# Air Cargo Explosive Screener (ACES) based on the integration of Mobility Analysis and Mass Spectrometry[1]

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## 1- Introduction

The present paper will briefly describe a new vapour detector whose aim is explosive screening of aeronautic cargo. The paper will be organized as follows:

- Legal environment of air cargo explosive screening,
- User requirements for an air cargo explosive screener,
- Technology proposed and
- Concept of operation and costs,

## 2- Legal environment of air cargo explosive screening

On August 13th, 2007, the US Congress approved Act 110-53 called ''Implementing Recommendations of the 9/11 Commission Act of 2007''. In its article 1602, the Act established that, within three years (August 2010), 100% of air cargo loaded on passenger aircrafts was **"**to be screened with a **level of security commensurate with passenger checked baggage**".

However, this objective has not been implemented as of today, nonetheless the target date been many months old. Aeronautical cargo security in the US is presently implemented via the Certified Cargo Screening Program (CCSP), which allows screening to take place early in the shipping process, prior to delivering the cargo to the air carrier. The same situation is to be found in the EU, with some differences among countries, but in general terms screening is done away from the airport through a delegation of confidence. This screening operation is considered considerably less secure than the screening made at the airport, such as it is conducted on passenger screened baggage.

Reasons for the decision to implement the CCSP in the US, and regulated agents in the EU, are essentially due to costs considerations. As declared by Mr. James Tuttle[2] on July 15, 2008**:** **"**The cost of technology-based screening is on the order of $0.08-0.12 per pound and is dominated by cargo handling and screening labour". And those costs are essentially due to a

[1] ACES technology has been supported by the following programs: EU FP7 EFFISEC, Spain Ministry of Science and Innovation INNPACTO, Castille & Leon ADE Line 4 CARGO, and NATO DAT.
[2] Statement for record, Mr James Tuttle, Division Head of the Explosives Division, Science and Technology Directorate of the U.S. Department of Homeland Security before the House Committee on Homeland Security, Subcommittee on Transportation Security and Infrastructure Protection, July 15, 2008

technology limitation: TSA has determined that: "The maximum size cargo configuration that may be screened is a 48" x 48" x 65" skid"[3], while size limitations in the EU are similar. Such size limitation leads to the high cargo handling costs indicated above, and therefore prohibits cargo screening at airports as a general rule. Neither the CCSP in the US, neither the regulated agent in the EU, can be considered an ideal solution from the security perspective, but rather a compromise between screening equipments state-of-the-art, and air transport requirements related to costs and timing.

## 2- User requirements for an air cargo explosive screener

Main User requirements for an Air Cargo Explosives Screener can be synthesized as follows:

- Able to screen **ULD pallets, containers and complete trucks up to 110 $m^3$,**
- Able to detect substances with a **vapour pressure as low as $10^{-11}$ atm** (RDX and PETN) in amounts as low as 10 g per cargo load,
- Very high Probability of Detection (PoD), and
- Very low False Alarm Rate (FAR),
- Cost below 0,01€ /kg of screened cargo

Requirements 1 to 3 require a very high sensitivity, while requirement 4 requires a very high resolution. Requirement 5 is automatically met if complete trucks can be screened without need to unload them.

Users face a significant challenge when asked to define precisely what they consider the sensitivity and resolution level required. Such difficulty lies in the fact that the physics underlying detection are still partially unknown, so a debate is open over exactly what are the sensitivity and resolution needed in order to comply with requirements 1 to 4.

Saturation vapour pressure of explosives, although quite controversial, has been measured many times and there is a broad agreement about its order of magnitude. However, in the real world, vapour pressure is considerably lower than the saturation value. For explosives hidden in cardboard boxes within thinfilmed pallets, our own data points out that real vapour pressure after 15 minutes is 100,000 times smaller than saturation. Therefore, sensitivity required in order to detect plastic explosives trough vapour analysis in palletized cargo is as low as 0.1 ppq ($10^{-16}$ atm). This sensitivity is many orders of magnitude better than sensitivity of current detectors.

In order to determine the required resolution, we will initially discuss a basic detection problem, which can be stated as follows: the higher the sensitivity level achieved by any detector, the larger the number of new species that appear above the detector threshold, and therefore the higher the discriminating challenge for this detector:

- If the vapour detector is sensitive only to species with a vapour pressure of about 1 atmosphere, it will only detect $N_2$, so an analyzer is not even necessary. At 10 times this sensitivity it will detect also $O_2$, and then $H_2O$, $CO_2$, Ar, $NH_3$, etc.
- At a sensitivity level of 1 ppm ($10^{-6}$ atmospheres of vapour pressure), just the human breath, coffee or wine contain over 200 vapour species,
- At a sensitivity level of 1 ppb ($10^{-9}$ atmospheres) there are typically many thousands of volatile species,
- Number of species to be found at 1 ppq ($10^{-15}$) is unknown. According to our tests, this number could well be higher than 100,000.

[3] http://www.tsa.gov/assets/pdf/non_ssi_acstl.pdf

We therefore conclude that, according to our own data, explosive vapour detection in aeronautical cargo requires a sensitivity at least of 0.1 ppq ($10^{-16}$ atm) and a resolution above 100,000.

