MAEGLIN Technical Overview

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Intelligence Advanced Research Projects Activity

Office of the Director of National Intelligence
IARPA
BE THE FUTURE

MAEGLIN
REVEALING THE UNSEEN

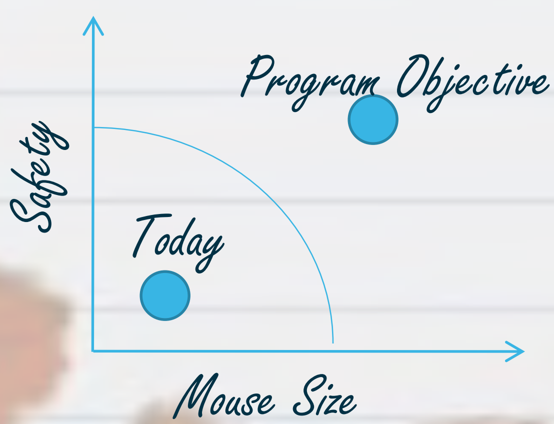
The IARPA Method:
IC Problem → Program Development

- The Heilmeier Questions:
  - What are you trying to do?
  - How is done at present? Who does it? What are the limitations of present approaches?
  - What is new about your approach? Why do you think that you can be successful at this time?
  - If you succeed, what difference will it make?
  - How long will it take? How much will it cost? What are your mid-term and final exams?

Operation Mouse Trap

Picture of mutant mice problem being addressed by your solution

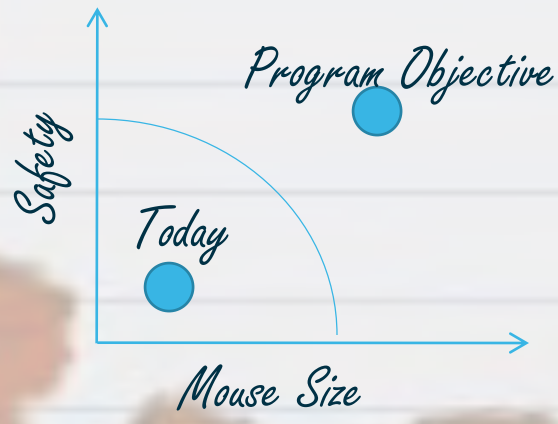
- Mutant mice are growing ten times as large
  - By 2020, mutant mice populations will inundate major urban areas
- Today's approaches are inadequate:
  - Mutant mice are larger than cats
  - Scaling mouse traps are ineffective, as well as dangerous to small children
- Program uses new advances in laser stunning devices, mouse recognition technology, and targeted sterilization techniques to neutralize the mutant mice population



Operation Mouse Trap develops safe, effective approaches to eliminate mutant mice without endangering humans

Current Approaches and Limitations

- Biologic attacks
  - Cats: Mutant mice are now larger than cats
  - Poisons: Mutant mice have developed immunity to existing poisons
- Physical attacks:
  - Spring-loaded traps: required spring speed would be supersonic, and the required traps would be lethal to pets
  - Mouse cages: too expensive, and often entrap small children
- Key technical needs:
  - Design safe system to capture and eliminate mutant mice
  - Must work with projected size of the threat
  - Must be cost effective for general use

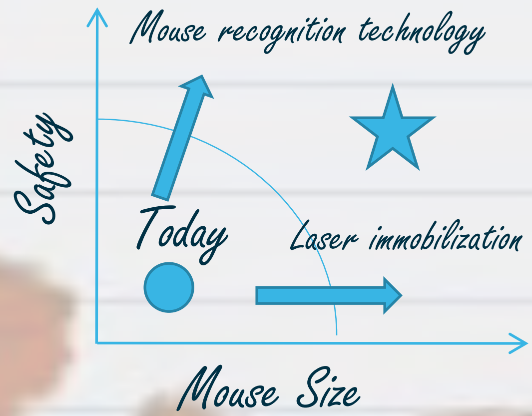


Existing approaches are inadequate because:

- They do not scale to meet the threat
- They are unsafe for pets and small children
- Not cost effective for general use

