# The Role of THz and Submillimeter Wave Technology in DHS

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## ABSTRACT

THz and submillimeter wave technology is of great interest to DHS S&T due to the non-ionizing and clothing penetrating properties of the spectral region. Imaging in the region allows for standoff imaging of concealed threats such as Improvised Explosive Devices (IED) at operationally relevant distances. DHS S&T is investing in this area with the development of components such as detectors and sources for active imaging as well as full sensor systems in the future. The fundamental characterization of the region is also being explored with DHS funding by imaging well-characterized rough surface scattering targets. Analysis of these images will yield data to be used in evaluating assumptions currently made in current performance models. This along with the relevant field applications will be addressed.

**KEYWORDS:** Explosive Device Detection, Terahertz imaging, submillimeter wave imaging, homeland security

## 1.INTRODUCTION

The Department of Homeland Security has several operational components, such as Customs and Border Patrol, and federal agencies, such as Transportation Security Administration and Office of National Protection and Programs. It also includes a research and development component, the Science and Technology Directorate. The Science and Technology Directorate, or DHS S&T for short, is responsible for funding the development of technology and knowledge products to support the operational components in the protection of the homeland. DHS S&T focuses in funding applied research that will result in a product that can be provided to the DHS components to test or use within 3-5 years of project initiation. In general, DHS S&T does not fund basic research or research projects that study fundamental science without a direct application. Instead, DHS S&T relies on the federal and other agencies that traditionally invest in those projects, for example the Office of Naval Research, Army Research Office, and National Science Foundation. When the projects in these agencies reach the maturity necessary, DHS S&T may choose to fund the continued research or collaborate. Along the same line, DHS S&T does not purchase commercial equipment for the DHS components' use. DHS S&T may choose to further develop current commercial products to meet the needs of DHS components that are not currently available.

DHS S&T customers are the DHS operational components. A full list includes Customs and Border Protection (CBP), Immigrations and Customs Enforcement (ICE), Transportation Security Administration (TSA), United States Coast Guard (USCG), United States Secret Service (USSS), Federal Protection Services (FPS), National Preparedness and Protection Directorate (NPPD), Federal Emergency Management Agency (FEMA), Federal Law Enforcement Training Center (FLETC), Office of the Inspector General (OIG), and United States Citizen and Immigration Services (USCIS). Requirements for technology development are derived from these components and then addressed within the Science and Technology Directorate. DHS S&T is broken into four groups that address research needed in critical homeland security needs. One of these groups, the Homeland Security Advanced Research Agency (HSARPA), accounts for the bulk of this research spanning across six divisions. The divisions are Borders and Maritime Security, Chemical and Biological, Cyber Security, Explosives, Human Factors and Behavioral Sciences, and Infrastructure Protection and Disaster Management.

## 2. THE EXPLOSIVES DIVISION

The Explosives Division addresses the threat of non-nuclear explosives used in a terrorist attacks against mass transit, civil aviation, and critical infrastructure. It is charged with developing methods of detection to prevent this threat from reaching it's target or detonating. Along this line the Explosives division works with the relevant DHS components to meet their requirements in this area. The applications that the division focuses on include aviation security as well as checkpoints in other venues such as federal buildings and borders and mass transit security. This paper will address non-

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aviation checkpoints and mass transit applications. However it is acknowledged that standoff technologies for these applications, once developed, can easily be adapted to aviation checkpoints.

DHS is interested in developing a tiered security system that can detect threats in a standoff manner as an individual approaches a venue entrance. This tiered approach is designed to detect a threat as soon as possible to provide as much time as possible for interdiction and to keep the threat from reaching its intended target. Once a threat is detected, additional tiers within the system could be used to clear or confirm the initial detection for a possible interdiction. This system would augment checkpoints at venues such as federal buildings where checkpoints currently exist and would provide enhanced security at venues such as mass transit stations where checkpoints do not exist. In both cases, the goal would be to impose little to no disruption to the movement of individuals entering and transiting through the venue.

