



Executive Summary:

Results of Two Year Study of Liquid and Homemade Explosives Detection

Over the past two years, Reveal Imaging Technologies, Inc., in collaboration with US and international security regulators and explosives experts from four different countries, has collected extensive data specifically regarding Liquid and Homemade Explosives (HME). This report presents the results of this extensive study, focusing on detection of these defined threats in real world operational environments, scanning over 8,000 international bags. Our work with international regulators has provided us access to sample explosives in a wide variety of configurations. The explosive mixtures represent a cross section of configurations, including various fillers and stabilizers, based on intelligence from around the globe. Hundreds of samples of liquid and homemade explosives have been scanned to create the single most comprehensive database of its kind. This data has enabled Reveal to develop an algorithm on the Reveal CT-80 EDS platform capable of non-intrusively detecting the full range of threats highlighted by this study, including liquids, precursor components and homemade explosives in passenger checked and carry-on baggage.

Reveal's TSA-certified CT-80 family of Dual Energy CT scanners accurately measures both density and effective atomic number of every object in a passenger's bag. Testing data demonstrates the CT-80's ability to reliably detect a very wide range of liquid and homemade explosives, in conjunction with the more traditional military and commercial explosives, with a low false alarm rate and without opening passenger bags.

Allowing liquids through the checkpoint and scanning laptops while still in their case offers the potential for a welcome improvement in passenger service. Passenger bags containing any amount of liquid, cleared by any member of Reveal's CT-80 EDS family, can be safely and confidently carried aboard aircraft. In addition, because CT scanners collect data from 360 degrees around a bag, laptop computers and other electronics can be left in the bag during the scanning process. Reveal's high throughput and low false alarm rate provide operational benefits while reducing airport operational cost.

The attached report describes the liquid and HME challenge in more detail, along with the following:

- An overview of available technologies
- Reveal's extensive HME and Liquids database and analysis performed to date
- Detection performance for HME, precursor and Liquid explosives
- Operational impact of reliable HME and Liquids detection
- Proposed passenger checkpoint configurations
- False alarms

Reveal is pleased to offer supporting information. We will contact you to arrange a restricted one-on-one briefing to discuss specific detection results, operational benefits and other aspects important to our stakeholders.



Detection of Liquid and Homemade Explosives (HMEs) using Dual Energy CT

The Liquid and HME Challenge:

Regulators' recent increased concern regarding the threat from liquid and homemade explosives has forced significant restrictions and inconveniences on the traveling public. The lack of effective detection technology, able to discriminate these unique explosives from innocuous materials commonly carried in passenger hand carried baggage, has forced security regulators to create and enforce new restrictions on carry-on baggage. These include limitations on the number of bags allowed for each passenger as well as a limit on the amount of liquid allowed to be carried in passenger cabin baggage. These new restrictions have a significant, negative impact on the passenger travel experience and commercial impact on airport commerce, while adding delay and additional cost to airport operators and airlines.

Military and commercial explosives have relatively well known and well constrained density and Z_{eff} (effective atomic number) properties. Liquid explosives, a new category of concern for civil aviation, present a difficult challenge, as their Z_{eff} and density properties are too close to other liquids for single and multi-view X-ray to differentiate and detect without an unreasonable increase in false alarm rate. Homemade explosives, by definition, present an even more difficult challenge. By their nature, the Z_{eff} and density of homemade explosives can vary widely, depending on materials used to make the explosives themselves, various materials added to increase stability, and the cleanliness or control of the "manufacturing" process.

While these new materials present a new set of detection challenges, the data demonstrates that it is possible to detect Liquids and HMEs with a manageable false alarm. Detection of these new explosives, in addition to more traditional threats, requires a technology that can accurately measure both density and Z_{eff} .

In addition, because CT scanners collect image data from 360 degrees around every object, it is possible to significantly improve overall checkpoint detection capability *while leaving laptop computers and other electronics in passenger bags*. There is no need to remove laptops to achieve outstanding detection performance. Leaving laptops in their cases improves passenger service while reducing the total number of items requiring inspection.

