# CBRNE Sensing at 20 years: A Retrospection and Prospects for the Future

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## ABSTRACT

In this keynote presentation to the 20th meeting of SPIE's CBRNE Sensing Conference, the author will review key papers, trends, and impacts over the past two decades. The author will also present his view on the status of CBRNE sensing within the Department of Defense, potential trends towards development in the future, and gaps in the overall landscape.
**Keywords:** CBRNE, Detection, Sensing

## 1. INTRODUCTION

Although the use of poisons and lethal chemicals in warfare perhaps predates recorded history, the world has seen the use of industrialized chemical gases for over a century now. While many thought that era was over, the current civil war in Syria is not only a claxon call that chemical warfare is not passé, but that it is a potential harbinger of the battlefield environment the United States and its allies will face in the future. The rising global trend for civil war and internal conflict, especially in large cities, increases the probability that industrialized chemicals will either intentionally or accidentally become a hazard to military and security forces or the localities' residents. Since the advent of chemical weapons, the world has added biological, radiological, nuclear, and most recently improvised explosive (CBRNE) hazards to the list of threats expected by military forces on the battlefield as well as to civilians in the homeland. The potential for greater proliferation of knowledge of these threats through the internet, coupled with the trends of rapid innovation and improvisation witnessed in Iraq and Afghanistan with Improvised Explosive Devices (IEDs), will make threat prediction difficult. Additionally, the non-attribution of strategic CBRNE acts will also make threat response difficult without a strong reliance on forensics to narrow down or identify the person(s) or group(s) responsible.

For those of us trying to develop detection capabilities for military, security, and emergency response forces, the current and future strategic environment means that there are literally thousands of lethal materials that can be used as weapons. As a result, we cannot only be concerned with detecting the handful of materials prohibited by the Chemical or Biological Weapons Treaties. Optical sensing of CBRNE threats are important to obtain "real-time" answers that allow actionable decisions to be made on-the-spot; to reduce the logistical burden by moving the analysis closer to the source of the sample; to rapidly screen materials to identify samples that need to be sent to a lab for additional analysis and minimize the number of these samples; and to nondestructively analyze large, valuable, or immovable objects for which excising samples is not possible. The trends in recent conflicts point to threats that are more improvised and "unknown", increasing the need for sensing to be more adaptable and flexible. With the Department of Defense increasingly interested in offloading forward decision making and analysis from soldiers to software, this will increase the need for algorithms to be more robust and accurate.

### 1.1 CB Sensing Conference – the Beginnings

In the late 1980s, Joseph "Joe" Leonelli was a US Army officer working in the Detection Division at the then called Chemical Research Development & Engineering Center on Aberdeen Proving Ground, Maryland. As the Army civilianized these positions Joe became a support contractor to the Center, working for SRI International. In the 1990s, he and his colleagues found that they were doing more and more research and development in the area of infrared detection of chemical agents and especially focusing on new developments in the area of Light Detection and Ranging (LIDAR) to detect the presence if aerosols. At that time they found a need to regularly bring together the diverse community working on this and other closely related chemical detection technologies to share advancements and discuss challenges. Thus began the "Air Monitoring and Detection of Chemical and Biological Agents" Conference, hosted by Optics East annually in Boston. [1] While there have been other venues and other SPIE Conferences where the CBRNE community has shared

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their advancements, we trace our lineage to this conference namely because it has been closely supported and followed by the same group of authors and organizers and has remained continuously active the longest.

### 1.2 Florida Bound

In the year 2000, Dr. Patrick Gardner was an Air Force Officer at AFRL and assigned as the Science Advisor to US Special Operations Command. He had the "brain child" of a Chemical Biological Sensing Conference. Despite the fact that the US Air Force thought he was crazy, he was able to launch his idea. He too found a home at SPIE, but decided to associate it with the Aerosense Symposium, previously held annually in Orlando. Pat struggled initially, with the Conference averaging less than 20 papers a year. In 2004, SPIE merged parts of the Optics East and Aerosense Symposia to create the Defense and Security Symposium in Orlando where the Chemical and Biological Sensing V conference remained. This meeting was also my first exposure to SPIE and where I presented some collaborative work I was doing with the Army Research Laboratory on the development of Surface Enhanced Raman Spectroscopy (SERS) substrates for the detection of biological spores. [2]

