

Customs Detection Technology

Project Group

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SHAPING THE FUTURE

- Exploring the potential of detection technology



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2 Introduction

2.1 Foreword

We live in an era when terrorism and serious crimes can easily cross national borders. Faced with these problems, Europe's customs authorities are increasingly called upon to carry out security-related tasks that go beyond their traditional tax-related duties.

Customs authorities are thus facing new challenges. They must ensure the smooth flow of trade on the one hand, while protecting the safety and security of the EU's citizens on the other hand. To find the right balance between these demands, customs procedures and control methods must be modernised, and cooperation between the different services must be reinforced.

The security of the EU, of the Member States and of ordinary people depends on finding the right balance at each and every point of entry of goods into the EU. If customs authorities fail to tackle the risks along the EU's external borders, the customs union and the EU's single market will become unsustainable.

Detection technologies have long played an important role in customs border checks, by making it easier to detect dutiable, prohibited and controlled goods and materials. As the volume of international trade has expanded, the role of customs authorities has evolved to deal with the resulting new threats. They have achieved this by placing an increased emphasis on supply-chain security and trade facilitation.

Significant advances have been made in detection technologies over the last 30 years. These advances have been especially driven by an increase in global terrorist activity, which has made security a top priority for European customs authorities. Although the detection of explosives concealed in airline baggage was a key priority, the need to improve detection capabilities in other areas was also recognised.

Research and development in detection technologies is a complex process, requiring an in-depth understanding of end-user needs, including operational goals and real-life constraints. Frequently, end users are forced to choose detection technologies which do not fully meet these needs, but which provide the 'next-best' available solution. The Customs Detection Technologies Project Group (CDTPG) has advised on key challenges in the field of detection technology. Security research funding, such as that available under the current Horizon 2020 'Secure societies' work programmes (and earlier funding under the European Commission's Seventh Framework Programme) has allowed customs administrations to engage with academia, industry and research bodies to develop innovative responses to their challenges. However, there still remains a need to evaluate existing detection technology applications and techniques on a more in-depth level to improve detection capability across the broad range of areas for which customs authorities have responsibility. To help in this task of evaluation, the CDTPG has produced guidance documents on standardised evaluation of detection technologies, and on the application of technology as part of detection architecture. In 2017, the CDTPG released a report concluding that customs authorities could become more efficient and effective by making full use of automated information and detection technology.

Decision-makers in customs administrations are faced with difficult choices when procuring detection technologies. A wide variety of illicit goods and materials is smuggled across borders, often by concealing these goods within legitimate shipments (so-called concealments). As global trade continues to grow, there is also a growing requirement to provide supply-chain security assurance.

Both these trends imply a greater need for new equipment, but budgets for equipment and support are constantly under pressure in difficult economic times.

It is therefore vital that detection technology capability is optimised by using new and existing technologies.

2.2 Executive summary

EU customs administrations are increasingly turning to detection technologies to help them facilitate legitimate trade while simultaneously conducting necessary border checks in a wide variety of environments.

Movements of cargo and passengers are projected to continue rising every year, but there is no guarantee of an increase in resources for customs administrations. This has led customs administrations to conclude that improved technology may be one of the few ways open to them to maintain or increase the efficiency of border checks.

2.2.1 The purpose of this document

This document is an update of the 2013 Shaping the future – exploring the potential of detection technology- report on detection technologies and is produced by the Customs Detection Technology Project Group (CDTPG)¹. It builds on the recently updated ‘Threats and technology solutions’ document, the 2017 ‘Vision’ document, the 2016 ‘Detection architectures’ paper, and the 2016 guidance paper on standardised testing and evaluation of detection technology protocols of the CDTPG. Technical, societal and political developments require the CDTPG documents to be regularly updated. Under its 2017-2020 mandate, the CDTPG will update both the ‘Threats and technology solutions’ document and this ‘Shaping the future’ document.

The ‘Shaping the future’ document considers a number of ways to improve and extend the longevity of detection systems and identifies the CDTPG’s goals.

This document recognises that off-the shelf technologies still have a role to play, but the group draws on its collective experience of a wide range of equipment to highlight some of the limitations in capability of many of the currently available systems. This experience is shared, so that if administrations are new to a given technology, they can be fully informed about it and can work to deploy the equipment to maximise its strengths. This knowledge is important for operators, as it helps maintain their confidence in the equipment through high standards of training. Best practices are shared among the member administrations.

2.2.2 Considerations for the deployment of detection technology

The procurement of detection technologies is a significant investment for customs administrations. It requires strategic financial planning to be undertaken to ensure that all costs for the purchase, operation and maintenance of the equipment are provided for over its economic lifetime. It also requires strategic personnel planning to ensure adequately trained staff are available throughout the service life of the technology. Factors such as existing and future threats, traffic volumes, and trade routes should also be taken into account.

¹ The group commenced work in January 2011 and currently consists of customs detection technology experts from Austria, Croatia, Germany, Finland, France, Greece, Hungary, Ireland, Italy, Lithuania, the Netherlands, Poland, Slovakia, Spain, Turkey and the United Kingdom. The group is chaired by the Risk Management and Security Unit of the European Commission’s Directorate-General for Taxation and Customs Union.

Procurement procedures can be quite complex. It is therefore advisable for Member States to consult with each other to learn from experience gained by others in the procurement process, and in the operation of similar detection systems.

Frequently, the capabilities of detection equipment are 'over-sold', resulting in disaffection and loss of confidence in a given technology following a period of use. A clear understanding of the technology's capabilities and intended purpose is important. Annex B of this document outlines the technical capabilities and practical limitations of currently available technologies.

The efficient and effective operation of detection equipment is dependent on timely maintenance being carried out. In addition, customs administrations should ensure that they agree with the equipment manufacturer a set number of hours per day or week that the equipment must be functioning. This will limit down time. In addition, an enforceable statement on the desired balance between productive and unproductive hours should limit down time. Typically, purchase contracts provide for a short period of maintenance/warranty. Experience has shown that follow-up maintenance contracts, especially for cargo-screening systems, can be quite expensive. It is therefore advantageous to include extended maintenance/warranty provisions in purchase contracts. Failure to maintain systems properly can lead to a reduction in performance, increased down-time and a shortened lifespan of the equipment.

The human element in the use of detection technologies should not be underestimated. In specialist areas, such as image analysis and dog handling, recruitment procedures should ensure that the selected staff members have the skills, required for the position.

Training programmes should be put in place to provide introductory, refresher and advanced training for operators of the various types of equipment. Customs administrations should consider the establishment of one or more common training centres in the EU. They should also consider a staff mobility programme, so experts from different Member States with detailed knowledge of certain types of scanning equipment and systems can travel to other Member States to share their knowledge.

2.2.3 Technology standards and good practice

Member States can learn from each other's experiences by sharing information on trends, seizures, concealments and best practice in the operation of detection systems. Methods for standardising and sharing this information should be explored, following the example of those countries that currently operate such information exchanges.

In order to carry out an objective assessment of technology performance, it must first be measured. Measurements may include standard statistics such as the number of inspections carried out, the number and value of seizures made, and the number of personnel hours involved. However, these standard statistics could be made much more useful if they were complemented with statistics on the amount of true positive, false positive, false negative and true negative results produced by each detection technology. This would provide a valuable insight into the effectiveness of individual technology applications.

Additional improvements could be achieved through the establishment of detection-technology quality systems which would continuously monitor all aspects that contribute to the quality of the technology output.

Essential aspects that contribute to the quality of the technology output include: it being fit for purpose; it being well maintained; it targeting appropriate goals; it being operated by trained personnel; and it being continuously monitored by staff and management.

To date, very few formal standards have been available for customs detection technology. The introduction of standards can help customs administrations to manage technologies. For example, standards could cover the setting of: procurement requirements, lifetime operation criteria, performance criteria, and standards for the final disposal of the equipment. Such standards could also help technology suppliers to better understand customs requirements. Examples of standard evaluation protocols are given in Annex C.

2.2.4 Research and development

The European Commission's Directorate-General for Taxation and Customs Union (DG TAXUD) considers security research and development to be fundamentally important to achieving the two goals of EU customs policy: improving supply-chain security and facilitating trade. The deployment of detection technologies allows customs authorities across the EU to manage risks with available resources, facilitate legitimate trade, and conduct effective and efficient checks.

In many instances, the detection technology used by customs authorities has not been specifically designed for customs purposes and represents the 'next-best' available solution. For a variety of reasons, there has been little opportunity for customs authorities in EU Member States to work with technology suppliers in the area of research and development. The EU's Seventh Framework Programme has given individual customs administrations the chance to participate in research projects focusing on the development of detection technologies. However, there is still a need for customs authorities to make their requirements more widely known among technology suppliers and the research community.

2.2.5 Conclusions and recommendations

The CDTPG has identified a number of areas where existing detection technologies are not suitable for the detection of current threats. It has also highlighted areas where operational performance can be improved through better training, sharing of information and best practice. Programmes such as Customs 2020 can help achieve these goals. The CDTPG believes that the introduction of quality standards and monitoring can optimise efficiency and effectiveness.

Finally, the recommendations we present for the short, medium and long term in the annexes will constitute the basis for discussions of EU customs administrations with academia, research institutes and the security industry. These discussions should address future research and development activities that address specific customs requirements for detection and control equipment based on evolving threats and the constantly changing sophisticated smuggling methods.

For further information, please contact DG TAXUD.A3 Risk Management and Security.

Mrs Lina Papamichalopoulou,
Head of Unit – DG TAXUD.A3. Risk management and Security
Tel. +32 2 298 6493
E-mail: Lina.Papamichalopoulou@ec.europa.eu

Mr Michel Verschraegen Head of Sector Security of the Supply Chain – DG TAXUD.A3
Tel. +32 2 296 2014
E-mail: Michel.Verschraegen@ec.europa.eu

Mr. Wil van Heeswijk,
Chair of the project group – DG TAXUD.A3
Tel. + 32 2 297 1615
E-mail: Wil.van-heeswijk@ec.europa.eu

Mrs Stella Nicoloudaki,
Assistant – DG TAXUD.A3.
Tel. +32 2 296 0979
E-mail: Stella.Nicoloudaki@ec.europa.eu

3 Conclusions from the ‘Threats and technology solutions’ document

3.1 The ‘Threats and technology solutions’ document

Based on the annex to the updated ‘Threats and technology solutions’ document No TAXUD/A3/020/2018, an analysis was carried out to provide more information on the available technology solutions. The annex was constructed based on a questionnaire filled out by CDTPG members. The questionnaire identified a large number of possible technical solutions and asked each CDTPG member to indicate which solution they applied for each type of border crossing, for each mode of transport and for each threat category². The number of solutions found to be applied was added up yielding a total number of technologies applied. The figures below depict this data for each type of border crossing (Figure 1), mode of transport (Figure 2) and type of threat (Figure 3).

Figure 1 below shows the number of technical solutions per type of border crossing. It shows that there are 163 possible technical solutions available for road borders. It also shows that there are 220 possible technical solutions available are for maritime borders. However, a limited amount of solutions is available for rail and postal border crossing points.