The Operation Mouse Trap Approach

- Scale:
  - Laser-based immobilization scales better than conventional mechanical traps, as shown be research from Acme Research (show sample results)
- Safety:
  - Mouse recognition technology will target only mutant mice (show an example)
  - Genetic engineering in lab rats has shown the creation of a sterilization serum, that should be extendable to mutant rats (show potential approach)
- Cost:
  - Operational use of these systems could dramatically reduce the infrastructure investment by … (show scenarios)



Each core technology challenge has demonstrated potential, and together can reach the program objective of eliminating mutant mice safely and effectively

Operation Mouse Trap Vision

Home use scenario	Farm defense scenario	Urban defense scenario

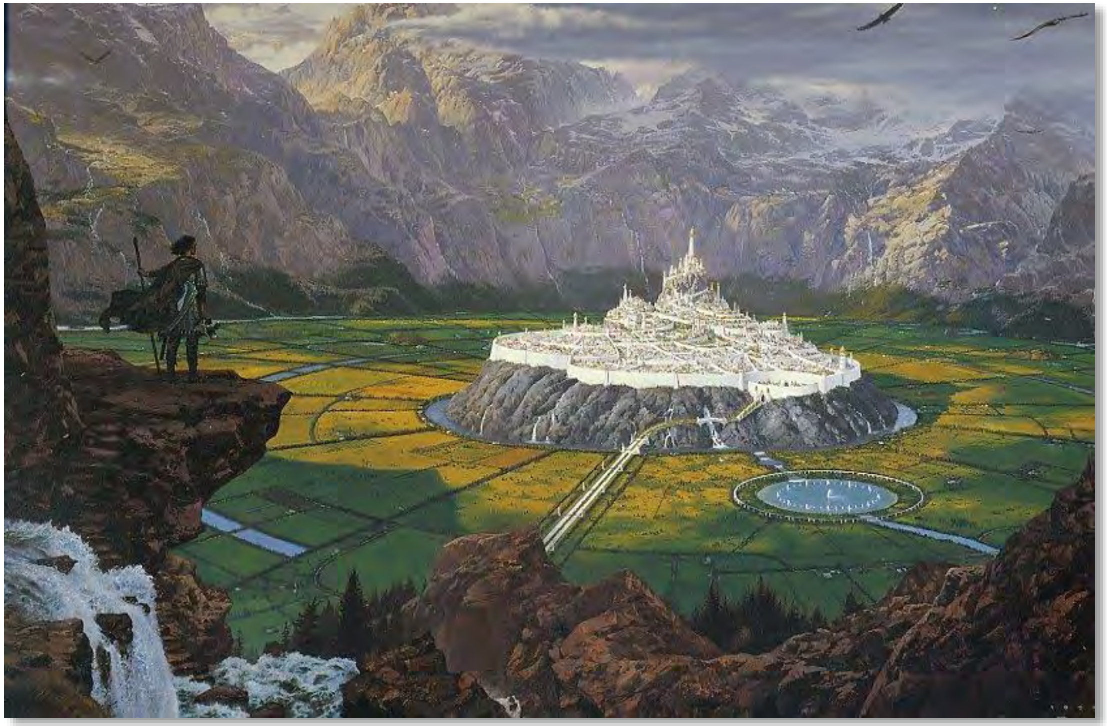
- Strong interest from Department of Rodent Elimination, and several other offices
- Envisioned capability is a shoebox-sized system
- Transition partner would reduce the cost to $40/box

Top Level Program Development Approach

- Identify requirements
  - What the mission really needs, and perhaps more importantly what it does not
  - Unique solutions may be possible when unneeded requirements are removed
- Identify key trade space in current SOA
  - Where do current approaches encounter the law of physics (can't break these) or current engineering capability (will require focused development, or an alternative approach to get past these)
- Define quantitative metrics that bound the mission needs, but leave maximum flexibility for potential solutions
  - The best solution to the problem is probably something the program office has not even thought of
- Develop a robust, quantitative test and evaluation plan that measures performance against program goals, not native parameters of expected solutions

What's in a Name?

