SCIENCE & SECURITY Issue 27

CASRA NEWSLETTER

It is a pleasure to publish our first newsletter in 2022!

In this 27th issue, the section "Research Put Across" introduces the newly developed and released training for high energy screening on CASRA's X-Ray Tutor 4 (XRT4).
In the "Security in Practice" section we present an interview with the Australian Department of Agriculture, Water and the Environment and their implementation process of CASRA's X-Ray Tutor 4 (XRT4).

As always, we are looking forward to receiving any feedback you might have as well as your input on topics you would like us to address in next year's newsletters.

With best wishes,

Dr. Diana Hardmeier
Director

Prof. Dr. Adrian Schwaninger
Chairman

TOPICS IN THIS ISSUE:

RESEARCH PUT ACROSS

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SECURITY IN PRACTICE

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A SPECIFIC CASE FOR TRAINING IN HIGH ENERGY X-RAY IMAGE INTERPRETATION

Text: Sara Bracceschi

High energy X-ray systems provide several advantages to Customs and border security administrations as they are capable of scanning shipping containers and trucks within a few minutes (and in some operations seconds). The high energy penetration of X-rays through steel allows for even the objects in the center of the container to be displayed in the X-ray image. However, the image analysis and interpretation of high energy X-ray images is a challenging task for cargo screening officers due to image-based factors, geometric magnification, distortion of objects, and ever-changing concealment methods. Theoretical and practical training with a computer-based training platform can increase detection performance while reducing image analysis and response time.

INTRODUCTION TO HIGH ENERGY X-RAY SYSTEMS

In our increasingly globalized world, international transport plays a critical role, be it ground transport, ocean, or air freight. Maritime transport accounts for 90% of all international trade, with more than 500 million containers being shipped every year [1]. Air transport offers the advantage of speed, although at a higher cost, and for a reduced amount of cargo if compared to land and maritime. Ground transport is used in support of both air and sea cargo in order to transport the load from its place of origin to the airport or seaport and then again to get it to its final destination.

It is the mission of Customs administrations to facilitate international trade while ensuring the safety of borders and citizens and at the same time to prevent fiscal evasion by collecting tax and duties. As it stands, for Customs administrations to comply with their goal, a significant increase of the cargo inspection capabilities is essential for any country that wishes to keep its position in the global trading and transportation network [2].

In order to raise their inspection targets, Customs administrations are encouraged to implement state-of-the-art equipment that can guarantee fast and efficient scrutiny, such as modern X-ray systems. Different types of X-ray machines exist on the market depending on their application. They are usually classified as conventional and high energy, depending on the doses of X-rays utilized, which also affects the dimension of the machine itself and consequently the size of the objects that can be scanned.

The implementation of X-ray systems to support security screening was introduced approximately 50 years ago to accelerate the process of baggage inspection. For these smaller items, conventional (or low energy) X-ray machines are used for both airport and air cargo, as they are suitable for low-density containers. High energy X-ray equipment is an established cargo screening technology that has been implemented at ports and borders since the late 1980s. The doses of X-rays in high energy systems are about one order of magnitude higher than the conventional X-ray systems,