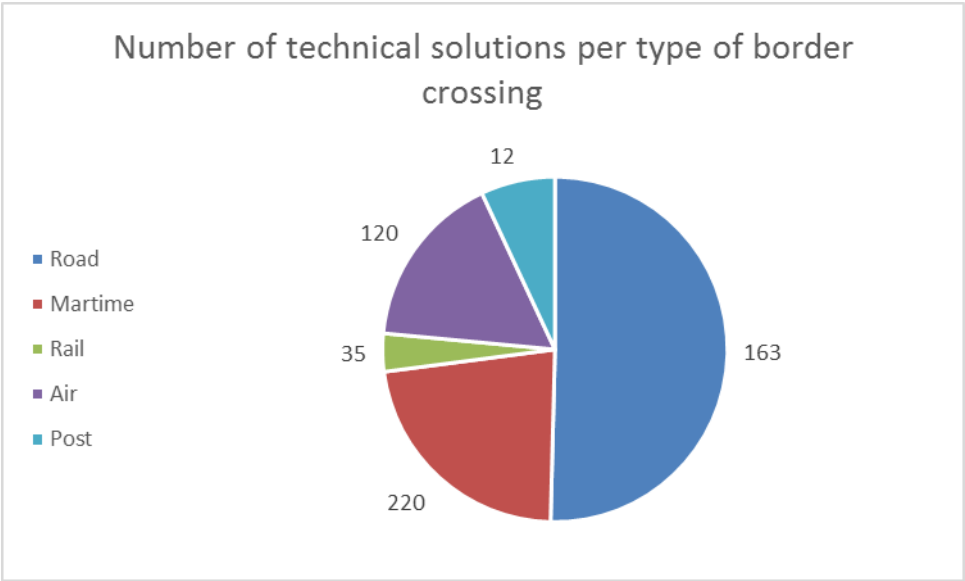


Figure 1: Technical solutions available per type of border crossing (total number).

In Figure 2 the number of possible technical solutions is given for modes of transport. It is clear that most solutions are available for freight (220), baggage (163) and (120) vehicles and far less solutions are available train carriages (8), ships (12), airplanes (16) and post (43).

² The used threat categories are determined by the World Customs Organization’s Customs Enforcement Network.

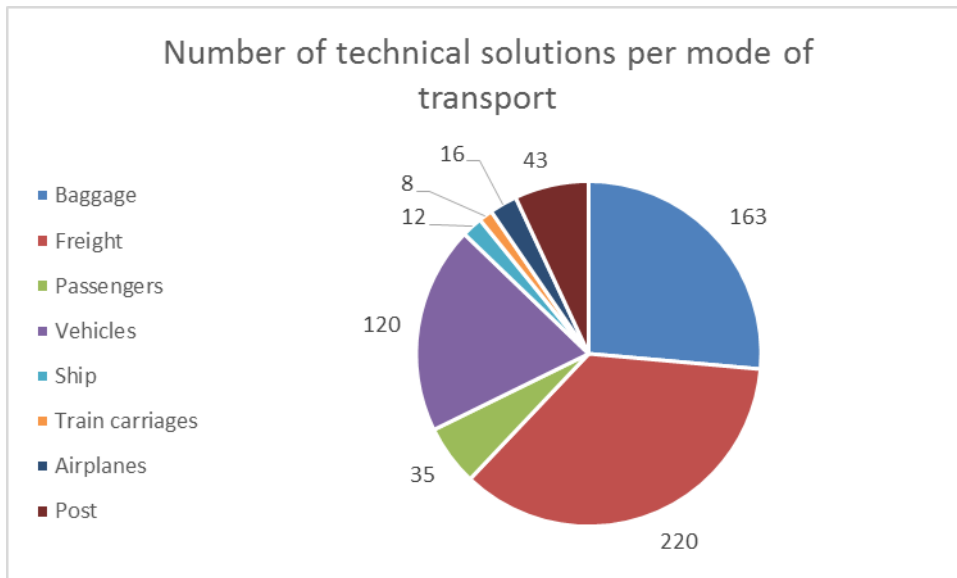


Figure 2: Technical solutions available per mode of transport (total number)

Figure 3 shows that there are 128 possible technical solutions available for checking for drugs and precursors. It also shows that there are 98 possible technical solutions available for checking cigarettes. In contrast, for waste, oil and illegal immigration a relative small number of possibilities exist.

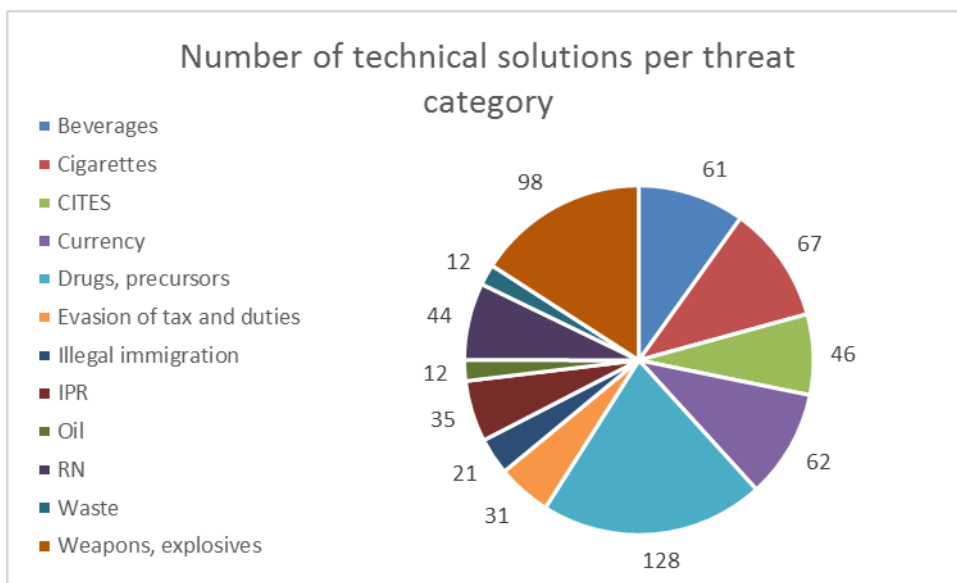


Figure 3: Technical solutions available per threat category (total number).

The above results make it possible to estimate which areas of inspection are making less use of technical assistance and may therefore be in need of further technological support. If a key area of inspection is found to be lacking in available technical solutions, Customs administrations can call for research and development in this area. For example, the CDTPG has suggested topics for the Horizon 2020 research and development programme to cover the inspection of train carriages and post. Figure 3 shows that this is an area with very few technical solutions available. In particular, there is a lack of solutions for the inspection of train carriages loaded with high-density materials.

Based mainly on this type of analysis in the first version of this document, the CDTPG has produced its 'Vision' document on detection technology use with EU customs administrations. The 'Vision' document provides advice about what direction research and development should take.

In addition to the numbers already mentioned the answers to the questionnaire also highlight that the EU Customs administrations make use of a limited set of technology solutions that does not change much from member state to member state.

3.2 Conclusions

There are not many technical solutions available for inspections at border-crossing points for rail traffic and post. There is a relatively small amount of technical solutions available for the inspection of train carriages, ships and airplanes. Oil products; illegal immigration; evasion of tax and duties; illicit movement of waste consignments; and goods that infringe intellectual property rights are the categories of threats where the fewest detection technology options exist. Parts of this analysis may form the basis for future research and development.

3.3 Short-term, medium-term and long-term goals

Short-term goals

- Evaluate the current situation on customs detection technology to indicate whether the available equipment is sufficient for effective and efficient inspections.

4 Challenges in the use of current and emerging technologies

4.1 Challenges in the use of current technology

Technology is an important part of the everyday operations of customs administrations. Together with other means of inspection, technology offers customs authorities a way to improve their efficiency while maintaining their effectiveness. With global trade and passenger movements set to rise in the coming years, technology will become ever more important.

The capability of new technology is often over-stated by manufacturers. Almost all manufacturers claim that their particular technology can help customs authorities to detect a wide variety of threats, such as narcotics, explosives etc. Unfortunately, many other factors must be taken into consideration. This means that the link between technology use on the one hand, and increased efficiency and effectiveness on the other, is not as clear as the product brochures claim.

The customs officer should be perceived as an integral part of the technology. To make the right decisions, in most cases, the customs officer must have a quick result and at the same time interpret the raw information the technology provides. This is particularly true for imaging technologies, which require a high-level of expertise. But even technologies that deliver already-interpreted information require officers to understand the technology and how the raw information is interpreted.

Inadequate knowledge may result in technology that fails to perform as expected, as customs officers may start to distrust the technology, making it less effective. It is perhaps more accurate to say that the weakness of any technology may actually reflect an expectation that exceeds the technology's current capability.

There is no single solution to this problem. There is no one piece of technology that can do everything, although some manufacturers may claim otherwise. Technology, when used correctly, can provide us with great benefits, but only if we understand and work within the scope of its capabilities.

Manufacturers will understandably concentrate on the positive aspects of their product and may not admit to its weaknesses. However, if their product's limitations are known, then expectations can be managed and the product will only be used in a way that plays to its strengths and avoids its weaknesses. It is therefore imperative to carefully test any technology before purchasing it. Lessons learned from this testing phase should be part of the training given to customs officers who subsequently use the technology.

As an example, the operator of a particle analyser (IMS) may put a visible amount of cocaine on the sample trap of a trace system, but find that the alarm fails to trigger. That officer might begin to make negative assumptions about the system, and in doing so might even influence the views of other colleagues. The operator in this case would not have understood that a particle analyser is a system designed to measure nanogrammes, and he would therefore have overloaded the device.

Users often venture beyond the capabilities of a technology, but it is important to understand that this is a limitation of the technology, and not a fault. For example, x-rays cannot penetrate very dense material, so the operator of an x-ray machine should not expect a clear image to analyse.

Historically, smugglers have attempted to exploit perceived gaps or weaknesses in our use of technologies.

Many customs officers will have experience of low-tech attempts to evade detection, such as coffee grounds to mask odours and carbon paper to 'evade' detection by x-ray. 'Trace' detection has been useful in identifying people with ingested narcotics, by picking up traces of contamination from clothing. However, some smugglers have sought to counter this by not touching the drugs, so no contamination would be detected on them by trace systems. Similarly, smugglers try to evade x-ray detection by placing illicit material behind very dense objects.

Annex B lists some of the types of technology which are available and some of their limits. The annex was not compiled to criticise these technologies, but to offer some background to those new to a particular technology. There is no silver bullet. There is no one piece of technology that can do everything, despite contrary claims from some manufacturer. Technology, used correctly, can provide us with great benefits, but only if we understand and work within the scope of its capabilities.

4.2 Challenges in the use of emerging technology

Some emerging technologies can conduct rudimentary chemical analysis, offering the potential to identify specific commodities. This could mean that, in addition to detecting prohibited goods, we might also be able to identify goods which are subject to taxes by the Member States, such as hand-rolling tobacco. We might also be able to detect certain commodities which are wrongfully declared in order to attract a lower tariff rate. But the first customs administration to use an emerging technology must also solve the problems that always occur when new technologies are implemented for the first time. Who is willing to make this step?

One of the attractions of some of the emerging technologies is that they are less reliant on the interpretation and decision making of individual operators. The advantage of this is that every inspection would be to a consistent standard. It would also let customs officers do what they do best, rather than loading additional responsibilities on them to understand science and technology. However, these new 'intelligent' technologies that rely on algorithms also need maintenance. However, these new intelligent technologies raise many questions. For example, what assumptions do we use when we programme the algorithms? And how can we assure privacy of personal data?