- In Tolkien's mythology, Gondolin was the great mountain-ringed city of the elves which remained hidden and safe for nearly 500 years. Its location was betrayed by Maeglin, out of spite after he was forbidden from marrying the king's daughter. Gondolin was then attacked by surprise and destroyed in a night.



- The **MAEGLIN Program** will provide a new method of discovering chemical fingerprints which currently remain hidden…

Problem 1:
Positive ID of Complex Chemical Mixtures

State of the Art

Forensic-quality positive ID requires human-enabled collection with post-collection analysis at US laboratory

Gaps in Current Technology

Snapshot in time → lack of persistence, limited throughput
Not suitable for difficult-to-access areas
Requires constant human input

What We Need

A small, low power, persistent, autonomous, remote chemical analysis capability
Must have high sensitivity, wide dynamic range, and ability to identify **ALL** components of a complex mixture

*** We Need to Bring Laboratory Capabilities to the Field ***

MAEGLIN Phase 2 Identification Track

Program Goal

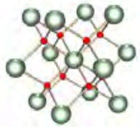
Chemical identification in challenging environments with a small autonomous device

Compound Classes of Interest

- Chemical weapons
- Narcotics
- Nuclear fuel cycle materials
- Poisons
- Explosives

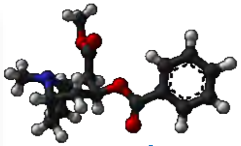
System Requirements

2-year unattended operation
Daily sample analysis
Autonomous & self-calibrating
1.5 liters & 7 kg (including power)
50-400 amu mass range
High dynamic range separation
Isotopic discrimination
Gas, aerosol, and solid sample analysis

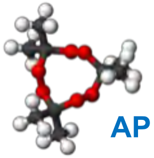


crystalline UO_2

sarin



cocaine



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Problem 2:
Low False Alarm Detection of Chemical Targets

State of the Art	Contact, close range, or dog screening
Gaps in Current Technology	Issues with sensitivity/fatigue, limited throughput, false alarm rate Not suitable for 100% screening, detection of multiple targets High clutter levels affect both detection probability & false alarms
What We Need	A very small, low power, persistent, autonomous, remote chemical detection capability Must have high sensitivity, wide dynamic range, and ability to positively detect multiple targets in a cluttered background

*** We Need to Enable Rapid, High Accuracy Screening***

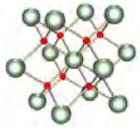
MAEGLIN Phase 2 Detection Track

Program Goal

Chemical detection in challenging environments with a very small autonomous device

Compound Classes of Interest

- Chemical weapons
- Narcotics
- Nuclear fuel cycle materials
- Poisons
- Explosives



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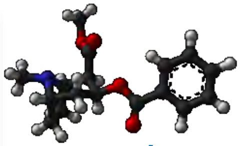
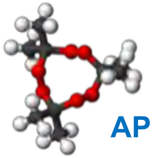


cocaine



AP

System Requirements

6 month unattended operation
Up to 4 hour collection time
Daily sample analysis
Autonomous & self-calibrating
0.5 liters & 1.5 kg (including power)
30-250 amu mass range
High dynamic range separation
Gas, aerosol, and solid sample analysis

Potential Applications

User/Application	Description
Drug Enforcement	Monitoring effluent from suspected drug manufacturing sites for warrant issuance & evidence collection.
Domestic Counterterrorism	Monitoring effluent from suspected explosives, chemical agent, or bioagent manufacture or storage sites. Screening/early warning at large public gatherings.
Transportation Security	Testing cargo holds and package storage areas for illegal substances and explosives.
EPA/DOE	Monitoring of industrial and nuclear sites to enforce public safety and compliance standards; early warning system for inadvertent or intentional release.
Food and Pharmaceutical Security	Autonomous monitoring of food and drug production and storage to ensure safety and quality standards, lack of tampering.
Mining & Other Confined Spaces	Autonomous monitoring of safety conditions in mineshafts and other confined spaces.
Environmental Safety	Monitoring remote areas for illicit dumping of materials, unusual uses, early warning system for forest fires. Monitoring petroleum harvesting sites. Early warning system for volcanic eruptions.





