understanding of the threat
- S3 is working on a 3-wavelength version of REVEAL by adding Visible and Near-IR channels to enable the measurement of particle size distribution

REVEAL-ASI provides complementary capabilities that improve situational awareness and understanding and enable the optimum deployment of point sensors with higher specificity

Sensing with Integrated Photonics

Dr. Aaron Zilkie
Rockley Photonics

Dr. Robert Wortman
Skywater Technology

RKLY
LISTED
NYSE

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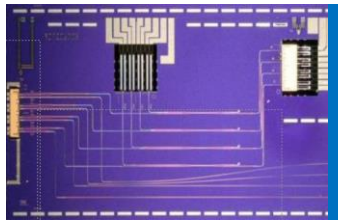
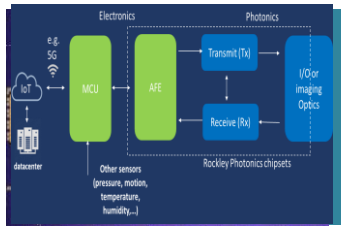
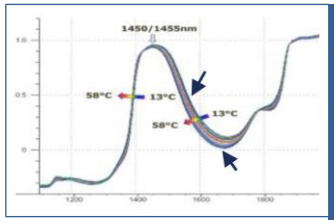
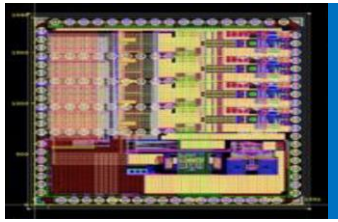
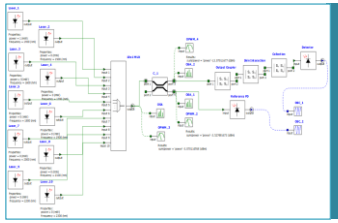
Full Technology Stack for Sensing Applications

Rockley is unique in its approach of innovating across the entire sensing technology stack.

200 Issued Patents and 292 Pending Patents*.

Semiconductor Technology & Process	Full Module & Product Capability	Measurement Science & Data Analytics
 Photonic ICs in silicon with integrated III-V	 System architecture and hardware design	 Biosensing algorithms, cloud analytics, and AI
 Electronic ICs	 Photonics-based sensing module (LED and IR)	 Biomarker data collection
 High-volume manufacturing process and ecosystem	 Firmware / software	 AI/ML-based analytics

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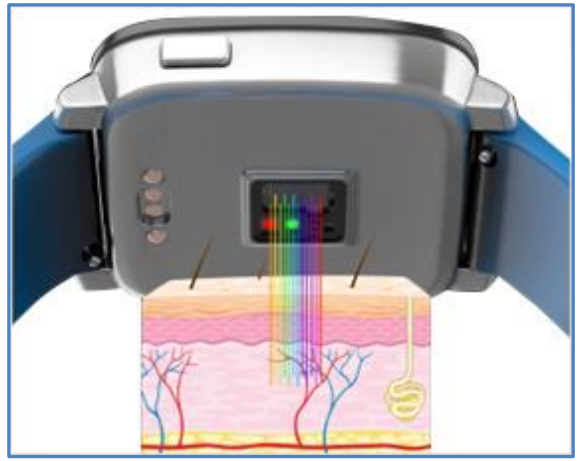
*As of March 31, 2022

Rockley Clinic-on-the-Wrist™ Sensor Wearable

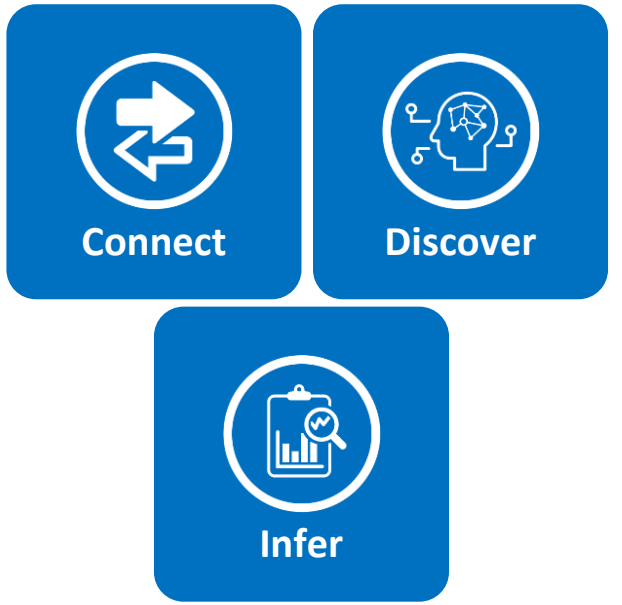
Clinic-on-the-Wrist™ Module



Multiple laser wavelengths probe non-invasively into the skin to extract a “spectral fingerprint” of user’s health.

Rockley Differentiation.

Rockley AI Platform



AI/ML derived algorithms refine accuracy and maximize functionality from spectral fingerprint.

The Result

A platform that is collecting much richer data than current LED PPG solutions

Capable of continued and long-term increase in functionality and use cases powered by AI/ML led inference and interpretation

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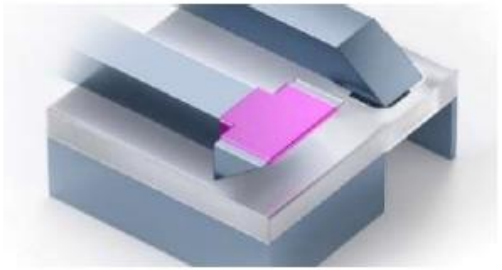
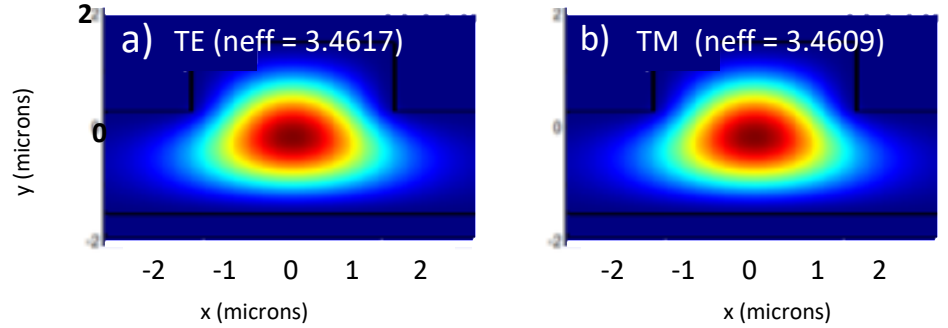
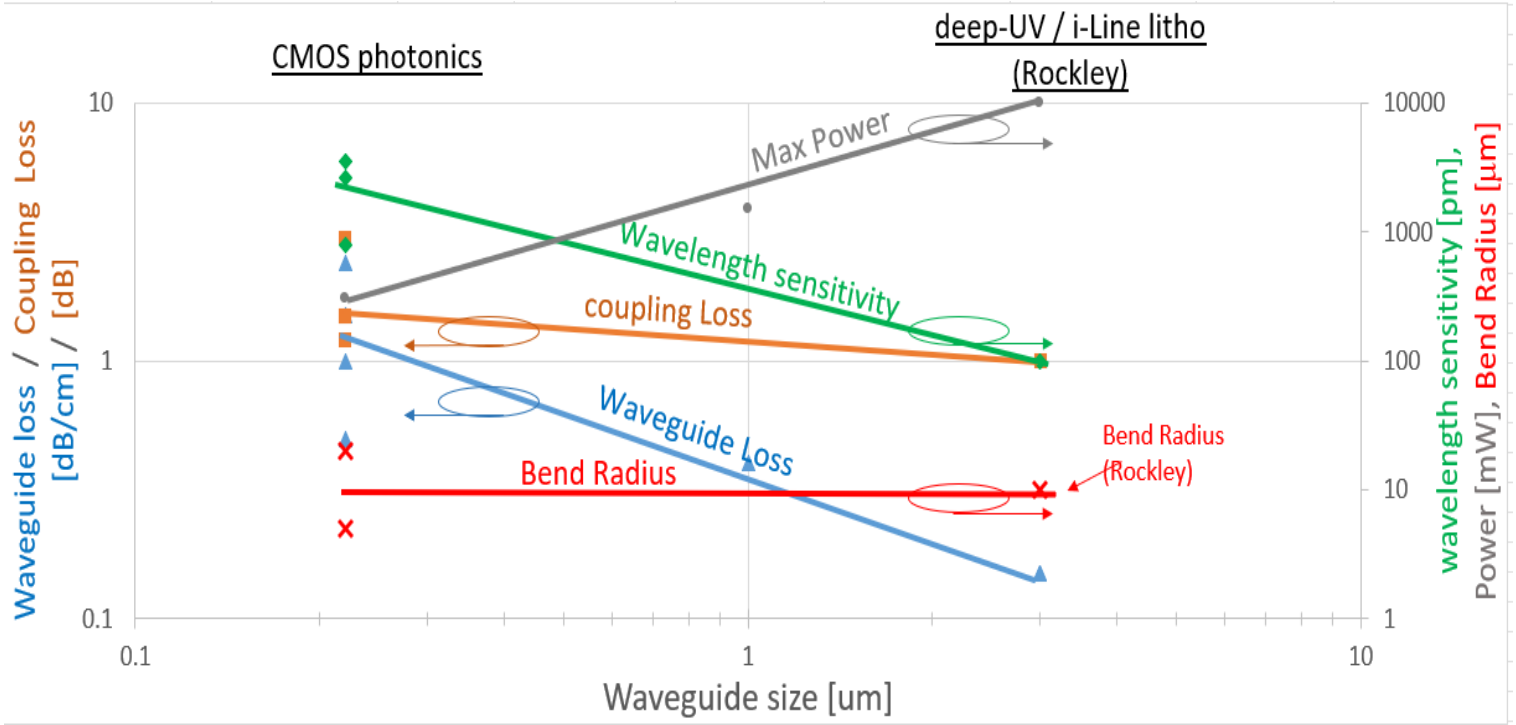
Multi-micron Silicon Photonics Platform

Platform Benefits

- ✓ Very low loss: Large-scale PICs possible
- ✓ High power handling capability
- ✓ Broadband performance
- ✓ Tight bends and tight waveguide packing for dense layouts
- ✓ Low polarization dependence
- ✓ KGD III-V die integration for high yield actives
- ✓ Built-in fiber and edge couplers
- ✓ Lower sensitivity to manufacturing variations







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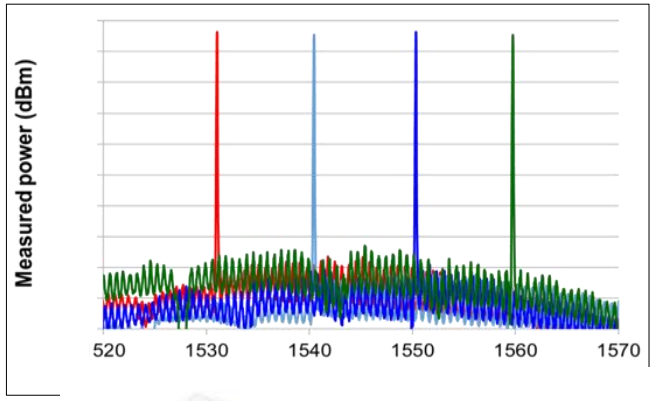
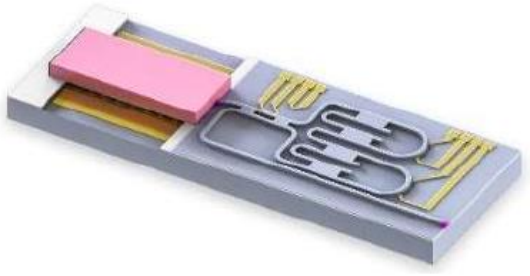
Key Platform Components

High-Density broad-wavelength lasers

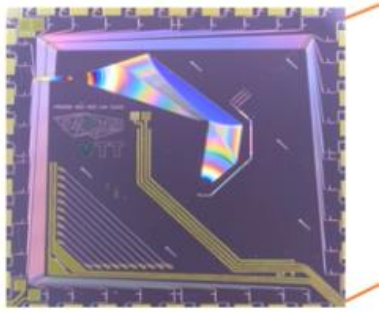
- Hybrid-integrated IR laser arrays (die attached to substrate)
- Widest wavelength offering: **600 nm trough >2000 nm**
- Narrow linewidths, fixed wavelength or tunable

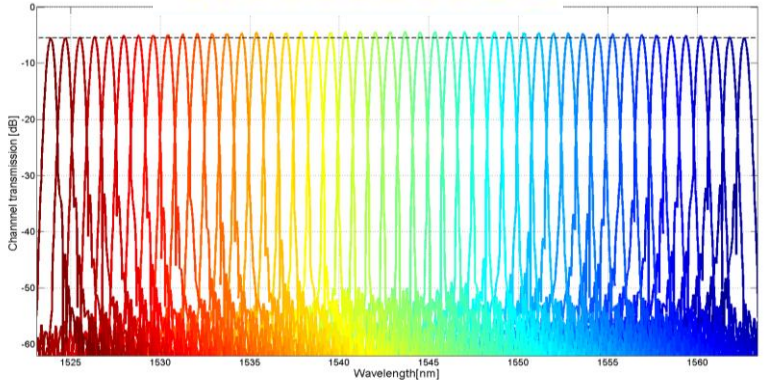




Integrated Filters

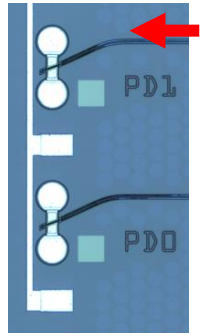
- Arrayed Waveguide Gratings and Echelles
- High channels isolation, ideal for in
- Integrated AWGs ideal channel spacings for Raman spectroscopy

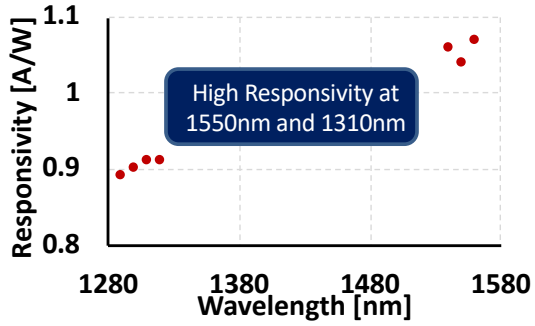




Integrated Detectors

- Ge and III-V Photodetector integrated into waveguide
- High responsivities 0.5 – 1 A/W over full wavelength range





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Applications and suggestions for PICARD

- Use Integrated Photonics to create Low SWaP-C sensors that can be injected directly into aerosol plumes via small, unmanned devices
  - NIR + IR reflection spectroscopy
  - Raman spectroscopy
  - Fluorescence spectroscopy?

- Attach Aerosol collection chamber to variants of existing low-SWAP Rockley sensors
  - Can employ MEMS pump for moving air through test chamber
  - Include Filters and dessicants via wafer level processing

- Apply ML / AI computational capability to discern chemicals from background

- Challenges to address:
  - Interference from attached/encapsulating/shielding particles
  - High specificity even among very similar chemicals
  - Size variation in aerosol droplet/particle sizes
  - Background/ambient chemistry
  - Other environmental factors (wind, humidity, temperature)

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Pursuing Intelligent Complex Aerosols for Rapid Detection (PICARD) Proposers' Day

Physical Sciences Inc. Capabilities Summary

Acknowledgment of Support and Disclaimer

This material is based upon work supported by the Army Contracting Command under Contract No. W911SR-20-C-0028. Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the Army Contracting Command.

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Title

Physical Sciences Inc.

VG-2022-251-2

Company

Physical Sciences, Inc.
Andover, MA

Key POC(s): Jay Giblin, jgiblin@psicorp.com; Elizabeth Schundler, eschundler@psicorp.com

Business Class: Small

Status: Nontraditional

Member Capabilities

- Phenomenological modeling
- System and optical design
- Field hardened sensor development
- Algorithm development
- User interface development
- Data networking
- Field testing
- Low rate production

Technologies Relevant for PICARD

Vapor/Aerosol Detection (CWAs, TICs, NTAs)

- Open path spatial ringdown spectrometer (Point Detection)
- LWIR HSI based on tunable Fabry Perot coupled with focal plane array (Standoff Detection, Wide Area)

Multivariate and Machine Learning Algorithms

Non-Contact, Surface Detection (Solid/Liquid CWAs, TICs, NTAs, and explosive contaminants)

- QCL based LWIR reflectance sensor
- Solid state, deep ultraviolet Raman sensor

Bioaerosol Detection

- Recursive Bayesian classifier for bioaerosol plume detection
- UAS for plume sampling

Desired Teaming Areas

- Aerosol Sampling
- Platform integration
- EMD

Point Vapor/Aerosol Detection

Physical Sciences Inc.

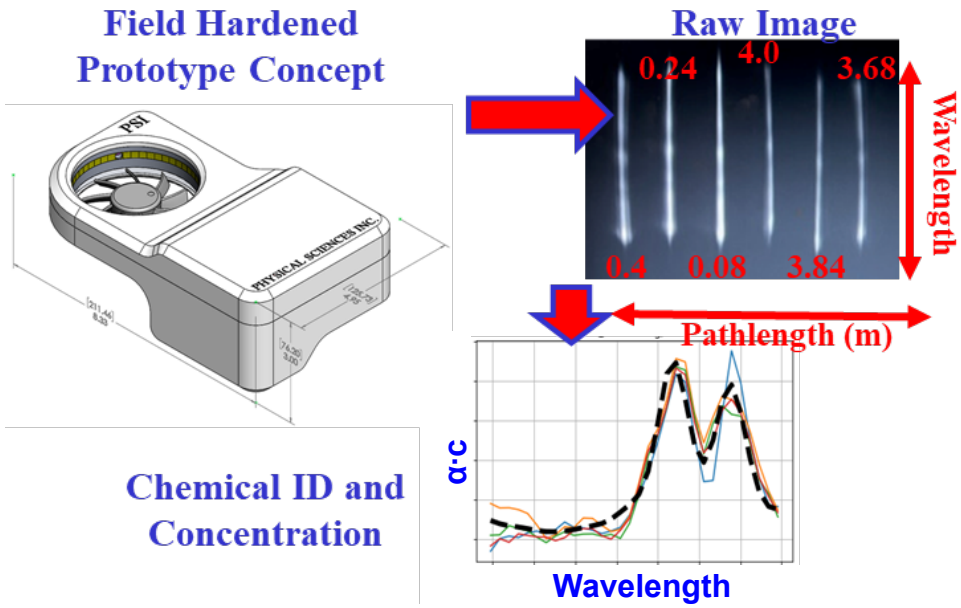
VG-2022-251-3

Multi-Path Extinction Detector (M-PED)

- Broadband QCL paired with open path multipass cell supporting 4 m of pathlength;
- Microbolometer measures transmission spectrum at six pathlengths;
- Fit to Beer's Law performed to detect, identify and quantify vapors and aerosols;
- Extending capability to aerosol detection with demonstration planned for Fall 2022
- Fieldable hardware concept generated (1200 cm^3, 1.1 kg, 12 hr battery life and $30K in single unit quantities)

Key Benefits:

- Open path architecture eliminates clear down issues;
- Ability to detect, identify and quantify chemicals;
- Aerosol detection capability in a portable, fieldable form factor at price supporting widespread deployment



Standoff Chemical Vapor/Aerosol Detection

Physical Sciences Inc.

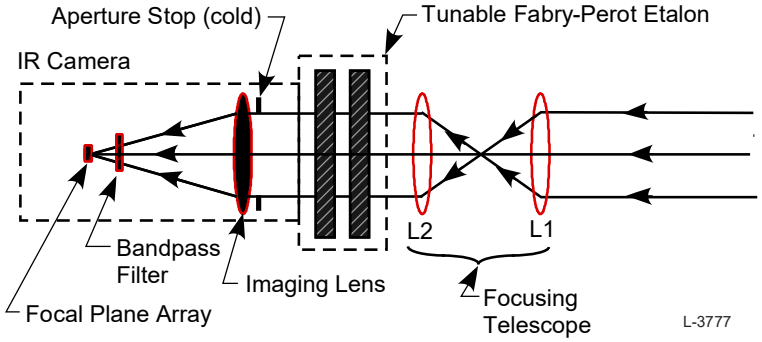
VG-2022-251-4

Adaptive Infrared Imaging Spectroradiometer (AIRIS):

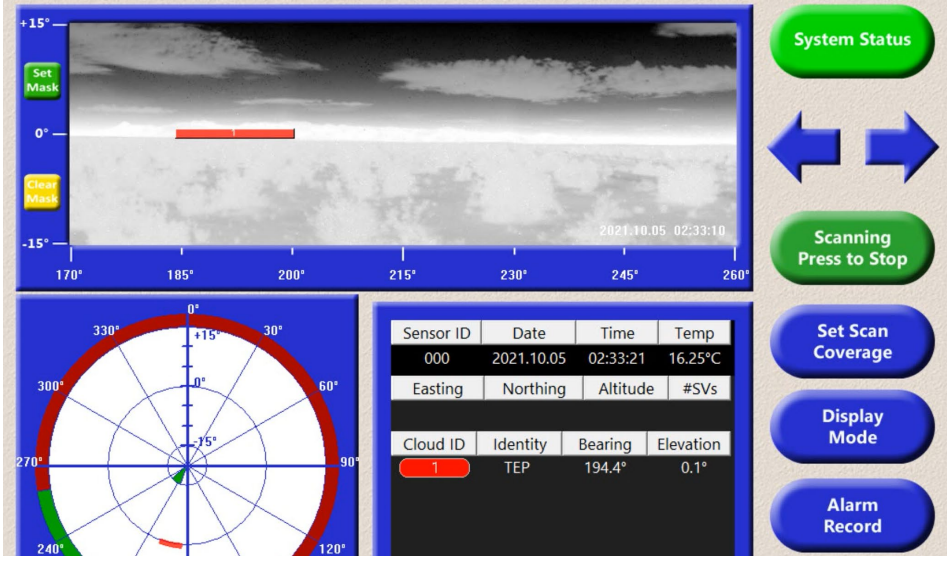
- **Passive HSI system operating from 8 to 11 μm**
- **High speed tunable band pass filter coupled to a cooled infrared focal plane array**
  - Piezoelectric actuated Fabry-Perot Etalon
  - Operates in low order (m=2 and m=3)
- **Detection of nerve and blister agents vapors and aerosols**
- **2 μflicks Noise Equivalent Spectral Radiance (NESR)**
- **Sensors can be networked to provide triangulation to target and estimate source strength (i.e. total mass)**

Sensor at Dugway Proving Grounds

Optical Configuration



Detections overlaid on thermal infrared image of scene using a real-time processor

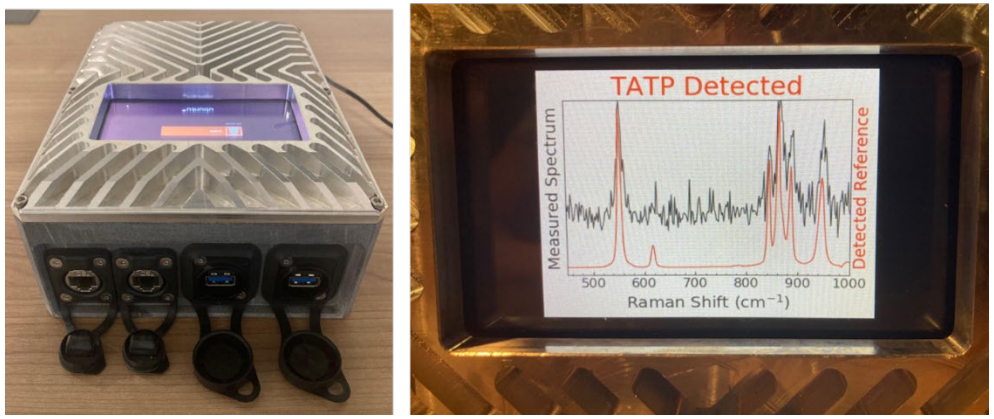


PSI Algorithm Capabilities

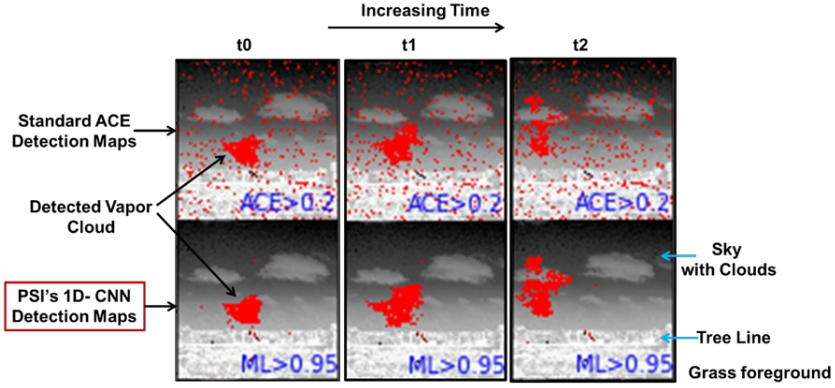
Physical Sciences Inc.

VG-2022-251-5

- Multivariate approaches for background estimation, scene segmentation, and signal correlation.
- Scattering phenomenology of particles.
- One-dimensional convolutional neural networks (1D-CNNs) for spectral classification for Raman spectrometers, LWIR reflectance spectrometers, and hyperspectral sensors.
- **Successfully demonstrated feasibility of the CNN approach to detecting chemical vapors with LWIR hyperspectral data from PSI's AIRIS platform**
- **PSI has successfully developed a 1D CNN for ThermoFisher's FirstDefender handheld Raman sensor. The CNN is been embedded on a NVDIA TX2 single board computer housed in an operational module.**



(Left) Operational module prototype (Right) Notification of TATP detection from a measured sample with the FirstDefender after data transfer to the operational module.