If a new technology is found to be extremely effective but rather expensive, its deployment might be restricted to a limited number of border locations. In that case, smugglers would simply evade those points. If the technology is too expensive, those Member States which could not afford the new technology could find themselves subjected to a greater level of illicit trade than before, which would place an unexpected additional burden on them.

How should customs administrations approach the use of emerging technologies? We could wait until the technology has matured so it fully meets our requirements. This might mean waiting a long time. The other option is to acknowledge that the emerging technology is not a complete solution, but recognise that it delivers more capability than we have now. One view is that purchasing such immature technology could be a waste of time and money, but from another perspective, the purchase and use of emerging technology stimulates productive interaction with producers and further development. Moreover, procurement of emerging technology may also result in the creation of new fields of technology and useful commercial competition.

With cargo shipping and passenger movements set to increase in the coming years, we may not have the luxury of waiting too long before technologies are fully mature.

Customs administrations need to consider how much they are able to invest, and what they want from technology. In particular, they must consider what they are prepared to compromise on in the short-term, as implementation may take longer than initially expected. A pragmatic, rather than a utopian, approach would be welcomed by both detection experts and commercial actors. If customs administrations are too small to promote development by themselves, cooperation with other governmental bodies could be a viable way of broadening demand. Cooperation with other governmental bodies has an additional benefit: it may reveal that a solution has been thought about elsewhere already, thus avoiding the need to develop new technology.

To move forward we must identify precisely what we want technology to do for us and how we want to use it. We will have to remember that various constraints may prevent development of a new technology. If so, user requirements may not be met, or significant investment may be required to meet those requirements. Are the risks of development worth the investment, and if so how the development should be funded?

No matter how well any new or existing technology purports to work, if a human operator is required, the technology's overall effectiveness will be determined by the experience, training and motivation of that operator. If little attention is paid to recruitment and training of the operator, then expectations for the technology may not be met. Training should be continuous. As technology becomes more advanced, it may prove useful to set up specialised teams that are more familiar with the use and interpretation of complex detection devices. These teams could also act as an interface with the customs laboratories.

4.3 Short-term, medium-term and long-term goals

Short-term goals

- Ensure the goals of recruiting and training are aligned with the financial investment in technology.
- Ensure that the experience gained by staff is re-invested in continuous training to improve the skills of customs officers who operate technology.
- Encourage customs officers to share with colleagues their experiences of different smuggling methods and successful seizures.

Medium-term goals

- Set up shared databases for listing the results of different detection technologies so that customs administrations can learn from each other.
- Invest in emerging technologies.

Long term goals

- Promote emerging technologies that can automatically detect a broad range of relevant targets, or specific items that are of interest to customs authorities.
- Promote the use of emerging technologies that fill the gaps identified in the 'Threats and technology solutions' document.

5 Sustainable use of detection technology

The volume of international trade is increasing and along with the emphasis on supply chain security and trade facilitation, the role of customs is evolving rapidly. To deal with the increased flow of goods and people associated with this growth, European customs administrations are looking to detection technologies to make their inspection processes more efficient and effective.

Along with this growth, an increase in illegal trade may be expected. Concealments of illicit goods can be highly sophisticated. These goods can be concealed in cargo, in personal belongings, or in small spaces on ships and planes. Illicit goods can even be concealed inside the human body. To reliably stop illicit goods from crossing borders with the increasing flows of goods and people, customs administrations in general — and detection technologies in particular — must work effectively and without interruption.

The main factors that ensure the optimal functioning of detection technologies include: staff with a clear understanding of the purpose and capability of the technology; financial planning; high-quality maintenance; carefully selected and trained personnel; and thoughtful use of the technology throughout its lifetime. Failure to pay attention to these factors has already resulted in high costs for repair, and in some cases it has even led to the systems not being used. If these factors are not given enough consideration, trade flows will ultimately be dealt with in a less efficient and less effective manner. This will expose society to risks and to reduced public trust in customs authorities.

5.1 Equipment cost

Investment in detection technology does not only involve the initial capital cost of the equipment. It also involves recurring costs that are often substantial.

Typical recurring costs include staffing, training, maintenance, repair, consumables and the other costs of day-to-day operation. Less frequently, significant costs such as changes to existing infrastructure and site-preparation costs may be incurred (e.g. in the case of container screening systems). During the lifetime of a system, upgrades may be required to deal with new threats, or to avail of new technological advances. Asset depreciation costs based on the system's anticipated life expectancy must also be taken into account.

Failure to undertake long-term financial planning to cater for these requirements may lead to the equipment performing less efficiently. In the worst cases, it could ultimately lead to equipment being taken out of use prematurely.

5.2 Financial planning

Decisions to purchase detection technology by customs administrations are usually taken on the basis of planned strategic and operational requirements, which seek to address current and envisaged threats.

The business case for new equipment should identify and quantify, as far as possible, all significant costs likely to be incurred from the moment of purchase, to the moment the technology is no longer used. Decisions on what equipment to purchase should take into account factors such as existing resources and staffing levels. It should also anticipate current and future traffic volumes and traffic routings.

There is no methodology available to measure the deterrent value of detection technology, but a case must still be made to show how the technology can produce an acceptable return on investment. Where possible, this case should include increased revenues and duties.

The role of customs authorities continues to evolve, and new threats continue to emerge, creating new requirements for detection technology. In this context, continuous monitoring and evaluation of the capabilities of customs detection technology are important considerations for customs administrations. When purchasing new technologies, an important balance must be struck between the merits of 'tried and trusted' technologies and ensuring that that new equipment is 'future proofed' against technological obsolescence, or an inability to deal with new threats.

EU customs administrations have invested heavily in detection technology in recent years. Established practices such as x-ray scanning, Radiation and Nuclear detection, chemical trace detection and the use of sniffer dogs can be expected to have a reasonably long life expectancy when maintained carefully. When introducing newer technologies, the possibility of their interoperability with existing systems needs to be considered. Existing detection technologies can continue to play a significant role alongside new technology applications introduced, to improve performance, or address specific shortcomings in existing border checks.

Long-term financial planning for the maintenance of detection technology is critical. Most equipment manufacturers provide a one-or-two-year warranty/maintenance provision in their purchase agreements. But subsequent maintenance costs of detection technology can be very expensive, so the inclusion of fixed long-term maintenance cost conditions in tender requirements can be very beneficial.

The possibility of upgrading existing systems should also be explored. For instance, single-energy x-ray systems can be upgraded to multi-energy systems, thus improving performance. This can be especially helpful in the area of material discrimination, making it easier to see what different materials are made of. Advanced software upgrades may also provide the potential for automatic threat detection.

Medium-term and long-term financial planning can help customs administrations take advantage of funding opportunities for the purchase and deployment of detection technologies, thus reducing their financial burden. Funding for development of ports and other border crossings under the Multiannual Financial Framework may be used to purchase detection technologies for customs administrations. More targeted funding for customs equipment is also available through the EU Hercule III and Internal Security Fund programmes, and through the cohesion policy instruments of the Directorate-General for Regional and Urban Policy (DG REGIO). There are also opportunities to plan for the purchase of detection technology in cooperation with other customs authorities. This can be undertaken by customs administrations and border guards through the EU's integrated border management strategy. This strategy promotes joint or coordinated procurement and the shared use of multifunctional equipment at the EU's external borders. The strategy also supports the implementation of joint inspections and staff training.

Another model that is worthy of consideration is 'detection as a service'. This model is relatively rare within the EU, but more common beyond our borders. In this model, companies build and maintain detection facilities and subsequently operate them on behalf of the authorities.

The authorities are charged per activity or in a lump sum. When planning for options like these, authorities are advised to carefully set quality standards for the service provider to follow as part of the tender process.

Quality standards must not only pertain to the technical characteristics of the technology, but should also take the resulting performance into consideration (including the staff's performance using the technology).

Unfortunately, the customs-policy area is less well-regulated than other policy areas, such as transportation safety. This means that there is little international standardisation to rely on for customs detection technologies.

The introduction of detection technology into established ports and other border crossings will often be more expensive than in a 'green field' location. It is important therefore for customs administrations to engage with port and other relevant authorities at an early stage in the planning process for new developments. This will help them to reduce — or perhaps share — equipment costs.

5.3 Understanding of purpose and capabilities

A single item of detection technology does not provide a solution for all customs needs. For example, there is little point in using x-ray transmission to screen all types of cargo or detect all types of illicit goods. As most customs administrations are hierarchical organisations, knowledge of the capabilities of detection technologies should not be limited solely to their primary users. Efficient and effective use of these technologies may be promoted if selection and inspection departments (in addition to the detection department) have some understanding of the capabilities of each technology. Managers, field officers and operators should all have realistic expectations of each technology's capabilities.

5.4 Procurement, maintenance and planning

The use of detection technologies requires significant investments by European customs administrations and the European Commission. The size of the investments creates expectations for the continuous performance of these systems throughout their lifetime. Regular maintenance, allowing for major mid-life service and the timely purchase of replacements, promotes continuous and trouble-free use of detection technology.

Purchasing detection systems through public tendering may involve a complex process. Purchasers should seek assistance and advice from Member States that have tendered for similar types of technology. This can be carried out through the detection technology spreadsheet constructed by DG TAXUD's Customs Detection Technology Project Group. Experiences of prior tender procedures and from the eventual use of the equipment may be valuable for any subsequent tender procedure. It might also be advantageous for Member States to cooperate in joint international tenders to increase their negotiation and purchasing power.

The purchase of equipment is only one aspect of procurement. It is crucial that all detection equipment is maintained regularly and according to the manufacturer's instructions. Regular maintenance is sometimes overlooked in the initial procurement, leading to significant unexpected costs when negotiating the extension of a maintenance contract with a sole provider of maintenance services. In addition, customs administrations are advised to add contract provisions to their purchase agreement that cover the time allowed for preventive and corrective maintenance. This will prevent customs administrations from suffering long spells where the technology is not available for use.

It has proven advantageous to negotiate long-lasting full guarantees and/or maintenance agreements at the procurement phase, thus reducing the price of maintenance significantly. This is advantageous for customs administrations as it allows them to predict the cost of ownership. Consideration should also be given to training the operators of the equipment in daily maintenance and troubleshooting. Moreover, radiation awareness and safety training are mandatory in most cases, and training may also promote the staff to use the technology in a well-informed way.

Procurement of new equipment, maintenance contracts and major service costs can generally be planned in advance. Such planning helps to minimise difficulties arising from capacity issues, difficult tender procedures, system down-time or lack of availability. A holistic strategic planning, encompassing all detection equipment is advised.

5.5 Use of technology and human resources

For every role it is important to choose the right people for the job. This is especially true for the operation of detection technology, as it requires special skills. It is accepted the operators are critical to the successful use of detection technologies. For example, officers who suffer from colour blindness, or an inability to conceptualise a three-dimensional object from a two-dimensional x-ray image, are not suitable for x-ray image analysis. The necessary aptitudes for operators can be identified through dedicated psychometric tests.