How is it Done Now?

Past/Current Detection Programs	Description
Autonomous Rapid Facility Chemical Agent Monitor (**ARFCAM**)	Autonomous chemical detectors and networked systems to detect target compounds
Joint Chemical Agent Detector (**JCAD**)	Hand held detector that automatically detects, identifies and alarms to target chemicals
Lightweight Autonomous Chemical Identification System (**LACIS**)	Networked hand held chemical agent detectors for site assessment
Portable High-throughput Integrated Laboratory Identification System **(PHILIS**)	Mobile laboratory suite for high precision identification of chemicals for on-site analysis
Next Generation Chemical Detector (**NGCD**)	Detector alarms providing chemical event warning and improved vapor detection

Specific technologies used in autonomous detection include:

- Terahertz Spectroscopy
- IR/Raman
- GC-MS
- IMS
- Surface Acoustic Wave
- Photo- / Flame Ionization
- Polymer Detection Materials
- Electrochemical

Laboratory Systems for Complex ID

Common laboratory techniques for positive chemical ID:

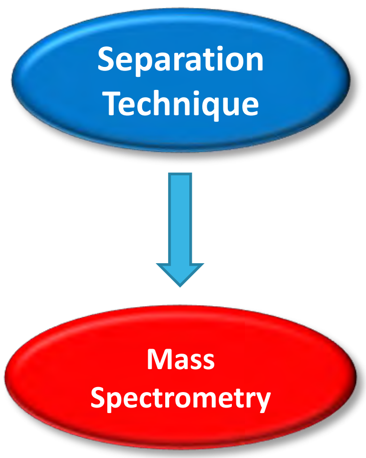
- Nuclear magnetic resonance (mg sample sizes)
- Infrared Absorption Spectroscopy (μg sample sizes)
- Mass Spectrometry (ng-pg sample sizes)

Capabilities common to all of these techniques:

- Uniquely identify a single chemical from a library of 100,000+ spectra
- Allow a trained spectroscopist to deduce a compound's structure from it's spectrum
- Integrate a "front end" separation stage for complex samples, making interferents generally a non-issue

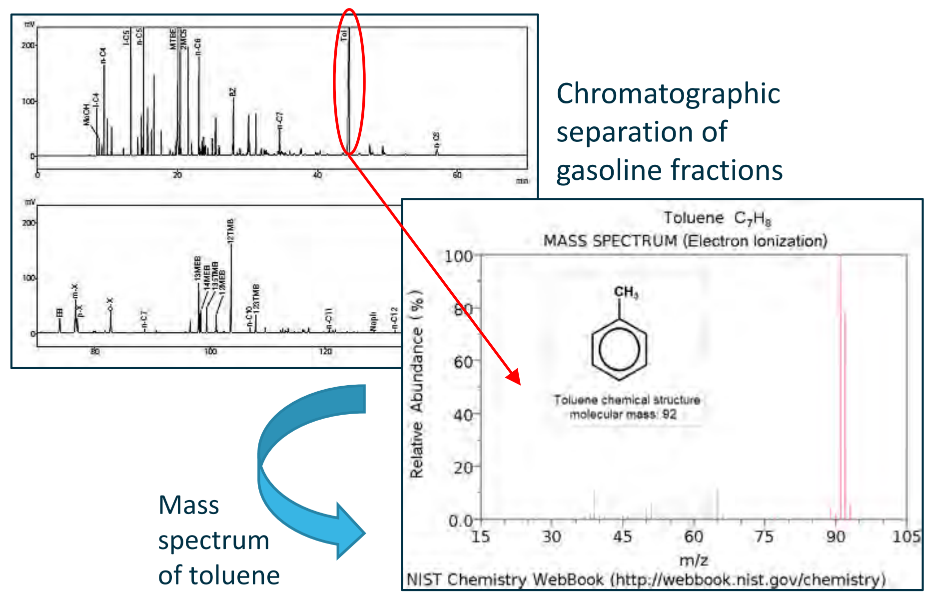
Hyphenated Mass Spectrometry

- Separation technique followed by mass-to-charge ratio analysis
- Common laboratory system for analysis of complex samples
- Increases dynamic range and enables ID of all components in a complex mixture with little to no sample preparation



Complex mixture elutes as a series of temporally separated single-compound peaks

Molecular ions and ionic fragments detected as a function of their mass-to-charge ratio; specific chemical ID from fragmentation pattern



Chromatographic separation of gasoline fractions

Mass spectrum of toluene

High sensitivity / specificity, limited throughput and timeliness, high SWAP

What is Available for the Field?