HSI Detection images of a B2ES vapor cloud based on PSI's 1D CNN technology (lower row) versus a standard ACE approach (upper row)

Differential Enhanced Waveguide Scattering (DEWS) for Chemical Aerosol Detection

SRI International

Anne-Marie Dowgiallo, Ph.D.

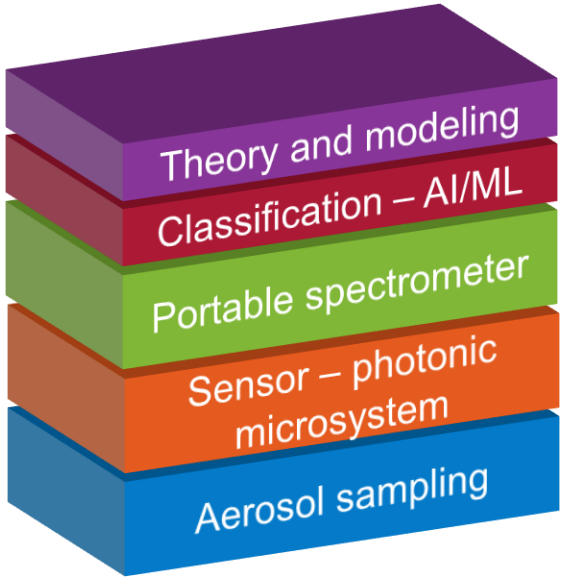
anne-marie.dowgiallo@sri.com
301-919-2333

Current Partnerships

Academic + industry teams with expertise in aerosol collection and delivery for automated 40x analyte enrichment, microsystem integration, Raman spectral modeling.

A Multimodal Platform for Chemical Aerosol Identification

- ✓ Rapid
- ✓ Low-SWaP
- ✓ High sensitivity and specificity



Capabilities

Chemical Sensing

Surface-enhanced Raman spectroscopy (SERS) and standoff IR spectroscopy for trace level detection and identification of chemical threats (i.e., explosives, illicit drugs, pesticides, toxins, etc.)

Integrated Photonics:
Photonic microsystems developed for atomic sensors, free-space optical communications, and microwave photonics with extensive foundry relationships (DARPA YFA - Atom Chip Optical Waveguide Trap, ASTRAL, PEACH, etc.)

Analyte Capture Agents:
Techneins™ - highly specific non-natural polymers (DARPA FoldFx)

Machine learning (ML) / Artificial intelligence (AI):
Physics-guided feature extraction and modeling of mixture of material for zero-shot and few-shot detection/classification problems (DARPA MATTRS and Providence, AFRL MOTIF, IARPA TrojAI)

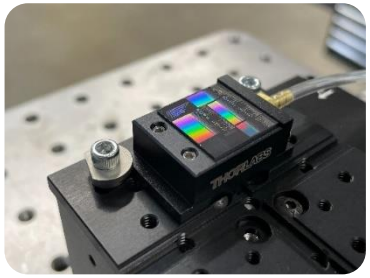
Aerosol Modeling:
Modeling software for light transmission and scattering through aerosol clouds based on Mie and 4-flux radiative transfer theory (AFRL).

Teaming Needs

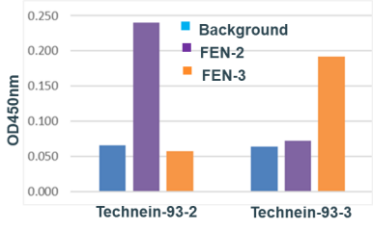
Aerosol Phenomenology

Microfluidics

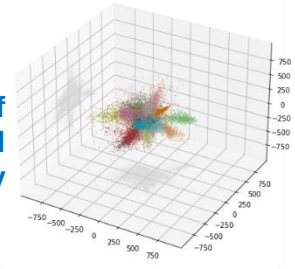
In-house PIC prototyping



Technein™ recognition of distinct fentanyl epitopes



Classification of hyperspectral imagery



Signature Science at a Glance

signature® science LLC

Signature Science: Who We Are

- Signature Science focuses on science and engineering solutions for national security threats

  We conduct:

  - Research, development, test and evaluation (RDT&E);
  - Laboratory operations;
  - Systems design and Integration;
  - Software and algorithm development;
  - Manufacturing/Production.

- Entering our 22nd year
- Support our clients from four offices
- Wholly-owned subsidiary of Southwest Research Institute

signature science LLC

Signature Science: What We Do

CBRNE Detection Systems

- Systems Design & Integration
- ISO 9001 Certified Manufacturing and Production
- Explosives Detection Systems T&E

Data Science

- Bioinformatics
- Data Analytics and Machine Learning
- Statistics and Experimental Design

Chemical/Biological Sciences

- CBRNE Signature Discovery
- Genomic Sequencing
- Synthetic Biology Solutions

Center for Advanced Genomics®

- Forensic DNA Casework
- DNA from Spent Shell Casings
- Forensic Genetic Genealogy

Laboratory QA Programs

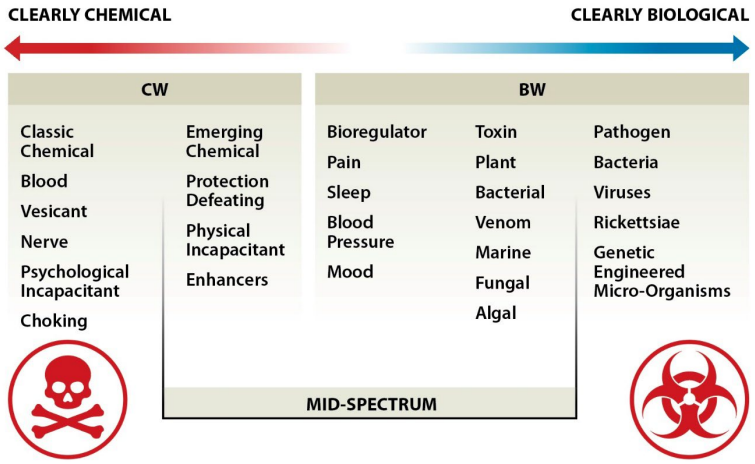
- NGB's WMD Civil Support Teams
- DHS's BioWatch Program
- JPEO-CBRND

CBRNE Training and Exercises

- Technical Training
- Field Training Exercise (FTX) Kit
- Quick Reference Guide

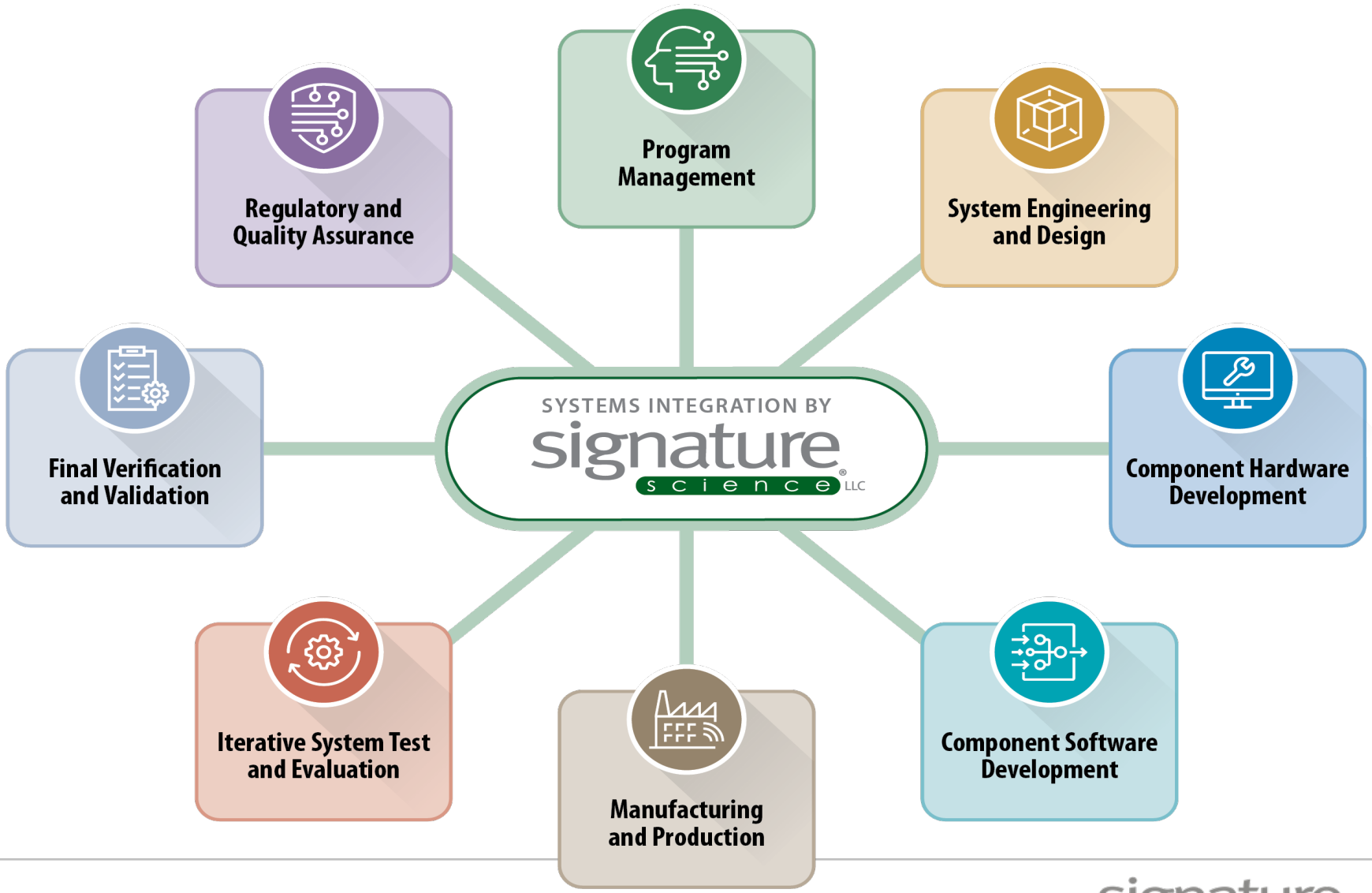
Long History Focused on Chemical Threats

- Our history has made us subject matter experts in next generation chemical and asymmetric threats
  - Iraq Survey Group WMD: Staffed and trained the teams
  - Chemical Signature Collection and Analysis programs
  - DARPA chemical threat programs
  - IC Chemical property prediction programs
  - Training "elite" teams in chemical detection and SSE
  - Chemical signature attribution analytical tools (algorithms and software)
- Threats are highly toxic, easily accessible, persistent solid/liquids that can be employed in multiple ways
- Used in recent times



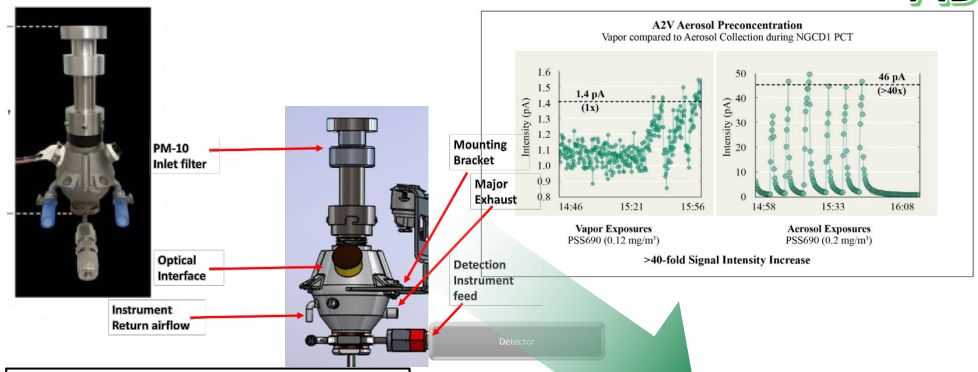
signature science LLC

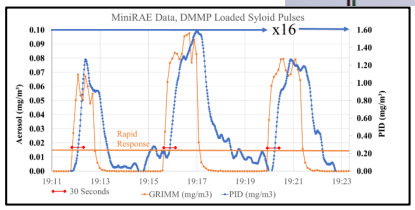
SigSci Systems Design and Integration



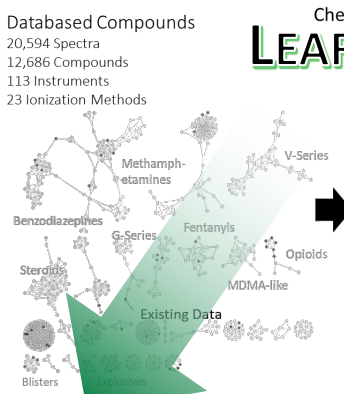
Signature Science PICARD Capabilities

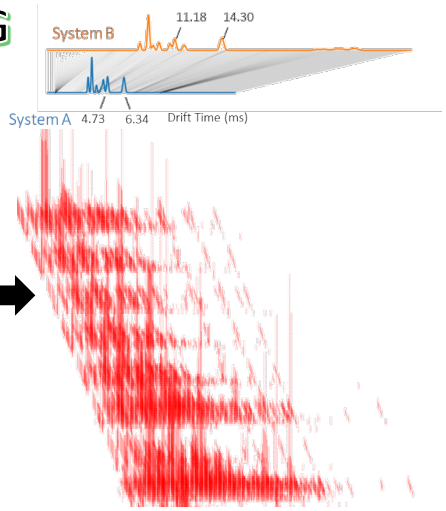
A2V Aerosol Collector





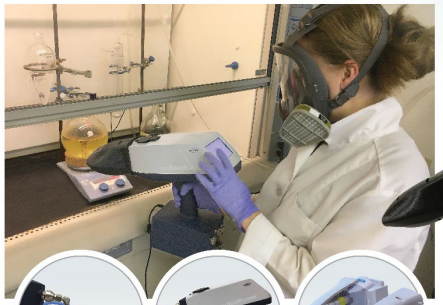
Advanced Algorithms and Machine Learning





PICARD

Integration and Test



Testing the TRL-6 System in SigSci's High Fidelity Laboratory

TRL-6
Integrated System

System for Field Narcotics Testing

Fully Integrated TRL-6

Integrated Module Cover

CHEMERA® High Resolution Mass Spec

CHEMERA – an advanced detection technology that truly is next generation

- Based on a high- performance fast and sensitive time of flight (TOF) mass spec engine
- Uses photoionization (PI) to ensure presence of intact mass for identification
- High confidence field identification with low false alarms

signature science LLC

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Optofluidic system for multi-modal aerosol analysis

Holger Schmidt

ECE Department, UC Santa Cruz

Optofluidics

Objective: Aerosol analysis – particle diversity, specificity, concentration range, signal analysis, compact instrument

- Optofluidics: non-solid media + integrated optics

- photonic function defined by fluid

  $\Rightarrow$ reconfigurable

- use light to detect, analyze, manipulate fluid or particles therein

  $\Rightarrow$ performance, integration

(I.M. White and X. Fan, *Nature Photon.* **5,** 591 (2011))
(H. Schmidt and A. Hawkins, *Nature Photon.* **5,** 598 (2011))

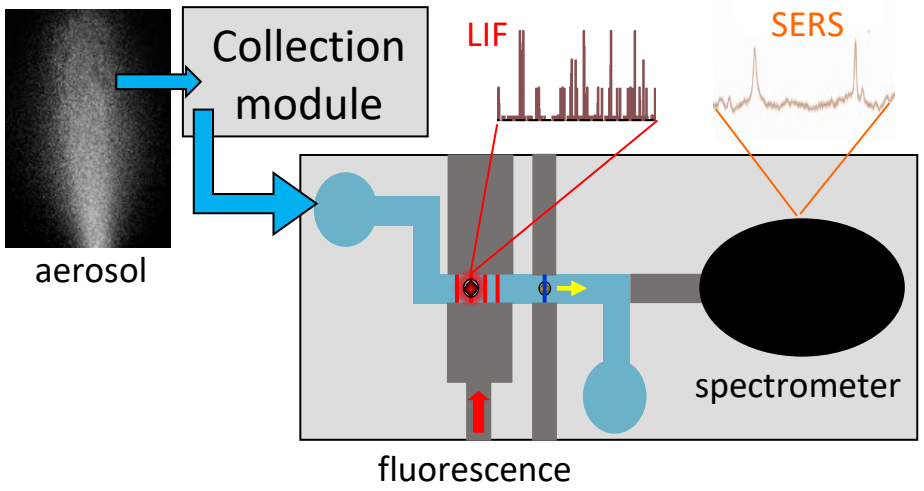
Selected capabilities

- ultrasensitive, versatile platform
- modular and scalable

- Amplification-free nucleic acid detection (Sci Rep 2015)
- 14 logs dynamic range (aM – mM) (Sci Rep 2015)
- Multiplexed single virus detection (PNAS 2015, Sci Rep 2017)
- Multiplexed single bacterial DNA detection (Lab Chip 2020)
- Multiplexed single protein detection (PNAS 2021)
- Vapor spectroscopy and slow light on chip (Nat Phot 2007, 2010)
- SERS on chip (APL 2007)
- Integrated sample prep on chip (Lab Chip 2018, Sci Rep 2015)
- Integrated spectral filters on chip (Lab Chip 2012)
- Integrated particle filters on chip (Lab Chip 2013)
- Real-time advanced signal analysis (Nat Comm 2022)
- Fully integrated all-in-one molecular analysis chip (Biosensors 2022)

Proposed approach

optofluidic waveguide platform with multi-modal optical analysis



- flow-based analysis with single particle sensitivity and ultra-wide dynamic range
- single particle fluorescence detection
- novel on-chip spectrometer for machine -learning enhanced Raman analysis
- translation to precommercial instrument
- maximal integration of sample handling and analysis

- highly versatile instrument: modalities, targets, concentrations
- adaptable to different use cases
- commercial partner ensures meaningful outcome

Team

- device design, ultrasensitive optical analysis, single molecule assays,
- data analysis algorithms

- optofluidic waveguide fabrication and optimization

FLUXUS™

- chip scale-up, system integration, translation to product

Michigan Aerosol Virus-Elicited Light Output Signal (MARVELOUS) Detector: Aerosol SARS-CoV-2 Particle Monitoring

Younggeun Park, Ph.D., Xiaogan Liang, Ph.D., and Katsuo Kurabayashi, Ph.D.

Department of Mechanical Engineering

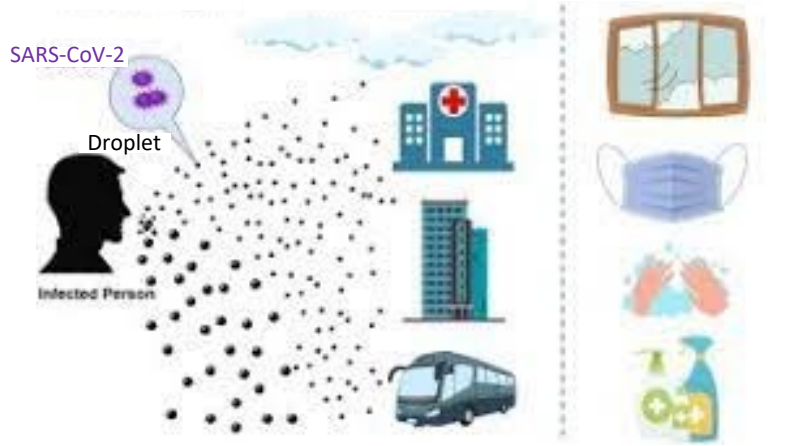
Department of Electrical Engineering and Computer Science
Weil Institute for Critical Care Research and Innovation

University of Michigan, Ann Arbor

MARVELOUS Detector: Background, Technology, and Application

Fundamental Challenges:
-Lack-of Real-Time Airborne Virus Monitoring Tool

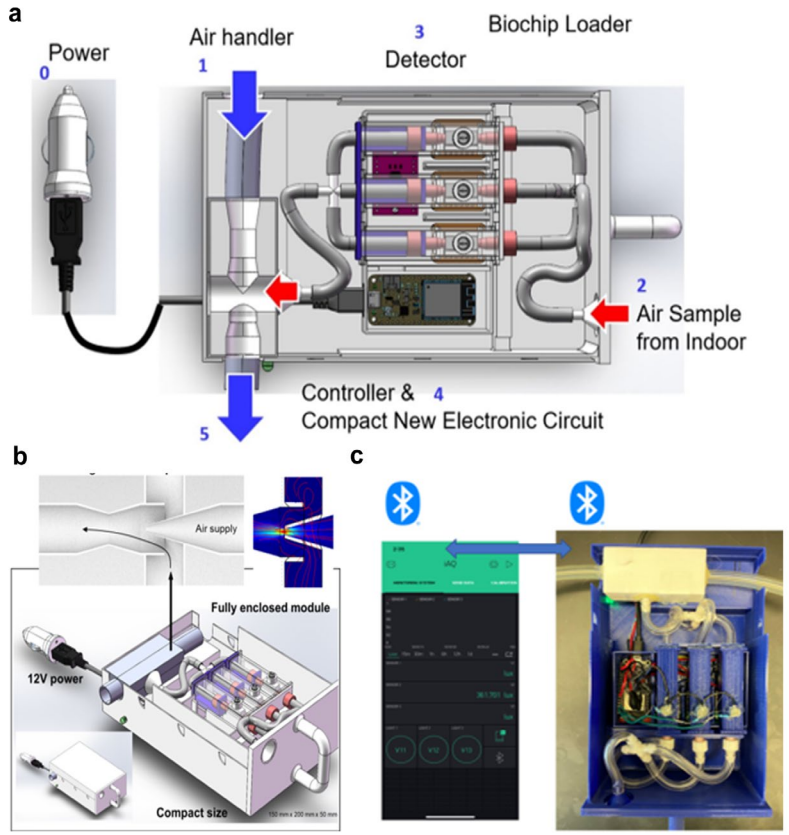
Aerosol Generation | Aerosol Transmission | Precaution and Control



Translational Focus:
-Early warning of air contamination
-Prevention of airborne virus transmission

Engineering and Technology

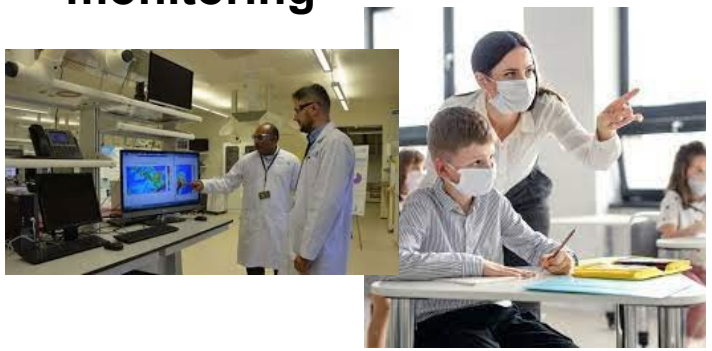
-Integrated Air Quality Monitoring System – MARVELOUS Detector



Application

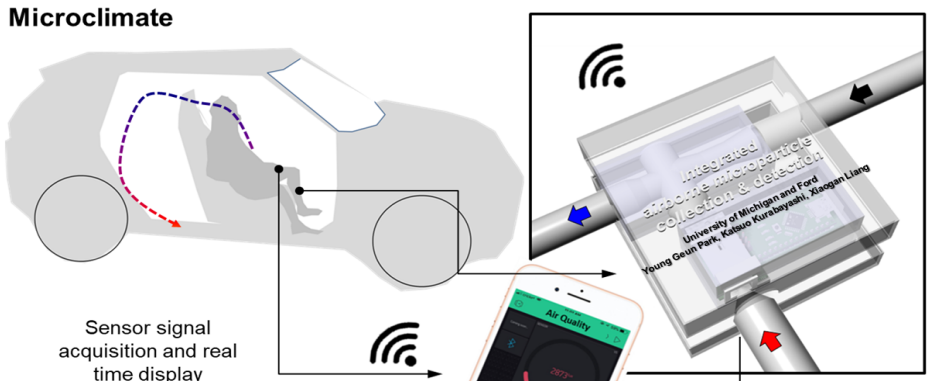
- Rapid COVID breath test

- Lab/classroom air safety monitoring



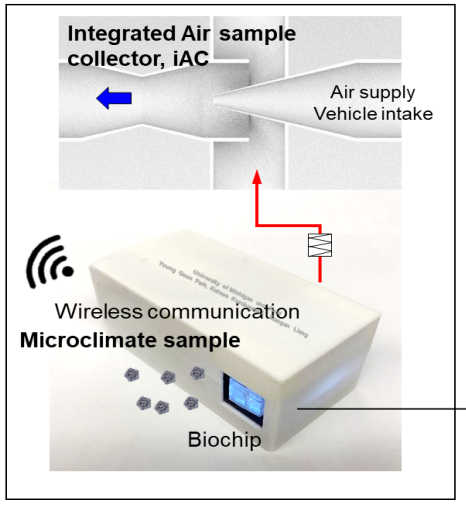
An integrated air quality monitoring system was developed

a

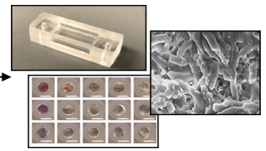


- **Minimal power consumption**
- **Rapid & sensitive monitoring**
- **Minimized platform**

