US ARMY RDECOM

The opinions, interpretations, conclusions and recommendations are those of the author and are not necessarily endorsed by the United States Government.

21st Century Challenges and Trends for the Detection of CBRNE Threats

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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Mission and Vision

MISSION: Be the Nation's premier provider of innovative chemical and biological solutions

VISION: Provider of World Class Solutions

Adapt to a Changing World

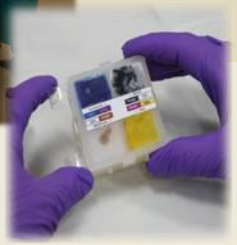
1915-1939
Response to Chemical Threat

1940-1969
Increased Research & Development

1970-1999
Progress Toward Elimination

2000-2009
Supporting the Global War on Terror

2010-Today
Address Emerging Threats



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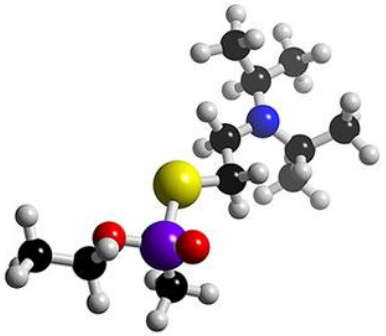
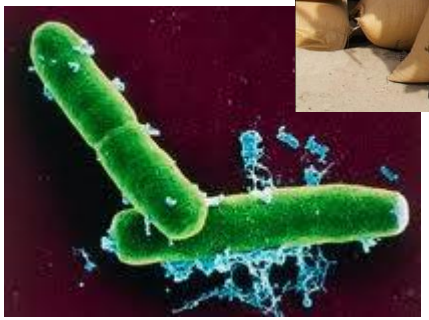
Strategic Environment through 2040:

- Rising trend for civil war and internal conflict.
- Rise of larger city states or mega-cities protected by an “empire” will lead to large areas of uncontested or under-governed regions.
- Rise of cities within cities. Within the mega-city we will see self governing regions or autonomous regions with their own security forces and facilities.
- The non-attribution of strategic acts (CBRNE, Cyber…) will make response difficult without strong reliance on forensics to narrow down or identify source.
- Greater proliferation of knowledge of threats through the internet.
- Rapid innovation and improvisation will make threat prediction difficult.

CBRNE Threat Evolution

- Chemical Warfare Agents
- Pesticides
- TICs/TIMs
- Drugs
- Radioactive metals
- Fuel/Oxidizer Mixtures
- Explosives
- Bacteria
- Viruses
- Toxins





There are literally thousands of lethal materials that can be used and we should not just be concerned with those prohibited by the Chemical or Biological Weapons Treaties.

Why Do We Need Field Sensing?

- Obtain “real-time” answers that allow actionable decisions to be made on-the-spot.
- Reduces logistics by moving the analysis closer to the source of the sample.
- Screen materials to identify samples that need to be sent to a lab for additional analysis and minimize the number of these samples.
- Nondestructively analyze large, valuable, or nonmovable objects for which excising samples is not possible.

Soldiers participating in the toxic industrial chemical protection and detection equipment training, use an Ahura Scientific FirstDefender to identify chemical agents, Nov. 18 2009, at Fort Hood, Texas. The handheld device uses Raman spectroscopy to identify a wide variety of chemical substances, from common household items to deadly industrial toxins. (www.Army.mil/protection detection equipment hazmat)

Requirements for Field Sensing

- Provide performance similar to a laboratory equivalent.
- Have the reliability and robustness required by the field conditions.
- Be resistant to vibration and shock.
- Have sampling technology that is easy to use.
- Address a wide range of sample types and physical phases (gas, liquid, vapor).
- Have limited maintenance and use few consumables.

The Predicted Future

- In 1985 Thomas Hirschfeld published a commentary in *Science* titled "Instrumentation in the Next Decade" where he highlighted three major trends for analytical instrumentation in the decade ahead.
  - "As the average instrument achieves a rather considerable level of intelligence, **'dumb' systems will become the exception**, and we will eventually begin to become proficient in exploiting the resulting capabilities."
  - "More sophisticated understanding of measurement science and of actual measurement needs will drive instrumentation design advances such as **miniaturized sensors** and yet **more 'hyphenated' instruments** and **'mapping' instruments**."
  - "The combination of sensor-based instrumentation and microminiaturization will make possible **distributed measurement** by allowing **point-of-use measurements by non-experts**."
- His insightful predictions suggested a future fueled by rapid advances in computation and miniaturization.