Hand-held Mass Spectrometers

- 50–450 a.m.u.
- ~5 pounds; ~3 liters
- Ruggedized
- Low sensitivity and dynamic range
- Small battery & large power draw

Desktop / Portable Mass Spectrometers

- Limited ruggedness
- Heavy: 20–60 pounds
- Requires experienced user
- Large power draw

Other Technologies

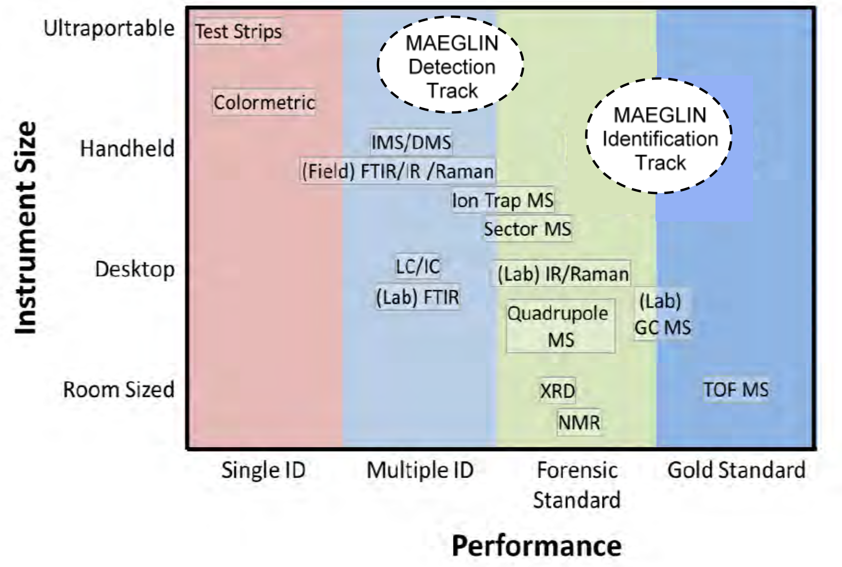
- Fluorescence, IMS, DMS, FTIR, Colorimetric, Raman
- Limited dynamic range & sample set
- Large power draw

Issues with Current Technologies

- Sensitivity
- Specificity; limited target set
- High power draw
- Insufficient resolution to ID a specific compound from a large library
- Strongly "tuned"; vulnerable to interferents

Current Limitations Summary

- **Non-mass spectrometry based chemical detection systems:** Cannot ID highly complex mixtures, handle extreme dynamic range, or discriminate isotopes
- **Field-portable mass spectrometry systems:** Achieve portability at the expense of sensitivity and selectivity; too power hungry for long-term emplacement.
- **Major power draws:**
  - Vacuum pumps
  - Mass analyzer
  - Ionization



MAEGLIN Phase 1 (BAA-16-01)

Phase 1, 18 month duration, IARPA-BAA-16-01			
Track	**Collection**	**Separation**	**Identification**
Goals	Low power, reversible gas phase collection, storage, release technology. An optional modular front end sampling adaptor to add additional capability for liquid or particulate aerosol and/or bulk liquid and solid phase collection and volatizilation.	Low power, non-destructive separation of chemical mixtures with a broad concentration range, potentially including the ability to "bleed off" all or part of the collected sample if desired. System will use minimal (preferably no) consumables.	Low power, high-accuracy identification of large library of chemicals from pure compounds or low-count mixtures. System will use minimal (preferably no) consumables.

Component development. Will be complete in July 1018.

Power system and vacuum technology NOT addressed in Phase 1.