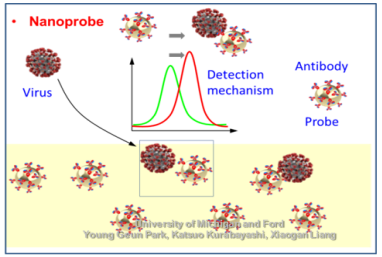
- **Integrated air monitoring system**

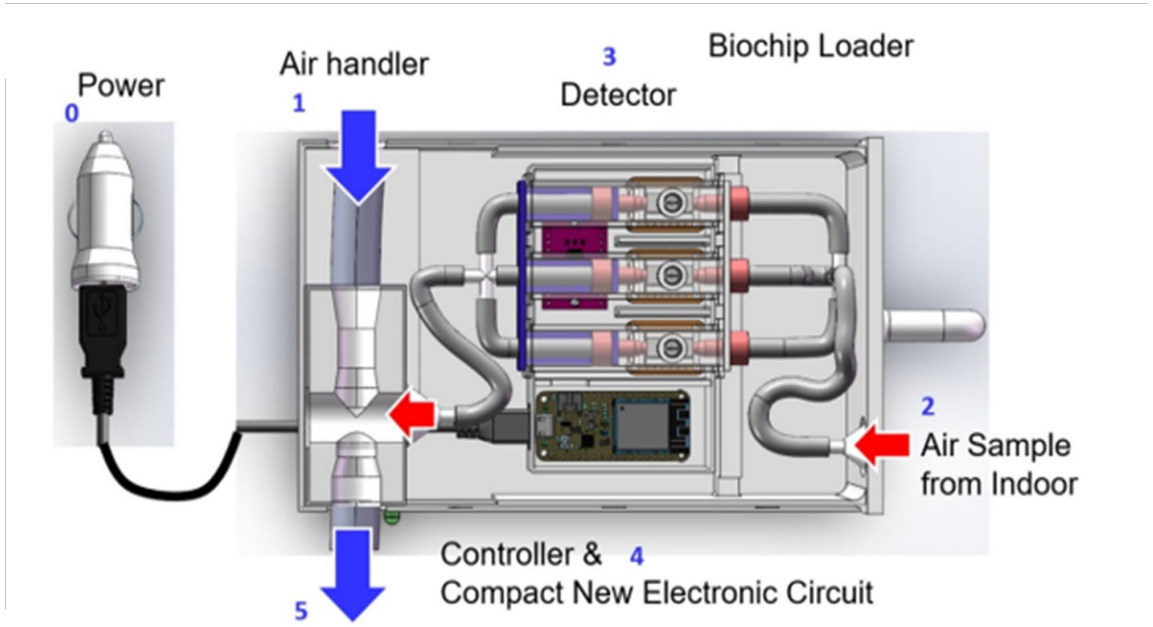


- **Virus and Bacteria Biosensor**

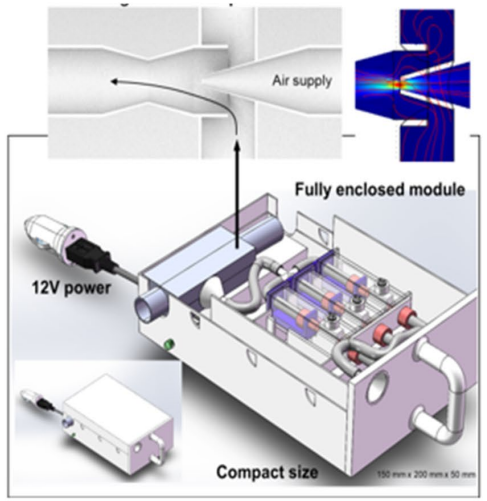


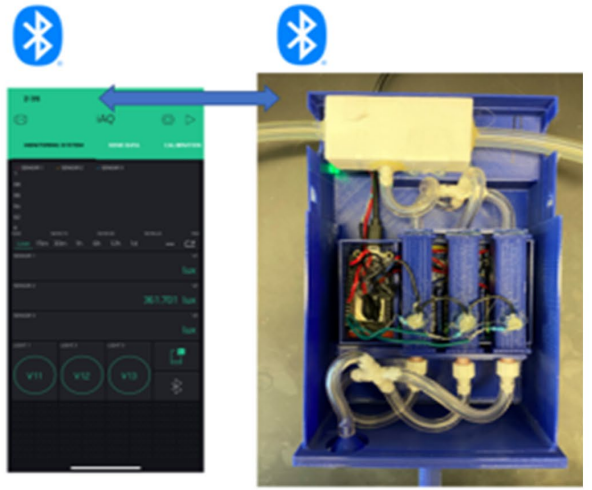
- **Photonic-Biogel**



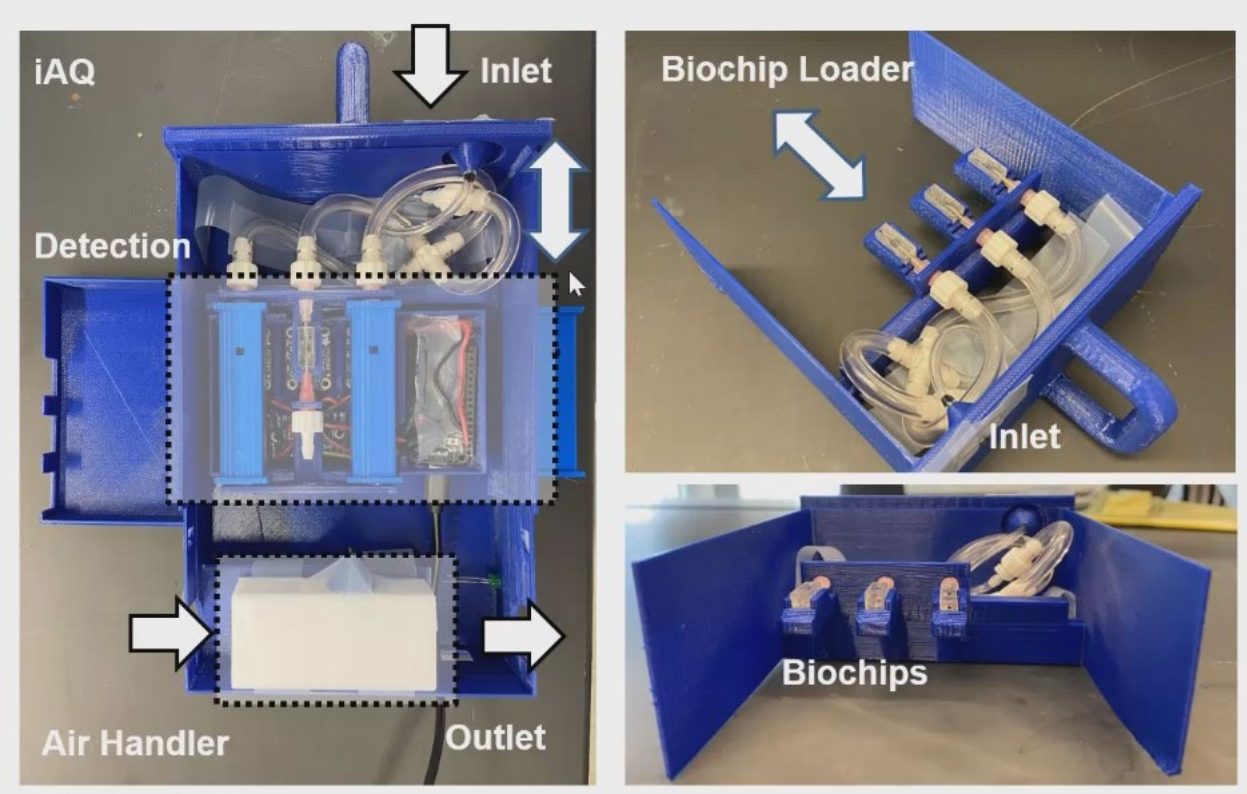


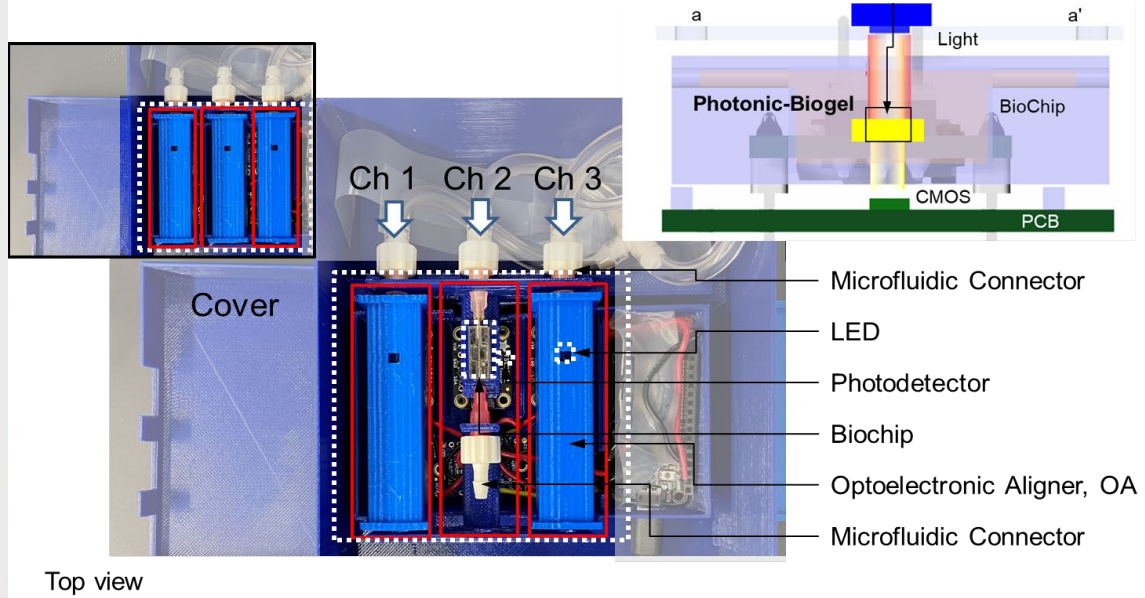
c





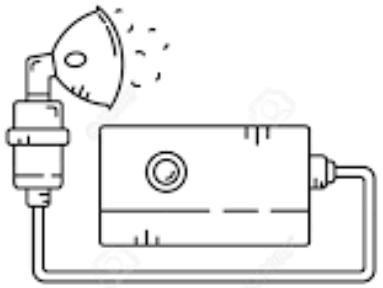
A prototype system was constructed



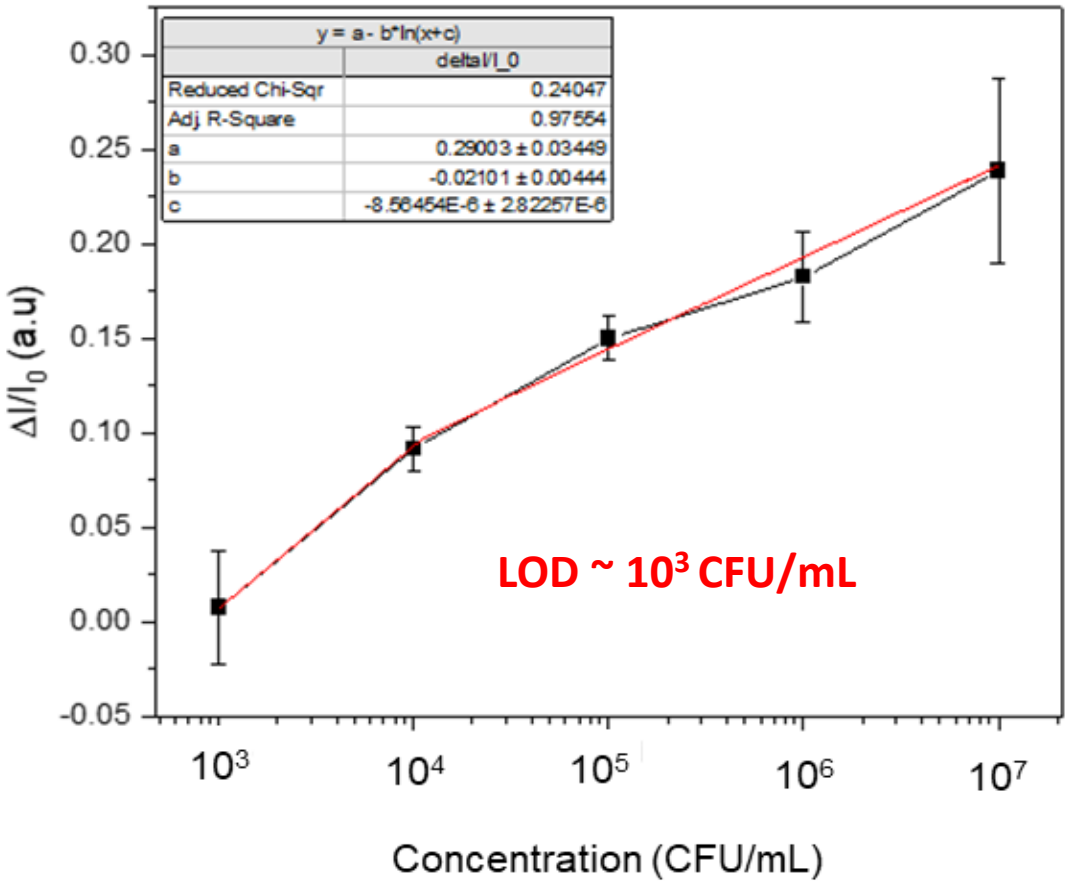


Top view

High-sensitivity airborne SARS-CoV2 was achieved



NEBULIZER



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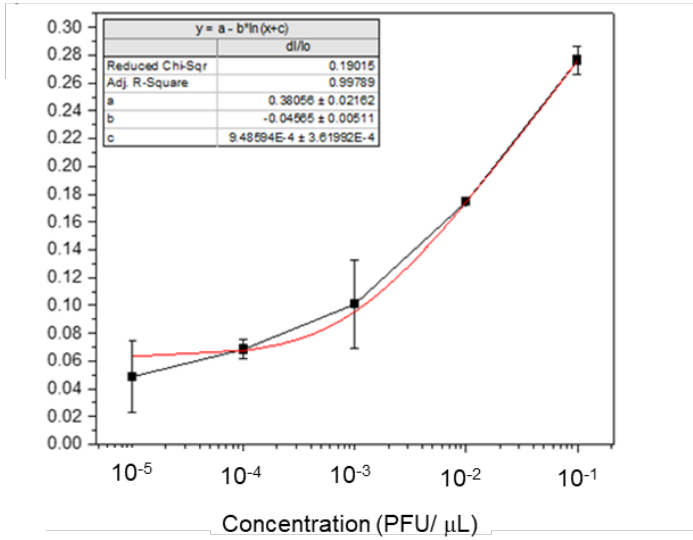
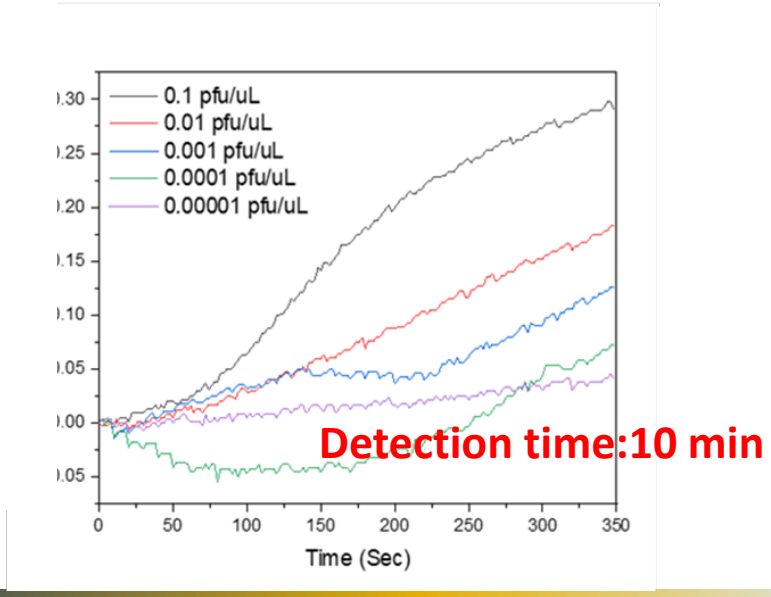
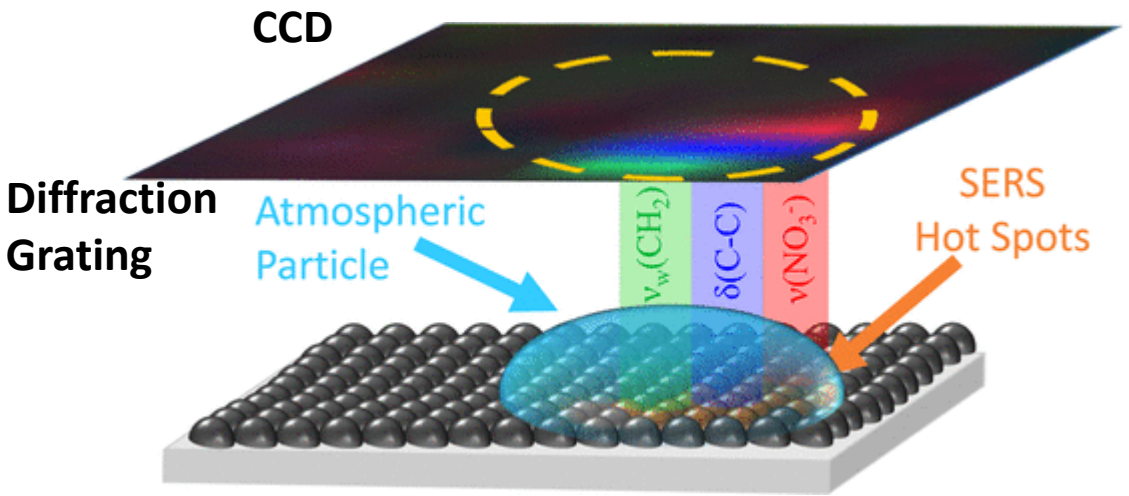


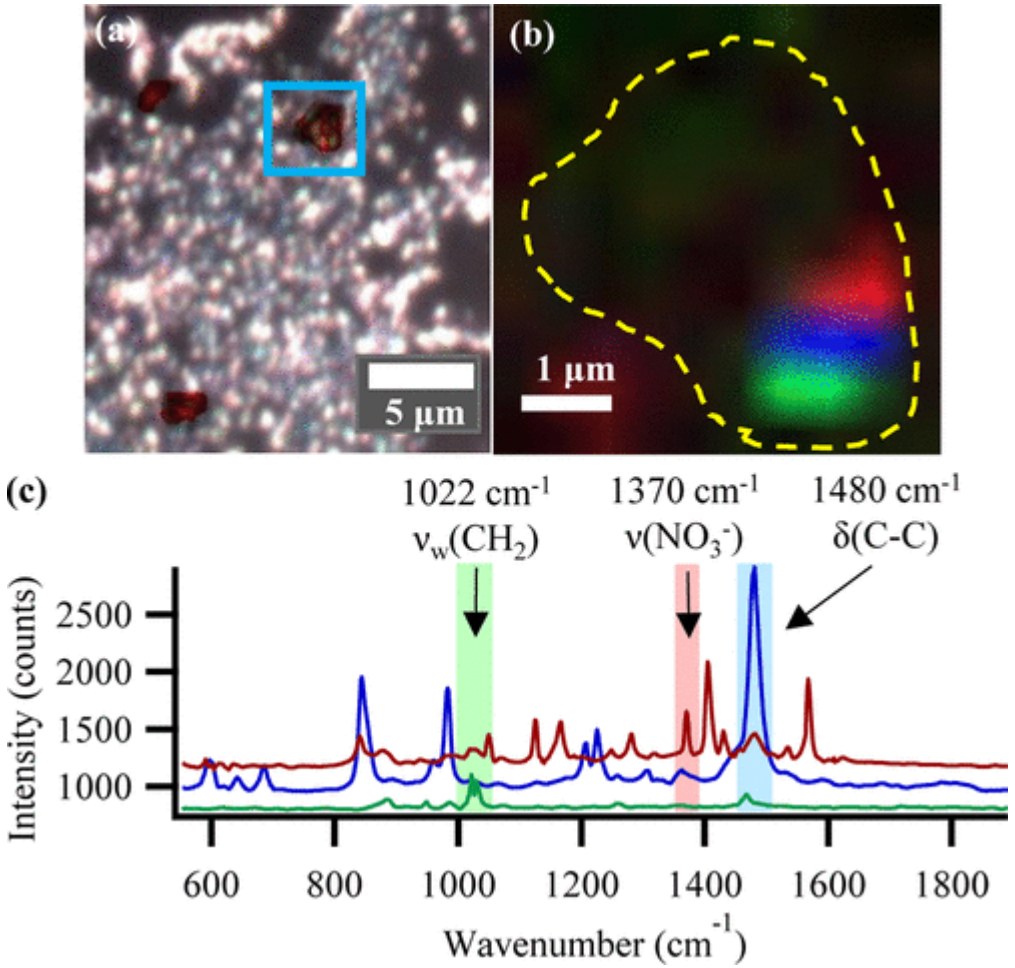


Surface Enhanced Raman Spectroscopy detects chemical aerosols.

Future System Modification



Demonstrated by Ault Group at University of Michigan



Craig, Bondy, and Ault Analytical Chemistry (2015)


Defense Architecture Systems, Inc.

DESIGNED FOR THE MISSION
MANUFACTURED FOR THE FIELD

September 26, 2022

PICARD
Pursuing Intelligent Complex Aerosols for Rapid Detection

Robert Plemons
robertp@dasystemsinc.com
202-297-7608
11820 W Market Pl. Ste P
Fulton, MD 20759

DAS
DEFENSE ARCHITECTURE SYSTEMS, INC.

Small Business
ISO 9001:2015 certified, Cleared Facility/Staff

DAS brings Cutting Edge to the Edge

A Partner for Cutting Edge Technology Developers

Promising technologies often fail

- Prototype integration
- Hardware failure
- Test incompatibility

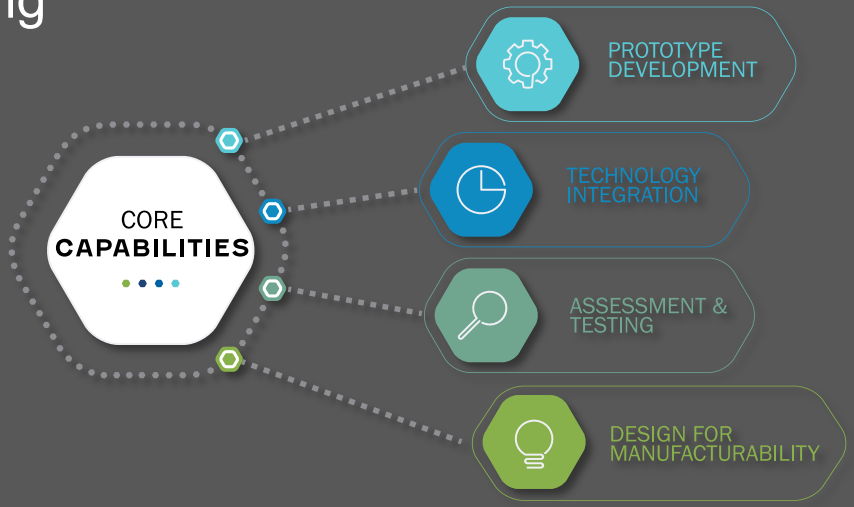
DAS provides solutions

- Mission focused
- Design, integration, and testing
- Aerosol system test and evaluation
- System hardening
- Design for test
- Design for manufacturing

Increasing Probability of Team Success

Mission and Origin

DAS is an established small business, experienced in CBRN defense technologies, technology transition, and manufacturing



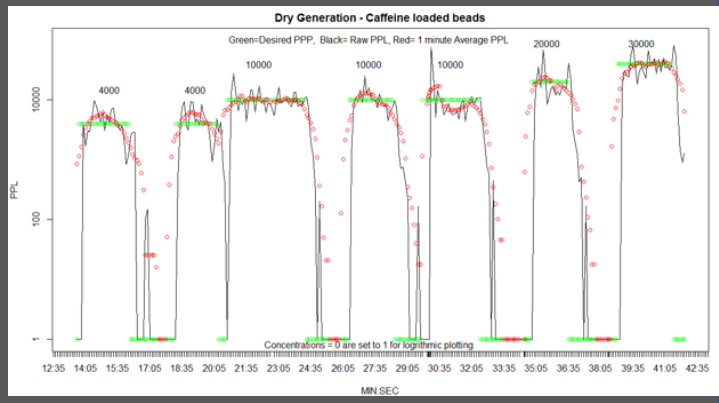
DAS was founded in 2010 to:

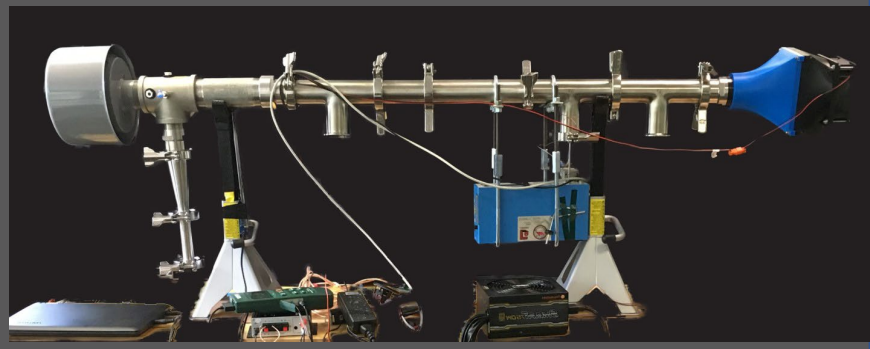
- Deliver integrated systems that provide actionable information to decision makers
- Leverage Best-of-Breed Solutions for Detection, Protection, Mitigation, and Recovery from CBRNE Attacks
- Provide streamlined test and evaluation support for emerging technologies

Aerosol Test and Evaluation

Fast Response Aerosol Chamber

- Designed and manufactured by DAS
- Closed system with HEPA filtering
- Fits within a 6-foot fume hood
- Delivers wet or dry aerosol
- Dynamically controllable delivery of aerosol with rapid changes in particle concentration
- Multiple iso-kinetic sampling ports for referee and test instrumentation





Experienced

- Leadership managed aerosol testing program at JHU Applied Physics Laboratory
- Collaborating with CCDC CBC for development of further TacBio 2 bioaerosol detection (Current CRADA)
- Testing expertise at Dugway Proving Ground (DPG) and Edgewood (CCDC CBC) including vapor and aerosols

Who needs help?