Operators looking for illicit materials often feel like they are trying to find a needle in a hay stack. This creates psychological challenges. Officers must maintain high levels of concentration and responsibility even though illicit materials may be rare. They must also be able to use their own judgement, even when other people have strong opinions on the outcome of the inspection. This means that the operator must be both mentally and physically fit for the job. Officers working with detection technology should have their performance continuously evaluated. The evaluation should be aimed at creating personalised training for the operator. Periodic training on differentiating x-ray images of legitimate materials from those of illicit materials has proven to be successful.

The use of technology by customs authorities lies at the intersection of legal, administrative and technical fields of expertise. Customs personnel rarely hold technical qualifications. Operators must be well trained to understand, work with and maintain the technology, and the best results are achieved if operators use a technology frequently. Most often, training is initially given by the manufacturer of the technology, and subsequent training is given by customs administration trainers. This subsequent training puts even more emphasis on practically derived, professional guidance. It is best practice to set up special units to work with technology so they can gather experience and expertise in one place. This is because if the technology is damaged from use by untrained personnel, the costs will be very high. There are also broader societal costs if illicit goods slip undetected across borders because staff are not trained how to use a particular technology.

5.6 Short-term, medium-term and long-term goals

Short-term goals

- Ensure regular maintenance of all detection technology throughout its service life.
- Set out the maximum down-time allowed for detection technology (ideally as short as possible) in the maintenance contract.
- Conduct financial planning to encompass the costs of purchase, training, maintenance, warranties and replacements for each individual detection technology.
- Work to create understanding of the detection technology in all relevant departments.
- Maintain contact with Member States employing similar detection technology to discuss challenges, compare performance, etc.

Medium-term goals

- Study how to fill gaps in detection capabilities with emerging technologies.
- Conduct financial planning to encompass the costs of purchase, training, maintenance, warranties and replacements for each individual detection technology.
- Work with other Member States to create EU-wide user platforms to discuss challenges, compare performance, etc.
- Develop a training programme to provide recurrent personalised training for operators that includes image analysis and system operation.

Long-term goals

- Prepare a strategic plan for all activities involving the use of existing and emerging detection technology. This plan should encompass all relevant organisational, financial, procurement, maintenance, training and staffing aspects.

6 Technology operational aspects

6.1 Training

Advanced technology is a prerequisite for a modern customs service to efficiently control the cross-border movement of goods. At the same time, it is important from both a national and an EU perspective to ensure that expensive investments in technology provide value for money. Operator training is a key factor in ensuring the successful and efficient use of such technology. Training should be required for newly appointed operators and experienced personnel alike.

Few customs administrations have developed training programmes dedicated to the needs of cargo screeners, especially in the area of image analysis. However, opportunities exist under the Customs 2020 Programme to initiate exchange programmes for training purposes. For example, the Danish customs service has provided training in image analysis to the Hungarian customs service. This training programme included a competitive game between operators, which helped optimise performance and share knowledge and working methods between operators from the different regions.

Another example of this type of training cooperation is the training in radioactive and nuclear material detection provided by the Slovakian customs service to other EU customs administrations at their recently established training facility for special technologies.

Customs officers will be able to further develop their skills following the inauguration of a European Nuclear Security Training Centre (EUSECTRA) on 18 April 2013 at the Institute for Transuranium Elements (JRC-ITU) in Karlsruhe, Germany. The goal of EUSECTRA is to improve the capabilities of Member States in addressing the threats from illicit incidents involving nuclear or other radioactive materials. EUSECTRA provides hands-on training with real materials to trainers, front-line officers, managers of front-line officers and other experts in the field.

Another good example of cooperation is the ‘train the trainer’ campaign for radiation and nuclear detection set up for EU customs officers by DG TAXUD and JRC in 2015-2016. The training succeeded in improving nuclear-security knowledge of the competent user groups in the EU Member States and EU candidate states. Similar training could also be envisioned for other detection technologies.

6.2 Sharing information

Imaging technologies are an important part of the technical assistance available to customs administrations. Transmission x-ray imaging is the imaging technology most commonly used by customs administrations. Customs administrations use a wide variety of x-ray equipment, ranging from small-luggage scanners to very large, fixed x-ray facilities that are capable of scanning large trucks. Customs analysts interpret the images produced by these devices, and make decisions based on the perceived presence of anomalies.

Customs analysts may feel a great deal of pressure to correctly interpret image anomalies, as failure to do so may result in false positives (and false negatives). Given the relatively low prevalence of non-conformities in shipments, it may be difficult to maintain low levels of both false positives and/or false negatives. X-ray analysts may be helped to make better decisions by making available to them a reference database with x-ray images showing known threats and benign items.

Because container scanning is a very small and specialist area, it may be difficult for individual Member States to develop useful procedures for it. The same smuggling modes are used in different locations around the world, and these modes then change so smugglers can escape detection.

For this reason, a shared database of source images and relevant data presented in a uniform format would serve the needs of x-ray analysts across the EU.

The CDTPG recommends that Member States collaborate on a systematic basis in gathering best practices, trends, information on seizures and ordinary image material. The Nordic countries have already embarked on cooperation that contains elements of this recommendation through the Nordic Customs Council. It is now being replicated in cooperation between Germany, Poland and the Czech Republic. When information is exchanged between these countries, nominal and other confidential information is removed. The information exchanged contains an x-ray image, a photograph of the anomaly and details of how the subject was concealed. It also contains a short description of the routing, type of goods and other relevant information. Other Member States may benefit from similar arrangements, particularly with their neighbouring countries.

X-ray analysts can use different criteria to base their decisions on. Familiarity with a wide variety of x-ray images of threats and uncommon benign items may inform changes to the criteria used. The introduction of this reference image database may help improve the detection ability of screeners, thus leading to fewer false positives (or false negatives). It is important that the database is consistent and easy to use, and that it contains information on seizures, modes of smuggling, trends, best practices and common x-ray images combined with relevant data. The current development of an open-source uniform format for x-rays may facilitate such a system.

In addition, now that development has begun on x-ray image interpretation algorithms, the lack of sufficient relevant images in individual Member States has become apparent. Libraries containing threat images and images without threat will be the cornerstone of any useful database.

6.3 Dealing with dangerous materials: chemical and biological threats

The cross-border movement of materials and equipment that can be used to handle and produce chemical and biological weapons is regulated. As there are radiological and nuclear materials and installations that can be used to handle or produce them. The regulated materials are listed in the EU list of common military goods under Council Regulation (EC) No 428/2009 of 5 May 2009 setting up a Community regime for the control of exports, transfer, brokering and transit of dual-use items. European customs authorities are responsible for the inspection of goods that cross borders and that are suspected of not complying with the regulation and ensuing national legislation.

The detection of weapons-grade materials and their precursors at the border by customs officers is challenging for many reasons. Customs officials have daily contact with various substances, some of which are unknown and possibly dangerous. Most of these substances will be admissible, but some are unauthorised. These substances may be used in technical devices and everyday items, or they may be purposefully hidden. Even though procedures may be in place to deal with dangerous goods, these procedures are rarely applied to unknown substances. It is important to have a good understanding of the human body, the impact dangerous materials can have on it, and a correspondingly cautious approach to unknown products.

Without this understanding and approach, incorrect or negligent treatment of unknown substances could result in serious incidents. In the worst case, the public could be exposed to hazardous material.

Field officers may come into contact with a wide variety of substances, ranging from radioactive and explosive goods to chemical and biological products (including narcotics, chemicals, unknown substances and mixtures etc.).

The effects of the different CBRN (chemical, biological, radioactive and nuclear) materials on human health are very different. Another challenge is that small amounts of some chemical or biological materials are often enough to create havoc. For these reasons, the best approach is to take a slow, step-by-step approach to classifying materials, recognising the limited capabilities of customs administrations to deal with these products. Only a small percentage of a country's customs staff knows how to handle hazardous substances and is able to use the tools needed to classify and isolate the risk these substances present. Customs services must have the necessary support and knowledge to move from 'stand-off' (examining a consignment and analysing its contents without opening), right through to opening a consignment. Full identification of a substance will most probably only be carried out in a dedicated laboratory. At all times, if safety cannot be guaranteed (e.g. when sufficient knowledge and support are not available), emergency services should be called in.

The ongoing development of material discrimination using x-ray and neutron-scanning technologies may allow customs authorities to screen for chemical and biological threat materials in stand-off mode. Trace detection technologies are available that can classify, or identify minute amounts of chemical or biological threat materials on surfaces or in the air. It may well be possible to use these technologies to collect classifying information in stand-off mode. At present, there is limited detection technology available to identify these types of threat materials in cargo or baggage. Customs administrations often have infrared, Raman, or detection kits available. Only Raman is suitable for the stand-off identification of materials in see-through containers. If samples of materials can be handled safely, infrared (IR) or detection kits may also be useful.

The trace-detection technologies for chemical-threat materials are essentially the same as those used for narcotics. Usually, the libraries containing databases of known materials will be adapted to a specific purpose, whether that be for narcotics or CBRN materials. One cannot expect the existing equipment to do the work without some modification. For detection of biological-threat materials, or for any biological material, customs authorities will need to gain experience of new technologies such as immunological and polymerase chain reaction-based technologies.

6.4 Short-term, medium-term and long-term goals

Short-term goals

- Conduct joint operations and joint training with neighbouring countries.
- Ensure that knowledge is shared between the different units within customs administrations, for example through regular meetings to present and discuss interesting smuggling cases.
- Ensure that enough qualified knowledge, support, staff or equipment are always available at every border-crossing point to deal with threats – including extreme threats – even if this involves the use of specialised officers.

- Develop a vision on what step-by-step inspections for customs administrations dealing with unknown substances should deliver at each step. Develop a vision for how these steps should be implemented.
- Develop a vision on what step-by-step inspections for customs administrations dealing with chemical and biological threat materials should deliver at each step. Develop a vision for how these steps should be implemented.

Medium-term goals

- Create a standardised format for x-ray images and related data exchange processes. For example, the Nordic countries and others use a standard reporting format for x-ray related cases.
- Ensure that x-ray images and relevant data are made widely available to people and companies developing x-ray image interpretation algorithms.
- Cooperate with relevant experts in CBRN detection to ensure sufficient knowledge and support is present at every step in the inspection process.

Long-term goals

- Create standardised systems for the communication of information on seizures, smuggling methods, trends and best practices. Create standardised systems for the communication and sharing of cases where inspections did not result in seizures. Use these systems of communication for training and the development of data analytical algorithms.
- Create EU training facilities (both virtual and real life) for the use of detection technologies.

7 Canine detection

When discussing the possibilities for improvement in detection technologies deployed by customs administrations, canine detection is worth discussing separately. Dogs have a long history of helping humans to accomplish difficult tasks. Dogs have an excellent sense of smell. When trained correctly, dogs can guide a handler to an odour source. Dogs are effective odour detection 'devices' because of their ability to discriminate specific scents among many overlapping scents, and their ability to trace a scent to a source of relatively high concentration. As they move about, dogs can also pick up the 'thread' of an odour that they are trained for. They can compare odour concentrations and head for the direction of increasing concentrations, following the odour to its strongest point.

Customs administrations have been employing sniffer dogs for decades with great success. However, the recent arrival of other detection technologies has raised the expectations of customs administrations, giving canine detection the stigma of inefficiency. As with any other detection technology, canine detection would benefit from a thorough understanding within customs organisations of its unique role, which is for differentiating and finding rather than identifying. Canine detection may also benefit from more targeted use and increased quality awareness on the part of handlers, instructors and their managers.