MAEGLIN Phase 2 (BAA-18-04)

Phase 2, 18 month duration, IARPA-BAA-18-04		
Track	**Chemical Detection**	**Chemical Identification**
Goals	Low power, high accuracy, integrated system capable of collecting complex chemical mixtures, screen backgrounds and interferents, and provide warning based on a robust chemical library. No definitive ID required.	Low power, high accuracy, integrated system capable of collecting and identifying target chemicals at low concentrations (potentially several orders of magnitude below ambient background). Full analysis of complex mixtures with positive identification of a broad range of species, including multiple target chemicals.

Integrated prototype demonstration.

Government Team

T&E Team

U.S. NAVAL RESEARCH LABORATORY

Sandia National Laboratories

EDGEWOOD CHEMICAL BIOLOGICAL CENTER
A U.S. Army RDECOM Laboratory

SETA Team

Booz | Allen | Hamilton
strategy and technology consultants

Contracting

AIR FORCE RESEARCH LABORATORY

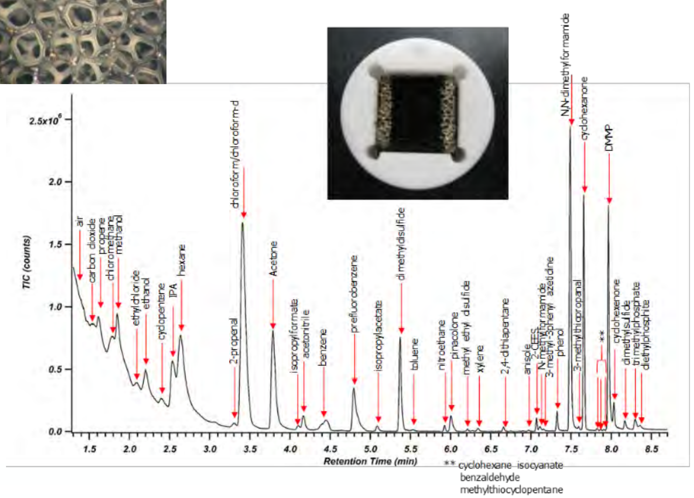
Phase 1 Performer Teams

Offeror	Collection	Separation	Analysis
BAE	X		
Hamilton (UTAS)			X
Zellers (UM)	X		
Leidos			X
MassTech		X	X
SRI			X
Sig. Sci.	X		
Yogesh (UM)	X	X	
Fan (UM)		X	

Phase 1 Performer Technology

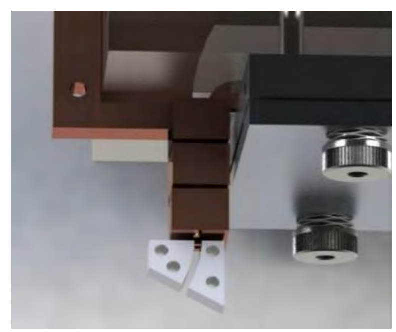
BAE SYSTEMS
INSPIRED WORK

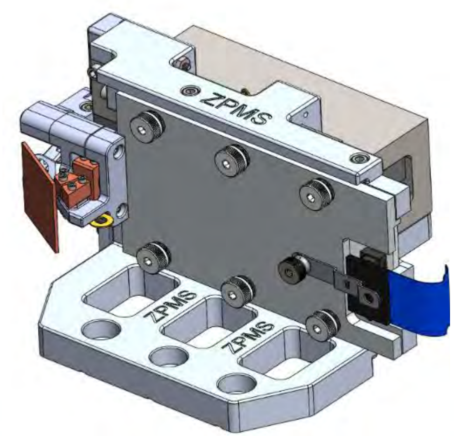
Collector element is a carbide open cell foam element with the surface etched to create carbide derived carbon (CDC) sorbent



leidos
MTL microsystems technology laboratories massachusetts institute of technology
O·I·Analytical a xylem brand
Northeastern

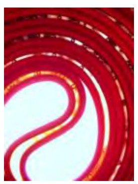
Mass spectrometer uses permanent magnets for ion separation, detection on a CCD array