Tomas Hirschfeld, "Instrumentation in the Next Decade", Science, 18 Oct 1985, Vol. 230, Issue 4723, pp. 286-291
DOI: 10.1126/science.230.4723.286

The Future of CBRNE Sensing

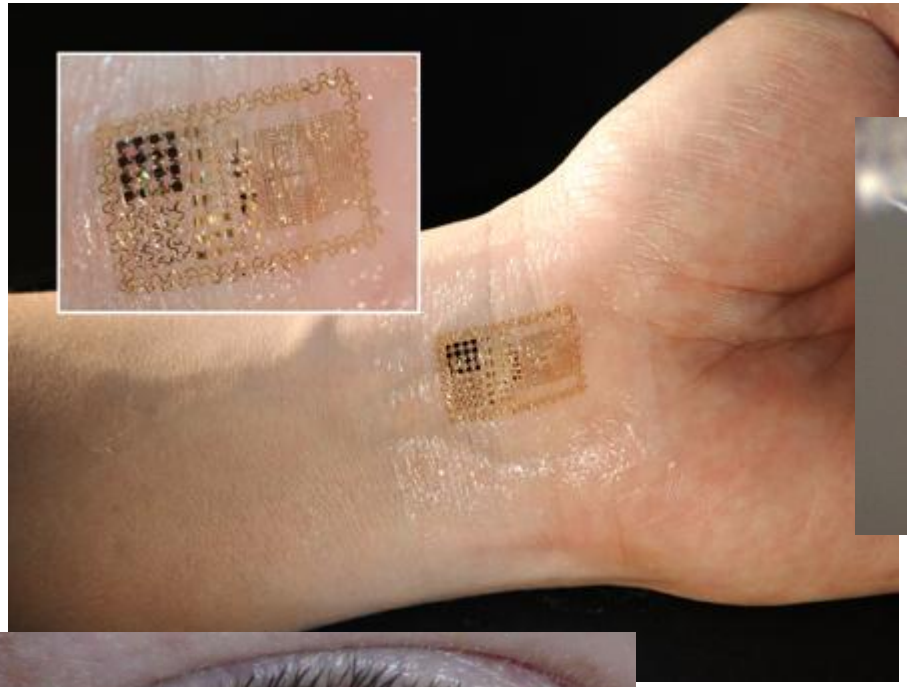
- Harnessing the power of mobile computing:
  - Wearable sensors
- Harnessing the advances in miniaturization
  - Integrated Photonics
- Distributed measurements
  - Unattended Sensors and Autonomy

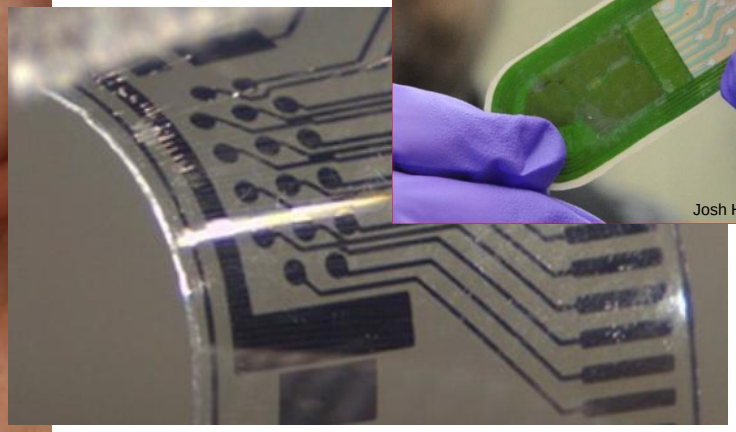
Harnessing the Power of Mobile Computing