Contact DAS, Inc

Defense Architecture Systems, Inc.
11820 West Market Place, Suite P
Fulton, MD 20759

bd@dasystemsinc.com
www.defensearchitecturesystems.com
(240) 468-4080

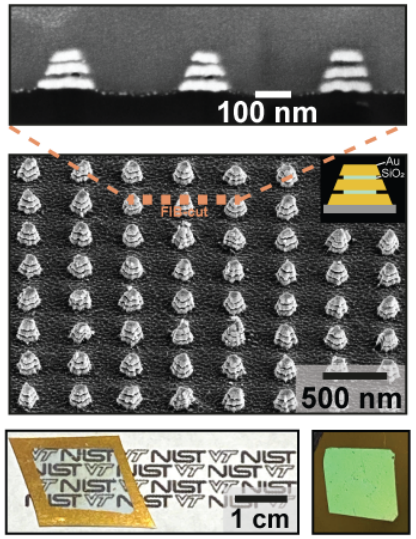
Hierarchical Multiresonant Plasmonics for Real-time SERS Molecular Analyses of Microdroplet Samples

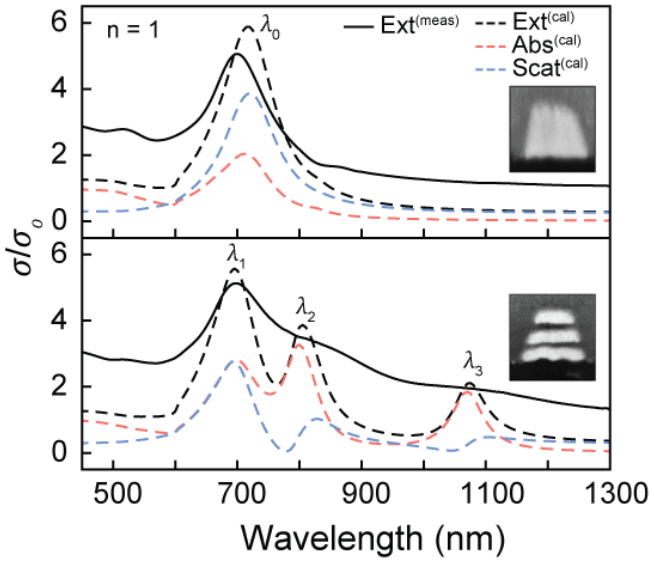
Wei Zhou

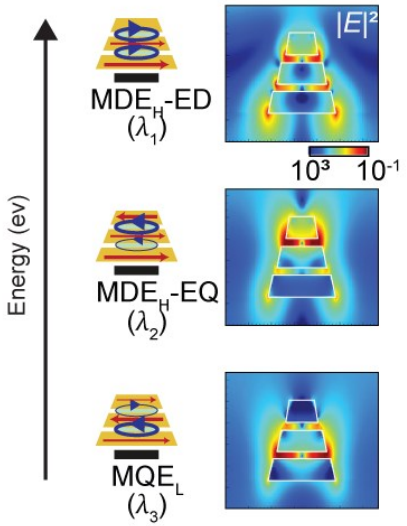
ECE Department

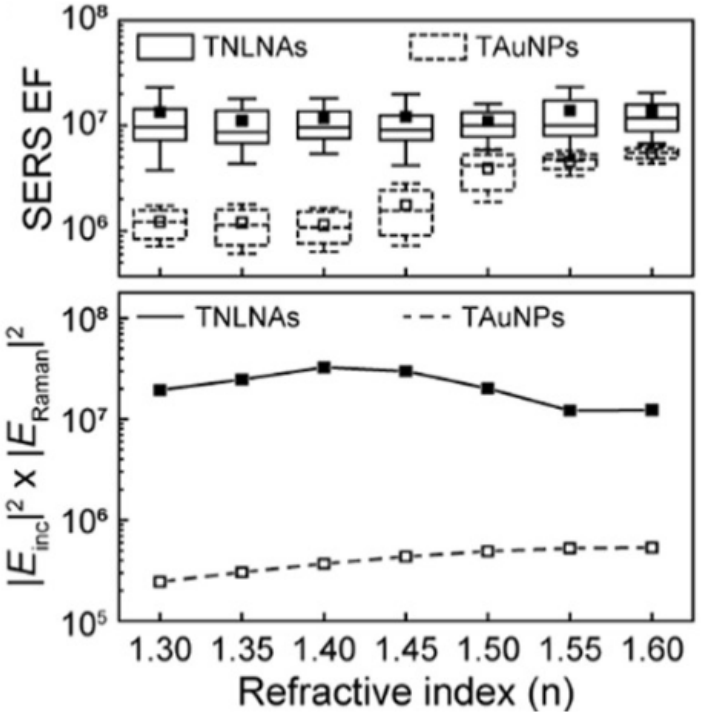
Virginia Tech

Broadband Multiresonant Plasmonics







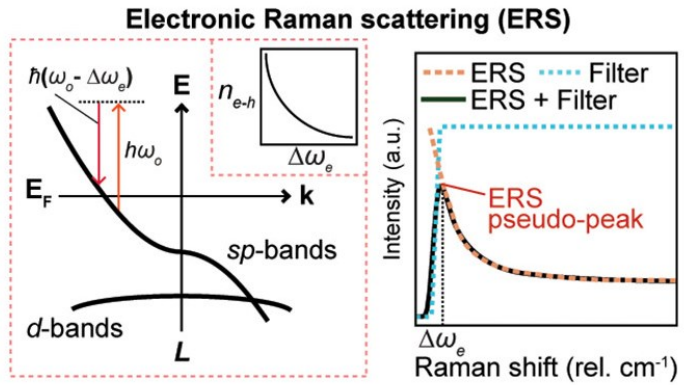


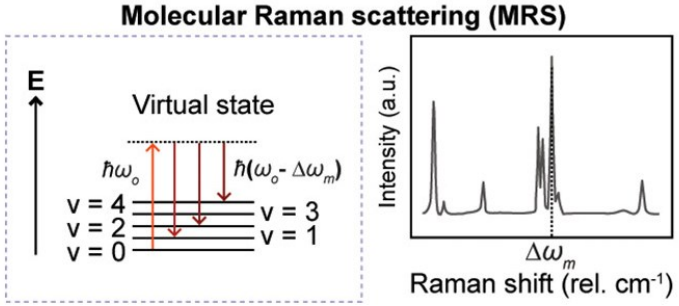
- We develop modularized **nanolaminate nanoantennas** supporting multiple hybridized plasmon modes.
  - Broadband multiresonant enhancement of nanoscale light-matter interactions.
  - Refractive-index insensitive **surface-enhanced Raman scattering (SERS)** performance.
  - Transparent SERS devices compatible with frontside and backside laser excitation.

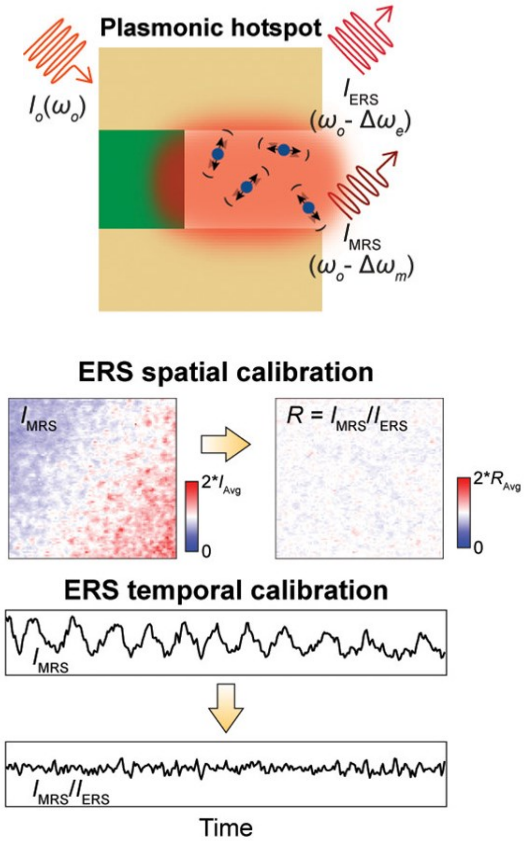
W. Zhou et. al. Nano Letters 18 (2018) 4409

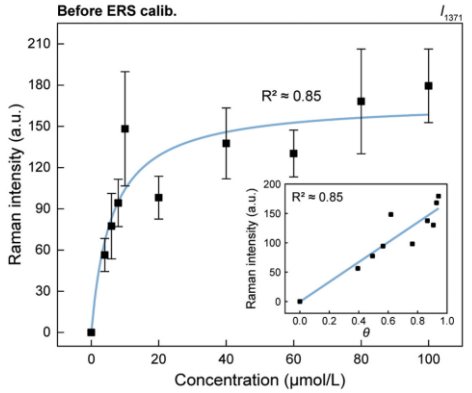
W. Zhou et. al. ACS App. Nano Mat. 4 (2021) 3175

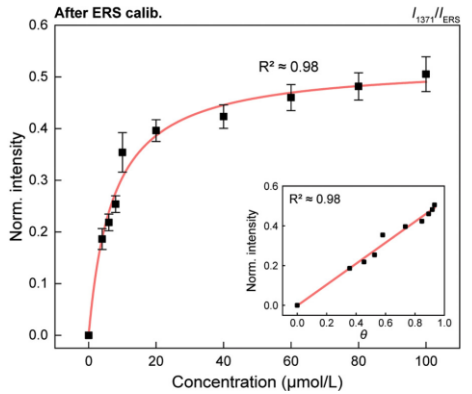
ERS Calibration Enabled Quantitative SERS Analyses











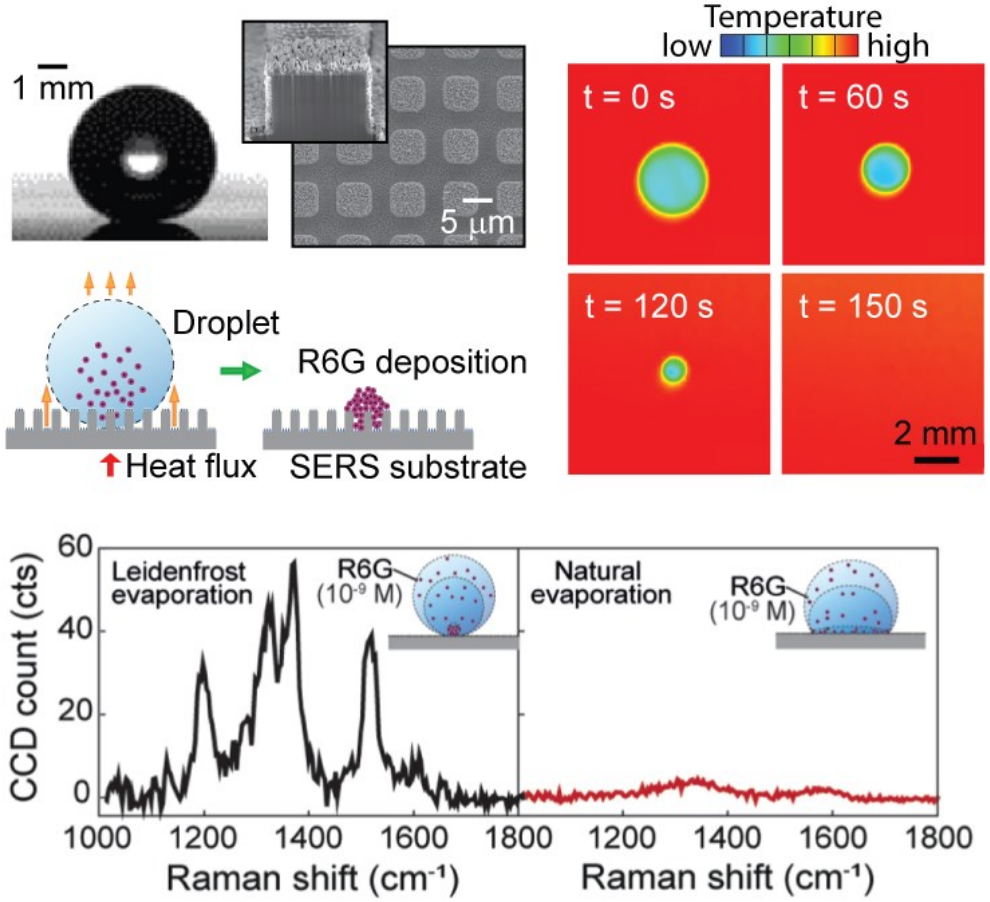
- We have discovered that plasmon-enhanced **electronic Raman scattering (ERS)** signals from metal can serve as an internal standard for spatial and temporal calibration of **molecular Raman scattering (MRS)** signals from analyte molecules at the same hotspot to enable quantitative SERS biochemical analyses.

W. Zhou et. al. J. Phys. Chem. Lett. 11 (2020) 9543

Superhydrophobic SERS Devices for Rapid Biochemical Detection of Microdroplet Samples

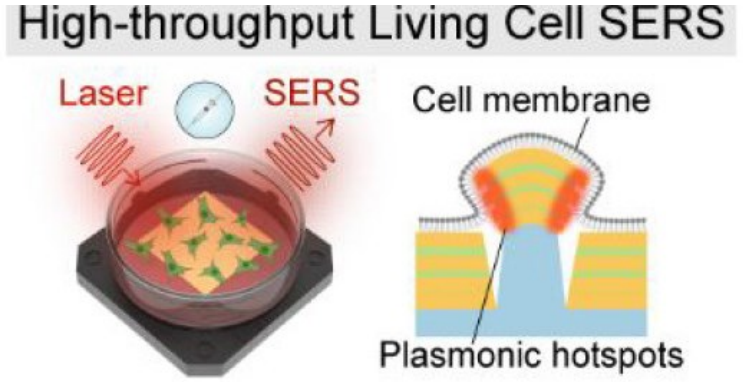
- We have developed novel **superhydrophobic SERS substrates** allowing a partial Leidenfrost evaporation-assisted enrichment approach for **ultrasensitive SERS detection** of ultralow (nM) concentration analytes in minutes.

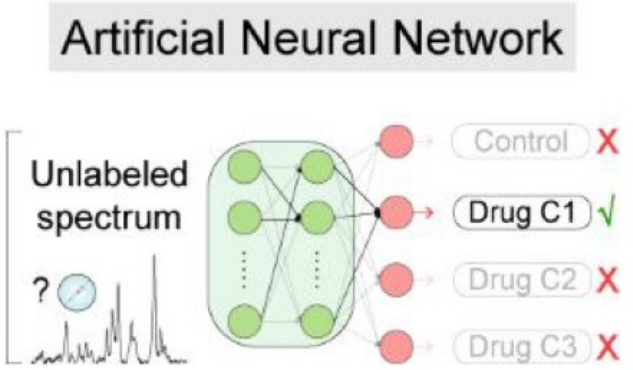
- **Superhydrophobic SERS substrates** consist of *nanolaminate plasmonic nanoantennas* on *hierarchical micro-nanopillar arrays with a hydrophobic Teflon coating*, which is a **biomimetic lotus structure**.

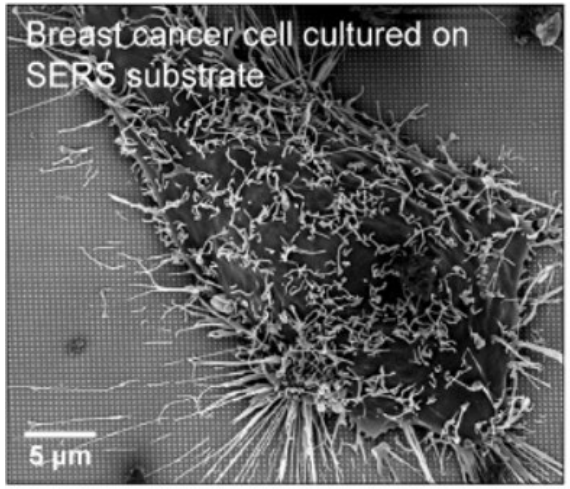


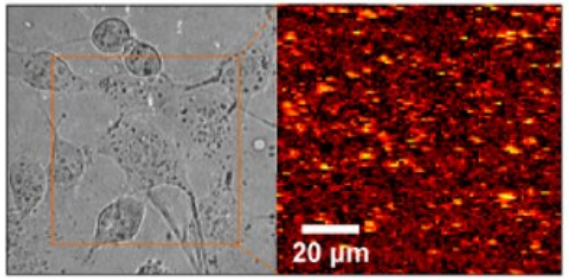
W. Zhou et. al. ACS Nano 14 (2020) 9521

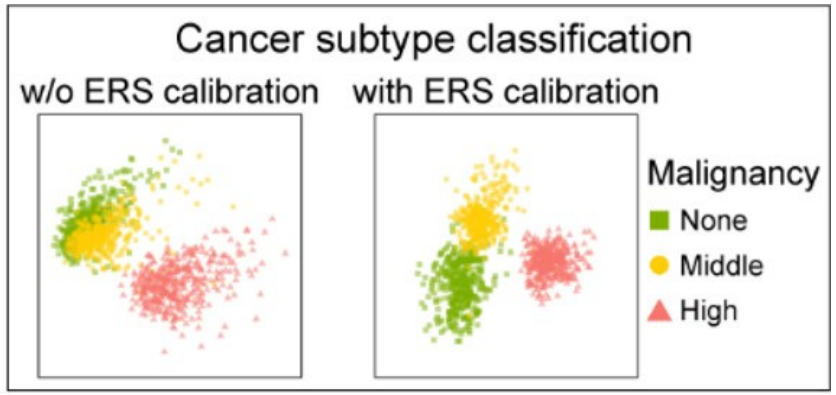
Machine-learning Empowered Real-time SERS Analyses

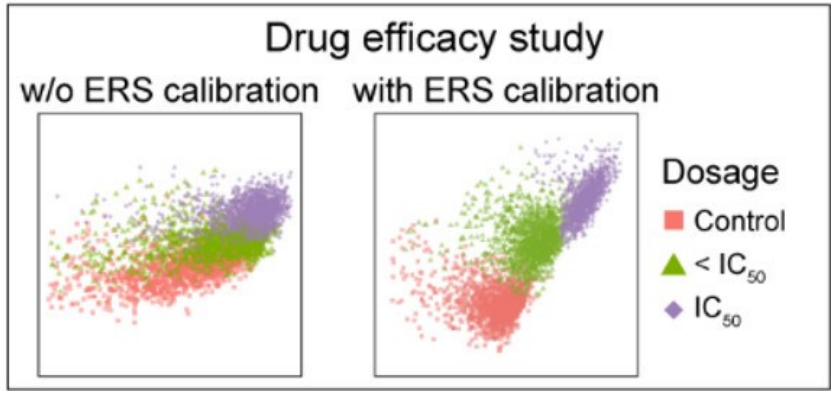












- We have employed non-supervised and supervised **machine-learning (ML)** methods to analyze and classify SERS spectra of molecular components associated with different cell lines and drug responses.

W. Zhou, M. Agah et. al. Nano Lett. 19 (2019) 7273
W. Zhou, M. Agah, et. al. Anal. Chem. 93 (2021) 4601
W. Zhou, M. Agah et. al. ACS App. Nano Mat. 5 (2022) 10358

Triton Systems Traceptor™ Vapor Concentration and Aerosol Sampling for Field Amplification of In-Situ Chemical Trace Detectors

Triton Systems®
Driven to Innovate

Dr. John Lock (jlock@tritonsys.com)
Director, Sensing and Separations Lab

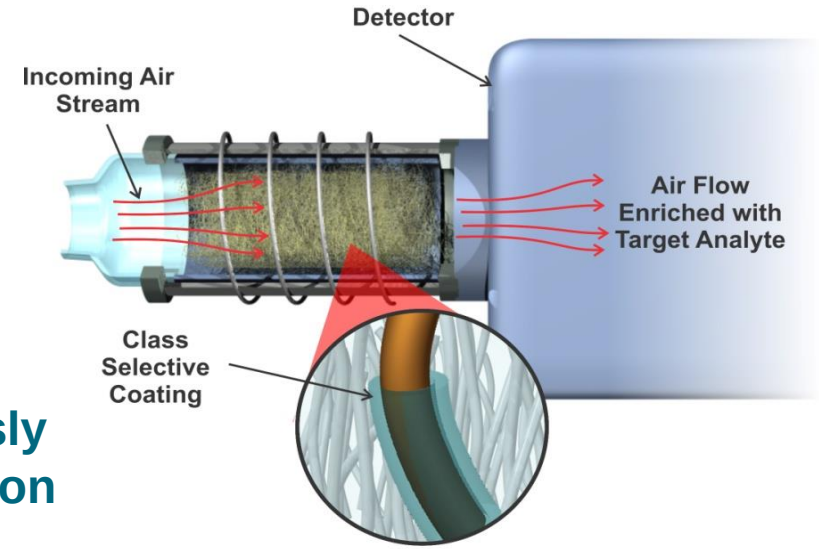
Dr. Ken Mahmud (kmahmud@tritonsys.com)
Executive Vice President

Triton Systems Vapor Pre-Concentrator

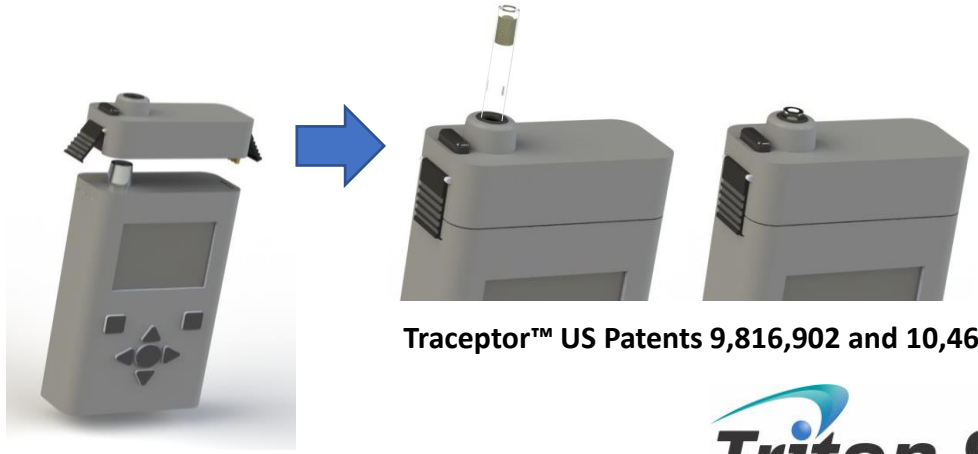
Trace detector “amplifier” developed for field use.

Features:

- **High flow**
- **Low power** needs (works with portable devices such as the JCAD)
- **Rapid** thermal desorption
- **Long life**
- **Enables detection** not possible with current detectors **of low volatility compounds**
- **Increases** sensitivity of current portable trace detectors **by 3 or more orders of magnitude** while **improving specificity**



Integrates seamlessly with existing detection devices



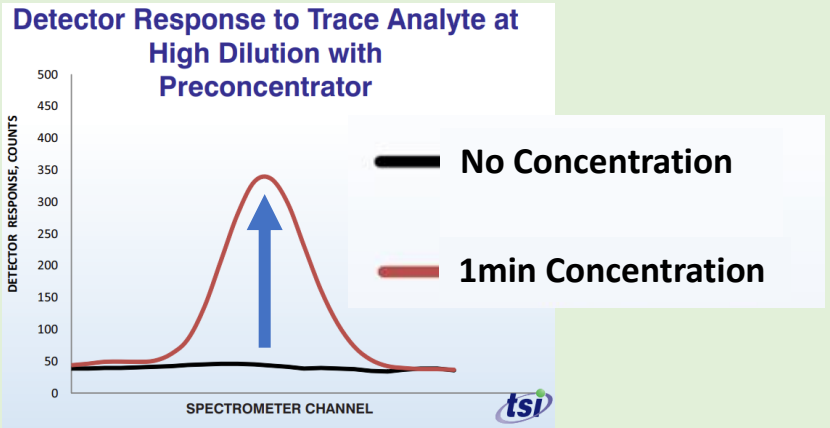
Traceptor™ US Patents 9,816,902 and 10,466,149

Triton Systems®
Driven to Innovate

Vapor Concentration plus Aerosol Capture

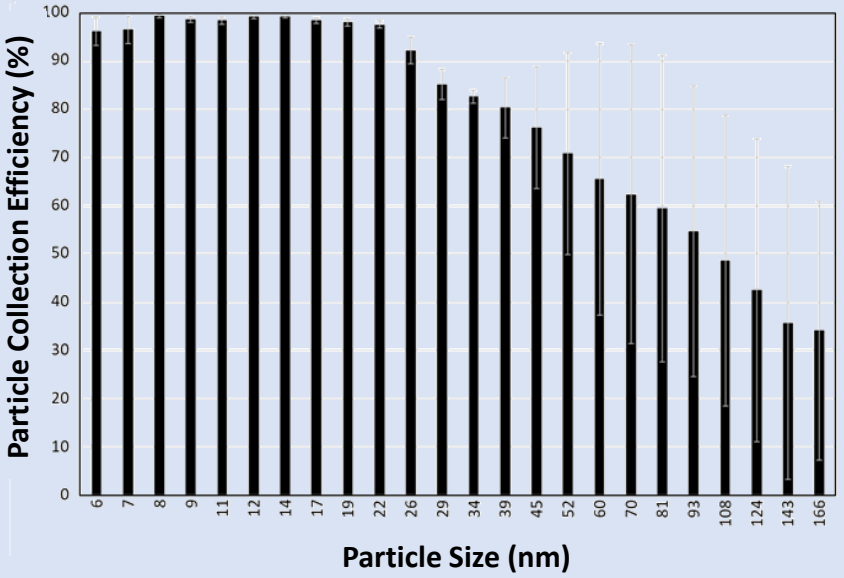
1. **Enables Over 1000x Concentration of Volatiles**

   > 3 Orders of Magnitude Increased Sensitivity of a COTS Detector. Shown here is IMS Data.