Threat items of interest will predominately be those of an explosive nature capable of inflicting massive damage and casualties. For venues with existing checkpoints, threats could also include prohibited items such as concealed guns and knives, both metallic and non-metallic. Suicide and leave behind bombings are both of a concern, so we would like to detect devices both worn and carried by a person.

## 3. THE EXPLOSIVES DEVICE PROBLEM

The standoff detection of explosives can generally be divided into countering Vehicle Borne Improvised Explosive Devices (VBIEDs) and Person Borne Improvised Explosive Devices (PBIEDs). A VBIED is any IED that is transported via a vehicle, from motorcycle to 18 wheel truck, to the intended target whether the person driving the vehicle is knowledgeable of the threat or not. A PBIED is any IED worn or carried by a person to the target location. The person can be a willing participant, kidnapped, or a coercion victim wearing the IED which is commonly termed a suicide bomber. In addition the IED can be dropped or left behind at the target and called a Leave Behind IED (LBIED). Each of these situations my need a different type of technology to detect the IED before it reaches the intended target or is detonated. This includes detection of the explosive chemical itself as well as imaging of the threat through concealment in a vehicle, bag, or under clothing.

The Standoff Detect team has invested in several imaging technologies in the past. Since the Standoff Detect team focuses on detecting threats from a distance this severely limits the technologies that can safely and effectively detect threats. A walk-by backscatter x-ray system was developed by Rapiscan with support from DHS S&T. The system consists of a series of backscatter x-ray sources and detectors off set from each other in a short hallway-like configuration. A person would walk through the hallway at a reasonable speed (as in not running or speed walking) while being imaged by the backscatter x-ray system. This would allow for images from several angles of the person quickly which both increases the imaging speed and effectiveness.

A non-imaging system that detects the presence of an explosive threat has also been developed by DHS S&T. This system involves interrogating a person at a distance of about 10 meters from the system with an acoustic wave. The properties of the return acoustic wave are analyzed and determine if a threat is present or not. At this time the technology does take a few seconds to scan an individual, but privacy issues are minimized as there is no image created.

## 4. CURRENT TECHNOLOGY INVESTMENTS

As stated above EXD has invested in a variety of technologies in the past to mitigate the IED threat. This continues with current efforts since no one sensor technology will solve the problem. Current efforts include investments in sub-milimeter or Terahertz wave modeling and a survey of commercial technologies and those in development to guide investment decisions. Other efforts not covered in detail here due to the nature of the technology outside the millimeter wave and Terahertz areas include optics based standoff trace explosives detectors and x-ray and gamma ray based VBIED imagers.

As sensor developers go about designing a particular sensor they have a multitude of design tradeoffs to make. Often these tradeoffs will be based on a particular application where the sensor is intended to be deployed. Performance models have been used to determine the tradeoff space for imaging sensors. While validated performance models exist in many areas of the spectrum, the sub-mmW / THz area of the spectrum is an exception. Notable attempts have been made to develop models for this region but all have limitations related to assumptions made in the reflectance as a function of angle and intensity.

DHS S&T is currently working with the National Institute for Standards and Technology (NIST) to establish scientifically valid and repeatable techniques for measuring the Bidirectional Reflectance Distribution Function (BRDF) values for materials of interest. The materials of interest include different clothing materials, skin, and threat objects such as explosives, guns, and knives. This is being performed in the time and frequency domains for both passive and active modes across a broad spectrum from 100GHz to 1.2 THz. The intent is to establish BRDF values for the materials of interest that could be input into sophisticated stray light models incorporating digital object representation of the threat to more accurately incorporate reflectance values in the performance models.

It is understood that the output from these models, while not validated yet in the absolute sense, should provide an accurate comparison of the reflectance with a variety of objects. This will provide a useful tool to designers to make accurate sensor design trades in order to have optimal performance from the developed systems.

The Explosives division is currently conducting an Analysis of Alternatives to assist with the overall program strategy for technology development. This begins with identifying DHS Components operational requirements and understanding their current concept of operations (ConOps). The Explosives division then determines the degree to which these current ConOps can be altered by future technology deployment. From this one can gather the trade space for future technology investments.