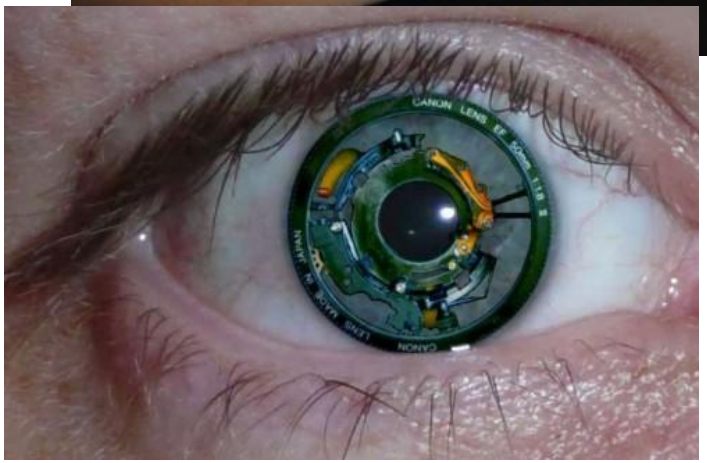
- Mobile computing provides
  - Computation processing
  - On screen display
  - Flash storage
  - Digital/Video camera
  - Wireless communications
  - GPS location

Mobile Computing will remain a key interface to facilitate the integration of Wearable CBRNE Sensors.

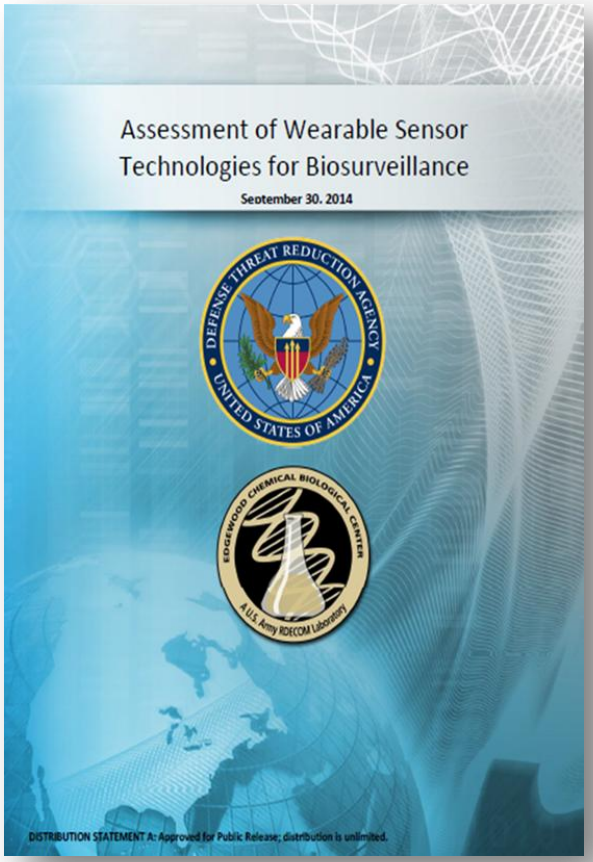
Wearables







Assessment of Wearable Technology



✓ **The Department of Defense (DoD) should initiate an Advanced Technology Demonstration (ATD) for wearable technologies.**

✓ **DTRA/JSTO should create a Wearable Sensor Technology Research Consortium.**

- JSTO should select a small number of common platforms to focus investment.
- JSTO/DTRA should engage FDA because medical decisions will likely result from wearable sensors.
- Development of a biosurveillance-capable wearable sensor will require a multi-year investment.

Where the DoD S&T Enterprise is Today

- **AFRL, ARL, ECBC, and USARIEM coauthored an updated report in March 2016**
- **Recommendations include:**
  - Collaborative approach will allow the substantial investment by many organizations in wearable technologies to be leveraged
  - Improved decision support will be provided by an interoperable architecture defined and implemented to incorporate physiological, defensive ensemble, and environmental data
  - Systems engineering analysis pipeline will speed development and save money by facilitating virtual trade space analysis
  - Animal chemical exposure models can be leveraged to validate the accuracy of the technology

