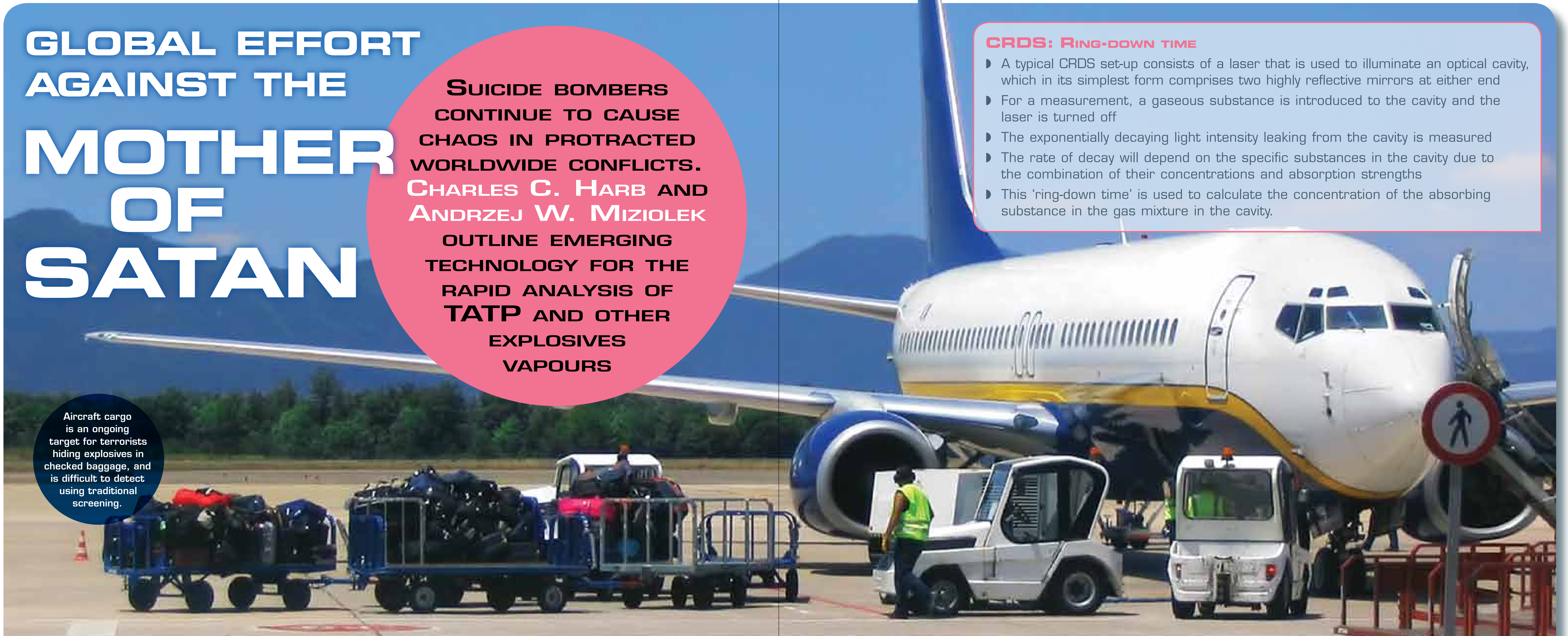
Explosives Analysis

Global effort against the MOTHER OF SATAN

Suicide bombers continue to cause chaos in protracted worldwide conflicts. Charles C. Harb and Andrzej W. Miziolek outline emerging technology for the rapid analysis of TATP and other explosives vapours



Aircraft cargo is an ongoing target for terrorists hiding explosives in checked baggage, and is difficult to detect using traditional screening.

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In 2013, the International Symposium on the Analysis and Detection of Explosives declared that the detection of explosives and illicit materials was a global effort. Defence groups along with forensic sciences, customs, and transport security worldwide are entrenched in the search for these compounds.