Any detection technology involves a crucial interplay between a customs officer and the employed technology. The interplay between the dog handler and the customs dog should therefore be of special interest to a customs organisation. Because a sniffer dog and a dog handler are both living beings it may be difficult to compare them with other inanimate detection technologies. Firstly, animal welfare must be taken into account. Taking proper care of a sniffer dog is extremely important as its overall health and will greatly affect its performance. In addition, canine detection requires its own understanding of possibilities and limitations, its own operational tactics, specialised training and quality awareness. It is only once these are in place that it is possible to make the most of the remarkable capabilities of the animals. Training is equally important both for the dog and the dog handler. A dog-and-handler team can be a tremendous benefit to any customs administration if they are continuously trained, monitored and sent to work on tasks where their skills are strongest. These strong points may be derived from continuous quality monitoring. Furthermore, dedicated training centres may provide additional quality awareness as quality procedures can be centrally coordinated.

Careful selection of handlers and dogs is the starting point in developing an effective detection capability. There are several personality traits which a candidate handler should possess. These qualities are: integrity, work ethic, teamwork, flexibility, trainability, confidence, responsibility, judgement and dedication. A dog handler must have initiative and be skilled in the appropriate canine handling tactics. They must also meet or exceed the physical requirements determined by the appropriate department, organisation or agency. For the dog, aptitude tests are carried out to assess the suitability of the animal to the job.

Limited scientific information is available on the performance of customs sniffer dogs and the factors that influence their performance. It may be difficult for an individual customs administration to determine the desirable and undesirable influences on the quality of the detection work of the individual dog-and-handler combination.

But open-source standards exist for almost every aspect of sniffer dog work³. These standards may yield crucial insights into ways to further improve training, everyday work and quality monitoring. Best practices from some EU Member States are also available⁴. Operational standards in comparable fields of expertise (such as explosives detection) may also be relevant for customs work⁵. These sources of information (and other reliable sources) deserve a wider audience and active use by the customs community.

Sniffer dogs can detect many things. In the EU, they are often used to detect drugs and drug precursors; cigarettes and other tobacco products; firearms and explosives; banknotes; and CITES. Dogs have been trained to detect living animals, although this is a significant challenge. The dogs are trained with relevant odours (snakeskin, feathers, etc.). In this case, the alert given by the dog must be passive lest an active alert would harm the smuggled animal. The secret of training a sniffer dog successfully is to make it link recognising targets and alerting its handler with the pleasant experience of a reward through play. Dogs learn this through customisation. Access to relevant risk material is essential to develop all these detection capabilities. Simulant materials that artificially replicate the qualities (smell or appearance) of target risk materials are available for sale commercially, but they have rarely been validated scientifically. Since the relevant risk materials degrade over time it is advised to replace them regularly. Sniffer dogs should never be allowed to get in direct contact with risk materials such as drugs, because this could be fatal for the animal. The training and testing of sniffer-dog-and-handler teams is a specialist job requiring a high degree of patience, persistence, empathy and expertise. A certification system may promote the quality awareness of handlers, trainers and managers alike. Many dog-and-handler teams are qualified for obedience tasks and the detection of a combination of risk materials.

A common issue with sniffer dogs, as with other detection technologies, is false negative and false positive reactions. Smugglers will go to great lengths to prevent our officers, in combination with their technologies, from finding the risk material. Given suitable training and quality monitoring, the dogs will alert their handlers to the smell of materials in the amounts they have been trained for. As well as teaching dogs to recognise and alert their handlers to the scent of the risk materials themselves, training should also encompass scenarios that are as close to real life as possible. Particular attention should be given to the presence of larger quantities of risk material and the masking of the scent of risk materials. Attention should also be given to international cooperation in the form of audits and combined training exercises to further improve quality. Monitoring of all training results, everyday work and testing is advised for all sniffer dogs working for customs administrations. This monitoring will yield an insight into the performance of sniffer dogs and their handlers.

In most customs organisations, dog handlers work outside centrally determined risk-oriented customs routines because of their special requirements. In many cases, dog handlers are called upon by other units to investigate situations where suspicions have arisen that cannot be resolved otherwise.

³ See <http://swgdog.fiu.edu/approved-guidelines/> as accessed through <http://swgdog.fiu.edu/> on 02-09-2013.

⁴ Report on the benchmarking project Customs Dogs — Deployment of Dogs For Customs Control Purposes; prepared by the German Customs administration with the contribution of Germany, Czech Republic, Greece, The Netherlands and United Kingdom; Bamberg, 2008.

⁵ Commission Regulation (EU) No 573/2010 of 30 June 2010 amending Regulation (EU) No 185/2010 laying down detailed measures for the implementation of the common basic standards on aviation security.

It may be desirable to integrate dog handlers more closely into routine working processes than current practices.

The more the dogs and their handlers work in routine customs situations, the better they will be able to separate the scent of relevant risk materials from the non-risk scents present in the background. Incorporation in routine customs operations would also help justify the investment in training given to dogs and handlers.

7.1 Short-term, medium-term and long-term goals

Short-term goals

- Better integrate canine detection into routine customs operations.
- Make good use of external knowledge of standards, procedures and best practices.
- Improve and develop customs inspection capability and performance standards with sniffer dogs.
- Introduce a certification system for customs sniffer dogs.
- Monitor scent-recognition training and testing.

Medium-term goals

- Condition dogs to several risk materials if possible.
- Take care of access to relevant risk material.
- Replace risk material regularly (e.g. at least yearly for heroin and biannually for cocaine).
- Monitor training and testing in real-life work situations.

Long-term goals

- Devise a monitoring system encompassing training, testing, work and all other results.
- Promote international contacts in the form of audits, mutual training exercises etc.
- Harmonise working methods and techniques.

8 Technology-evaluation aspects

Evaluation of the use of technology by customs is a rapidly evolving field. Over the years, the use of technology has increased and the types of technology used have become more diverse. Not long ago dogs were the only ‘technology’ used by customs administrations. Nowadays, dogs are just one of a number of ways to detect smuggled goods. In its projection for the future use of detection technology in EU customs administrations, CDTPG foresees a further increase and diversification in the use of technology⁶. This development will help customs administrations become more efficient and effective. But increased use of technology (and with it, the generation of new data) also raises ethical questions. Customs administrations will need to begin to reflect on these questions.

8.1 Technology-performance measurement

Quantitative information, such as the number of inspections carried out, the number of seizures made, the value of seizures made, and the number of personnel hours involved, is currently used to measure the performance of detection technology⁷. These measures are usually published in monthly or yearly reports. They are also published in business plans that detail the expected improvements as a result of the deployment of improved or new technology. However, these measures do not give a complete assessment of the performance of detection technology. The prevalence of non-conformity, missed threats and deterrence cannot be inferred from these measures.

A more complete assessment is needed to properly describe the efficiency and effectiveness of detection technology. To arrive at a more complete assessment, statistics on the results of goods inspected by regular customs selection may be combined with statistics on the results of random inspections (see figure 4). These combined statistics when extrapolated to the total amount of goods up for selection produce a more complete picture of efficiency and effectiveness⁸. In doing so also characteristics of the population processed by selection are derived. Further, calculating conditional probabilities it becomes possible⁹. Aggregation of these data over time using multiple technologies may even allow for a calculations on the correlation between the technology used and characteristics of the population^{10 11}.

⁶ Vision on detection technology use with EU Customs administrations, EC/DG TAXUD/Customs Detection Technology Project Group, TAXUD/B2/026/2017, 2017.

⁷ R. Ireland, T. Cantens, T. Yasui, An Overview of Performance Measurement in Customs Administrations, WCO Research Paper No 13, 2011.

⁸ N. A. Macmillan, C. D. Creelman, Detection Theory: A User’s Guide, Lawrence Erlbaum Associates, 2005.

⁹ The chance of detection given the presence of a threat [=P(detection | threat) follows from Bayesian inference using performance measures TP, FP, TN and FN.

¹⁰ I. Ben-Gal, Bayesian Networks, in F. Ruggeri, F. Faltin, R. Kenett, Encyclopaedia of Statistics in Quality & Reliability, Wiley & Sons, 2007.

¹¹ T. F. Sanquist, P. Doctor, R. Parasuraman, Designing Effective Alarms for Radiation Detection in Homeland Security Screening, IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS—PART C: APPLICATIONS AND REVIEWS, VOL. 38, NO. 6, NOVEMBER 2008.

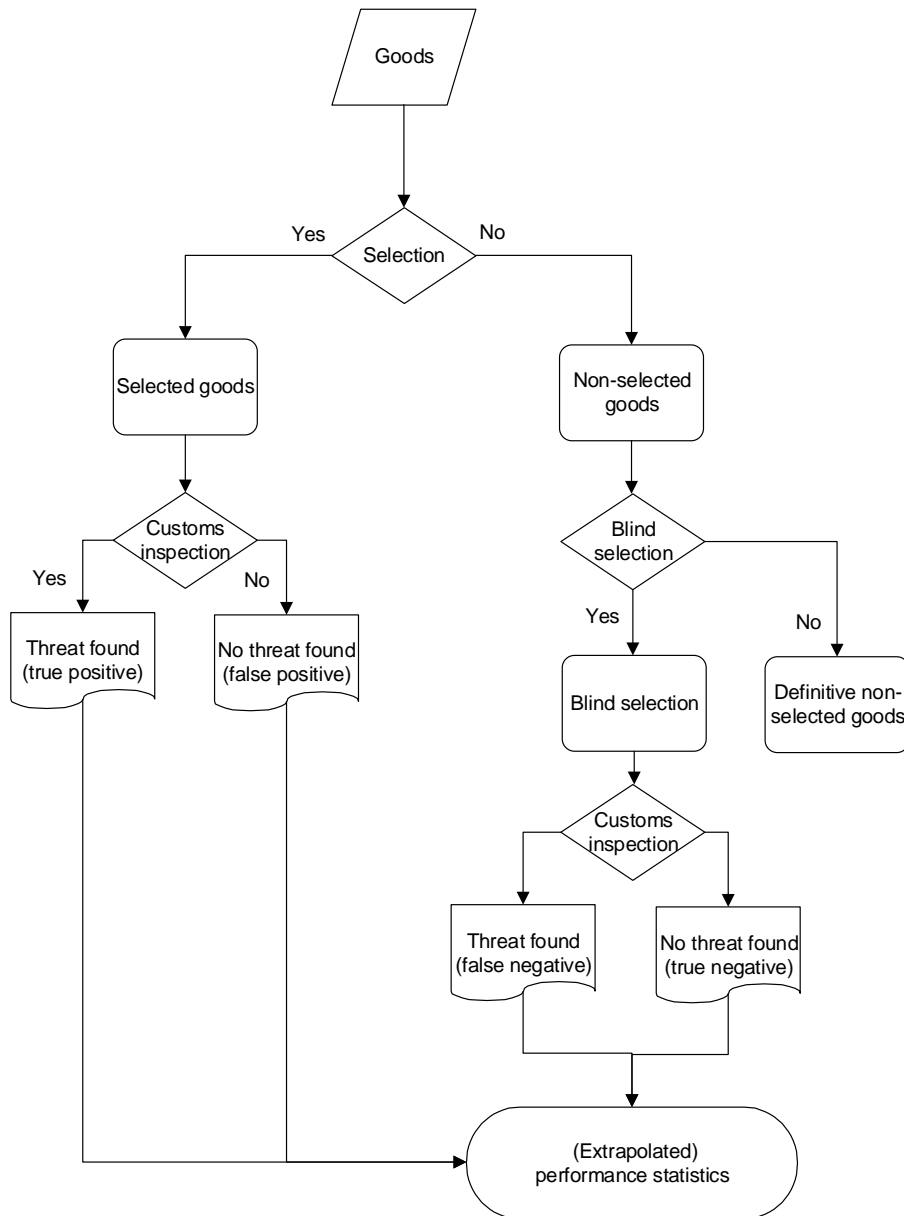


Figure 4: Results of customs inspection (using a technology) upon regular and random selection

For some customs inspections that are assisted by detection technology it may not be possible to randomly inspect non-selected goods. Model inspections of a combination of goods partly containing threat material and partly not containing threat material prove to be a good alternative. An estimation based on a carefully designed model may closely mimic the real-life situation and produce reliable performance statistics. For example, threat image projection of customs-oriented threat material in x-ray images (which is achievable for both small and large x-ray scanners) may be a practical tool to produce the data required to calculate performance statistics. In a small number of EU Member States, experiments have been carried out to study the practicality of collecting performance statistics and of model inspections to estimate these statistics¹².