The Explosives division is also cataloguing existing commercial systems by technology type and capability including imaging systems. For systems under development, we have surveyed several federal agencies to get a comprehensive understanding of what they are engaged in. At the same time, DHS is monitoring developments in THz electronics and emerging fields such as compressive sensing.

## 5. PLANNED FUTURE TECHNOLOGY INVESTMENTS

The collection of operational requirements and technology analysis stated above will help establish a program designed to provide standoff detection of threats prior to or at a venue entrance that specifically meet component requirements. From the preliminary results, it is anticipated that the overall solution will include a number of orthogonal technologies that will work in concert as a system of systems. Although the system of systems is not a unique requirement, the implementations of the technologies involved are unique to domestic applications. The implementation of a standoff detection system domestically has to contend with a number of functional limitations that are not present in overseas military applications. In other words, our sensor needs are not the same as those for the Department of Defense.

The current ConOps analysis has determined that screening of persons outside a venue, i.e. a public sidewalk, is not desired. Therefore, one is left with shorter standoff ranges. The structure and location of the venue entrance constrains the line of sight available for optimal sensor placement and limits the standoff ranges to 10 to 15m. In some instances it may be necessary to remotely deploy these sensors at the venue entrance yielding sensor ranges as little as 1 to3m. These shorter ranges coupled with the expectation that the standoff system will not impede the flow of persons through the venue imply that the sensor needs to be fast due to the short time to interdict a detected threat. Therefore the sensor's "speed" may drive the overall design. Given the short time that these imaging sensors will have to observe an individual and the fact that these persons may be walking at a fast pace, it may be necessary for imaging to approach video frame rates.

The sensors added to a venue need to integrate into the existing ConOps as much as possible including maintaining the number of security personnel working the checkpoint and throughput. Therefore, these imaging sensors will be unmanned and by necessity automated. Aided Threat Recognition (ATR) algorithms must be employed in the sensors for this automated opertation. Using ATR a detection event could be used to alert guards at a building checkpoint to a person or drive additional sensors to focus on the individual that alarmed in an effort to clear that individual or to guide an interdiction.

The emerging field of compressive sensing is another area that is being investigated by DHS. It is not necessary to know what every person is carrying, but whether that person is carrying a threat object. If certain phenomenology or signatures can be shown to be present for threat objects and absent when there are no threat objects, then this greatly simplifies the ATR required and possibly the sensor design.

DHS components and private authorities that might deploy the sensors have significant budget constraints; consequently the initial cost and life cycle cost will be paramount. If the overall goal is for widespread deployment of these sensors at venue entrances, then the most challenging aspect of the sensor design may prove to be cost, life cycle cost, maintainability, and reliability. For most applications, the sensor will need to be on 24 hours a day 7 days a week with very little idle or downtime. Hence the reliability and robustness of the sensor must be quite high to sustain in the operational environment. In addition, maintenance should not be burdensome and should be similar to the maintenance required for other security systems.

## 6. DOING BUSINESS WITH DHS

All research funding opportunities can be found on the Federal Business Opportunities website, www.fbo.gov. DHS S&T funding opportunities can also be found on http://baa2.st.dhs.gov. A company or university must register on the site in order to submit white papers or proposals. As stated before all DHS S&T funding opportunities will be posted on this website and openly competed. If there is not a broad area announcement or BAA that fits a technology on the site one may submit research ideas to the Long Range BAA, BAA 11-03. This BAA is not a funded BAA where monies have been set aside ahead of time to support proposals submitted under the BAA. Rather it is an opportunity to have ideas evaluated and seen by the relevant program managers in the technology area. If it is determined that a proposal is of interest and funds are available a contract or grant may result. However, a white paper or proposal may be deemed selectable but unfunded until either funds become available or another BAA is released in the technology area. The Standoff Detect team is planning to release BAAs in the area of IED detection in the next couple of fiscal years although exact release dates have not been determined.