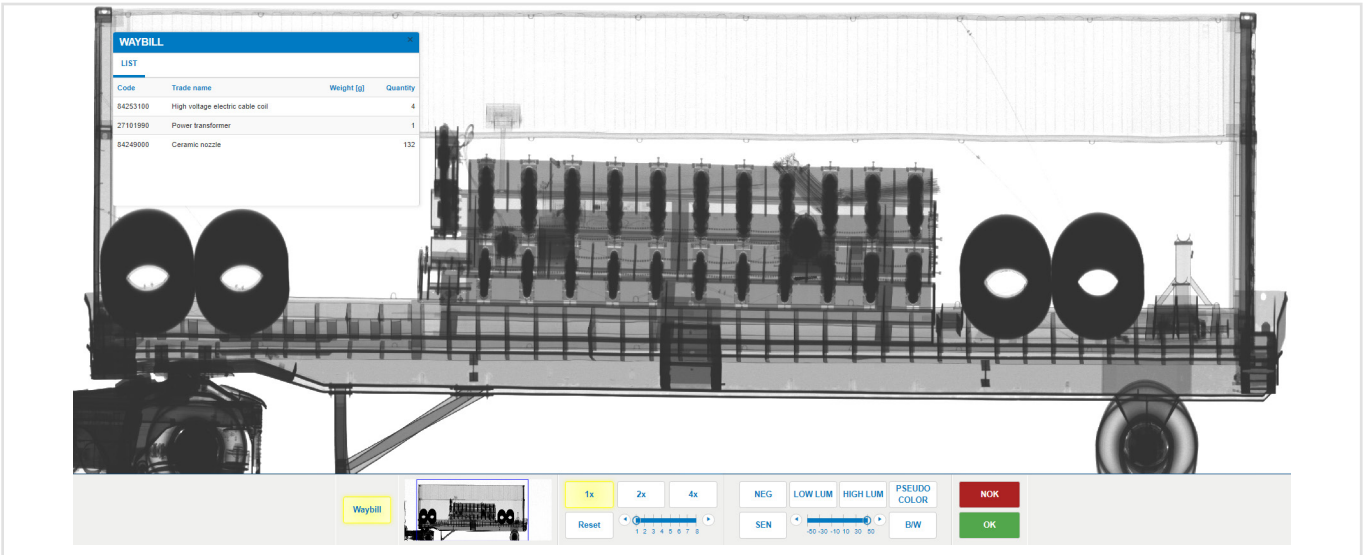

Figure 1: CASRA's XRT4 Customs High Energy User Interface including a waybill.

thus allowing the non-intrusive inspection of much denser and bigger objects, such as vehicles and cargoes.

THE ADVANTAGES OF HIGH ENERGY X-RAY SYSTEMS IN CARGO SCREENING

High energy X-ray systems are a great ally of Customs administrations at ports and borders where non-intrusive inspection solutions are a must-have in order to facilitate the identification and interdiction of smuggled goods and threat materials without delaying the international flow of goods.

Despite the larger dimensions of the systems themselves, high energy technologies offer operational flexibility as they can either be placed on a gantry, on a fixed portal or installed in a mobile truck, thus adapting to the site conditions and necessities of each location. Depending on the scanning modality, throughput can average up to 20 scans per hour, or higher. As for the doses of X-rays, high energy systems come in different types. Systems which use 1 MeV [3] usually have a steel penetration of about 125 mm and can be used for vehicle inspection (such as private cars); whereas 6 MeV systems reach up to 330 mm of steel penetration, ideal for scanning shipping containers or trucks transporting cargo. 9 MeV systems can even scan a moving train.

Due to the high penetration into steel, high energy systems allow to inspect even the objects positioned - or hidden - in the center of the container. To that purpose, the majority of high energy systems implement a fan-shaped X-ray beam because the intensity of the beam increases in the center of the scanned container. Fan-shaped beams also guarantee that the whole of the vehicle is scanned, without leaving any dead angle. Operationally speaking, that translates into one single X-ray image containing both the conveyance and the cargo itself. Relevant information from the manifest is usually integrated to allow for the identification of smuggled goods, in addition to security threats (Figure 1).

By passively screening the content of the trucks and providing Customs screening officers with an X-ray image of high resolution, high energy systems reduce or even eliminate the lengthy and costly process of physical inspection, where the container has to be opened and manually inspected. If we rewind the clock by a couple of years when the COVID-19 pandemics began, additional social distancing measures and health regulations made manual inspection not only undesirable but also unsuitable as they posed an increased risk of infection to travelers and Customs officials alike. In this context, Customs were urged more than ever to leverage non-intrusive inspection equipment and automatic detection.

THE CHALLENGES OF HIGH ENERGY X-RAY IMAGE SCREENING

A discussion around high energy X-ray systems for non-intrusive inspection would not be complete without looking at the other side of the coin, the image analysis and interpretation of those X-ray images generated with such powerful devices. Screening officers for vehicle and cargo inspection are entrusted with an extremely challenging task. The large size of the vehicle and the substantial amount of data collected in one single X-ray image, containing both the means of transport and its cargo, make it very difficult for the X-ray screeners to detect contraband goods [4]. The detection becomes even more complicated when the threat items are small, such as a weapon, and even more so when the weapon has been decomposed into parts purposedly concealed in different vehicle compartments and among the cargo. An error such as the non-detection of illicit goods can lead to severe consequences for public safety. On the other hand, operational bottlenecks can occur when the percentage of false alarms is too high and too many vehicles are queued to be manually inspected, which is the everlasting conundrum of Customs screening.

Figure 2: Illustration of the effect of viewpoint depending on object orientation, Schwaninger, Hardmeier and Hofer (2005).