## 3- Technology description

Figure 3-1 shows the schematic architecture of ACES:

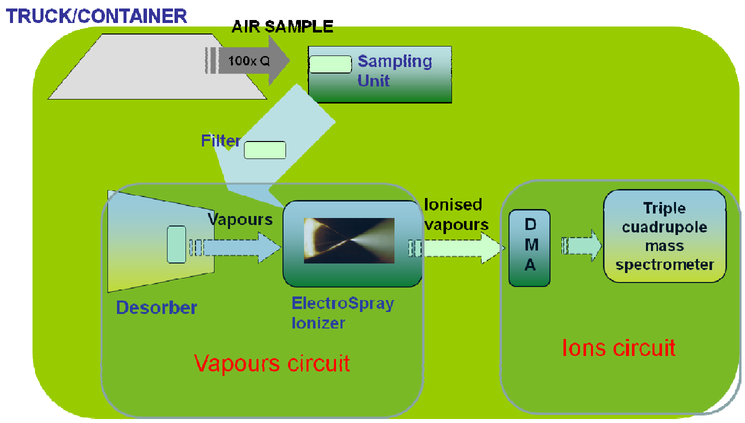


**Figure 3-1: MS-based vapour detector architecture**

The ACES equipment incorporates the following main subsystems:

- Sampling Unit,
- Vapours circuit, which integrates a desorber and the ElectroSpray Ionizer, and
- Ions circuit, which integrates a DMA[4], and a triple quadrupole API Mass Spectrometer

The vapours circuit is kept at a temperature around 200ºC, in order to tackle contaminations issues, which have proved to be a severe problem for such sensitive equipments in the past. Since contamination is not an issue for ions, the ions circuit is kept at room temperature, in order to optimize operation of the DMA-MS.

A picture of the present ACES Analyzer open-paneled is shown in Fig 3.-2, along with its main elements.

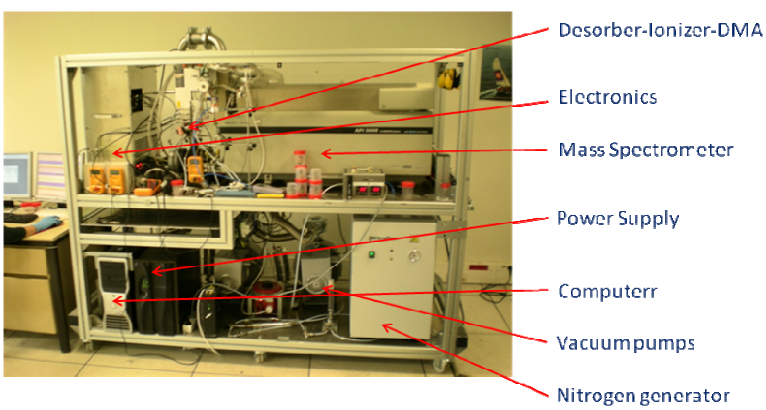


**Figure 3-2: ACES Analyzer main elements**

[4] See for example Juan Rus, David Moro, Juan Antonio Sillero, Javier Royuela, Alejandro Casado, Francisco Estevez-Molinero, Juan Fernández de la Mora "*IMS–MS studies based on coupling a differential mobility analyzer (DMA) to commercial API–MS systems*", International Journal of Mass Spectrometry Volume 298, Issues 1-3, 1 December 2010, Pages 30-40, Special Issue: Ion Mobility. doi:10.1016/j.ijms.2010.05.008

Most of those elements are present-state-of-the-art, and so have been acquired in the open market. However, ACES incorporates some elements which represent a qualitative technological improvement over present equipments, and they have been developed internally. These elements are the following:

- ElectroSpray Ionizer, and
- DMA,

## 4- Concept of operation and costs

We have previously reached the conclusion that, in order to optimize simultaneously the security and the cost perspectives, cargo should be inspected at the airport, just before loading, and at the highest possible level of aggregation.

The ACES system operates as follows:

- Operators take air samples from the target object using the ACES portable sampling system. The sampling unit concentrates the air sample (vapours) onto a cartridge. Several operators can take samples simultaneously in different trucks or containers. Figure 4-1 shows the ACES Sampler extracting air from a truck, in order to analyze in a single operation the complete contents of the truck cargo bay.
- The cartridge is brought to the ACES Analyzer. Distance from the Sampler to the Analyzer can be anyone, and different transport methods (such as for example an automatic pneumatic system) can be envisaged as a function of operational requirements within each airport.
- The cartridge is analyzed by the ACES Analyzer, which integrates the mobility analyzer and the tandem mass spectrometer.
- The computer, located in the Analyzer itself, provides provide a fast, reliable and detailed diagnostic of the explosives contained within the target.

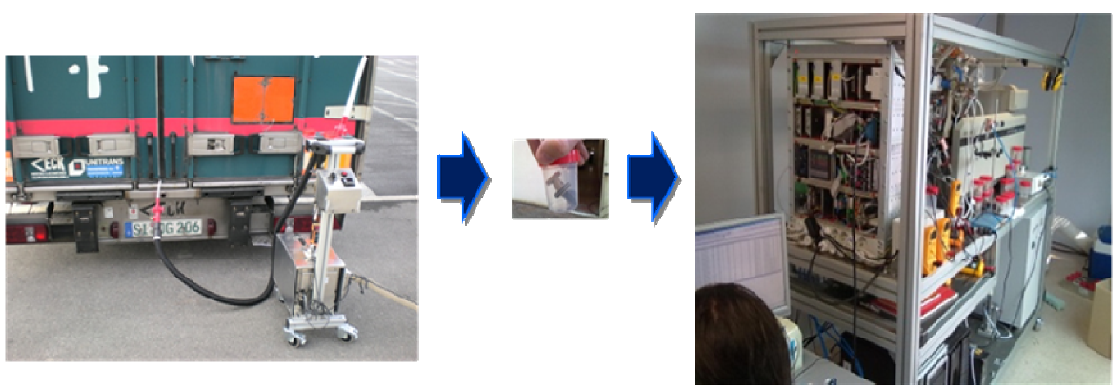

**Figure 4-1: ACES operation**

As a direct consequence of being able to screen complete trucks, ACES cost of operation is considerably lower than present equipments. ACES aim is to achieve a cost below 0.01€/kg in operation.