¹² See abstract 'CBT Cargo Flughafen Amsterdam Schiphol' in <http://www.fhnw.ch/pptint/wspages/list-projects/> (article to be submitted).

Combining these measures may promote better insight into the performance of customs administrations and yield quantitative quality awareness. They may also create the basis for comparison, provided comparable situations are compared.

8.2 Detection technology architectures

Customs administrations use a variety of different technology to stop illicit trade. The different types of technology are usually employed at different stages of the inspection process. In the first stage, (also called the 'first line') a large number of consignments are screened for suspected anomalies. If these consignments do not raise suspicion, then the consignments are rarely analysed by a second stage (also called 'second line') technology to conduct a cross check. However, if the consignment raises suspicion, then a second line technology is commonly used to identify the anomaly. Finally, a 'third line' of inspection can be carried out, which usually consists of physical inspection by customs officers.

The detection quality of the process described above is mostly dependent on the first-line screening process. All other second-line and possible third-line technologies are only used to resolve false positives and identify true positives. This process may not necessarily be the best routine to find anomalies and prevent false positives and false negatives from occurring.

Alternative screening processes may also be devised. Costs in terms of time used, personnel hours and overall detection results may subsequently be calculated. This alternative approach is further elaborated on in the 'Detection architectures' document written by the CDTPG.

8.3 Detection-technology quality systems

A quality system is a set of procedures put in place to continuously monitor every aspect of a process that contributes to the quality of the output. For customs processes, using detection-technology quality systems may prove useful to prevent the loss of knowledge caused by changes in personnel and managers. Investments in detection technology only pay off in an environment where everything that affects the quality of a detection technology is optimised to promote that quality. It is essential that detection technology is fit for purpose; focused on suitable goals; well-maintained; used by competent and continuously trained officials; and continuously evaluated for performance by staff and management. Operators, analysts and managers of detection technology should have a good understanding of the physics, chemistry and human factors underlying the use of detection technology. All these factors that influence the quality of detection may be recorded and monitored by a quality system.

This report has made brief references to the prior report of the Customs Detection Technology Expert Group ('Threats and technology solutions') and the World Customs Organization's Guidelines For The Procurement And Deployment Of Scanning/Imaging Equipment. The prior report and the guidelines recommend setting up a routine to check each of the essential stages in the customs inspection process. B. A procedure may be written for every essential stage that describes how all necessary actions should be carried out. From all these procedures, a quality system may be constructed that promotes quality and traceability. The prior report and the guidelines stresses that quality systems should be continuously improved.

The minimum benefits of constructing a detection-technology quality system are listed below:

1. The introduction of traceable monitoring for known influences on quality, or direct measures of quality.
2. The installation of a routine to improve quality.
3. The guarantee that quality can be assured independently of individuals and/or individual approaches.
4. The build-up of a source of quantitative detection-quality information for external use.

Typically, a quality system monitors the output of a technology in three stages that are carried out at different times. There are also three stages for customs detection technology. In the first stage, earlier results are analysed again. In the second stage, new work scenarios are created to be analysed. The third stage consists of system comparison, e.g. comparing two Member States using the same technology. The results of all three stages should be discussed with all relevant personnel, operators, analysts and managers. Possible points for improvement that emerge from these discussions should be documented and followed up on.

Quality systems have been created in the food, chemical and pharmaceutical industry, as well as for hospitals and laboratories. These systems have mostly been certified by the ISO standards organisation. As yet, no formal system exists for customs detection technology. The EU and World Customs Organization (WCO) have published some reports and standards for certain detection technologies. These reports and standards may assist in the construction of a more formal quality system. Although the criteria for quality in the use of detection technology might differ from location to location and from technology to technology, they are more likely to be comparable.

8.4 Ethical evaluation of technology use

Technology is changing rapidly. Although technology was at one time an individual tool for use in specific contexts, it may become an all-encompassing decision-making environment in the near future. This raises questions about how we should use this technology, and what consideration we should give to the general public in deciding how to use this technology. By using technology for inspections, customs administrations generate information on goods that belong to somebody else. Inspection may also involve exposing these goods to radiation in a way that the owner of the goods may not like. Expanding the use of technology may result in all goods being inspected.

At present, the general public does not consider that the use of inspection technology on a certain shipment of goods diminishes the value of those goods. Only when goods are inspected manually and samples are taken does the general public consider that the value of the goods has been diminished. The argument often used by customs administrations when they seek to improve, or extend the use of technology is that it will lead to a decreased need for manual inspection or sample taking. If this change leads to fewer false positive decisions, it may be argued that this will be of benefit to the general public. Even though customs administrations are legally allowed to inspect goods using appropriate means of inspection, minimising the impact (or even the perception of impact) of these inspections may benefit both customs administrations and the public.

The introduction of a new inspection technology may have a different effect on the depreciation in value of the goods inspected than a technology already in use.

The general public may be unaware of the benefits of a new technology. Changes in governmental activities can cause at least some unease by members of the public. Based on a thorough experimental assessment of the technology, sufficient data can be supplied to the public to show the difference between the existing and new technology in terms of impact on the goods inspected. If other sources of information also favourably assess the new technology, then public acceptance of the technology is likely to grow. Assuming no differences between old and new technologies in their effects on the goods, focus groups can be used to study the public's perception of whether the new technology diminishes the value of goods it is used on.

The law only allows customs administrations to gather information for customs enforcement. If customs administrations decide to collect more information than before by using new technology, then a clear justification is needed. Data on goods that can be related to an individual are every bit sensitive as any personal information. The amount of data and the type of data generated should therefore be weighed carefully. But if the data is not created in the first place, it cannot be used in the wrong way and cannot be stolen. It is clear that access to data generated by customs detection technology will have to be strictly restricted to only those who need to see it for customs purposes. The data should also be protected according to standards that apply to privacy-sensitive information. As for the technology itself, a thorough experimental assessment should be carried out on the data it produces. This data must be compared to the data currently being produced by the incumbent technology to assess the additional value created by the new technology.

In principle, the same ethical evaluation should be carried out whenever customs administrations increase their use of technology, or generate new streams of data. Assessments should be carried out to weigh the benefit and risks of this increased use of technology as described above. The general public should also be able to contribute to these assessments and should be consulted before the introduction of any new technology. It is also important to bear in mind that greater use of technology will not automatically eliminate errors in the inspection of goods. Careful assessment may well prove that more limited use of technology (and the data this technology generates) may result in more efficient threat mitigation. This also leaves room for programmes where voluntary information-sharing replaces mandatory information-extraction.

8.5 Detection-technology standardisation

Customs authorities in the EU use a large variety of detection technologies. The technologies are typically used to help indicate the presence of risk materials. Customs administrations seek out a large variety of risk materials, and encounter an even larger variety of non-risk materials. This combination makes customs work challenging, and it is why detection technologies make a significant contribution to this work. As has been done with other important applications of detection technology, customs authorities could choose to standardise their use of detection technology.

Two examples of highly standardised applications of detection technology easily spring to mind.

The first example is explosives on airplanes. In order to mitigate the risk of explosives on board airplanes, security services use an array of procedures, some of them employing detection technology¹³. The second example is the spread of nuclear and radiological material.

The risk of nuclear and radiological material spreading to unauthorised actors is prevented by worldwide actions, some of which make use of detection technology¹⁴.

In both cases, the operational detection capabilities of the equipment used are the target of standardisation¹⁵. The main output of the standardisation process is a uniformly formulated display enabling a neutral judgement to be made on detection capabilities. Also, pre-operational standardised testing has recently been the subject of increased interest as a possible goal for standardisation, in particular for explosive detection.

There are significant benefits for customs administrations if applying a unified approach to detection capabilities. Standardisation of the use of customs detection equipment may also provide additional benefits in improving technology-assisted customs work, as well as promoting a level playing field for suppliers of technology equipment to customs administrations. By illustration, application of standards in the routine for radiation detection has resulted in credible equipment being installed, seriously hampering the illicit transportation of nuclear and radioactive material. It also made clear that to achieve a certain level of detection capability, more time in country A may be needed than in country B. Furthermore, all suppliers are clear what type of minimum detection capability an end-user is looking for. These benefits are not currently enjoyed by many European customs administrations, or suppliers of detection technologies, even though there has been a lot of mutual exchange of knowledge and procedures.

The best type of standardisation for detection capabilities thus consists of a combination of pre-operational and operational requirements. For environmental reasons, the creation of post-operational standards may also be taken into consideration. In the research and development phase, standards consisting of pre-described detection capabilities and/or abstract detection evaluation scenarios will be useful. In constructing these standards, customs authorities may promote research that serves their purposes. In the next phase, prototypes may be tested in an operational environment following a standardised procedure. These standards will give customs authorities a balanced view of the capabilities of new equipment, and they will give the developer useful feedback on the further development of its equipment. In finalising the pre-operational phase, the detection technology that has been marked as ready, should be able to receive standardised applicability-testing to ensure it is fit for certain duties in both customs and industrial settings. Once in operation, capability monitoring — or even complete quality systems — can be standardised. Once detection equipment has reached the end of its service life, it may be disposed of according to an agreed standard.

Until now, there has been little standardisation tailored for customs purposes. A multilateral approach to creation of standards may benefit customs authorities and their suppliers.

¹³ See: http://ec.europa.eu/transport/modes/air/security/cargo-mail/index_en.htm.

¹⁴ Safeguards techniques and equipment, International Atomic Energy Agency, 2011.

¹⁵ See e.g. IEC 62244 — Installed Radiation Monitors for the Detection of Radioactive and Special Nuclear Materials at National Borders or ANSI N42.35 — Evaluation and Performance of Radiation Detection Portal Monitors for Use in Homeland Security.

The most natural way to introduce standards is to start with operational standards. Standards aimed at research and development may be derived from these operational standards once such standards are in place.