Challenges with Wearables

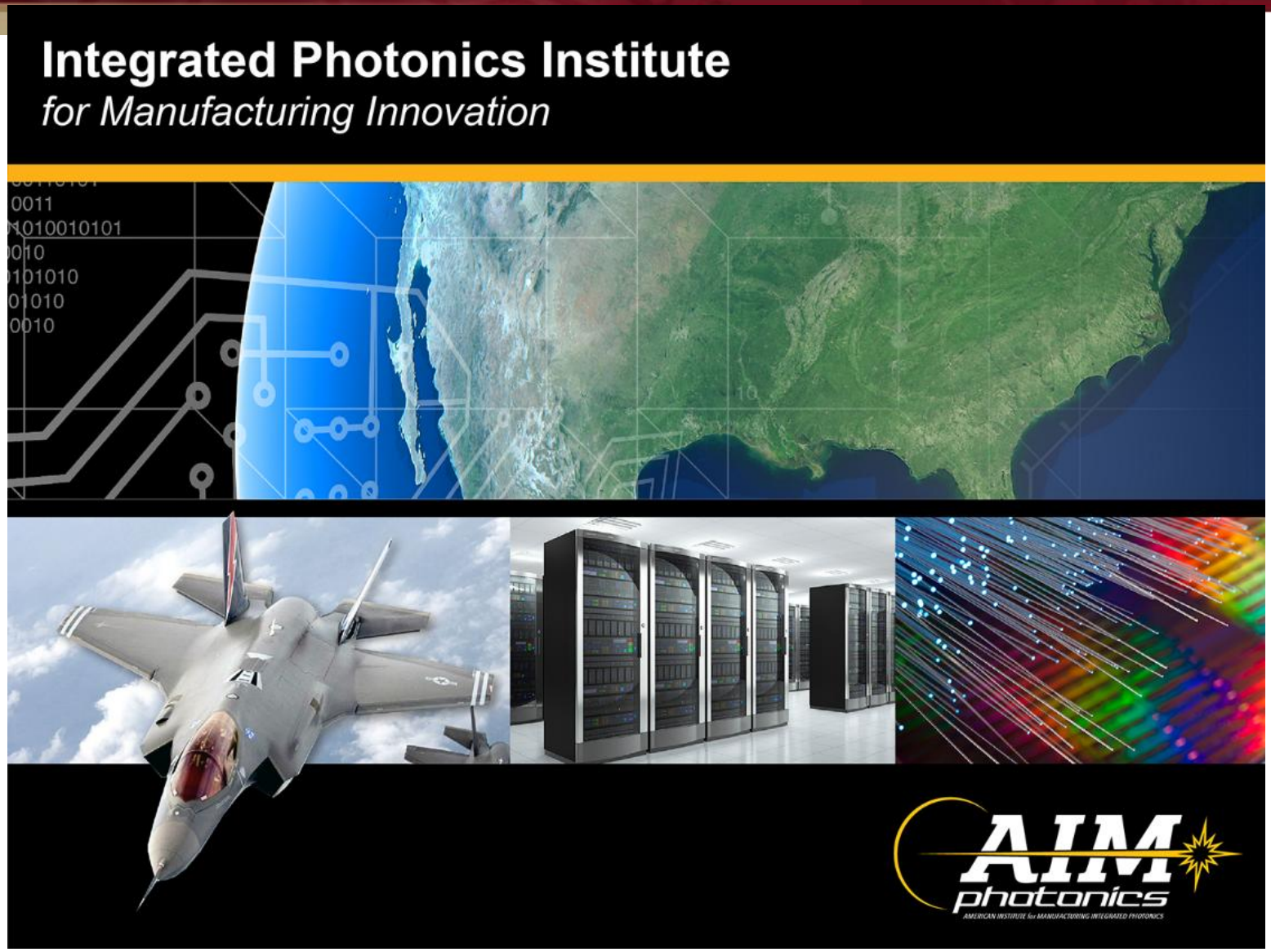
- As sensors become smaller, sampling becomes more critical.
- Sampling needs to be simple, integrated and intuitive to the operator.
- Sampling must be representative of the threat and adequate for the mission.

The world's best mirco or nano sensor is worthless if the sample never gets to the device.