When we consider solely the X-ray image itself, the identification of prohibited items is affected by a set of image-based factors [5]: the viewpoint of an object; the superposition of the object by other objects; and the complexity of the image itself.

The recognition of a dangerous item, such as a weapon, becomes more challenging when the object is displayed from an unusual viewpoint (Figure 2).

Similarly, the detection of an illicit good can be affected when such an item is mixed with other goods, resulting in the superposition (overlapping) of different items and henceforth in a sum

Figure 3: Example of an empty container (left) and of a heterogeneous cargo (right).

of densities. Lastly, the identification of threat and illicit goods depends on the level of complexity of the image itself, due for instance to the type of cargo. An empty container or a homogeneous cargo does not present the same level of image interpretation difficulty than, for instance, a heterogeneous cargo (Figure 3).

When it comes to high energy X-ray images the issue of concealment methods adds an additional layer of complexity, as the possibilities are as varied as the types of merchandise transported.

Until not too long ago, concealment tactics were quite simple such as hiding the contraband in one's bag or in a shipment and on one's person. But the advancement of technology in support of the border control function, has gone hand in hand with the appearance of new and constantly more sophisticated concealment methods to circumvent technological progress, such as for instance the use of hidden compartments; the exploitation of dense objects to function as shields; the disguise of contraband as safe, innocent items; the insertion of contraband with electronics and machinery; the separation of an illicit object into its components and the hiding of contraband among perishable goods.

Last but not least, with high energy X-ray images, two natural side-effects of all X-ray systems become particular challenging in the image interpretation and analysis process: the geometric magnification and distortion. Those two phenomena are a result of the fan-shaped X-ray beam which if, on the one hand, allows for the whole container to be scanned, on the other hand, causes the objects that are closer to the beam source to appear bigger and to shift upwards in the image. Ultimately these effects allow us to see a 2D image of a 3D vehicle, but they come at a price. Figure 4 provides a visualization of the cargo scanning process and shows the fan-shaped X-ray beam irradiating a truck from the radiation source.

Knowing and understanding the magnifying and shifting properties of the X-ray beam is helpful in locating the exact position of a potential anomaly, which is the final step of vehicle inspection. A screening officer that understands those two phenomena will be able to recognize if, for instance, certain organic packages that appear in the image – that could likely be drugs or currency – are located on top of a vehicle seat or hidden inside the seat upholstery. In the first case, the vehicle will probably be cleared as there is no concealment intention, from which we can deduct that the organic packages do not contain an illicit material. In the second example, on the contrary, the concealment intentionality is evident, and the vehicle will be subject to a physical inspection.

Similarly, a screening officer who understands the implications of geometric magnification and distortion in the X-ray image, would be able to identify if certain contraband goods are positioned among the merchandise on top of the container floor or if the goods are hidden in a special compartment built into the container floor. In both of these examples the vehicle will undergo a physical inspection, but the officer who undertakes such task, will find it useful to know exactly where to look for the contraband goods.

CONCLUSION: THE IMPORTANCE OF TRAINING

The image analysis and interpretation of X-ray images generated with high energy systems is a complex and challenging task, as several factors come to play in the detection of security threats, illicit goods and anomalies, be it undeclared merchandise, firearms or protected species illegally traded.

To make such tasks more effective and efficient, there is a critical theoretical knowledge that the screening officers should acquire, which is a perfect complement to practical exercises and training. A new hire in the screening operation or a screening officer that is transferred to high energy X-ray systems for the first time, would benefit from an initial preparation that delves into the topics of how high energy X-ray technologies affect the image analysis and interpretation; vehicle types, sys-

tems and components; and concealment methods, just to mention a few. Besides, in order to analyze accurately such big amount of data in each image, the screening officers should know what image analysis process to adopt on a case-by-case basis and apply a specialized methodology for threat and illicit good identification.