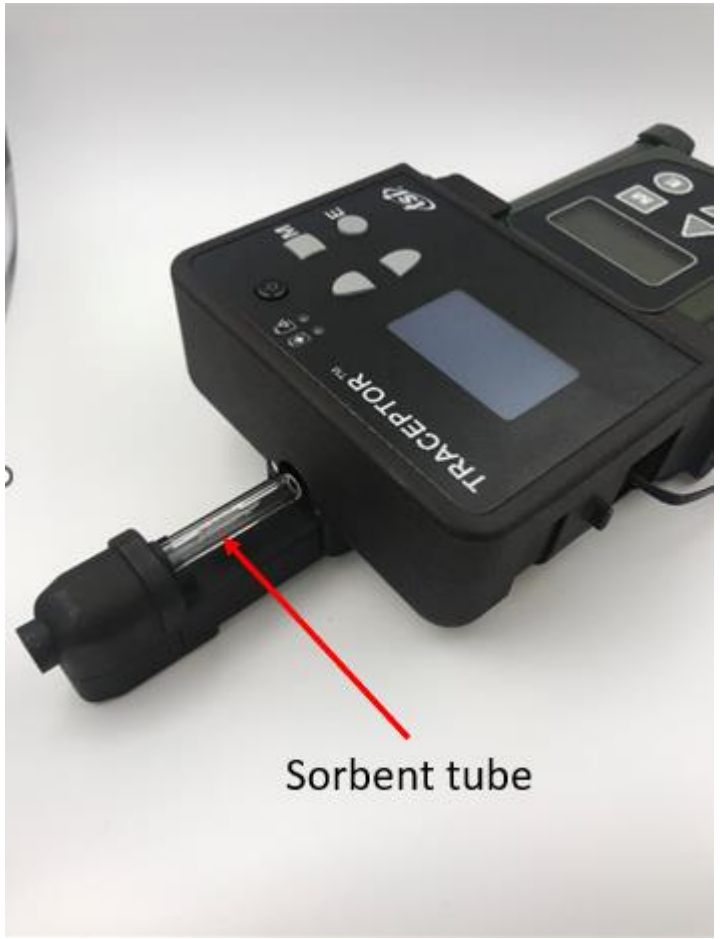


2. **Facilitates Capture of Aerosol Particles**

   Nearly 100% of < 25nm Particles captured shown here. Aerosol capture is tunable via sorbent packing design optimization.



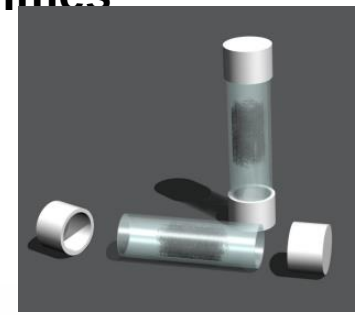
In-Situ Aerosol Sampling



Traceptor coupled with a Handheld Trace Detector

Take Aways:

- Enables **1500x Signal Amplification.** Demonstrated for both **CWA and Explosives** Vapor Trace Detection
- **Selective Concentration.**
- Performance demonstrated for Army and DHS programs and Next Generation Chemical Agent Detection platforms.
- **Rapid** (Approx. 1sec) **Heating Rate** with **Low Power** (Approx 20J per Cycle)
- Consumable Sorbent Cartridges Can Be **Cycled Many Times**



Contact:

John Lock (jlock@tritonsys.com)
Director, Sensing and Separations Lab

Ken Mahmud (kmahmud@tritonsys.com)
Executive Vice President

Triton Systems®
Driven to Innovate

Identification of Chemical Species in Aerosols by Miniaturized Dual Frequency Combs Based Waveguide Enhanced Coherent Raman Spectroscopy (DC-WE-CARS)

Daniel Lauriola

William Yang Terziyan

BaySpec
Pervasive Spectroscopy

Intelligence Advanced Research Projects Activity (IARPA)

Lightening Talk on PICARD Proposers' Day

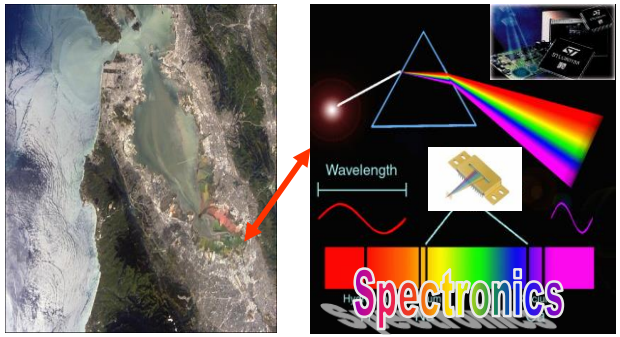
Monday, September 26, 2022

Arlington, VA

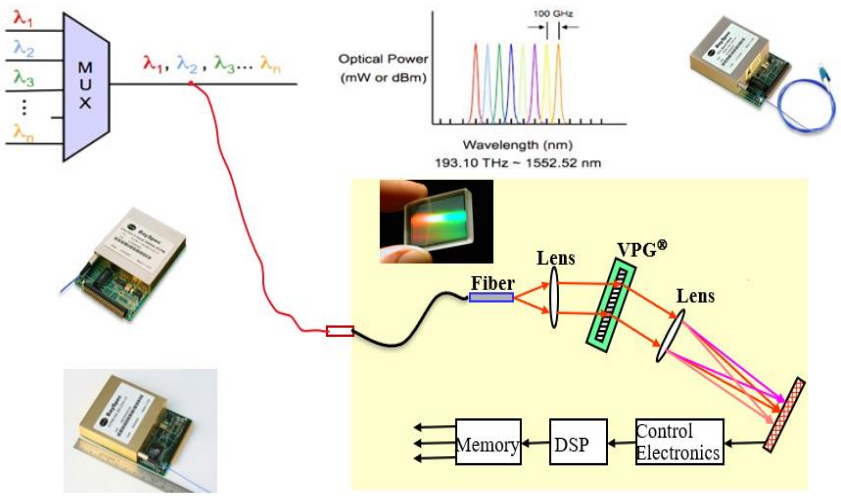
PICARD

Who is BaySpec

- BaySpec (*Bay Spectronics*)
- San Jose, California; Founded 2000
- Started by Optical and Laser Engineers
- We Design, Develop, and Manufacture



Miniaturization of Spectrometers of All Kinds; Have Made Several Tricorders!



- Vertical Integration
- Customized solutions
- Best performance/price/size

The Quandary/Challenge of Conventional Raman Spectroscopy/Portable Mass Spectrometry on Trace Detection

BAYSPEC
Pervasive Spectroscopy

Raman

- **High Specificity & Selectivity**
- **Low Sensitivity: takes too much time to detect**
- **Can be compact and light weight (HH; W<5lbs; Size < 5L);Wearable Raman Achieved**
- **NOT so good for trace or fast chemical detections**

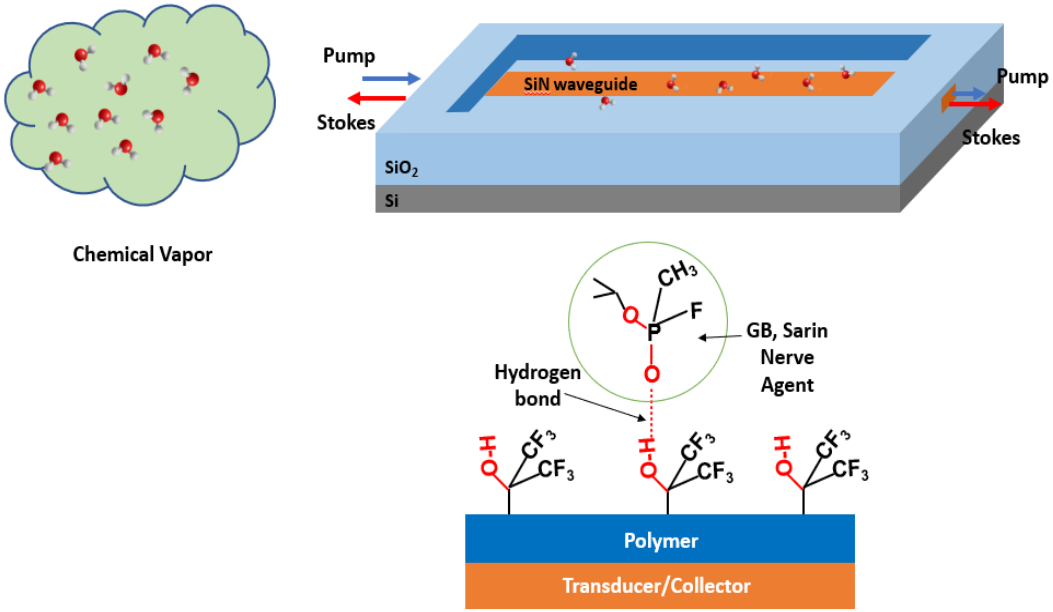
Portable Mass Spectrometry

- **High Specificity & Selectivity**
- **High Sensitivity**
- **Compact, but not as compact (Portable/Transportable; W< 25-35 lbs; Size < 30-60L)**

  (dilemma of smaller pumps for sacrificing vacuum/sensitivity/ mass resolution)
- **Decent for trace chemical detection; detection limit: 1-2 ppb**

PICARD

Waveguide Enhanced Raman Spectroscopy (WERS) for Detecting Trace Chemical Vapors

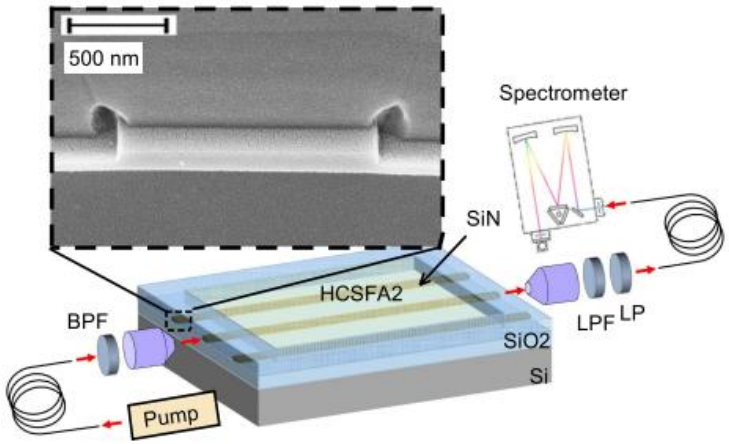


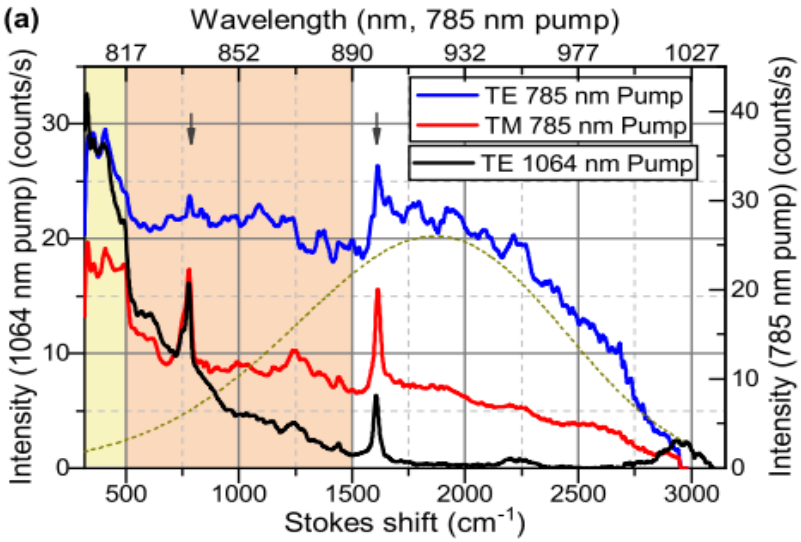
- Require waveguide coating with capture materials, and be exposed to analytes
- Nanophotonic waveguide, CMOS compatible (PIC)
- Raman signals from analyte in evanescent region
- nPIC confine and enhance Raman efficiency ~ 10^3 - 10^8 X to conventional RS

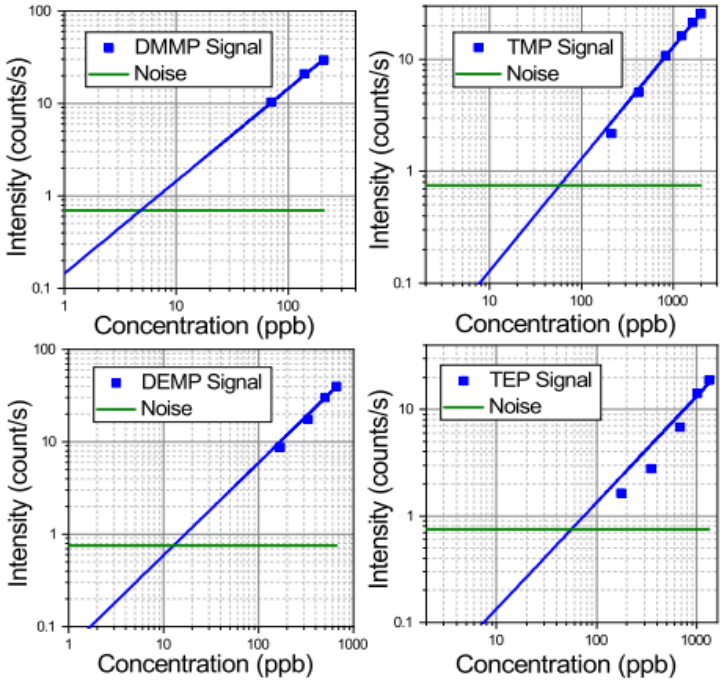
Feasible with Compact Raman (spontaneous) Spectrometers

1. Erik D. Emmons; Phillip G. Wilcox; Erik S. Roese; Ashish Tripathi; Jason A. Guicheteau; Kevin C. Hung; Benjamin L. Miller; Ethan P. Luta; Matthew Z. Yates; Nathan F. Tyndall; Todd H. Stievater, Proc. SPIE 12004, Integrated Optics: Devices, Materials, and Technologies XXVI, 120040L (5 March 2022); doi: 10.1117/12.2610654
2. E. D. Emmons, P. G. Wilcox, J. A. Guicheteau, N. F. Tyndall, D.A. Kozak, M.W. Pruessner, C. A. Roberts, R. A. McGill, T. H. Stievater, B. L. Miller, E.P. Luta, and M. Z. Yates, CLEO, OSA Technical Digest (Optica Publishing Group, 2020), paper AM2K.2 •https://doi.org/10.1364/CLEO_AT.2020.AM2K.2
3. N. F. Tyndall, T. H. Stievater, D. A. Kozak, K. Koo, R. A. McGill, M. W. Pruessner, W. S. Rabinovich, and S.A. Holmstrom, Opt. Lett. 43(19), 4803–4806 (2018)

As Elegant As Spontaneous WERS Is, Can It be Further Improved for Trace Chemicals in Aerosols?





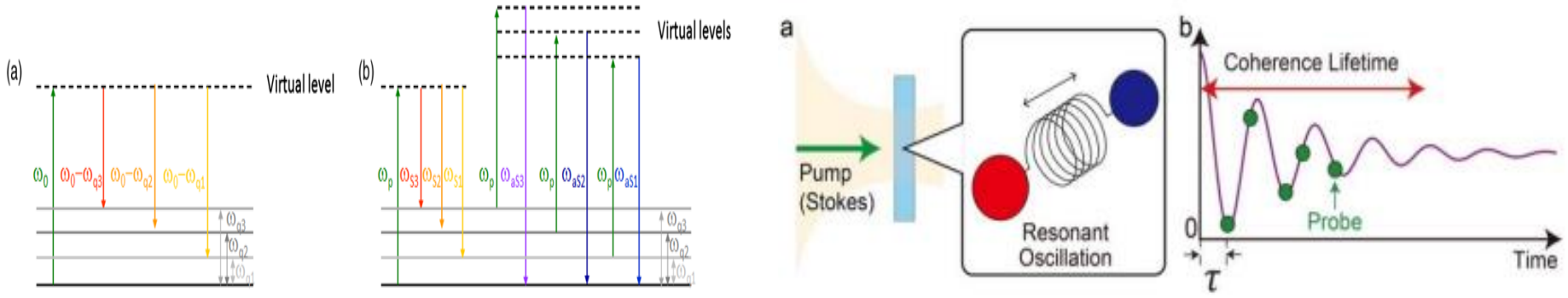


Detection Limits:

- DMMP: 5 ppb
- DEMP: 10ppb
- TMP, TEP: ~50 ppb

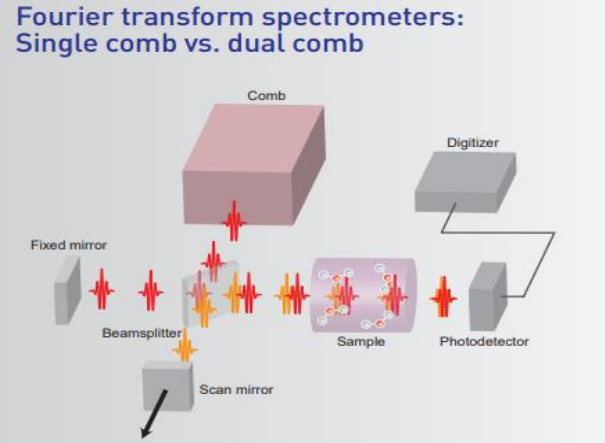
N. F. Tyndall, T. H. Stievater, D. A. Kozak, K. Koo, R. A. McGill, M. W. Pruessner, W. S. Rabinovich, and S.A. Holmstrom, Opt. Lett. 43(19), 4803–4806 (2018)

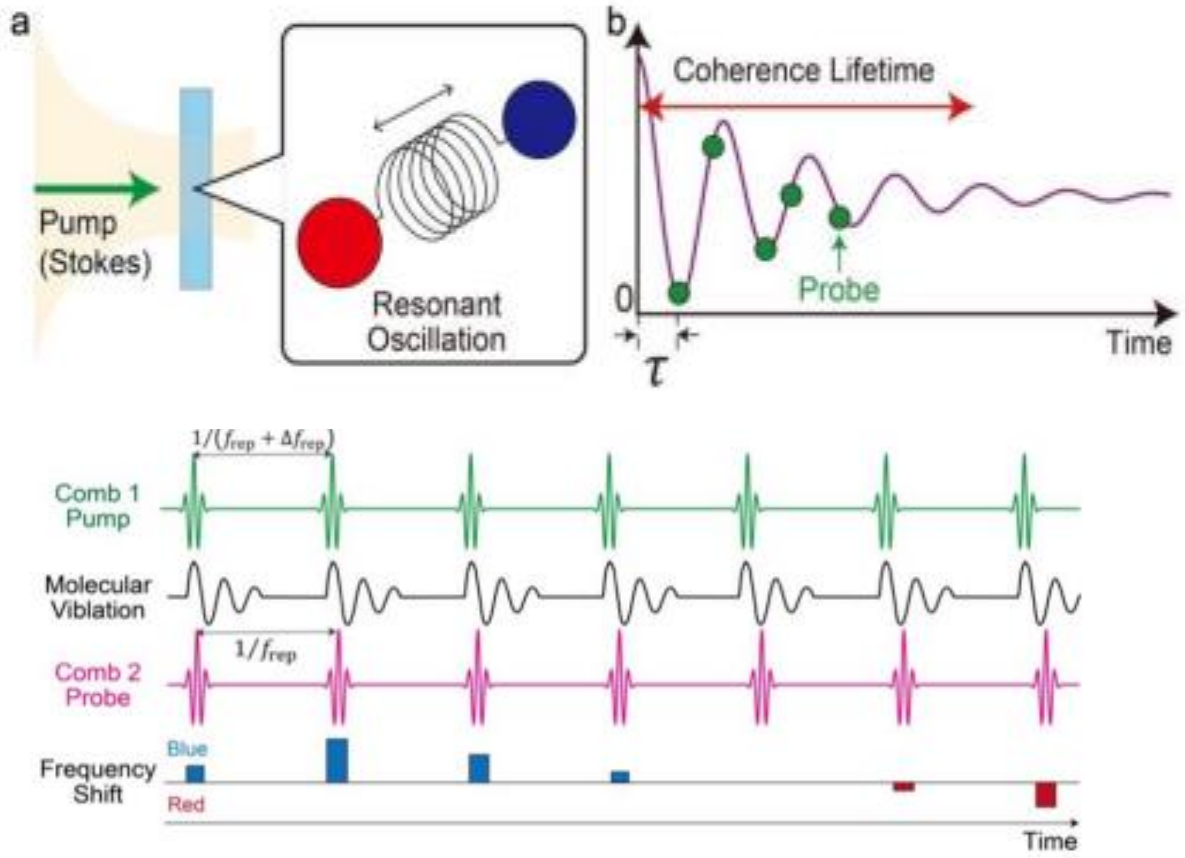
Further Enhancements: Coherent Raman Spectroscopy (CARS) Over Conventional Raman Spectroscopy



- **NO fluorescence interference- one of the many 'beauties' of CARS compared to Spontaneous Raman**
- **MUCH stronger signals: > 10^5-10^6 X further enhancement factor possible over spontaneous Raman**
- **DC(FT)-CARS: spectral characteristics same as Spontaneous Raman, and removal of NRB compared to standard CARS**
- **SUPER fast measurements speed-single shot in 42 µs**

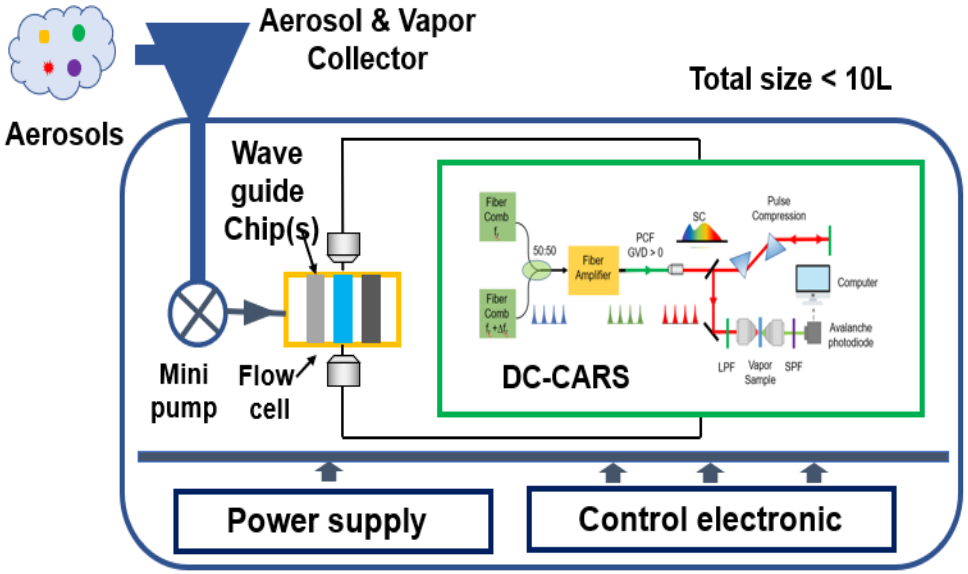
Dual Frequency Combs CARS(DC-FT-CARS)





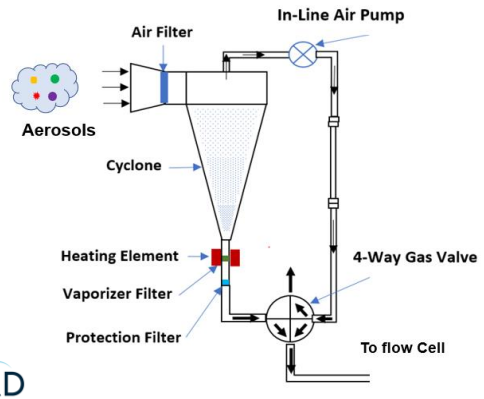
- **Time Domain CARS generates Raman spectra free from NRB**
- **Enhanced Sensitivity with high selectivity and Super fast**
- **DC-CARS May be the Ultimate Tool for Molecular Spectroscopy**