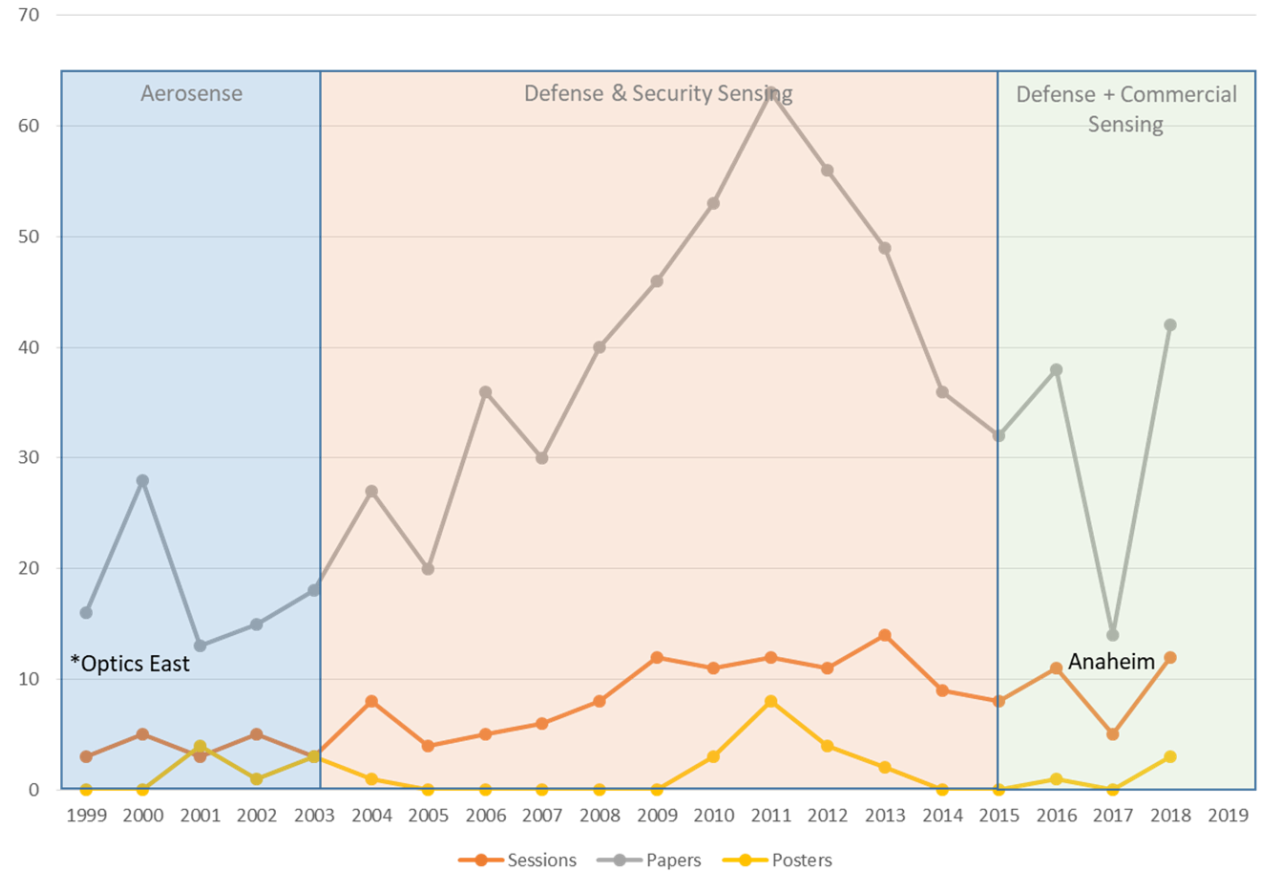


Figure 1. The Evolution of the CBRNE Sensing Conference at SPIE

### 1.3 Years of Growth

In 2006, I joined Pat Gardner as a co-Chair of the CB Conference, and we established a game plan on how to expand and grow the conference. The number of chemical and biological sensing papers in the conference had been slowly growing, but were not enough to double the size of the conference as we wanted. So in true military fashion, we divided the problem and agreed to work in parallel expanding the content. Dr. Gardner had a specific interest in adding radiological and nuclear sensing into the mix, while I agreed to add explosives sensing based on my Counter-IED work with the Joint IED Defeat Organization (JIEDDO). By 2008, we were able to rebrand the conference as the Chemical, Biological, Radiological, Nuclear and Explosives Sensing conference and met our goal of doubling the participation, with 40 papers presented. [3] That growth continued until 2011 when the conference reached a height of 63 contributed papers. [4]