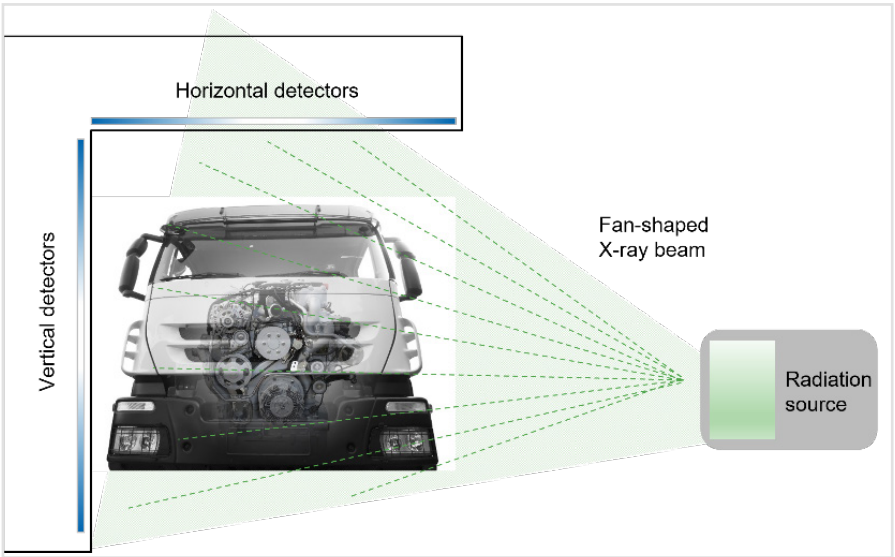

Figure 4: Simplification of the scanning process of a truck.

Such theoretical knowledge should go hand in hand with practical exercises that can guarantee knowledge transfer. Results of several studies have shown the importance of individually adaptive computer-based training to achieve and maintain a good detection performance in cabin baggage screening [6,7], hold baggage screening [8,9], and also in cargo screening [10].

CASRA's computer-based training (CBT) system, X-Ray Tutor 4, allows the screeners to be confronted with large X-ray image libraries which present the threats and illicit goods under different perspectives. Additionally, the individually adaptive software can present the trainees with images that are tailored to the knowledge and skills of each individual person through a systematic analysis of all training data. Ultimately, CBT accomplishes the dual goal of increasing detection performance while reducing image analysis and response time.

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THE AUSTRALIAN DEPARTMENT OF AGRICULTURE, WATER AND THE ENVIRONMENT'S IMPLEMENTATION OF X-RAY TUTOR 4 IN ITS TRAINING PROGRAM

Text: Sara Bracceschi

Biosecurity refers to measures aimed at preventing the introduction and/or spread of harmful organisms to animals and plants in order to minimize the risk of transmission of infectious disease. In this interview John O'Brien, National Radiation Manager of the Detection Capability Division with the Australia Department of Agriculture, Water and the Environment will describe the challenge that his division was facing in early 2020 and will comment on his experience developing X-ray training modules focused on bio-security threats by using CASRA's XRT4 Expert license.

INFOBOX: X-RAY TUTOR 4

CASRA's computer-based training application X-Ray Tutor 4 (XRT4) combines training and testing modules for single view, dual view and 3D CT images all in one solution, thus supporting various areas of operation.

The XRT4 Expert license allows a whole range of customization and tailoring to reflect the customer's requirements. Expert administrators can build their own training and testing sessions, both practical and theoretical. Additionally, own images can be uploaded in different formats and can also be combined with image libraries provided by CASRA.

INTERVIEW

The aim of the Australian Department of Agriculture, Water and the Environment is to enhance Australia's agriculture, environment, heritage and water resources through regulation and partnership. In this article we will discuss how CASRA has supported the Detection Capability Division of the Australian Department of Agriculture, Water and the Environment in the development of biosecurity training modules, through an interview conducted with John O'Brien, National Radiation Manager, Detection Capability Division, Department of Agriculture, Water and the Environment.

WHAT IS THE ROLE OF THE DETECTION CAPABILITY DIVISION OF THE AUSTRALIAN DEPARTMENT OF AGRICULTURE, WATER AND THE ENVIRONMENT?

The division's role within the Department of Agriculture, Water and the Environment is primarily to administer our X-ray equipment. We also play a role when it comes to detective dogs as a border clearance or screening tool and work on future detection technologies.

WHAT ARE THE MAIN DIFFERENCES BETWEEN YOUR MISSION AND GOALS AND THE ONES PURSUED BY CUSTOMS?

Australia is quite unique, as it is New Zealand, in the way that we undertake border screening. In Australia it is split between two agencies. Biosecurity is what our agency is primarily responsible for, which is the protection of Australia's flora and fauna. More specifically, our function involves the use of X-rays for bio-security screening and that relates to the inbound screening of passengers and mail, as well as shipping containers, all freight or passenger pathways into Australia, but also sea cargo and cruise ships. We primarily screen inbound for plant and animal material that could carry pest-borne diseases into Australia and harm Australia's agricultural industry. That is our primary reason for being, compared to Customs which is very much focused on duties, alcohol, narcotics, weapons and those sorts of items.