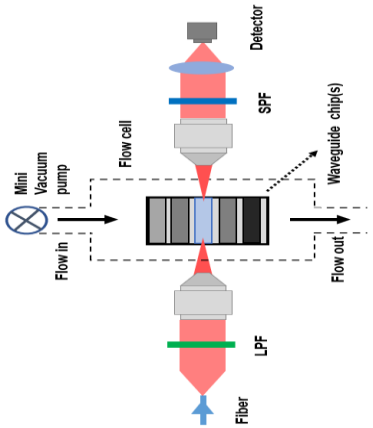
Suggested Approach of System Implementation

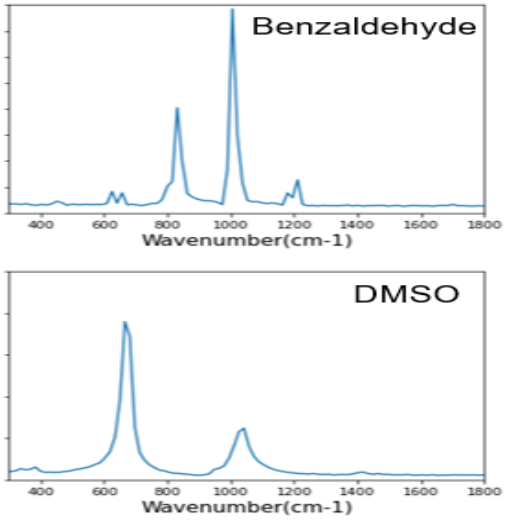


- Paired coherent optical frequency combs
- Broadband molecular spectroscopy
- Dramatic gains in:
  1)Spectral resolution
  2)Sensitivity
  3)Data acquisition speed
  4)Fluorescence free Raman

Aerosol Collector and Dual-Comb-CARS Spectroscopic System with Nanophotonic Waveguide Enhancement







Spectra obtained by Direct FT-CARs

PICARD

Achievable Performance Metrics

Criteria	Achievable Performance
Multiple Chemicals Sensitivity	Detect simultaneously> 55 agents and precursors
Size of Device	<0.01 m^3 (10L)
Identification Sensitivity	1 ng/mL -5 ng/mL for aerosols routinely; 1-5 ppb for various vapors of chemical interests routinely (The ultimate target is to go for sub ppb levels)

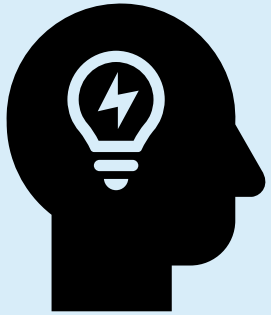
BLUE RIDGE
DYNAMICS

PICARD

Iran Air Flight 655

USS Vincennes

Problem Space



- **Many organizations focus on the technical solution with the User Interface as an afterthought.**
- **Bad designs can be tragic**

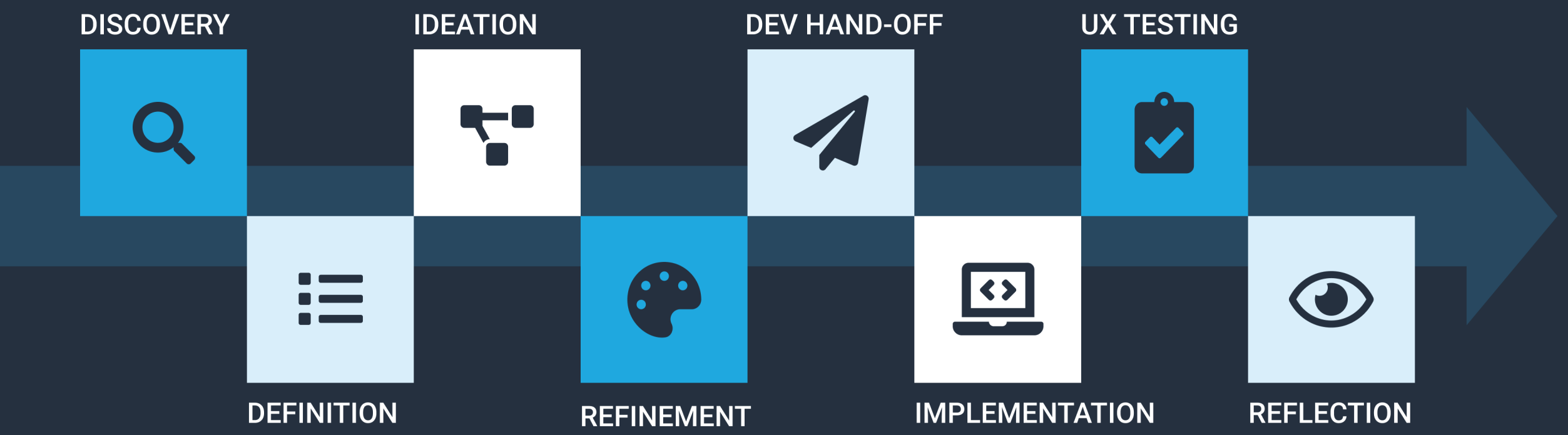
Commercial UI/UX Designs don’t always translate into DoD & Intel spaces well

- Fewer Users to research and test with
- Less in domain data for training
- Model mismatch
- Research shows users trust AI recommendations more than they should

Blue Ridge Dynamics

- **Founded in 2016**
- **UI/UX Design for DoD & Intel**
- **Development**
- **Integration**

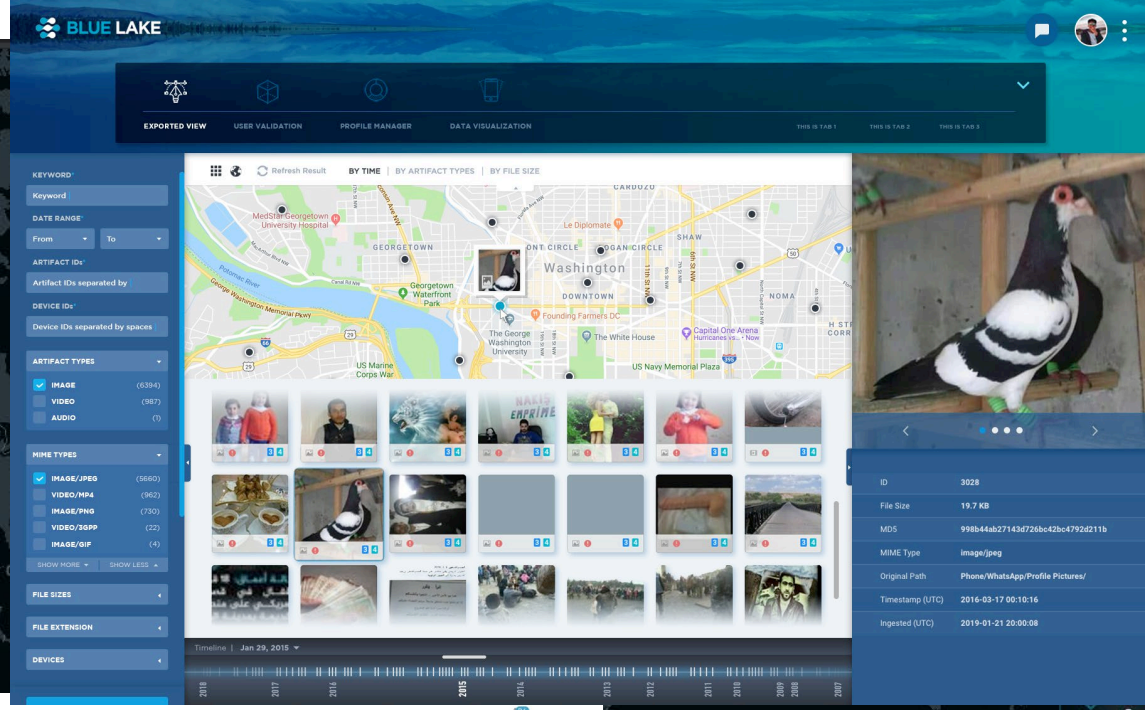
Custom UX Process

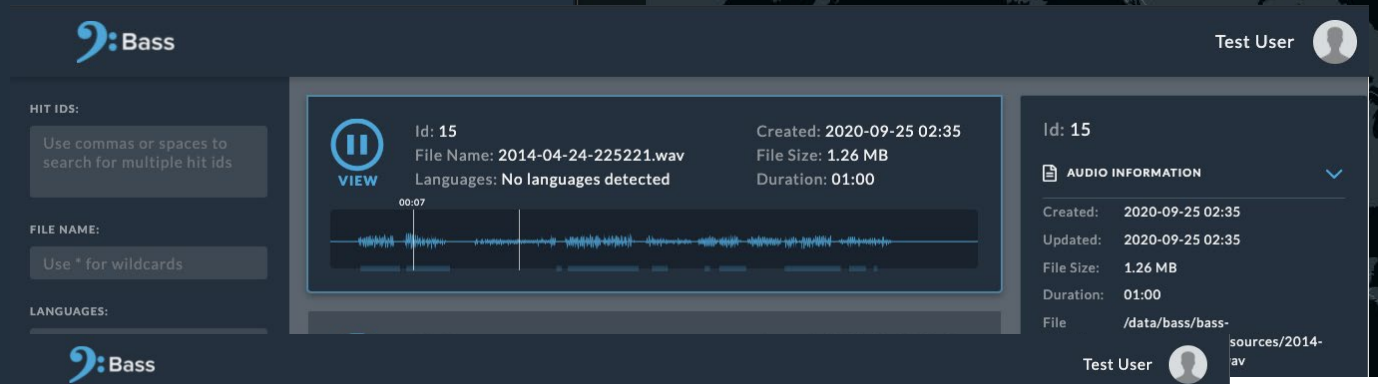


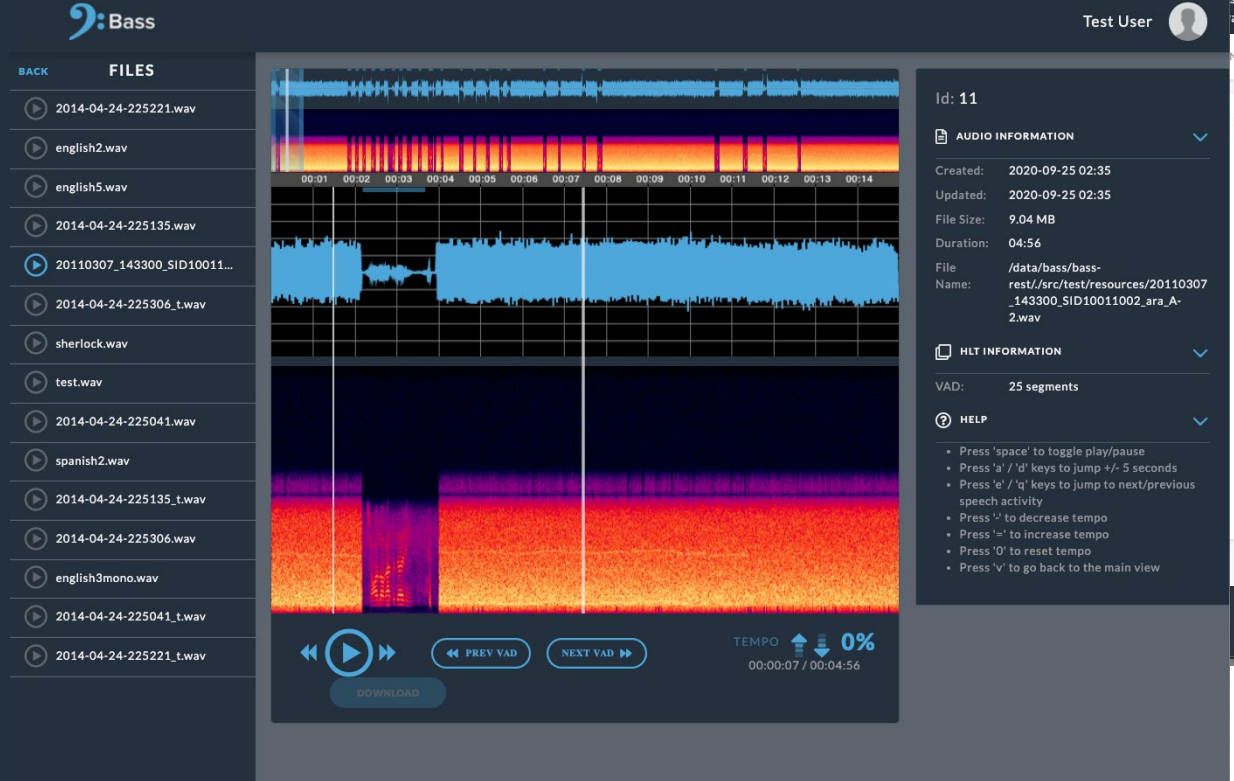
Government Partnerships

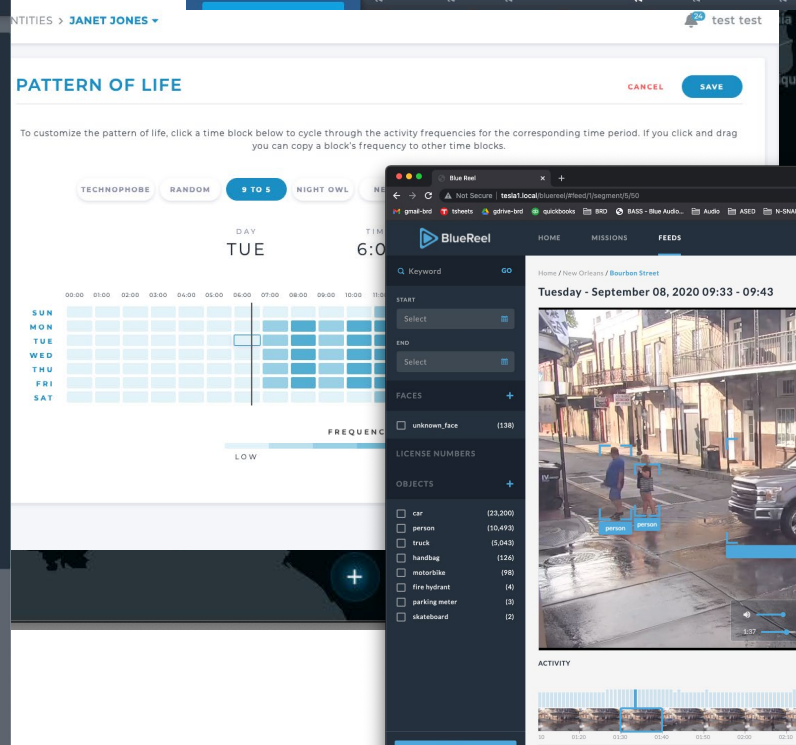
DARPA

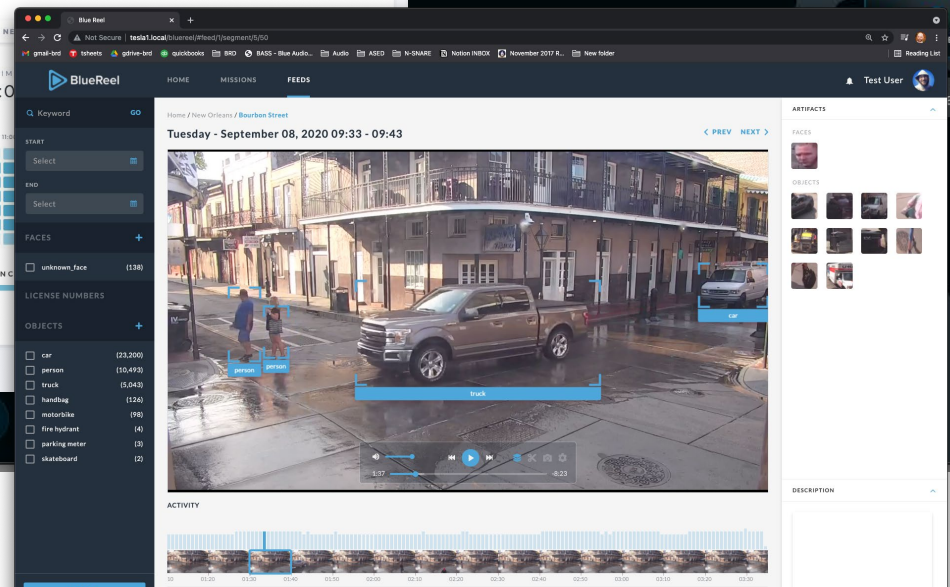
Previous Work











BRD Can Provide

- UI/UX Design
- User research
- UI Development
- Technology Integration
- QA Services

BRD Seeks Partners Who

- Have technology they want to productize.
- Don’t have UI/UX designers.
- Don’t have a UI for their technology.
- Need integration help

Thank you

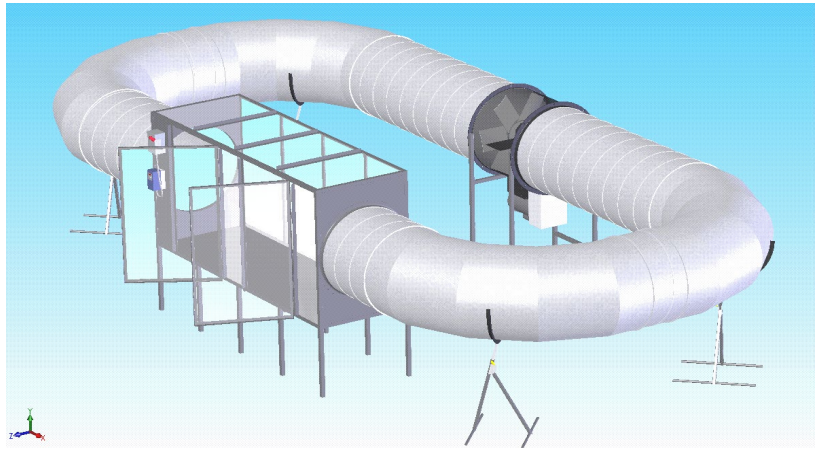
INNOVAPREP

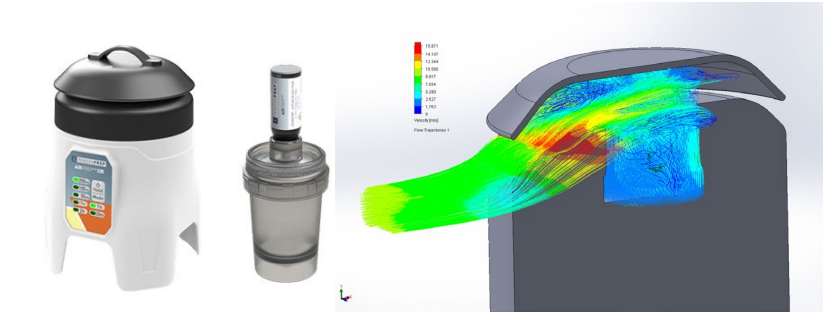
InnovaPrep PICARD Lightning

September 2022

Solutions

- UAV-mountable Biosamplers
- Bioaerosol T&E Wind tunnel/Chamber Lab
- Widely Distributable Bioaerosol samplers
- Computational Fluid Dynamics (CFD)
- Rapid Sample Concentration



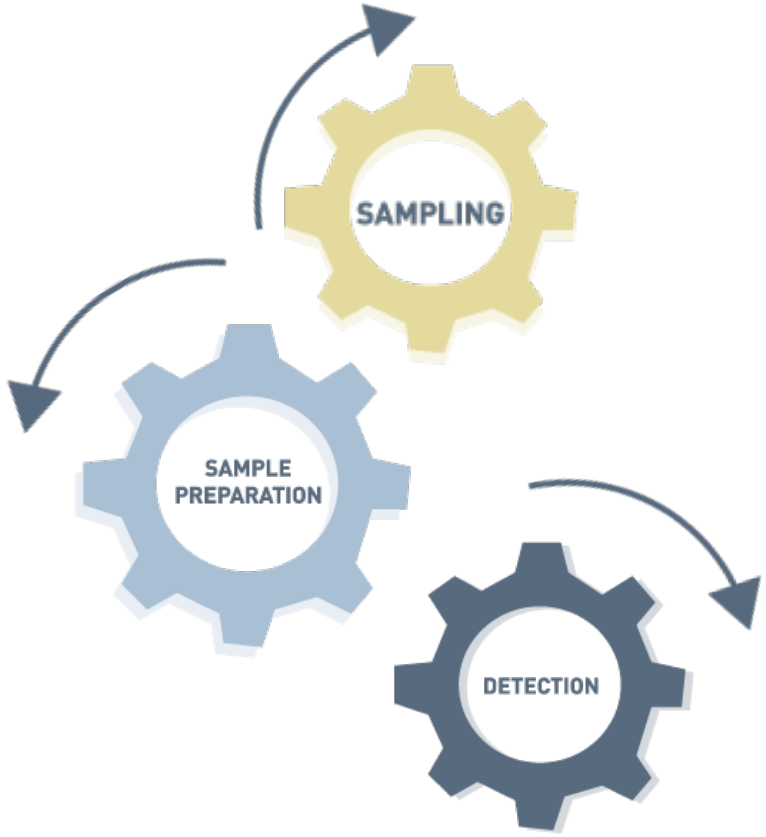



INNOVAPREP
Power OFF
Triggered
Continuous
1m ON 1m OFF
5m ON 15m OFF
Extended Run
Check Status
INNOVAPREP
Elution Fluid
AIRPREP™
FLUIDPREP™

INNOVAPREP

We make sampling and sample prep tools to detect threats

Faster, Easier, Better



Dave Alburty | 816-506-2843 | dalburty@innovaprep.com

NEXT GENERATION OF HIGHLY MINIATURIZED HIGH PERFORMANCE MASS SPECTROMETERS FOR IDENTIFICATION OF CHEMICAL SPECIES IN AEROSOLS

Krisztian Torma

William Yang Terziyan

BaySpec
Pervasive Spectroscopy

Intelligence Advanced Research Projects Activity (IARPA)

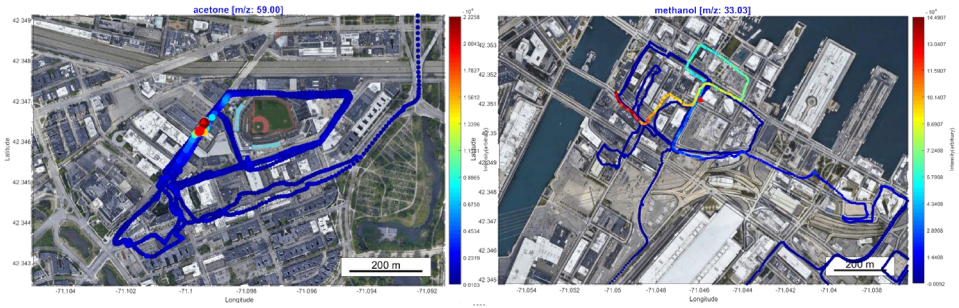
Lightning Talk on PICARD Proposers' Day

Monday, September 26, 2022

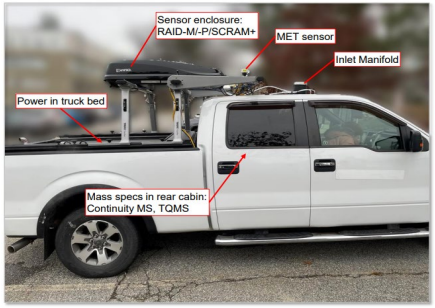
Arlington, VA

PICARD

Technical Overview of BaySpec's Miniature Mass Analyzers



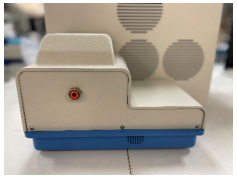
- Based on miniature Linear Ion Trap
- Miniature vacuum pumps
- MS/MS: tandem MS enabled
- Miniature Ion Funnel built in
- Wide mass range (covers <u>all</u> SIGMA+ chemicals (17-500 amu; expandable)
- High sensitivity across the entire mass range
- Vapor, solid, liquid (considering aerosols)