Overview of Available Technologies:

Automated image processing and detection algorithms use available data to differentiate explosives from commonly carried materials. Traditional dual energy X-ray systems, including new multi-view X-ray, are able to measure density and (Z_{eff}) to varying degrees of specificity. Single energy CT is able to measure density very accurately, but cannot measure Z_{eff} . Dual Energy CT accurately measures both Density and Z_{eff} .

The results of 8,000 international bags scanned during the two-year study demonstrate the Density and Z_{eff} regions near the homemade and liquid explosives are quite crowded. Conventional single and multi-view scanners, even with well known and well



characterized explosives, are limited in their ability to differentiate these materials from innocuous bag contents, typically exhibiting 30% to 40% or higher false alarm rates. Even single energy Computed Tomography, or CT systems have difficulty with this new set of threats, as they share a density region with more false alarm objects than more traditional military and commercial explosives.

Reliable in-situ detection of these new explosives requires very accurate measurement of **both** density and Z_{eff} . Only by using both of these parameters, along with very sophisticated detection algorithms, can threat materials be separated from the universe of typical objects and materials found in passenger baggage.

Extensive Homemade and Liquid Explosives Database:

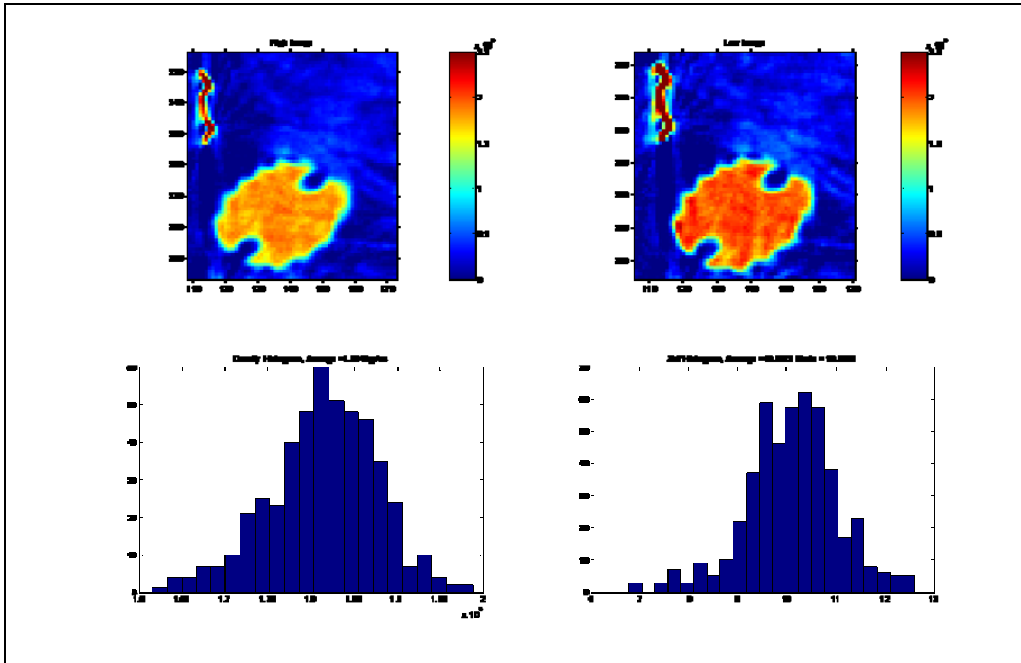
Over the past two years, Reveal Imaging has worked with US and International security regulators and explosives experts to collect data specifically regarding Liquid and Homemade explosives. Reveal Imaging has scanned both raw explosives as well as explosives concealed in real baggage using our CT-80 Dual Energy CT EDS system. Partnering with international regulators and explosives specialists from four different countries, we have collected hundreds of samples of Liquid and Homemade explosives to create the single most comprehensive database of Liquids and HMEs available. Our work with international regulators has provided us access to targeted threats, in a wide variety of configurations. The threat mixtures represent a cross section of explosive configurations and packing scenarios, including various fillers and stabilizers, based on intelligence from around the globe.

The resultant data demonstrates the CT-80's ability to reliably detect a very wide range of Liquid and Homemade explosives, in conjunction with the more traditional military and commercial explosives, with a low overall false alarm rate.