WHAT WERE THE SPECIFIC NEEDS YOU WERE FACING WHEN YOU ENGAGED WITH CASRA?

When we first engaged with CASRA in 2020, we were undergoing an internal review into our departmental work related to African Swine Fever (ASF) response. As a result of that review, we set as a goal to enhance our capability of cross-skilling partner border agencies for the screening of ASF risk products. ASF is a contagious viral disease that affects domestic and wild pigs. Because ASF is not currently present in Australia, it causes close to 100% mortality rate in pigs and therefore represents a very high risk to our pig farmers in Australia and to the associated industries that rely on pork meat and products.

Once we implemented CASRA's XRT4 platform, we were able to successfully create an introductory training module on such platform, that also our colleagues and our partners in the Australian Border Force and Home Affairs could undertake to enhance their skillset, hence meeting our goal of cross-skilling. Alongside that, we decided to undergo a redevelopment of our 2D X-ray training program. Such program was very much locally focused in the various states in Australia rather than being an overall national program and we recognized the need to have a more enhanced training package that was more measurable and that was based on more defined program outcomes.

WHY DID THE AUSTRALIAN DEPARTMENT OF AGRICULTURE, WATER AND THE ENVIRONMENT CHOOSE CASRA?

During those developments, we identified that CASRA's XRT4 platform was a suitable option to develop additional training or performance-based metric modules for our own biosecurity officers to be trained on. Also, CASRA supported us with the development of a specific training module on pork meat with images provided by AWE, while we were getting familiar with the XRT4 platform, before being fully trained to take on such task ourselves with our Expert license.

bit more familiar because they see the same symbols and characters when they are using the platform to train.

From our perspective as the developers of the training modules, the platform has got some very good data reporting ability and even if at the moment we do not have all the specific bio-security categories, we can still see a lot of information that we haven't been able to have access to before. Additionally, rolling out updates is quite straightforward as it is making changes, and you can push those straight out.

also see how our officers were responding to the platform. Our vision had always been for the XRT4 platform to be a part of our training mix on X-rays for us internally, specifically for biosecurity officers.

As for those biosecurity modules, initially we created them in collaboration with CASRA. In this early phase, we were able to do some development ourselves but also got some assistance from CASRA around the overall structuring of the modules, presentation integration into the platform, as well as on some of the reporting metrics and how to set those up. That was the first piece.

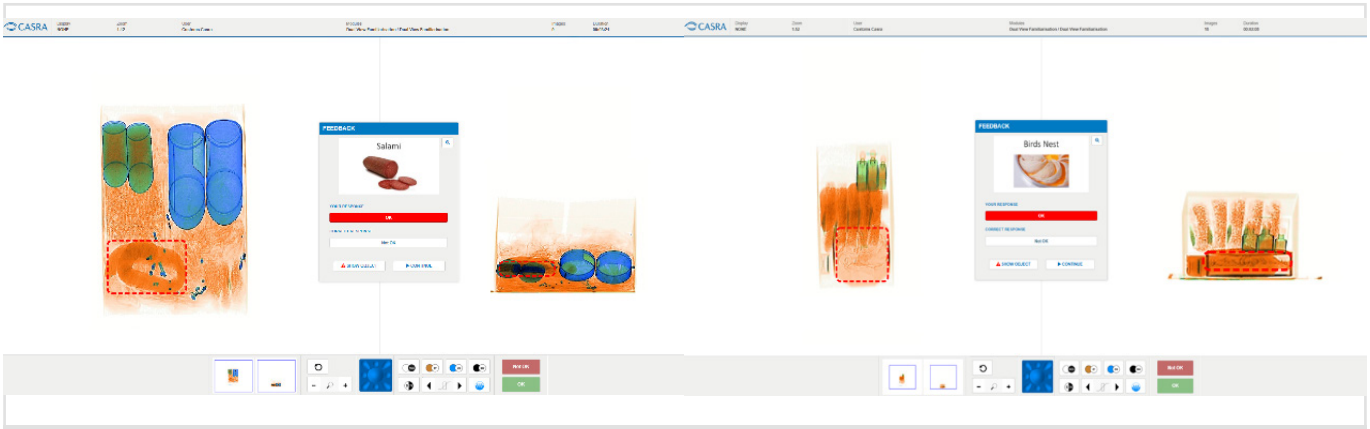

Figure 1: Image displayed in XRT4 training created for the Australian Department of Agriculture, Water and the Environment.