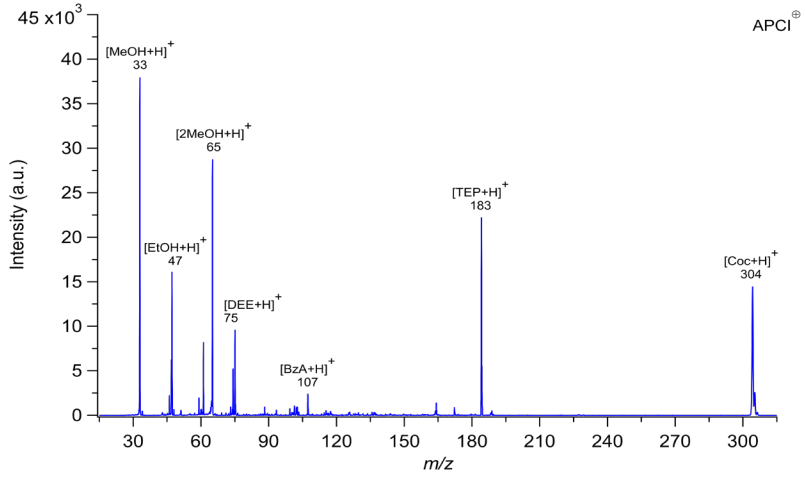

TQMS


Continuity MS

Current Performance of Miniature MS–Continuity

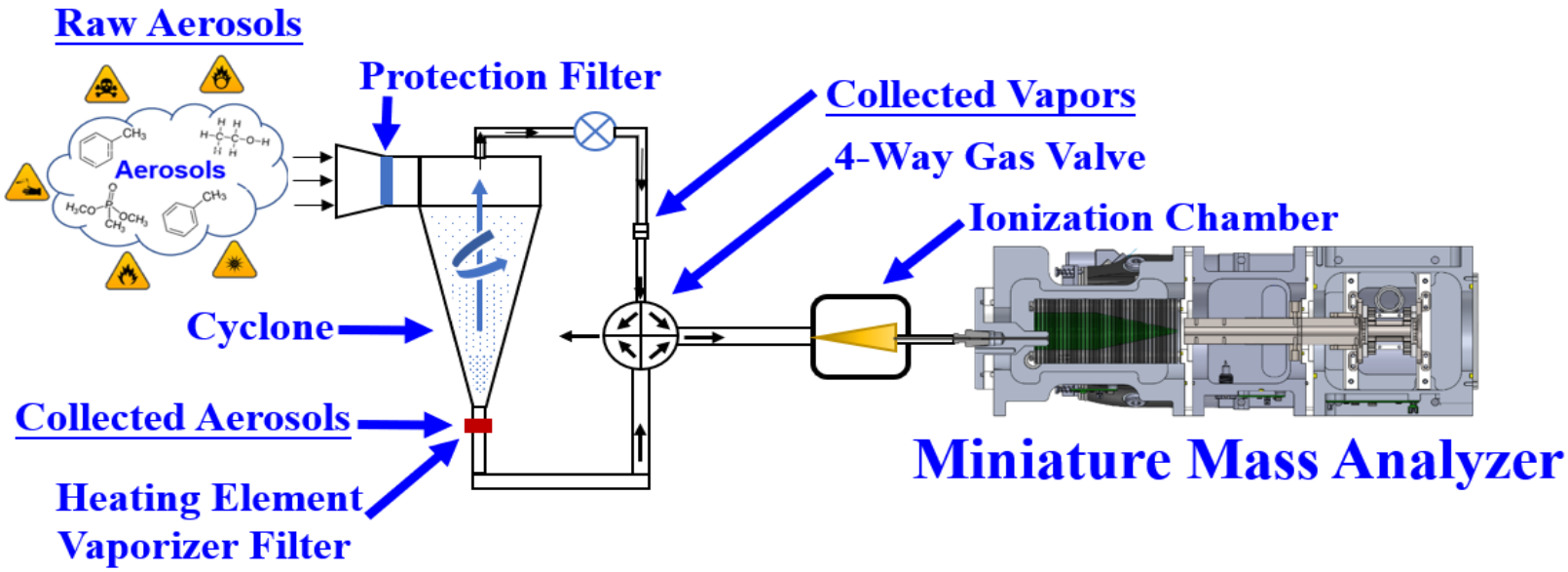


	SIGMA+ Metrics	Current
Identification sensitivity	<1 ppb, <30 s integration	<1 ppb
Chemical sensitivity	>20 agents and precursors	>50 agents and precursors
Time to detect/ID	<2 seconds	~1-2 s (dual polarity)
Probability of false alarm	10^{-6}	10^{-6}
Size, Weight	<200 L, <25 kg	<59 L, <22 kg



PICARD

Suggested Approach of System Implementation



- Built on DARPA's SIGMA+ experience
- Field proven, a work horse
- Dual/multiple ionization source to provide broadest coverage of chemical library
- Tandem Mass Spectrometry
- High sensitivity; high specificity; high speed

Achievable Performance Metrics

Criteria	Achievable Performance
Multiple Chemicals Sensitivity	Detect simultaneously >55 agents and precursors
Size of Device	<0.01 m^3 (10 L)
Identification Sensitivity	1 ng/mL -2 ng/mL for aerosols routinely; 1-2 ppb for various vapors of chemical interests routinely (The ultimate target is to reach sub-ppb levels)

Aerosol identification on the MX908

Matthew Aernecke, PhD

Principal Research Scientist, 908 Devices

908 Devices Capabilities - PICARD

- Handheld mass spectrometry (point sensor)
- Aerosol collection and analysis via specialized module
- In-house aerosol testing capability

© 908 Devices | Private & Confidential |

Our Approach to Mass Spectrometry

Conventional lab ion traps

908 micro-ion traps

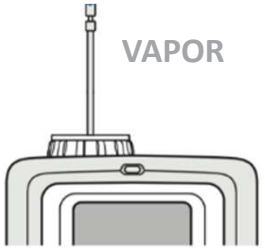
< 0.0001 torr

Require 100,000 RPM 'turbo' pumps; large, fragile, immobile

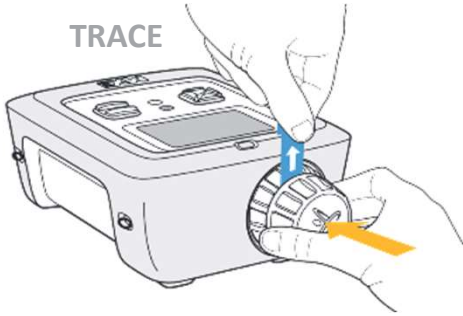
1 torr

Enables miniature, low-power rugged 'rough' pumps.

VAPOR



TRACE



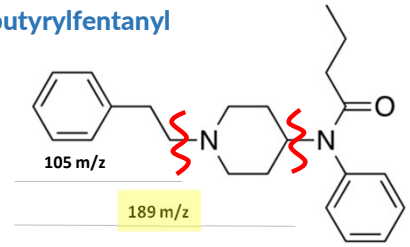
~ 10 ppb sensitivity
~50-100 ng LOD for solids/liquids
+/- APCI ionization source
mass range 60-550 m/z
3-4 hrs battery

908devices

Under the hood - MX908 Collision Induced Dissociation (CID)

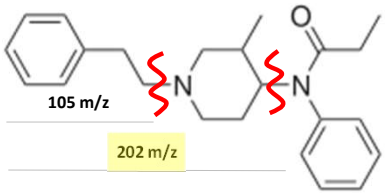
Fentanyl Isobars

butyrylfentanyl

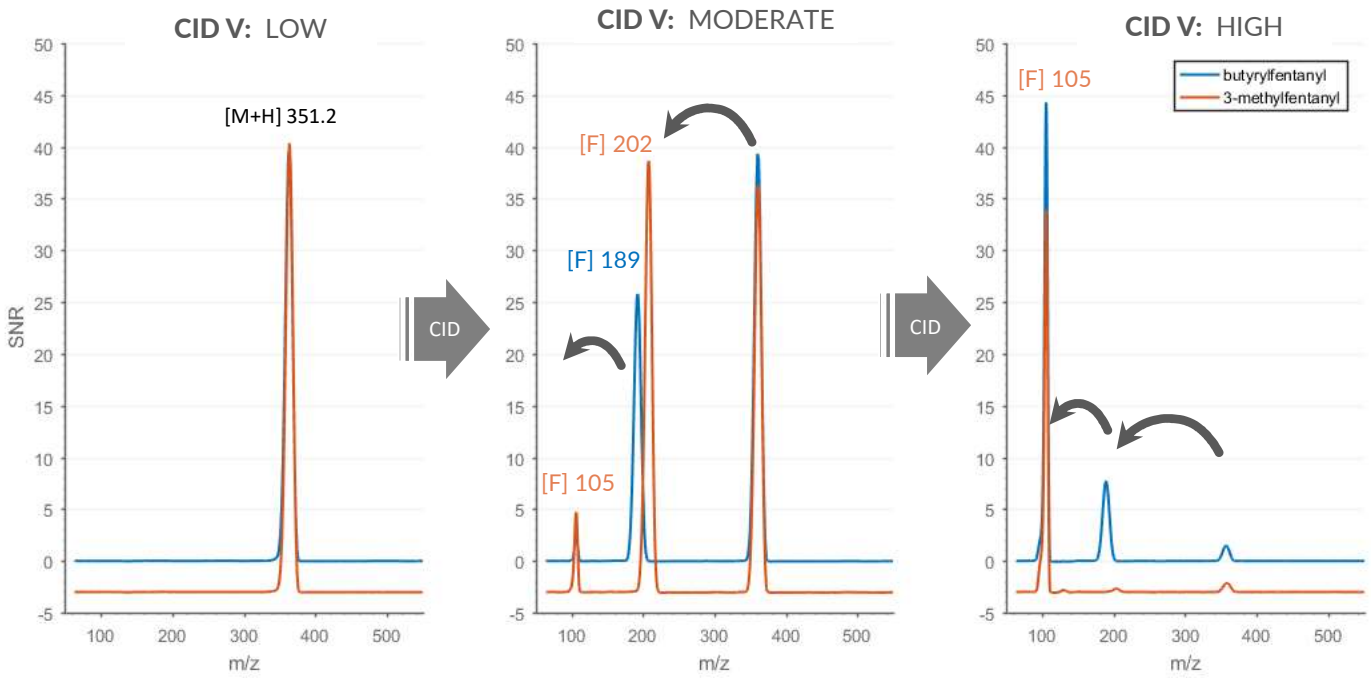


350.2 m/z

3-methylfentanyl



350.2 m/z

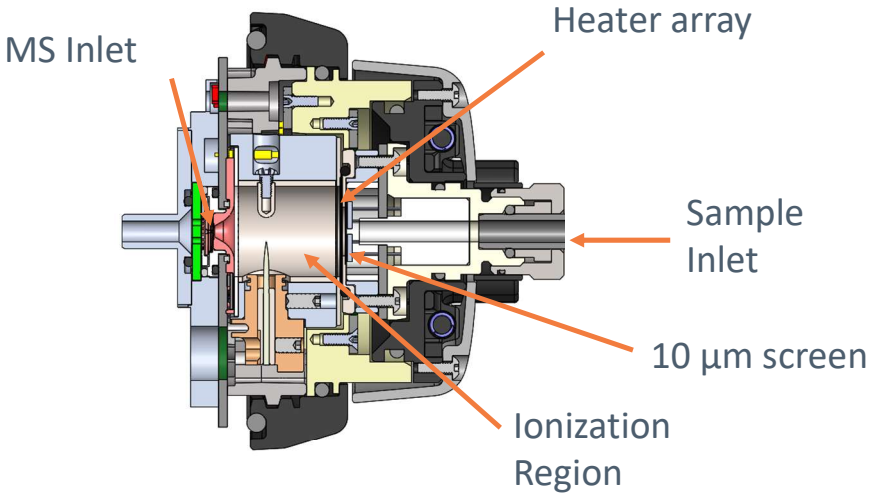


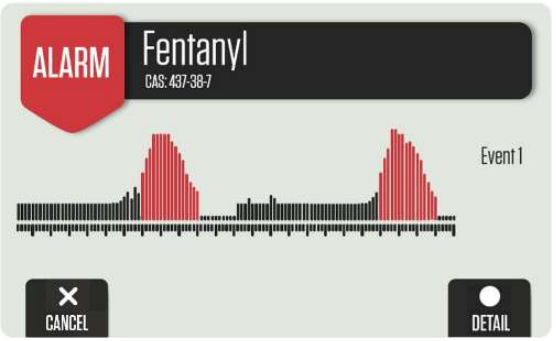
Chained probability: Joint probability of M+H, M+H yielding daughter ion 1, daughter 2, ... daughter ion *N*

250 milliseconds

MX908 Aerosol/Vapor Module

- Aerosol/Vapor Module can run:
  - Any Mission VAPOR mode (CW, Explosives, Hazard Survey)
  - **Aerosol Hunter:** Vapor analysis with fixed interval desorption for detection of aerosol targets.
- Targets include:
  - Traditional CWAs: V-Series agents, G-Series agents, and Mustard
  - Novichoks
  - Fast acting incapacitating agents: Fentanyl and analogs, U-series agents, and W-series agents
  - Lachrymatory agents (capsaicin)
- Results are shown on screen
  - User is alerted to when a target is detected.

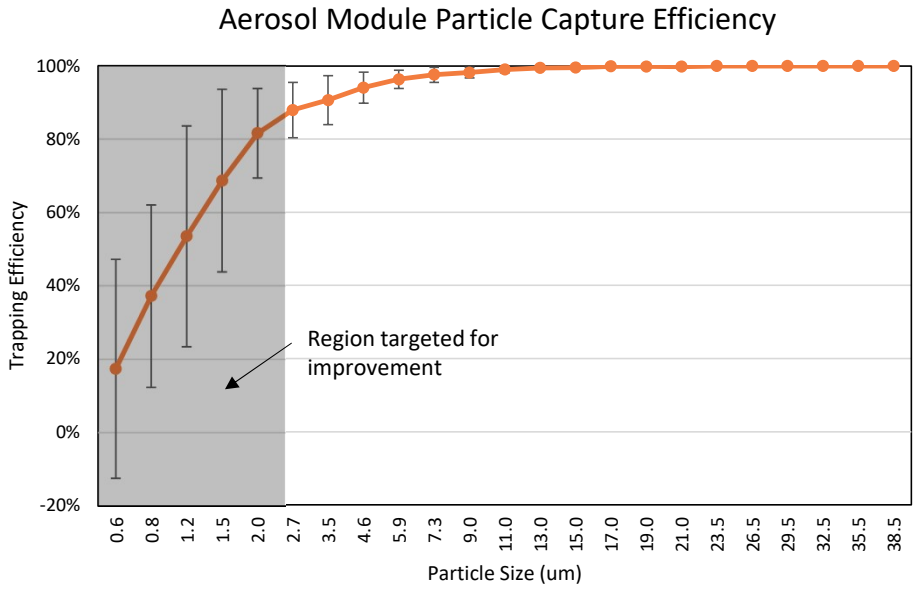




908devices

Particle trapping efficiency

Module has a capture efficiency of >80% for particles with diameters above 2.5 microns – providing capability for threats where mass-weighted mean particle diameter is less than 10 um



Particle Diameter (um)	5ft settle time (static air)	Particle Mass (ng)	# particles to hit 50 ng
0.5	41 hrs	8.0E-5	620,000
1.0	12 hrs	6.4E-4	78,000
3.0	1.5 hrs	1.7E-2	2,900
10	8.2 min	6.4E-1	78
50	22 sec	65.4	1
100	5.8 sec	640	1

908devices

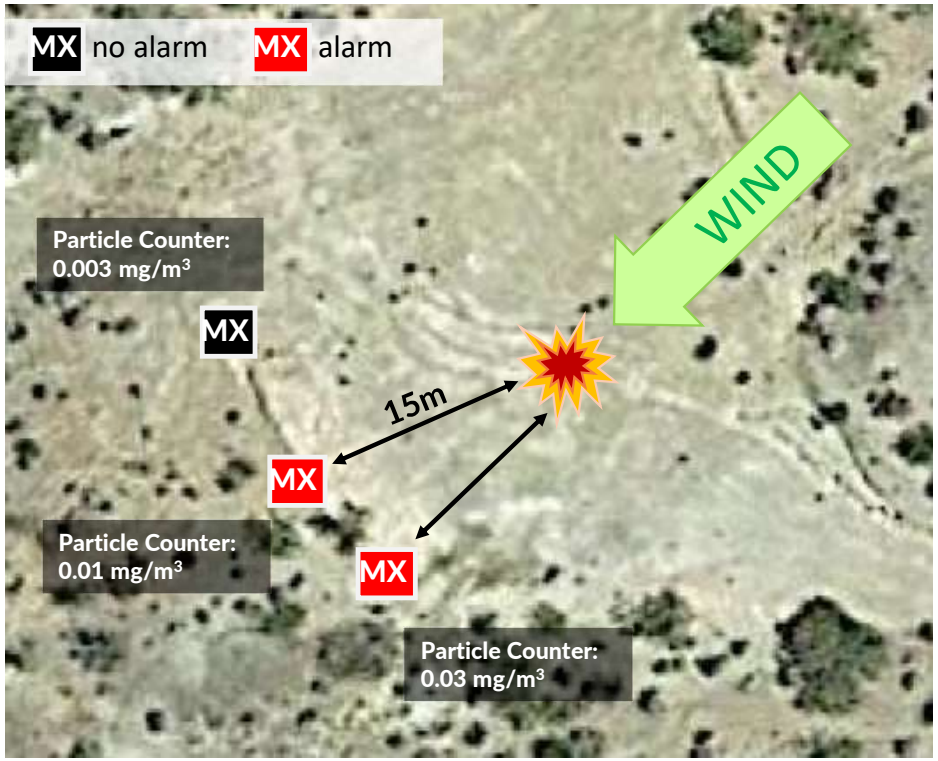
https://www.cdc.gov/niosh/topics/aerosols/pdfs/aerosol_101.pdf

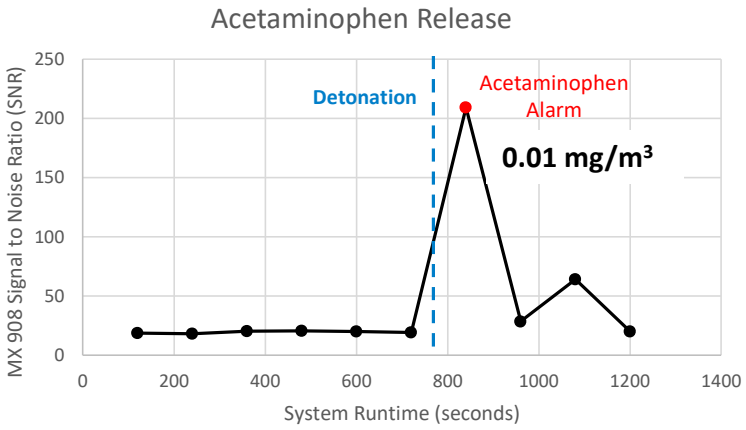
Field Releases

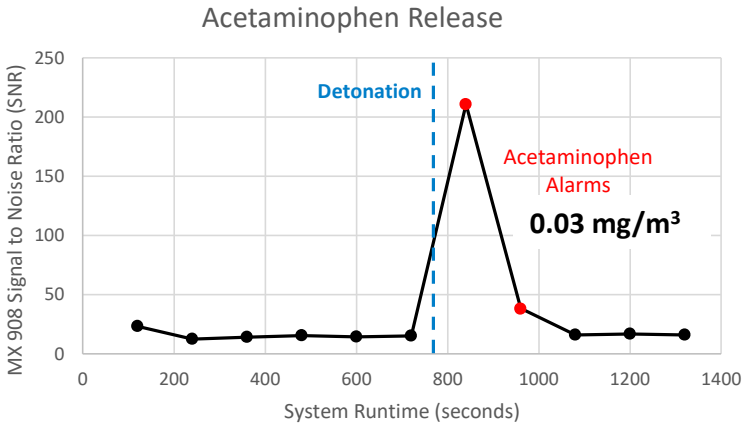
Mallinkrodt
pharmaceutical grade
ultrafine
acetaminophen

MX908 + AlphaSense Optical Particle Counter
0.3-40 um size range, 1 Hz refresh rate

Example Release



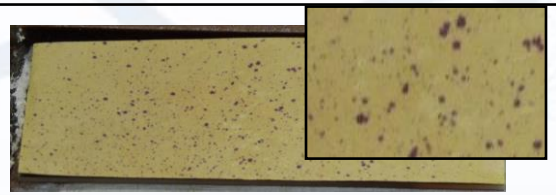
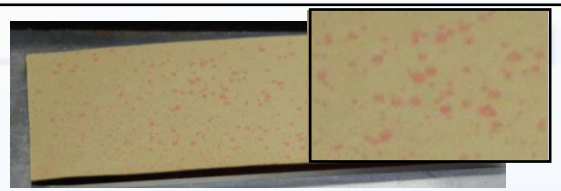
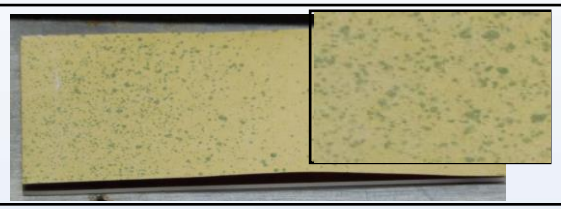




908devices

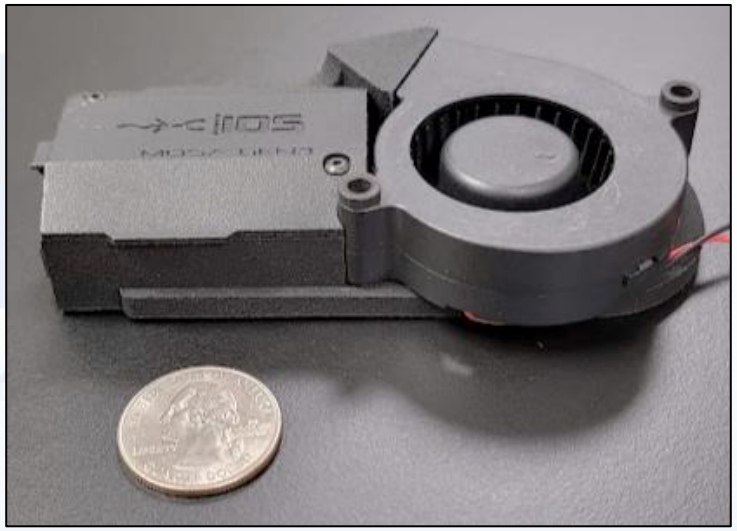
Low SWaP fieldable device for rapid identification of Chemical Warfare Agent(CWA) Liquid Aerosol

CWA colorimetric sensing paper

CWA	CWA class	Developed color	Aerosol size	CWA liquid aerosol test at agent testing lab	Response time with naked eye
GD	Nerve	Purple	110±5 μm		2.6 sec
HD	Blister	Red	110±5 μm		2.7 sec
VX	Nerve	Green	100±5 μm		3.0 sec

IWTSD(Irregular Warfare Technical Support Directorate) program

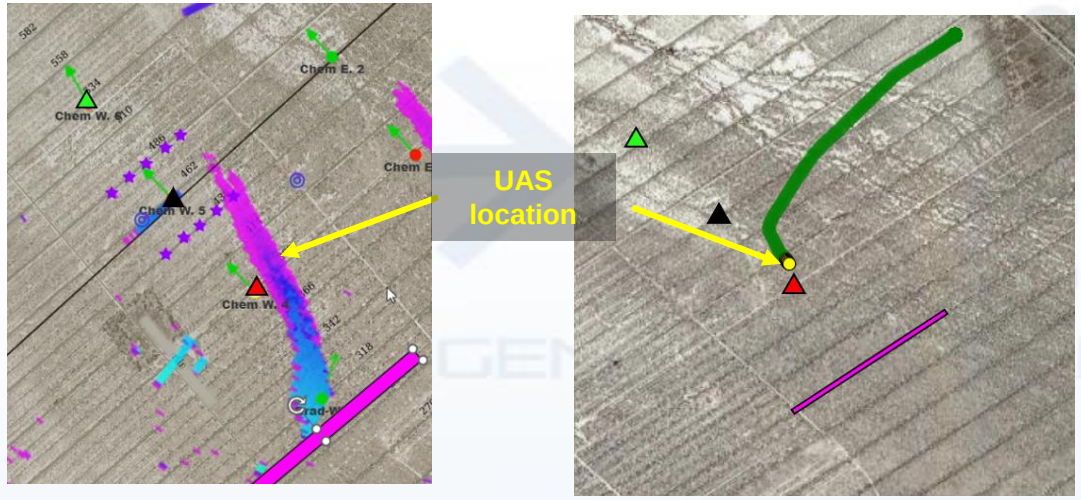
Low SWaP optical readout unit



CSIRP (JPEO-CBRND; JPM CBRN Sensors) program

Standoff detection and point detector identification

LIDAR-assisted chemical identification



LIDAR-feed chem detection

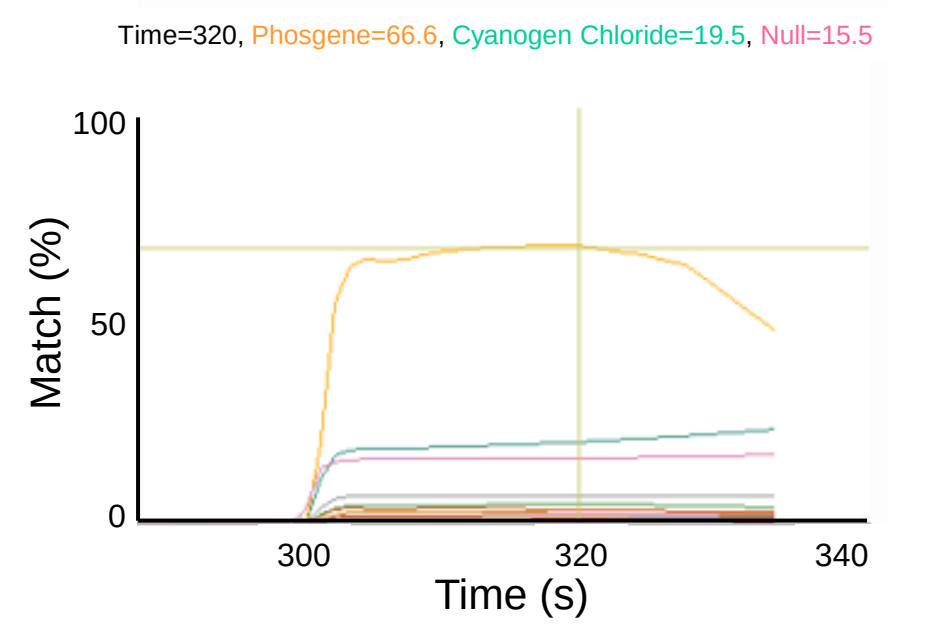
IOS readout unit chem identification

Real-time chem identification on ATAK

CSIRP (JPEO-CBRND; JPM CBRN Sensors) program

On-board AI for enhancing chemical identification

Edge-computed classification
for improved *specificity*



Phosgene exposure at 300 seconds

We have developed AI algorithms to improve detection specificity

CSIRP (JPEO-CBRND; JPM CBRN Sensors) program

Looking for Partners

- Compact low SWaP LIDAR detectors
- Experts in edge computing of neural net algorithms

Rapiscan systems
An OSI Systems Company

Pursuing Intelligent Complex Aerosol Rapid Detection (PICARD) program.