### 1.4 Changes and Challenges

In 2012, SPIE moved the Defense and Security Sensing Symposium from Orlando to Baltimore in an effort to better connect with Defense contractors and gain greater visibility from senior leaders in the Pentagon. Also in that year, Dr. Gardner left the conference as a co-Chair leaving me to fend for myself to organize it all. Over the next six years, a number of events made it challenging for the conference to remain the size it had at its height. While the conference initially was able to maintain around 50 papers the first two years in Baltimore, restrictions on government travel made attendance difficult for many participants through 2016. Adding to that challenge, SPIE changed the name of the Symposium to Defense + Commercial Sensing and decided to rotate the conference for a period of six years between Baltimore, Anaheim, and Orlando. Participation in Anaheim was particularly difficult and returned to the historic lows of the early days of the conference. The good news is that we were quickly able to recover the follow year in Orlando and again this year in Baltimore. Over the twenty year history of the conference, participation has remained strong with a mean of 33.6 (standard deviation of ± 15) and a median of 34 papers. That truly makes Anaheim an outlier.

## 2. CONFERENCE METRICS

### 2.1 Citations

As part of this reflection on the twenty year anniversary of the CBRNE Sensing Conference, I wanted to get an idea of who our audience is and how wide of an impact we have had on the community. So I enlisted the help of the SPIE Digital Library Staff to answer a number of questions. First I wanted to know "What is the most downloaded proceedings paper from the Conference over the past 20 years?" The answer is a paper titled "Atmosphere issues in detection of explosives and organic residues" authored by C. G. Brown, M. Baudelet, C. Bridge, M. K. Fisher, M. Sigman, P. J. Dagdigian, and M. Richardson. Downloaded 1,347 times at the authoring of this manuscript, this paper makes a comparison of LIBS emission from molecular species in plasmas produced from organic residues on a non-metallic substrate by both a 5 ns Nd:YAG laser (1064 nm) and a 40 fs Ti:Sapphire laser (800 nm) in air and argon atmospheres. The authors use Principal Component Analysis (PCA) to identify similarities of the organic analytes via the emission spectra and the corresponding receiver operating characteristics (ROC) curves show the limitations of the PCA model for the nanosecond regime in air. [5] While the most downloaded may be the most read manuscript, it does not necessarily mean the most impact. Therefore I wanted to know "What is the most cited proceedings paper from the Conference over the past 20 years?" That honor goes to T. M. Griffin, N. Popkie, M. A. Eagan, R. F. McAtee, D. Vrazel, and J. McKinly with the paper titled "Instrument response measurements of ion mobility spectrometers in situ: maintaining optimal system performance of fielded systems." According to Web of Science, this paper has been cited 27 times since its publication in 2005. [6]

### 2.2 Authorship

Next I wanted to understand who the authors are presenting at the CBRNE Sensing Conference. Over the past twenty years the conference has published 702 total papers, authored by a total of 2118 individuals. On average each paper has 3 co-authors. Surprisingly, 1645 individuals comprising over 77% of the authors only publish once within the conference. To me that presents an untapped number of people to help grow the conference or at least get feedback on why they never returned. There does exist a core group of 52 authors that have contributed between 5 – 20 papers. Many have presented at least one paper since the beginning of the conference. These individuals are truly the heart and soul of the CBRNE Sensing Conference and deserve a great "Thank You" for keeping this venue alive all these years. There is one individual who has truly done more than his fair share. This person has contributed 33 conference papers, is a long time participant, Committee Member and friend; Dr. Paul M. Pellegrino, of the Combat Capability Development Command - Army Research Laboratory. I was also interested in understanding the author affiliation of the participants to the conference. Again quite surprisingly, the authors almost evenly come from academia, industry, and government labs (in which I included DoD, DoE and FFRDCs). We have long touted in our call for papers that "This conference provides an unprecedented forum for authors from Government, industry, and academia to address a wide variety of CBRNE sensing issues, technologies, and advances in algorithms and signal process of threat related scenarios." We based this statement purely on anecdotal evidence and personal awareness of who was attending and presenting at the conference. Now at least we have some statistical analysis to back up that claim. I would certainly challenge other similar conferences, SPIE or not, to do a similar analysis. I doubt that many would have as even a distribution of authors as ours.