Harnessing the Power of Miniaturization

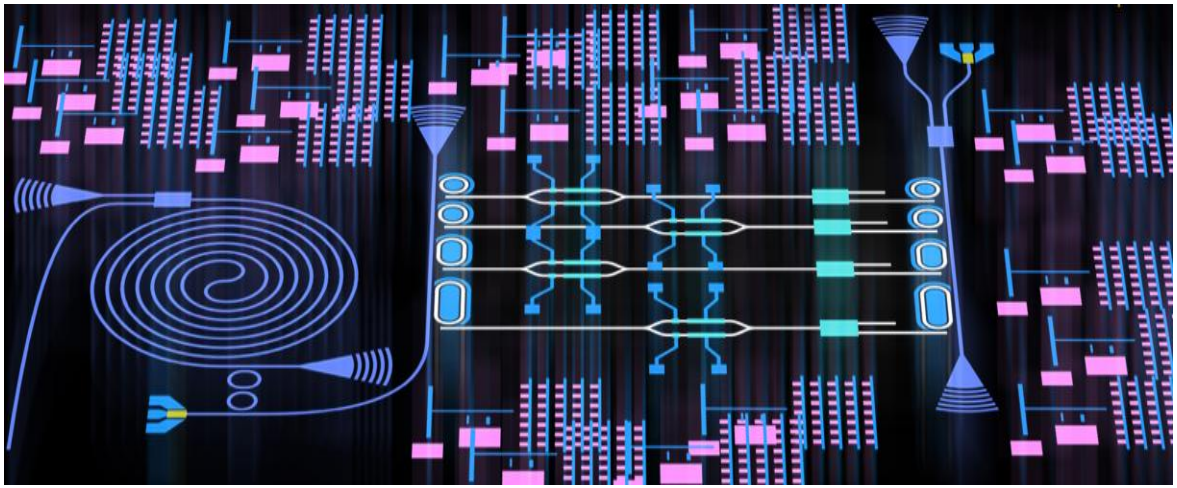
- US National Investments in Manufacturing Innovation
  - NextFlex, the Flexible Hybrid Electronics Manufacturing Innovation Institute: This Institute is focused on developing a new era in flexible hybrid electronics.
  - American Institute for Manufacturing Integrated Photonics (AIM Photonics): Institute's goal is to emulate the dramatic successes experienced by the electronics industry over the past 40 years and transition key lessons, processes, and approaches to the photonic integrated circuit (PIC) industry.

AIM Photonics



What are PICs?

<u>Photonics</u> is the use of light to transform and transmit information to and from the perceptible world.
Wildly successful in telecomm.

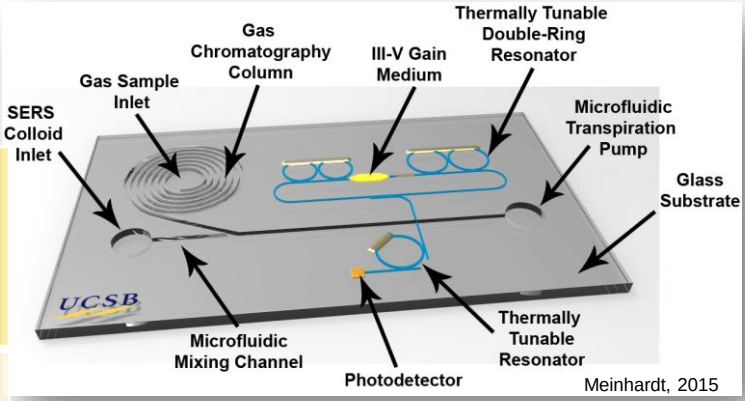


<u>Photonic Integrated Circuits</u> are entire photonic *systems* on a chip.
Mostly just components in past.