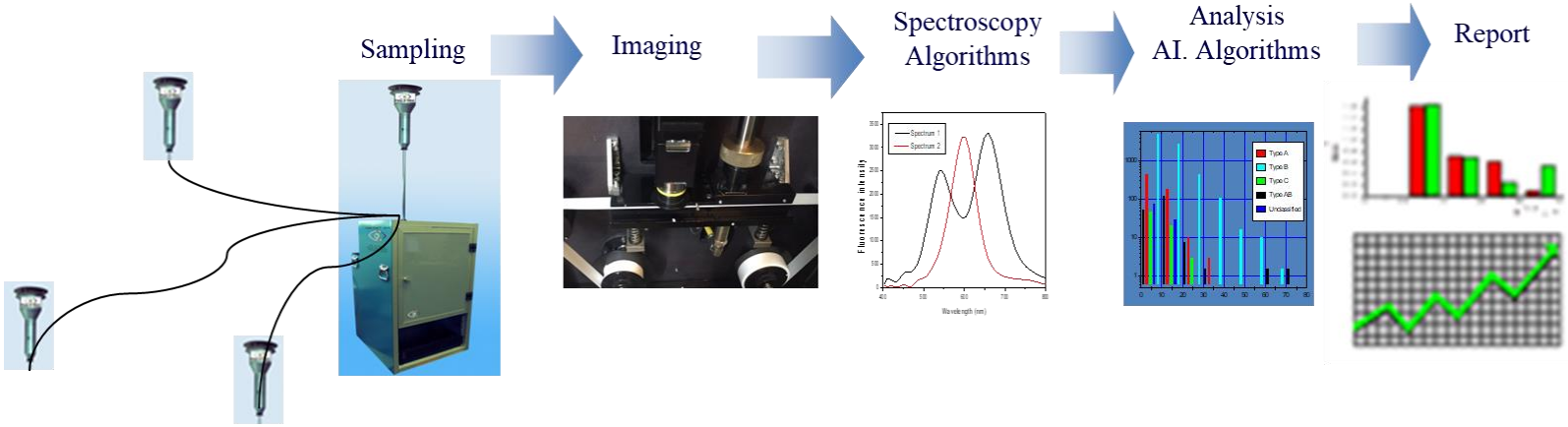
HyperEye – hyperspectral imaging solution for aerosolized chem/bio threat detection

Rapiscan Systems-GreenVision Partnership

- Rapiscan Systems has teamed with GreenVision Systems Ltd. - a producer of unique hyperspectral imaging (HSI) systems for a variety of industry applications
- Our proposed solution is rated TRL 7 and is in low rate initial production
- The system has been thoroughly tested and validated in a variety of operational settings

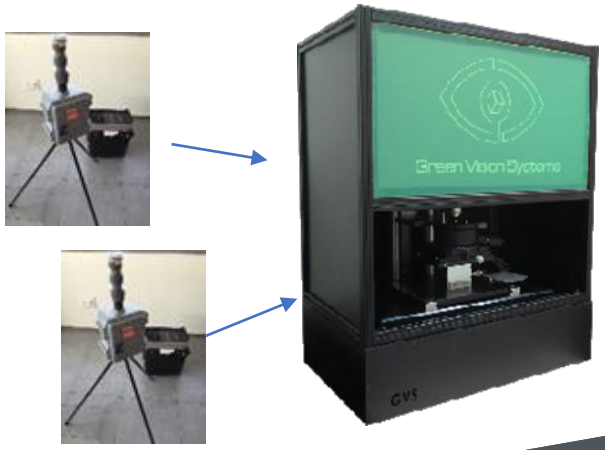
HyperEye is well-aligned with PICARD's goals

- Detects and characterizes aerosols; detects and classifies biological agents (viruses, fungus , bacteria, spores, anomalies) as well as hazardous particulate matter (CWA, TIC, VOC, PAH)
- High PoD; low FAR; high specificity and selectivity; anomaly detection; background environment learning capability



The HyperEye system is configurable for multiple environments

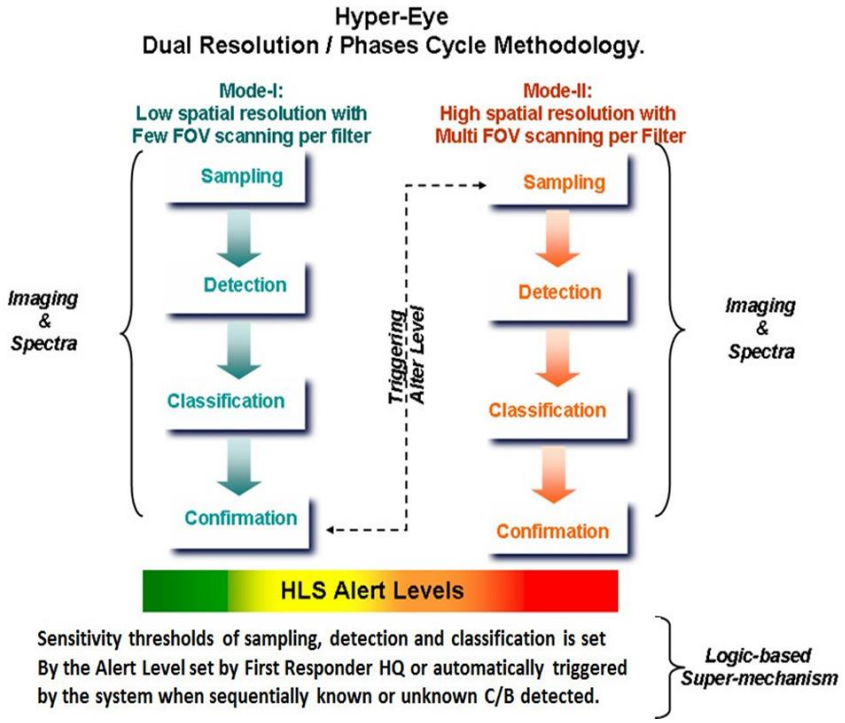
- Standalone Remote Operation System for outdoor air monitoring for aerosolized biological and chemical contaminants
- Central processor with distributed collection units for indoor air monitoring; this configuration can also process additional sample media such as saliva
- Near real time performance with accuracy equal to or greater than PCR testing
- AI/ML algorithms enable sophisticated anomaly detection



The HyperEye: A Flexible and tuneable system

- Employs hyperspectral microscopic chemical imaging coupled with adaptive learning algorithms to identify chemical and biological material that may be present on aerosol particles.

- System operating parameters are tunable by user to accommodate changing background environments or threat levels – selectivity and sensitivity can be adjusted



HyperEye Advantages and Strengths

- High spectral and spatial resolution; High SNR
- Versatile spectral light ranges (UV, NIR, SWIR)
- Detection, quantification per classified type; per aerosol type , particles size distribution; adaptive background databases; anomaly detection
- Full user control
- Versatile platform for various applications capability of real time analysis
- Low cost of maintenance field operation with remote diagnostic capabilities

Rapiscan systems
An OSI Systems Company

Points of Contact

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  jfennell@rapiscansystems.com

- Dr. Neale A. Messina
  nmessina@rapiscansystems.com

Co-Creating Possible.

Improving the World
by Revolutionizing Technology Realization

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We streamline the **concept to production journey.**

Technology as a Service

Innovation as a Service + **Manufacturing as a Service**

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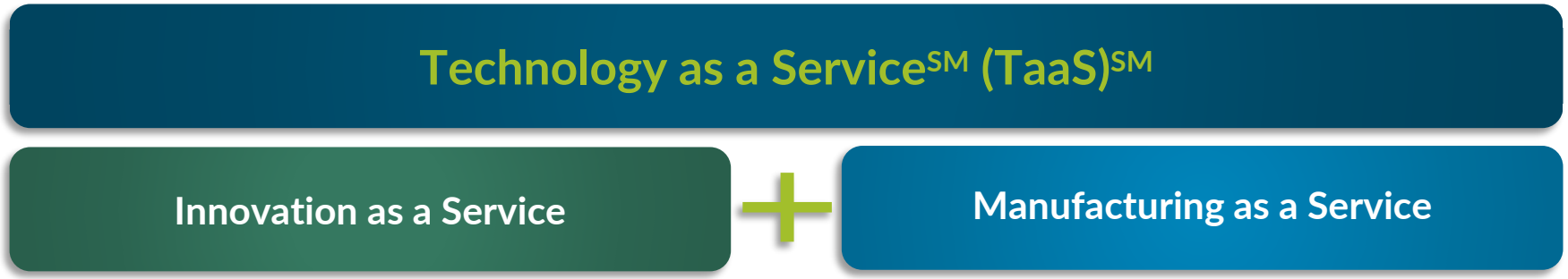
SkyWater's Unique Model Accelerates Disruption

WHO WE ARE



Advanced Technology Services (ATS)
enable co-creation of differentiated solutions which are the unique expression of the combined customer/SkyWater multi-disciplinary technology teams.

Wafer Services
supply customers with ICs and microdevices for commercial or mission ready products.

OUR TaaS MODEL

Co-creates disruptive technologies

Builds long relationships through collaborative development and manufacturing

Leverages world-class capabilities

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SkyWater is Defining a New Category

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Conventional Foundry

- Minimal customization
- Digital processors, CPUs, GPUs
- High volumes
- 300 mm substrates

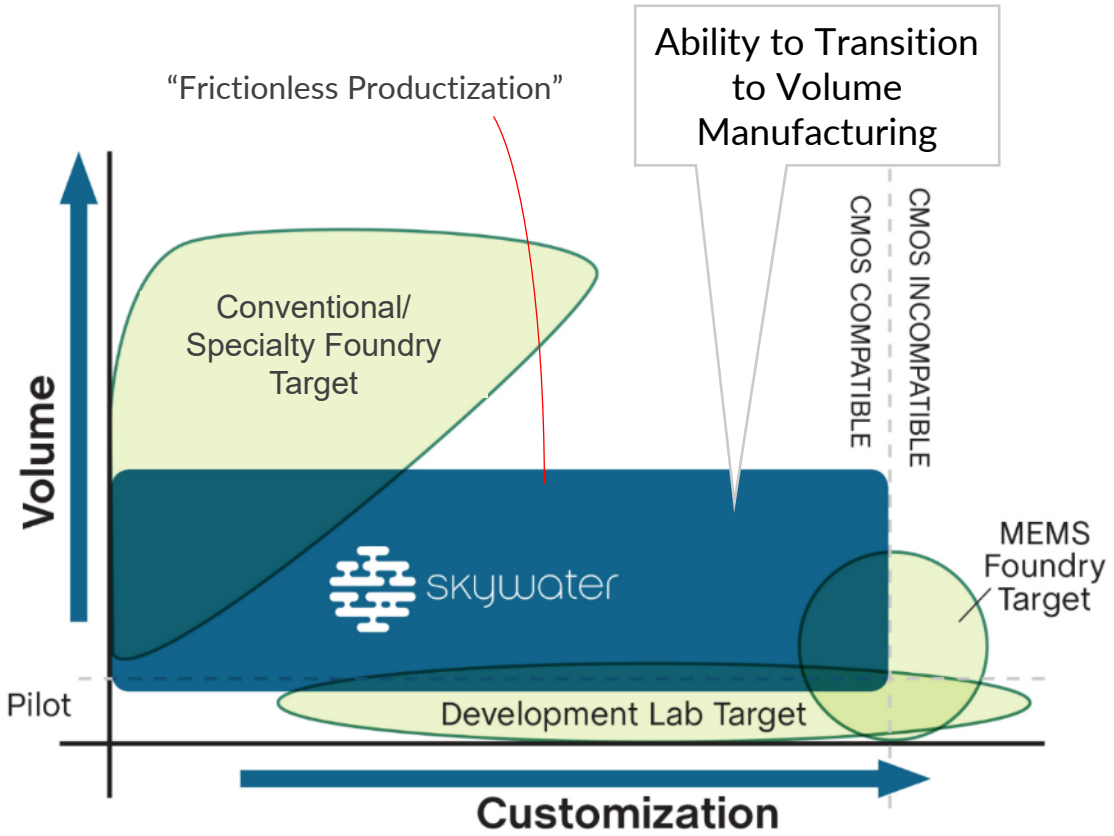
Specialty Foundry

- Moderate customization
- Specialty technologies
- Medium volumes
- 200 mm and 300 mm substrates

Technology Foundry

Advanced Technology Services + Wafer Services

- ✓ High customization
- ✓ Next-generation technologies
- ✓ Variable volumes
- ✓ 200 mm substrates



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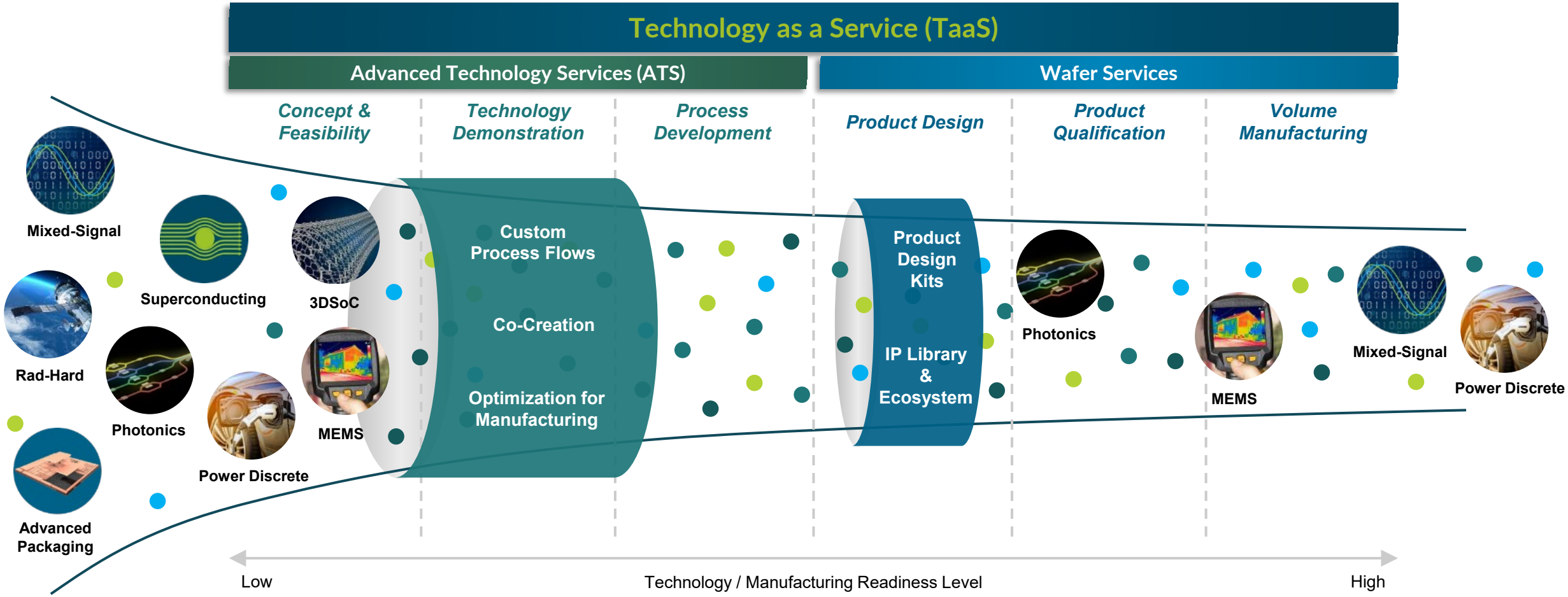
Model Enables Early Foundry Engagement



✓ **Efficient R&D** ✓ **Accelerated Time-to-Market** ✓ **Volume Manufacturing**

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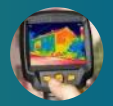
Partnership Pathways: Prototype to Production

	Research		Commercialization
	Advanced Technology Services	**Qualification**	**Wafer Services**
Primary Activity	**R&d:** Proof of Concept Tech Demonstration Process Development	**r&D:** Maturing & Qualifying Capabilities, Process Flows, and Products for Scale	~~r&~~d: Volume Production
Technology Readiness & Manufacturing Readiness	TRL / MRL: 3~6	TRL / MRL: 6~8	TRL / MRL: 8~9
Operating & Business Model	• NRE • Tooling	• MPW • NRE • Tooling • Early Access Program • Flow Transfer	• 1x Setup • Per Wafer
Example Start Points	 3DSoC  90nm Rad-Hard	 MEMS  Photonics	 Mixed-Signal  Power Discrete

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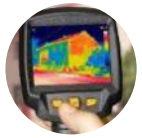
Technology Categories

Mixed-Signal CMOS

Flexible Solutions for Commercial & Defense

Rad-Hard

Leading Strategic Rad-Hard Solutions



MEMS

Microfluidics

Microbolometers

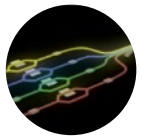
Power

MOSFET Differentiated Flows

Support for IGBTs, TVSs

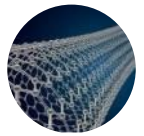
Superconducting

Foundry service provider for quantum and supercomputing applications



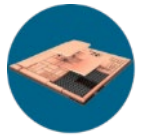
Photonics

Capabilities for passive photonic device integration



Carbon Nanotubes

CNT enabled 3DSoC for AI and edge computing



Heterogeneous Integration

Capabilities for passive and active solutions for high performance applications

Connected Devices, Sensors and Sensor Integration

Advanced Computing & Artificial Intelligence

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Photonics

Technology Trends

400G+ Datacom
market demand for increasing data rates continues

CMOS+
opportunities for monolithic integration of optical and electronic systems

Integration
Active light sources, modulators, and detectors

Technology Applications


Datacenter Transceivers


Optical Interconnects


Automotive LiDAR


Bio Diagnostic Arrays

SkyWater Capabilities Today

- Advanced Technology Services enable co-creation of differentiated integration architectures
- Diverse processing capabilities & ecosystem partners for key device fabrication & integration
  - Waveguides
  - Diffraction gratings
  - Modulators
  - Detectors
  - Grating couplers, fiber couplers, passive fiber alignment
  - Capabilities to support exotic materials: Nb, Ge, HfO_2

Key Differentiators

- ✓ Trusted IP Security
- ✓ Efficient development in a production environment
- ✓ Rapid scale-up to production on high yielding 200 mm line
- ✓ Support for novel photonic device architectures

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MEMS

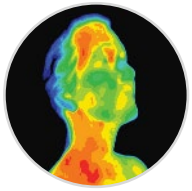
Technology Trends

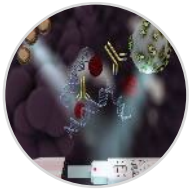
CMOS+
opportunities for monolithic integration of sensors and CMOS

Functional Surfaces
enable highly specific chemical/ molecular sensing

Transducer Arrays
are enabling higher fidelity sensing and imaging

Technology Applications


Thermal Imaging


Bio-Diagnostics


Genetic Sequencing


Inertial Navigation

SkyWater Capabilities Today

- Advanced Technology Services enable co-creation of differentiated integration architectures
- Deep Reactive Ion Etching for TSVs and high aspect ratio features
- Support for processing of a wide range of materials

Key Differentiators

- ✓ Trusted IP Security
- ✓ Efficient development in a production environment
- ✓ Rapid scale-up to production
- ✓ Support for novel device architectures
- ✓ Automotive and Medical certifications

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Carbon Nanotube Microelectronics

Technology Trends

3D Monolithic
Stacking for high density interconnected devices

Novel CNT
Device architectures leverage unique properties

Low Temp Processing
Enables backend integration of device layers

Technology Applications


Neuromorphic Computing


Edge AI


Extreme Low-Power IoT

SkyWater Capabilities Today

- SkyWater is executing phase 2 of DARPA funded 3DSoC program; partners with MIT, Stanford
- 3DSoC program is transferring lab demonstrated concepts into a foundry with commercial grade design enablement resources
- CNT CMOS and ReRAM process allows backend / low temperature integration with nontraditional processing

Key Differentiators

- ✓ Trusted IP Security
- ✓ Efficient development in a production environment
- ✓ Support for novel device architectures
- ✓ Rapid scale-up to production on high yielding 200 mm line
- ✓ Close university collaboration accelerates translation of ideas into production environment

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Heterogeneous Integration

Technology Trends

2.5D/3D/ Integration
packaging architectures for intimate chip/chiplet connection

SWAP Improvement
HI packaging provides for shorter interconnect lengths and higher density

Continued Scaling
HI provides paths to continued system performance increase as Moore's scaling slows

Technology Applications


Advanced Computing


High Density Memories


Imaging


Communications

SkyWater Capabilities Today

- Silicon interposer development ongoing, supporting both bridge & TSV-enabled interposers
- FOWLP technology transfer with Deca underway, with initial test vehicle incorporating elements of Gen 2 technology
- Xperi licensing agreement executed in May 2022, tech transfer and initial customer engagements underway
- SkyWater contributing to NIST Microelectronics and Advanced Packaging Technologies Roadmap initiative to help define path for development of domestic HI capabilities

Key Differentiators

- ✓ Trusted IP Security
- ✓ Efficient development in a production environment
- ✓ Open foundry model, providing access to a wide array of HI technologies
- ✓ Ecosystem of differentiated technologies for integration into HI architectures, e.g., ASICS, CNT, photonics, superconducting, MEMS
- ✓ 200mm wafer processes for all HI technologies

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Healthcare Market

Sample market growth drivers

Reimbursement, regulatory shifts	Aging population	Advances in genetics	Remote monitoring
Insurance covering more OTC products	Increasingly tech-savvy, smartphone-connected	PoC testing for early disease detection	At home diagnostics and monitoring

Design Trends & market dynamics

- Medical-grade performance pushing to Consumer Health
- Broad system repartitioning, functional integration
- Ubiquitous connectivity
- Drive for efficiency; battery life often the limiting factor
- Time to market demands

Emerging challenges for OEMs

- Global trade friction and uncertainty
- IP threats increasing rapidly
- Regulatory changes enable more consumer choice and simplify purchase path, but increase OEM challenges
- Supply chain fragility
- Maximizing R&D ROI: combining rapid cycles of innovation with production capabilities

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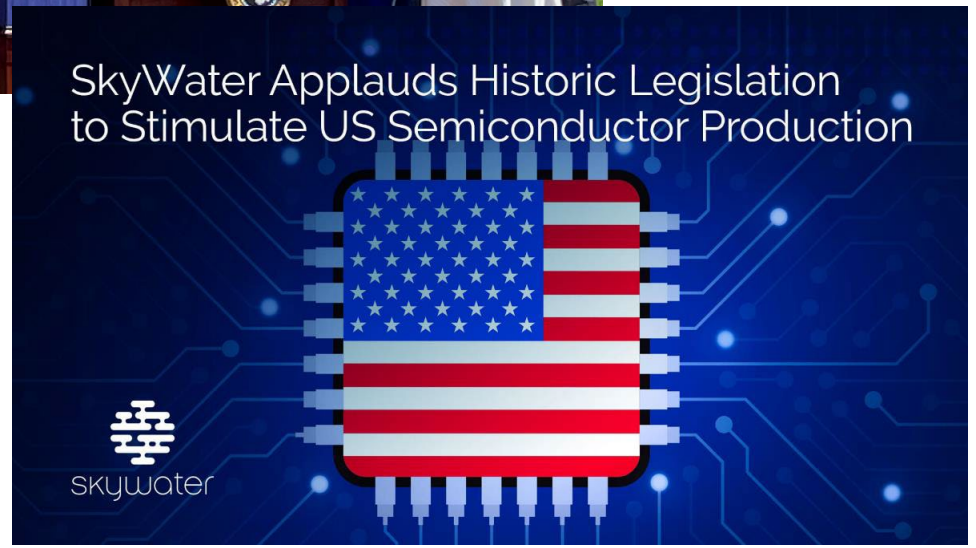
President Biden Signs the CHIPS & Science Act of 2022



August 9, 2022: SkyWater President & CEO Thomas Sonderman attended the signing of the historic CHIPS legislation in a Rose Garden ceremony at the White House. From **President Biden holding up a SkyWater wafer** at the virtual Chip Summit last year to the **signing of the CHIPS & Science Act of 2022**, SkyWater has supported this critical initiative every step of the way.

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SkyWater announces plans for a $1.8B fab in partnership with Purdue University and the State of Indiana

Pictured from left: Purdue University President Mitch Daniels, Indiana Secretary of Commerce Bradley Chambers, SkyWater President and CEO Thomas Sonderman, West Lafayette Mayor John Dennis, Indiana Gov. Eric Holcomb, Lafayette Mayor Tony Roswarski

July 20, 2022

SkyWater President & CEO Thomas Sonderman addresses the audience in the Neil Armstrong Hall of Engineering on the Purdue Campus.

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