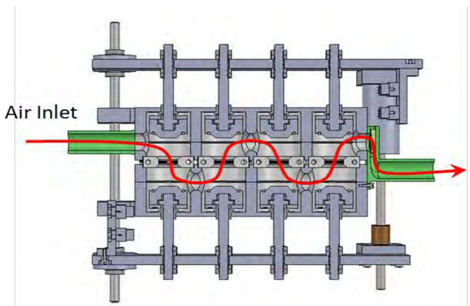




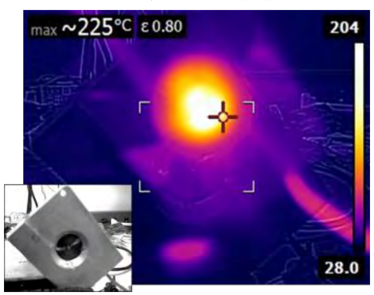
Phase 1 Performer Technology

signature science LLC
mcba Consulting
SwRI



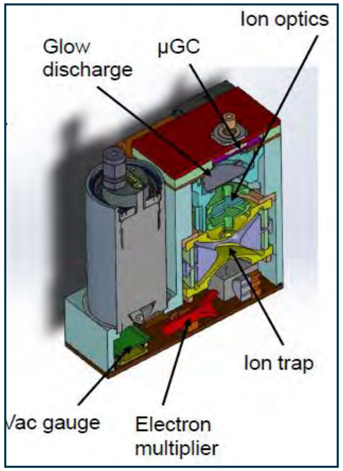


Four coiled ribbons in a series flow path, each coated with a different sorbent. For desorption ribbons moved into cell, which face seals ribbons, forming capillaries



MassTech
Georgia Tech
SES Science & Engineering Services

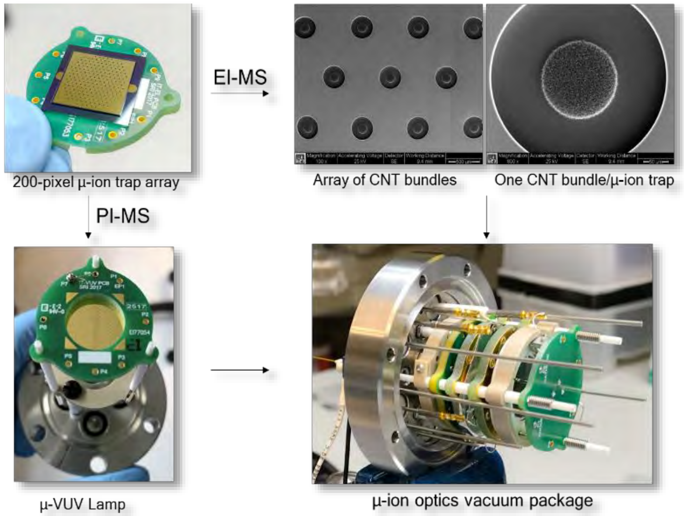
Ion trap mass spectrometer with micro gas chromatograph serving as the cathode for glow discharge ionization



Phase 1 Performer Technology

SRI International
Duke University

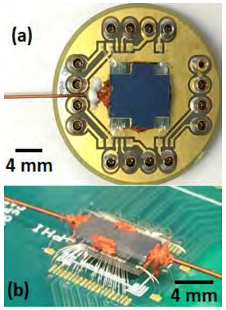
2D micro-ion trap mass spectrometery using a 200 trap array of identical cylindrical ion traps and dual photo & electron impact ionization