Typical data collection and analysis starts with the theoretical properties of different explosives and mixtures and compares to the actual measured properties to develop comprehensive detection algorithms. For example, a typical analysis includes:

Explosive: Sodium Perchlorate

- Composition :
 - 66-72% Sodium Perchlorate (NaClO_4)
 - 22-27% Diethylene Glycol ($\text{HO-CH}_2\text{-CH}_2\text{(-O-CH}_2\text{-CH}_2\text{)-OH}$)
 - 1-12% Unknown non-toxic ingredients
- Theoretical Properties:
 - Density ~ 1.80 +/- 0.1gr/cc, Z_{eff} : 10.87 +/-0.35
- Measured Properties:
 - Density = 1.81, Z_{eff} =10.34



High Energy and Low Energy Images of Sodium Perchlorate, along with histograms of Density and Z_{eff}

This process has been performed with over 25 different explosives, precursor components and mixtures.

Detection Performance for Liquid and HMEs:

All data collection efforts are based on real world threat scenarios, with appropriate threat weights and concealments. Explosives, baggage and parcels have been configured by different regulatory agencies to accurately reflect intelligence-based threat scenarios.

Reveal has used the collected data to develop automated detection algorithms for Liquid and Homemade explosives. These algorithms have been tested and the results are available upon request. At this time, Reveal's CT-80 family can provide a probability of detection (Pd) for Liquid and Homemade explosives equal to the Pd required for US TSA "Certification."

False Alarms:

EDS false alarm rate depends on a number of variables; the system's measurement accuracy, the universe of target materials and mass threshold, and the type of bags being scanned. Based on data collected to date, Reveal anticipates the CT-80 will generate a very low false alarm rate when configured to detect Liquid and Homemade explosives in passenger carry-on baggage.

The CT-80 generates an image for each bag that is fully compliant with the STP. Operators use the high quality image to review all bags for prohibited items as well as to



review any alarm images. Alarms that cannot be cleared using the image are subjected to proven alarm resolution techniques.

False alarm contribution from some different types of liquid and HMEs are as follows:

Material	CT-80 FAR increase
Peroxides (and mixtures)	< 1.5%
Chlorates (and mixtures)	< 2.5%
Nitrates (and mixtures)	< 4.0%

Operational Impact of Reliable Liquid and HME Detection:

With reliable, proven technology available to detect Liquid and Homemade explosives, recent security regulations can be reconsidered to improve passenger service without sacrificing passenger safety.

The Reveal CT-80 can reliably detect threat quantities of Liquid explosives in typical passenger carry-on baggage. Even with actual bags containing currently restricted objects such as other liquids, creams, perfumes, alcohol, etc, the CT-80 can detect explosives or precursor materials with a low false alarm rate.

The recent liquid ban has caused significant passenger service issues and hardship to duty free commerce. The CT-80 family can be used in a security checkpoint configuration as a primary or secondary screening technology for passenger carry-on baggage. This opens the possibility to remove or significantly relax the current liquid restriction while actually improving the overall checkpoint's ability to detect threat materials.

Detection Measurements made with Laptops Left in Bags:

Because CT scanners collect image data from 360 degrees around every object, it is possible to significantly improve overall checkpoint detection capability *while leaving laptop computers and other electronics in passenger bags*. All of the detection capability discussed herein assumes laptop computers are left in passenger bags, not removed and scanned separately.

Detecting Liquid and Homemade Explosives at the Passenger Checkpoint:

Reveal's dual energy CT supports a number of different checkpoint screening configurations. The CT-80 can be used as a primary or secondary screening process. In a primary configuration, the system is used to inspect 100% of passenger carry-on baggage. There is no need to remove laptops to achieve outstanding detection performance. Leaving laptops in their cases improves passenger service while reducing



the total number of items requiring inspection by up to 50% as compared to today's checkpoint regulations.



Reveal "FUSION" EDS – Over 300 bags per hour with automated liquid and HME detection

Conclusion:

Reveal's extensive work on Liquid and HME detection opens an opportunity to provide welcome improvement to the passenger screening process. Many companies have claimed the ability to detect these threats over the past year, but few have been able to demonstrate true, data based detection ability. We would be pleased to share additional specifics regarding the explosives types, threat weights, configurations and detection performance. Due to the security sensitive nature of this information, a private conversation is required in order to share more detailed data. We will contact you directly to schedule time for a more comprehensive discussion.