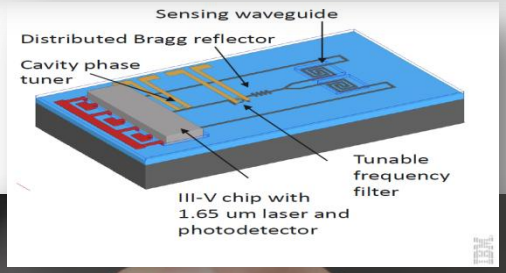
PIC Sensor Applications

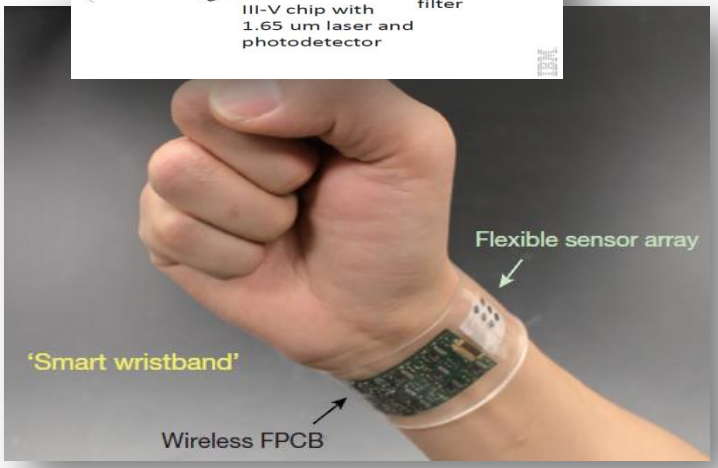
- Initial focus: Contact Sensing
  - Fully Integrated and Disposable
  - (Proximity and Distance sensing in future)

	Chemical	Biological
Leave in place	▪ Industrial process monitoring/control ▪ Leak warning/mapping ▪ Wearable: Exposure warning ▪ Water quality (toxins)	▪ Wearables (non-invasive, invasive, & alert): Metabolite, Glucose, Vitality, Biohazard exposure ▪ Water quality (pathogens)
Handheld	▪ Chemical residue testing (e.g. crime forensic, explosives, chemical weapons) ▪ Pharmaceutical & illicit drug testing	▪ Health diagnosis ▪ Food quality ▪ Foodborne pathogens ▪ Biometric authentication
Lab on a chip	▪ Novel synthesis	▪ Antigen discovery ▪ Drug therapy studies



Meinhardt, 2015





Distributed Measurements

- Mobile or stationary unattended sensor platforms working in coordination offer distinct advantages.
  - They may each have different payloads, sensors, and endurance capabilities in order to augment or cue each other.
  - A network of small, inexpensive platforms with low-performance sensors may be able to use its spatial diversity to outperform systems using single, very expensive, high-performance sensors.
  - The use of multiple platforms may allow each sensor to perform different tasks in order to optimize the overall sensor mission.

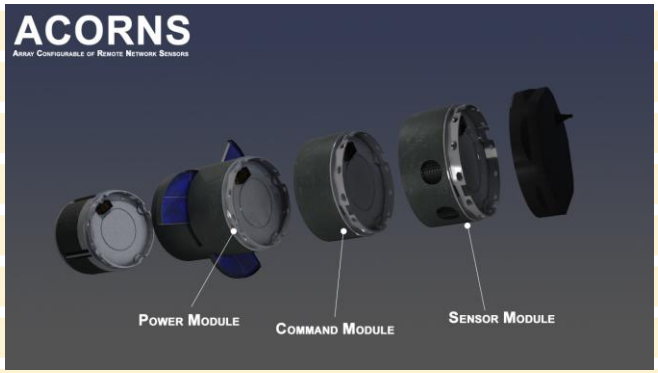
ACORNS CBRN Detection Toolkit

- ECBC is developing an enhanced UAS Toolkit to include CBRN Detection/Collection mission capability and Situational Awareness (SA) suite.
  - Use existing capability and technology enhancements to create more robust UAS system
  - Create an agile and configurable system of systems for CBRN detection and collection
  - Common detection platform with integrated reporting capability

System of Systems for Detection

Capabilities

- Chemical
- Biological
- Radiological
- Camera Arrays (Still/Video)
- Motion Detection and Warning
- Acoustic
- Seismic
- Meteorological
- Collection
- Water Sampling
- VOC Kit
- Sono Bouy
- Obscurants
- Explosive Detection
- Magnetometer
- Configurable



CBRN Detection/Collection Toolkit

Deployment Method

- **Point Detection**
- **UAV**
  - Sweeping
  - Drop-Off
- **UGV**
  - Sweeping
  - Drop Off
- **NRTBDA**
  - BQM-109
  - SM-2
  - MGM-140
  - AGM-84H
  - AGM-158
- **Vehicle Mounted**

Tactical Detection Toolkit

CCSI Compliant → JWARN

Concluding Comments

- The trends in recent conflicts point to threats that are more improvised and “unknown”, increasing the need for field sensing to be more adaptable and flexible.
- The Army is increasingly interested in offloading forward decision making and analysis from soldiers to software. This increases the need for algorithms to be robust and accurate.
- As sensors become smaller and more mobile, developers and users can no longer ignore sampling and methodology.

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