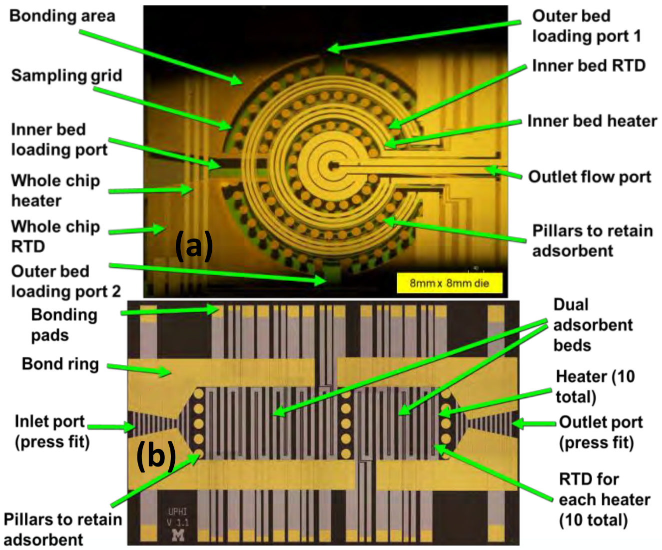


Ted Zellers

University of Michigan

Collection via passive diffusion using two concentric sorbent beds, <0.25 second injection with "hold and fire" stage

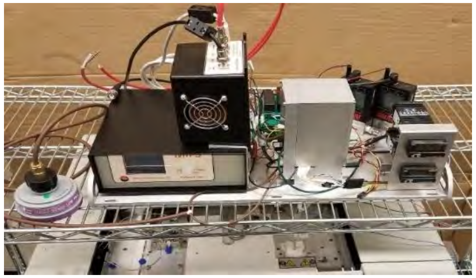


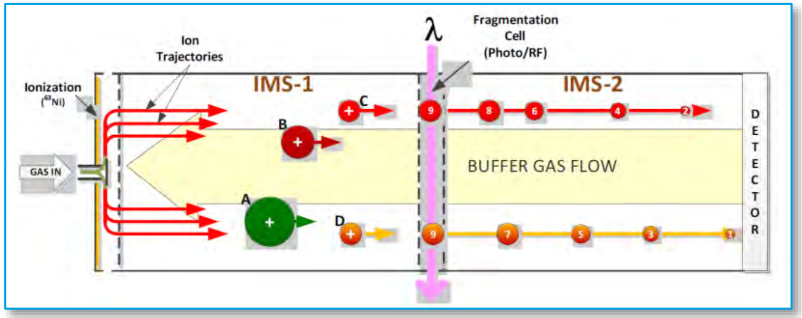


Phase 1 Performer Technology

UTC Aerospace Systems

New Mexico State University

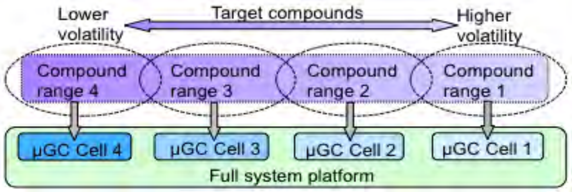


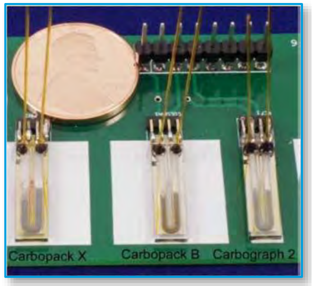


Tandem ion mobility spectroscopy (IMS/IMS)

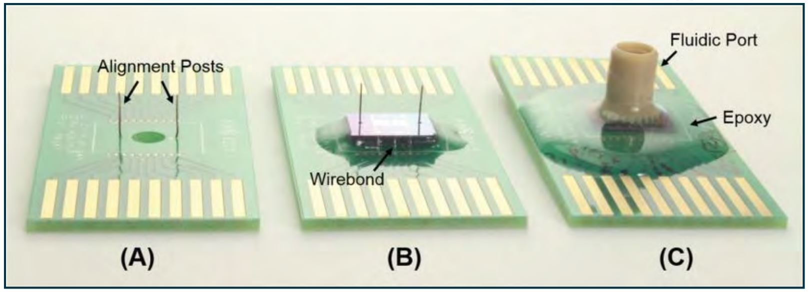
Yogesh Gianchandani

UNIVERSITY OF MICHIGAN





Microfabricated preconcentrators, micro gas chromatographs, electrostatic micropumps, and Knudsen pump



Phase 1 Performer Technology

Sherman Fan

UNIVERSITY OF MICHIGAN

Adaptive multi-channel three dimensional gas chromatography