Legal constraints set by the judicial system impose important restrictions on the allowable methods used by agencies to detect these compounds. The chain of evidence – a crucial step in any investigation – dictates that any material evidence gathered must be maintained in its *original form* and *unaltered* by investigators if it is to be presented as evidence in a legal inquest. This explains the interest in vapour analysis where the solid/liquid is left undisturbed.

Services involved in protecting defence, security, transportation, shipping and public thoroughfares from the use of explosives all have interest in technologies that can be used as portable, sensitive detectors for illicit and prohibited substances while maintaining the legal status of the sample.

Enter TATP

In discussions with these teams, we determined that they are interested in detecting a range of explosives such as ammonium nitrate (used in so-called fertilizer bombs); potassium chlorate (used in smoke grenades and fireworks); and high explosives (HMX, PETN, TNT).

However, organic peroxides such as triacetone triperoxide (TATP) and diacetone diperoxide (DADP) have emerged as higher-threat compounds for use by terrorist and paramilitary organisations in IEDs, due to their ease of manufacture from commonly available components.

Tracing the traces

Analysis of 'bulk' organic explosives is a straightforward task for well-equipped forensic laboratories, but it is considerably more difficult to analyze 'trace' amounts of organic explosive residues, particularly in highly contaminated post-blast samples. This usually requires an elaborate sequence of solvent extraction from swabs and some form of gas chromatographic (GC) or electrophoretic separation.

Suitable detection techniques include ion mobility spectrometry (IMS), mass spectrometry (MS) and thermal energy analysis. Such analytical systems lack the sensitivity to analyze explosive residues in vapour samples, however – due to very low vapour pressures of organic and inorganic homemade explosives (HMEs). These techniques also alter the sample itself, making them unsuitable from a legal standpoint.

Field-portable instruments that can cope with trace residue detection without altering the sample itself are in crucial need. Additionally, these systems must handle a high volume of continuous measurements when deployed at high traffic venues. Just as importantly, these instruments need to offer quantitative reproducibility to limit the number of false-positive results.

Comparing the technologies

Although there are many commercially available instruments purporting to perform these tasks, at present they all have major limitations. For example, *Terahertz Radiation Technology* can see through garments to identify hidden objects, but it cannot detect the compounds therein. Instead, it requires a human to operate the unit and make an intuitive, often-flawed visual identification.

These types of machines also have the disadvantage of being time consuming, so they slow down the flow of traffic in, for example, an

CRDS: Ring-down time

- A typical CRDS set-up consists of a laser that is used to illuminate an optical cavity, which in its simplest form comprises two highly reflective mirrors at either end
- For a measurement, a gaseous substance is introduced to the cavity and the laser is turned off
- The exponentially decaying light intensity leaking from the cavity is measured
- The rate of decay will depend on the specific substances in the cavity due to the combination of their concentrations and absorption strengths
- This 'ring-down time' is used to calculate the concentration of the absorbing substance in the gas mixture in the cavity.

Advantages of rtCRDS:

- *Produces results requiring only vapour from samples, and does not alter the sample itself* – preserving sample integrity as evidence in a legal inquest, crucial to judicial system constraints
- *Uses state-of-the-art manufacturing, such as 3D printing* – to produce inexpensive, lightweight sensors in a range of form factors to facilitate mounting on fixed or mobile platforms
- *Real-time spectra obtained in 2-4 seconds, covering a wave-length range in excess of 1,300 nanometres, with at least 150,000 data-points* – could be combined with a GC to create a real-time infrared spectrum that separates the mixture into individual components and displays the results as a 3D hypertemporal cube
- *Spectral 'molecular fingerprints' unique for each material* – avoid-ing false positive readings common to many detection systems
- *Spectra of TATP and DADP that are distinctly different from their reactants, acetone and peroxide* – very important since acetone and peroxide are found commonly in benign forms throughout society
- *Measurements can be performed at atmospheric pressure and temperature* – making operations under vacuum conditions unnecessary, even though this remains a re-quirement for competing technologies, such as MS
- *Measurements require no sample preparation, no carrier gases and no ionization sources* – aids rapid analysis time, essential for defence and security groups as measurements can be made in the field and on the spot. Specifically, headspace from containers such as luggage or shipping crates can be quickly analyzed. Fixed or mobile sensors analyzing ambient air for tell-tale explosives signatures can be used in airport, stadia, and a wide variety of vulnerable sites where a large number of people are present.