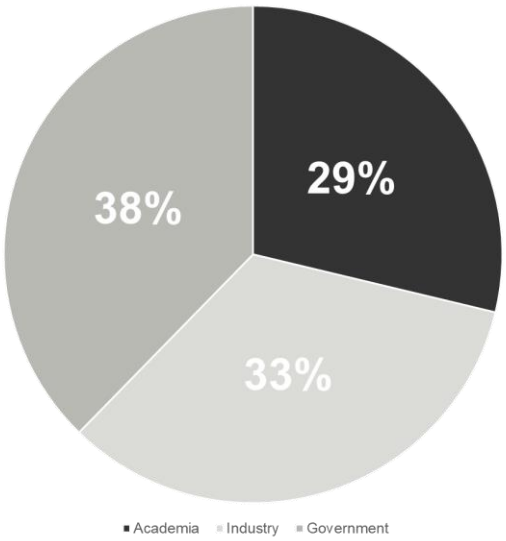


Figure 2. Author Affiliation

## 3. TOPICAL THEMES

One thing has remained constant over the past twenty years, and it really should not be a surprise. That one thing is the topical themes. Using a simple word counting algorithm on just the conference paper titles, I wanted to identify topics or themes. Naturally "detection" was the most used word in a title. Rounding out the top ten words we had "chemical", "standoff", "spectroscopy", "Raman", "explosives", "imaging", "biological", "sensor" and "agent". Based on that and a review of all the sessions, I can say that the conference has remained a constant venue to discuss the following CBRNE themes:

- Chemical Detection
- Standoff Detection
- Explosives Detection
- Biological Detection
- Hyperspectral Imaging
- Raman and SERS
- Infrared
- LIDAR
- Fluorescence

## 4. FUTURE PROGNOSTICATIONS

While the modern era of chemical warfare began just over 100 years ago, armies have been using toxic gases, biological threats, as well as incendiary and explosive devices for most of recorded history. The threats from CBRNE hazards are also continuing to advance. "Innovation warfare" has allowed warring parties with limited resources to improvise or reuse older technologies with great effect. Today's military and homeland protection forces must therefore be prepared for a wide range of threats, including many "old ones". Non-state actors coupled with the non-attribution of strategic acts from CBRNE hazards will make a national response difficult without strong reliance on forensics to narrow down or identify the source. This is certainly a topic discussed within the conference, and I predict it will continue to be a significant theme in the foreseeable future. Another key technology for the future will be the increased automation of sensors for battlefield awareness and decision making. While the conference has periodically hosted sessions on the development of algorithms for CBRNE sensing, the inclusion of artificial intelligence (AI) and machine learning (ML) specifically for use these sensors is probably warranted. I believe that further miniaturization will put CB sensors on every soldier and vehicle, raising battlefield awareness and potential ethical questions. We have recently launched a series of sessions on Photonic Integrated Circuits (PIC). While I hope those continue, I also hope that the conference can further attract others who are working on miniaturized sensors with different sensing modalities. With every soldier a sensor, the US military should

have unparalleled awareness of the hazards our soldiers face. This will also place higher demand on reducing false positives and ethical concerns on just when and to whom to report the extent of the threat. Rapid innovation, improvisation, and proliferation through the dark web will make threat prediction difficult, so sensors will need to be more adaptable and flexible. Finally, urban and underground combat will increase the threat of accidental or unintentional exposure to industrial chemical hazards complicating detection and remediation. The conference should seek to find ways to showcase how sensors can be repurposed to respond to more than the traditional CBRNE threats.

## 5. CONCLUSIONS

The world remains a very dangerous place and CBRNE threats continue to be a concern to the DoD, DHS, and their international equivalents, resulting in necessary improvements and innovation in sensing for the foreseeable future. The CBRNE Sensing Conference within the SPIE Defense + Commercial Sensing Symposium continues to provide an unprecedented forum for authors from government, industry, and academia to address a wide variety of CBRNE sensing issues, technologies, and advances in algorithms and signal process of threat related scenarios. I hope and truly believe that this forum will remain a critical resource for a vibrant community of likeminded scientists to come together to solve current and future CBRNE sensing challenges. The large number of one time authors presents the Conference Committee with an untapped resource of individuals who could help shape further and future improvements to the program. However, the core group of over 50 authors who have published consistently in the conference are truly the heart and soul of the community and should be heartily commended.

## 6. ACKNOWLEDGEMENTS AND DISCLAIMER

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