8.6 Short-term, medium-term and long-term goals

Short-term goals

- Produce real or model statistics on true-positive, false-positive, false-negative and true-negative inspection results.
- Calculate performance statistics.
- Develop standards for monitoring the capability of operational detection.
- Develop national and international procedures for the monitoring of quality in the use of individual customs detection technologies.
- Make an ethical evaluation part of the applicability study for new technology.

Medium-term goals

- Compare performance statistics within the EU.
- Develop standards containing pre-described detection capabilities and/or abstract detection-evaluation scenarios to share with the research-and-development community.
- Develop standards for prototype testing in an operational environment.
- Develop standards for applicability testing for customs purposes.
- Compare procedures on the monitoring of quality in individual detection technologies within the EU.
- Develop national and international quality systems for detection-technology quality systems that deal with quality in the use of all customs technologies.

Long-term goals

- Evaluate the effectiveness of performance statistics in European tender procedures.
- Evaluate the use of detection technology as part of the architecture and customs processes.
- Develop standards for the disposal of detection technology.

Compare how well individual customs detection technologies are being used within the EU

9 Research and development in customs detection technology

9.1 Introduction

‘Relative to the security-oriented market, the customs-oriented market is small, lacking coherence and focus and is therefore relatively labour-intensive to supply.’ These are critical observations made by a detection-technology supplier at the European conference on detection of explosives (EUCDE) conference in Rome in 2013. This remark also signals a way forward for customs authorities.

European customs authorities work with detection technology that — in most cases — was not specifically developed for customs purposes. Most of the detection technologies currently used by customs administrations have been developed for the detection of explosive devices. In later stages of their development, other risk materials may have been added to the technology’s detection capability. Unfortunately, this late concentration on customs risks may have led to sub-optimal solutions. To promote research and development specifically for customs purposes, customs authorities could choose to engage more intensively with the research-and-development community and with detection-technology suppliers.

9.2 How to promote research and development

European customs authorities can exert more influence on research and development in detection technology by producing a common list of requirements shared by all customs authorities. The CDTPG has published a vision on detection technology use by EU customs administrations to assist Member States in producing exactly such a document.

For example, European customs authorities could produce a number of standard procedures to evaluate detection capability in baggage or cargo. This would be of great value to suppliers and the research-and-development community. They might also set the desired detection capability for each threat, and for each customs scenario. CDTPG publications on standardised testing and on threats and technology solutions may prove to be of additional value in this work. In addition, European customs authorities could assist the research and development work of suppliers by providing operational test environments and access to customs risk material.

Other fields of expertise may serve as an example. For example, legislation is in place in the security field detailing how threat material should be detected. Some discussion exists on whether this type of legislation limits innovation instead of setting out possibilities. There are also alternative approaches to standardisation which focus on the desired output of security-oriented detection. However, neither the legislative route, nor the alternative route to standardisation currently exists for customs purposes. And neither of these two routes are being considered for customs purposes.

At present, contact between customs administrations and technology suppliers takes place on an individual Member-State basis. Groups of Member States — or perhaps even EU-wide groups — could take it upon themselves to create standard evaluations, or push for the development of official standards. The creation of common tests is a first step in standardisation, and to promote this first step the CDTPG published its ‘Discussion on the standardisation of the evaluation of customs detections technologies’ report. This report highlights the different options in each technology category. It is forecast that further interaction between groups of customs administrations and industry will occur in Horizon 2020 projects.

Another way that customs administrations could actively participate in research and development is through pre-commercial procurement and procurement of innovative products as an end-user. Some research, development and demonstration topics under the former Seventh Framework Programme and topics under the current Horizon 2020 programme exist due to suggestions made by customs administrations and DG TAXUD. Research, development and demonstration topics are especially suitable for customs administrations to act as an end-user. End-users are typically involved in describing their needs at the beginning of a project, in prototype testing of the project, and at the end of the project. They may participate either as a full partner in the project, or as part of an end-user group. Examples of projects in which customs administrations have acted as end-users include: ACXIS, CRIM-TRACK, MODES-SNM and HANDHOLD¹⁶. Other possibilities for research and development may arise from the opportunity to engage in competitive pre-commercial procurement under Horizon 2020. Under Horizon 2020, a small number of Member States can jointly apply for funding to develop customs technologies that are 'close to market' (i.e. almost ready to be deployed). Other national programmes may exist in which end-users can submit their detection needs and evaluate prototypes. Customs administrations are advised to contact their national contact point for Horizon 2020 — under the 'Secure societies' work programmes.

Finally, by actively informing technology suppliers, EU and national research-and-development programmes of their needs, customs administrations may create more possibilities for them to act as end-users in projects. Discussions with scientists at conferences and with technology suppliers on the needs of customs administrations may spur ideas. This could promote cooperation with new actors, going beyond cooperation with the traditional partners of customs administrations. Challenges are seldom overcome by a single actor, and are seldom solved by thinking in a rigid way.

A word of caution is necessary with regards to radiation safety. Some of the possible technology solutions that might be of interest may use of ionising radiation. It is best practice to always consult the relevant regulatory body for any possible use of radiation. Failure to consult with the relevant regulatory body in a timely fashion to obtain a necessary licence may make it impossible to carry out experiments.

9.3 Short-term, medium-term and long-term goals

Short-term goals

- Use the possibilities provided by the Horizon 2020 'Secure societies' work-programme where a lack of effective technical equipment is identified.
- Participate in research, development and demonstration projects.
- Communicate detection needs to research-and-development programme departments.
- Discuss challenges with technology suppliers and the scientific world at conferences.

Medium-term goals

- Develop standards containing pre-described detection capabilities and/or abstract-detection evaluation scenarios to share with research-and-development groups.

¹⁶ EU Research for a Secure Society, Security Research Projects under the Seventh Framework Programme for Research, European Union, Luxemburg, April 2016.

Annexes

Annex A: Detection technology goals

DETECTION TECHNOLOGY GOALS	
1. Conclusions from the ‘Threats and technology solutions’ document	
Short term	<ul style="list-style-type: none"> Evaluate the current situation on customs detection technology to indicate whether the available equipment is sufficient for effective and efficient inspections.
2. Challenges in the use of current and emerging technologies	
Short term	<ul style="list-style-type: none"> Ensure the goals of recruiting and training are aligned with the financial investment in technology. Ensure that the experience gained by staff is re-invested in continuous training to improve the skills of customs officers who operate technology. Encourage customs officers to share with colleagues their experiences of different smuggling methods and successful seizures. Also expose operators to historical work carried out in their own administration.
Medium term	<ul style="list-style-type: none"> Set up shared databases for listing the results of different detection technologies so that customs administrations can learn from each other. Invest in emerging technologies.
Long term	<ul style="list-style-type: none"> Promote emerging technologies that can automatically detect a broad range of relevant targets, or specific items that are of interest to customs authorities. Promote the use of emerging technologies that fill the gaps identified in the ‘Threats and technology solutions’ document.
3. Sustainable use of detection technology	
Short term	<ul style="list-style-type: none"> Ensure regular maintenance of all detection technology throughout its service life. Set out the maximum down-time allowed for detection technology (ideally as short as possible) in the maintenance contract. Conduct financial planning to encompass the costs of purchase, training, maintenance, warranties and replacements for each individual detection technology. Work to create understanding of the detection technology in all relevant departments. Maintain contact with Member States employing similar detection technology to discuss challenges, compare performance, etc.
Medium term	<ul style="list-style-type: none"> Study how to fill gaps in detection capabilities with emerging technologies. Conduct financial planning to encompass the costs of purchase, training, maintenance, warranties and replacements for each individual detection technology.

	<ul style="list-style-type: none"> • Work with other Member States to create EU-wide user platforms to discuss challenges, compare performance, etc. • Develop a training programme to provide recurrent personalised training for operators that includes image analysis and system operation.
Long term	<ul style="list-style-type: none"> • Prepare a strategic plan for all activities involving the use of existing and emerging detection technology. This plan should encompass all relevant organisational, financial, procurement, maintenance, training and staffing aspects.
4. Technology operation	
Short term	<ul style="list-style-type: none"> • Conduct joint operations and joint training with neighbouring countries. • Ensure that knowledge is shared between the different units within customs administrations, for example through regular meetings to present and discuss interesting cases. • Ensure that enough qualified knowledge, support, staff or equipment are always available at every border-crossing point to deal with threats – including extreme threats – even if this involves the use of specialised officers. • Develop a vision on what step-by-step inspections for customs administrations dealing with unknown substances should deliver at each step. Develop a vision for how these steps should be implemented. • Develop a vision on what step-by-step inspections for customs administrations dealing with chemical and biological threat materials should deliver at each step. Develop a vision for how these steps should be implemented.
Medium term	<ul style="list-style-type: none"> • Create a standardised format for x-ray images and related data exchange processes. For example, the Nordic countries and others use a standard reporting format for x-ray related cases. • Ensure that x-ray images and relevant data are made widely available to people and companies developing x-ray image interpretation algorithms. • Cooperate with relevant experts in CBRN detection to ensure sufficient knowledge and support are present at every step in the inspection process.
Long term	<ul style="list-style-type: none"> • Create standardised systems for the communication of information on seizures, smuggling methods, trends and best practices. Create standardised systems for the communication and sharing of cases where inspections did not result in seizures and related data. Use these systems of communication for training and the development of data analytical algorithms. • Create EU training facilities (both virtual and real life) for the use of detection technologies.
5. Canine detection	
Short term	<ul style="list-style-type: none"> • Better integrate canine detection into routine customs operations. • Make good use of external knowledge of standards, procedures and best practices.

	<ul style="list-style-type: none"> • Improve and develop customs inspection capability and performance standards with sniffer dogs. • Introduce a certification system for customs sniffer dogs. • Monitor scent-recognition training and testing.
Medium term	<ul style="list-style-type: none"> • Condition dogs to several risk materials if possible. • Take care of access to relevant risk material. • Replace risk material regularly (e.g. at least yearly for heroin and biannually for cocaine). • Monitor training and testing in real-life work situations.
Long term	<ul style="list-style-type: none"> • Devise a monitoring system encompassing training, testing, work and all other results. • Promote international contacts in the form of audits, mutual training exercises etc. • Harmonise working methods and techniques.
6. Technology evaluation aspects	
Short term	<ul style="list-style-type: none"> • Produce real or model statistics on true-positive, false-positive, false-negative and true-negative inspection results. • Calculate performance statistics. • Develop standards for monitoring the capability of operational detection. • Develop national and international procedures for the monitoring of quality in the use of individual customs detection technologies. • Make an ethical evaluation part of the applicability study for new technology.
Medium term	<ul style="list-style-type: none"> • Compare performance statistics within the EU. • Develop standards containing pre-described detection capabilities and/or abstract detection-evaluation scenarios to share with the research-and-development community. • Develop standards for prototype testing in an operational environment. • Develop standards for applicability testing for customs purposes. • Compare procedures on the monitoring of quality in individual detection technologies within the EU. • Develop national and international quality systems for detection-technology quality systems that deal with quality in the use of all customs technologies.
Long term	<ul style="list-style-type: none"> • Evaluate the effectiveness of performance statistics in European tender procedures.