WHAT WERE THE MAJOR BENEFITS RECOGNIZED IN USING THE XRT4 PLATFORM?

XRT4 has a fairly intuitive interface. We have had a small percentage of officers that are not necessarily very tech savvy and a bit resistant to change and who haven't loved it, but by enlarge we haven't needed to write a lot of information for people to be able to use it. They have just been able to get on and train on it. It has pretty much worked quite well out of the box.

What has also been very beneficial for our officers is the fact that it mirrors the control interface that they use on our existing 2D X-ray unit, being the Smiths Detection units, so it makes it a little

Jackie Lowe, who has recently joined John's team as an X-ray technical manager and has been leading recent enhancements to the 2D training course added that in addition to the reporting capability, it is very useful to be able to see the status of the users. She mentioned how they encountered the need, for instance, to do a couple of reloads and how the unrolling and re-enrolling of the users has been fairly easy and rapid.

HOW WAS THE PROJECT ROLLED OUT?

Our approach was a phased one, and I am referring here to the new biosecurity modules that we rolled out rather than just the ASF module, since that was more of a proof of concept and a trial to

We then tested it internally with members of Detection Capability, to check if there were any major glitches that we had not noticed. Since the people involved in this first test were from our division, it was a safe environment for testing as even in the case in which glitches were discovered, that would have not undermined the whole program.

Subsequently, we selected a more diversified team to roll out a pilot. The team was composed of operational officers from our broader training division that are not in Detection Capability, from our policy team and from back-office functions so that we had a really broad set of people providing feedback. That pilot was critical to investigate what a poten-

tially acceptable pass grade should be and to also evaluate the difficulty level of the modules that we had developed. We built on this initial baseline data to begin the operational rollout. For that, we firstly selected a specific state in Australia, Queensland, which was our soft launch. Queensland was the perfect candidate as it had just enough officers to be able to give us a good indication of whether the program was going to be a success once formally launched. From the soft launch we gathered that there were certain aspects around messaging and communications that needed to be refined. After that, the program was launched nationally.

That was the approach we took for the initial launch. Following on from that we had some additional feedback from our pathway teams around the pass marks and the feedback received from the officers regarding their performances. We refined yet again our messaging and communications so that our officers would fully understand what it meant to pass: that is that if the pass mark is 80% that doesn't mean simply getting 80% of the images correct but also having to take into consideration if the correct area in the bag was identified, as well as not marking the clear images, because that is how we had set our pass marks.

We have learnt a lot from the launch and were able for instance to do a relaunch purely focusing on benchmarking and baselining officers' performance without necessarily letting them know how they had performed at the end of the module so that nobody is stressed, and that's effectively the process that we have taken up to this point.

WOULD YOU SHARE WITH US THE USERS' FEEDBACK ON THE PLATFORM?

Users' feedback on the platform, as mentioned before, has been largely positive. There have been small subsets that have said that they are uncomfortable with certain aspects but once we have been able to explain how those aspects work, we have not just reduced but eliminated those concerns altogether.

WHAT WERE THE MAIN FINDINGS OF THE STUDY?

The overall project is still going and will keep going for a while yet, so it is too soon to speak about findings. We have only just recently relaunched the benchmarking again and so far, we have not received any negative feedback and it seems that officers are getting through the platform quite well. Actually, our officers have recently been inquiring about their performance since with this relaunch we decided not to inform the users of their marks until we will have the opportunity to review the data and speak with our executives to decide what that pass mark should be. At that point, officers will be notified.

WHAT WOULD BE A PLAUSIBLE NEXT STEP IN YOUR TRAINING PROGRAM?

I mentioned before when talking about XRT4 reporting capability that, even if we did not have all the specific biosecurity categories, we still managed to collect very relevant data that we did not have access to before using the platform. That is because the platform as it was, had several different categories for security threats and prohibited items but not all the specific categories for biosecurity threats. We are now working with CASRA on implementing those categories which will be available later this year and with that, we will be able to advance our biosecurity training program even further.

Last but not least, we are interested in duplicating the success we have had in our 2D training program for our new 3D training program provided by CASRA.

Science & Security – CASRA Newsletter
ISSN 1664-5715

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