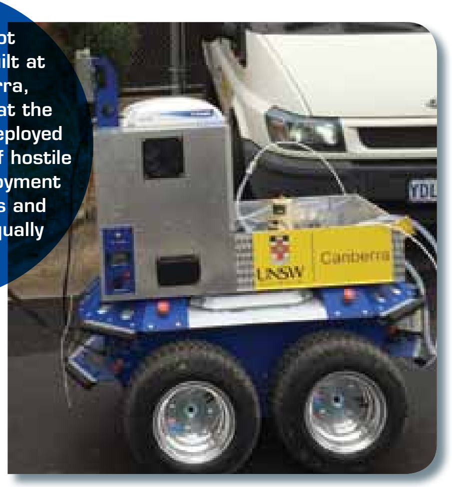
airport queue. IMS systems offer a high level of sensitivity and rapid analysis time, but struggle with selectivity and are prone to saturation and false positives.

Fourier Transform Infrared Spectrometers (FTIR) give excellent qualitative measurements of the substances in a compound across a wide bandwidth of operation and produce a spectrum in a relatively short period of time, but lack sensitivity and quantitative reproducibility.

The only real alternatives to instrumentation are detector dogs, which are heavily used by both military and civilian agencies. While they are useful at detecting 'something', be it narcotics or explosives, they are not able to unequivocally state what chemicals are present, and in what concentration.

A dose of the vapours

Real-time headspace analyzers are highly desirable for rapid measurements in hostile environments as well as high-traffic locations such as airports and rail stations. Headspace analyzers are portable, non-destructive devices capturing gaseous vapours being emitted by a liquid (or solid) in a closed space above the sample – that is, the 'headspace.' The gases captured in this closed space can



The mobile robot rtCRDS system built at UNSW in Canberra, Australia shows that the technology can be deployed for remote sensing of hostile environments. Deployment on drones, vehicles and ships should be equally viable.

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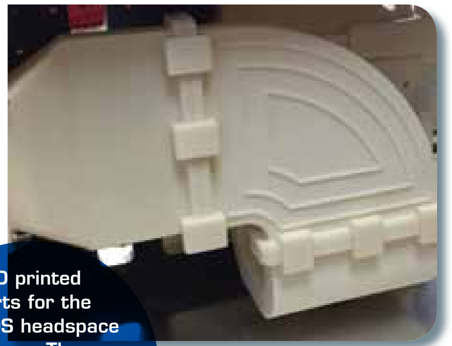

3D printed parts for the rtCRDS headspace sensors. These systems can be manufactured rapidly and deployed in many environments.

then be analyzed without altering the liquid or solid itself.

A promising means of undertaking this analysis is *real-time Cavity Ring-down Spectroscopy (rtCRDS - see Box above left)* – a highly sensitive optical spectroscopic technique that enables measurement of absolute optical extinction by samples that scatter and absorb light at specific wavelengths – which in turn enables determination of molecular concentration down to a level of parts per trillion. ✵

Dr. Charles C. Harb, CEO and Founder of RingIR, Inc. is the inventor and developer of rtCRDS technology. He has more than 20 years' experience in Laser and Optics R&D with emphasis on optical sensing systems and gas spectrometry. Dr. Andrzej W. Miziolek was a Research Physicist at the US Army Research Labora-tory before retiring in 2015. He has worked in applied spectroscopy for more than 40 years, focusing on security and protection and environmental applications.