	<ul style="list-style-type: none"> • Evaluate the use of detection technology as part of customs processes. • Develop standards for the disposal of detection technology. • Compare systems on the quality of their use of individual customs detection technologies within the EU.
7. Research and development in customs detection technology	
Short term	<ul style="list-style-type: none"> • Use the possibilities provided by the Horizon 2020 ‘Secure societies’ work-programme where a lack of effective technical equipment is identified. • Participate in research, development and demonstration projects. • Communicate detection needs to research-and-development programme departments. • Discuss challenges with technology suppliers and the scientific world at conferences.
Medium term	<ul style="list-style-type: none"> • Develop standards containing pre-described detection capabilities and/or abstract-detection evaluation scenarios to share with research-and-development groups.

Annex B: Limits of current and emerging detection technologies

The aim of this annex is to illustrate the limitations of current technologies and technologies that will soon be available. In this section are listed a number of technologies, grouped by type. The titles used are more likely to reflect terminology familiar to end-users than the more complex scientific names. Further information about these technologies can be found in the 'Threats and technology solutions' document published by the CDTPG.

Where tables for each technology are included, the following considerations apply.

In the first column the limits of detection are given. These are only an indication of examples of better or worse performance that can be experienced.

The third column illustrates practical limitations, which are explained briefly below

- 'Human interpretation' is one such limiting factor, which can cause a variation in performance.
- 'Operator dependency' is another limiting factor, and means that the interpretation results in a correct outcome as a result of the experience and proficiency of the operator, who acts as the reference library for the technology.
- 'Library dependency' is a factor that excludes the operator but influences performance in a different way. For example, a library may contain too few compounds, which increases false-negatives, or it may contain too many compounds, which increases false-positives. Mixtures are often not included in libraries, which gives rise to inconclusive or false results.
- 'Limited scope' is a limitation that arises when a technology is only applied to a specific class of materials e.g. drugs.
- 'Limited' is a limitation that can be used in combination with other factors (e.g. human interpretation), where the role of human interpretation has been limited in favour of a library, or relative to comparable current technology.

In the fourth column, safety, health and environmental (SHE) limitations are covered. Sample taking is just one aspect of the limitation. Even though sample taking may also be considered to be a practical limitation itself, the SHE aspects of sample taking can be considered to outweigh the practical aspects. Radiation safety may also be applicable to this column if a radiating source is employed by the technology. Regulations on radiating sources may vary from Member State to Member State. Similarly, the use of laser equipment may also result in additional safety precautions. The term 'biological rhythm' is used for any technologies that involve human interpretation (including canine detection), as the interpretation quality deteriorates after an extended time, thus reducing performance.

In the fifth column, a broad separation between possible applications for the detection technology is displayed. Applications might include: finding drugs ('organics'), judging waste, using the technology to verify tariff classifications (e.g. 'inorganic material'), or using the technology to stop dual-use goods ('metals'). Some tasks require specificity, particularly those in alarm-resolving situations. Other tasks have less need for specificity ('some specificity') e.g. in screening situations. 'Shape anomalies' are tasks where the objective is to filter a distinctive shape e.g. cigarettes or a gun, out of an image or a varying audible signal. A more comprehensive approach to giving insight in technology tasks can be found in the 'Threats and technology solutions' document written by the CDTPG.

Annex C: Description of current technologies

The descriptions of each technology are derived from a number of sources, including user experience, validation experiments, preliminary testing, presentations of producers at conferences, demonstrations by the producers, and the expert opinion of customs experts. It is advised to thoroughly test new technology for customs applications, as most of this technology is developed for security environments. Wherever possible, it is suggested to coordinate testing with other EU Member States to reduce the workload on both customs administrations and technology producers.

C.1 X-ray- and gamma ray-based screening technologies; other non-intrusive inspection technologies (NII)

X-ray transmission (TX) (high energy/low energy)

All x-rays, whether powerful freight scanners, or very low dose human x-ray scanners, face the same challenges.

X-rays cannot make autonomous decisions, and there is a burdensome requirement for human operators to interpret what may be a very complex image. In addition to having materials of different types overlaying each other on an image, the orientation of the object in relation to the x-ray path also affects how it appears to the operator, and the object's profile could therefore be reduced. The successful interpretation of the image is very much dependent on the training, experience and motivation of the operator.

The intensity of the x-ray image is related to the number of x-ray photons which pass through objects on their journey from the x-ray emitter to the receptor. Different materials have different properties in respect of their transparency to x-rays. The quality of the image depends on the thickness and type of materials the x-rays have to pass through.

Photons not absorbed by one material may be absorbed by another material. Through interaction with a number of materials, the number of photons will decline at each interception along their journey.

The receptor interprets the photons received as an image. Where photons have been absorbed and little or information gets through due to the level of opaqueness of the materials, the resulting image will be dark and lacking in information.

Threat material may be deliberately located to take advantage of these limitations.

X-ray backscatter (BX) (small and large)

Because the detector of this equipment is positioned at the same side as the emitter, the receptor looks at what energy is scattered from the objects it interacts with. This equipment has low penetration and is best suited to configurations where there is no intent to screen dense goods or in the inspection of non-metallic surfaces (e.g. walls, tyres, plastics) for the presence of anomalies and concealments.

X-ray diffraction (XRD)

Current technology (for baggage, post, parcels) can be large, heavy and very slow (60 seconds per bag). Image quality is adequate, although the equipment can quite accurately detect explosives and some narcotics, based on a comparison made to an on-board library. However, complete material discrimination should not be expected. Diffraction systems are less able to penetrate metal objects in bags, and may flag up an area on an image to indicate if this has happened.

The size and slowness of the technology requires consideration to be given to the floor space available and the amount of items that must be scanned per hour.

Gamma ray transmission

The detection limits in the use of gamma ray transmission are largely the same as those for x-ray transmission for the same energy. The limitations for gamma ray transmission may even be greater than with x-ray transmission, when one is aiming for material discrimination. The presence of a radioactive source is considered to be a larger issue for radiation safety than an x-ray source. Gamma ray technology therefore presents a larger radiation-safety risk than x-ray technology.

X-ray- and gamma ray-based screening technologies; other non-intrusive inspection technologies

Technology	Indication of lower limit of detection (order of magnitude)	Practical limitations	Safety, health and environmental issues	To be used for
X-ray transmission, high energy	1-10 kg	<ul style="list-style-type: none"> Human interpretation Operator dependency 	<ul style="list-style-type: none"> Radiation safety may apply Biological rhythm 	<ul style="list-style-type: none"> Organics, non-specific Inorganics, non-specific Metals, non-specific Shape anomalies
X-ray transmission, low energy	1-10 kg	<ul style="list-style-type: none"> Human interpretation Operator dependency 	<ul style="list-style-type: none"> Radiation safety may apply Biological rhythm 	<ul style="list-style-type: none"> Organics, non-specific Inorganics, non-specific Metals, non-specific Shape anomalies
X-ray backscatter, large	1-10 kg	<ul style="list-style-type: none"> Human interpretation Operator dependency Limited scope 	<ul style="list-style-type: none"> Radiation safety may apply Biological rhythm 	<ul style="list-style-type: none"> Organics, non-specific Shape anomalies
X-ray backscatter, small	1-10 kg	<ul style="list-style-type: none"> Human interpretation Operator dependency Limited scope 	<ul style="list-style-type: none"> Radiation safety may apply Biological rhythm 	<ul style="list-style-type: none"> Organics, non-specific Shape anomalies
X-ray diffraction	100 g - 1 kg	<ul style="list-style-type: none"> Human interpretation Operator dependency 	<ul style="list-style-type: none"> Radiation safety may apply Biological rhythm 	<ul style="list-style-type: none"> Organics, some specificity Inorganics, some specificity
Gamma ray transmission	1-10 kg	<ul style="list-style-type: none"> Human interpretation Operator dependency 	<ul style="list-style-type: none"> Radiation safety may apply Biological rhythm 	<ul style="list-style-type: none"> Organics, non-specific Inorganics, non-specific Metals, non-specific Shape anomalies

C.2 Technologies for field analysis of samples

Infrared spectroscopy

Infrared spectroscopy is a non-destructive analysis which uses a low-intensity infrared light on a substance and measures the spectrum of the scattered light. This spectrum of scattered light is unique to each chemical substance. Infrared devices have an on-board library of spectra of different chemicals. Library sizes will vary between manufacturers, and it is important to ensure new substances are first identified forensically before they are added to this library. Infrared devices work well with single substances and simple mixtures with a high purity of a particular substance. They are less effective with complex mixtures, as there are too many peaks from which to determine any given product. Common mixtures may be entered in the library to circumvent this issue. Infrared spectroscopy requires samples to analyse. Miniaturised infrared devices have become available but their libraries may be limited.

Raman spectroscopy

Raman spectroscopy is a non-destructive analysis which uses a laser on a substance and measures the spectrum of the scattered light. This spectrum of scattered light is unique to each chemical substance. Raman devices have an on-board library of spectra of different chemicals. Library sizes will vary between manufacturers and it important to ensure new substances are first identified forensically before they are added to this library. Raman devices work well with single substances and simple mixtures with high purity of a particular substance. They are less effective with complex mixtures as there are too many peaks from which to determine any given product. Common mixtures may be entered in the library to circumvent this issue.

Raman is not an eye-safe laser, so it should be used with care. Raman can be used for white and light-coloured powders, but not dark colours, such as heroin, as it is likely to burn it. It should never be used on anything which is suspected to be an energetic substance as it could ignite it.

Raman spectroscopy does not always require samples placed inside it to analyse. Raman systems can be used through clear plastic and some glasses. Raman systems have also been considered to be suitable for detecting cocaine hydrochloride in bottles of alcohol. While this may be true of clear glass, Raman struggles with dark glass, especially if the liquid contained within is dark (e.g. rum), as the signal gets much distorted. If liquids are the target of inspection then spatially offset Raman (SORS), a slightly different technique, should be considered.

X-ray fluorescence spectroscopy

X-ray fluorescence spectroscopy is a non-destructive analysis that exposes the sample to an x-ray source, causing it to fluoresce and emit secondary x-rays, which are measured as a spectrograph. These spectrographs are unique to particular metals. X-ray fluorescence has an on-board library of spectra of different metals. Library sizes will vary between manufacturers and it important to ensure new substances identified in dual use goods are added to this library. X-ray fluorescence can be used directly on common products containing metal suspended in the matrix. If the metal is covered in paint or plastic, this needs to be removed before analysis.

Chemical reaction-based tests

Tests based on a chemical reaction to identify risk materials are very common but lack specificity, yielding false positives caused by common chemicals with comparable reactivity. Tests employing more than one chemical reaction for one type of risk material may improve in specificity. Some types of chemical reaction-based tests require sampling, while others can be applied directly to the supposed risk material.

Immunochemical reaction-based tests

Tests based on an immunochemical reaction tend to be more specific than chemical reaction-based tests. False positives do occur, but they can usually be attributed to a less common chemical with a structural resemblance to the risk material. Immunochemical reaction-based tests are usually applied to the material, but require a few additional steps to develop the result. The tests have low-nanogramme detection limits, making them prone to the detection of innocuous traces of risk material.

Fluorescent interaction-based tests

In principle, tests based on fluorescent interaction of the risk material with the test material can be very selective. However, their practical use limits the selectivity, because any fluorescent reaction is regarded as positive indication for the presence of risk material. This will yield false-positive interpretations. A combination of fluorescence interaction and immunochemical reaction will display the benefit of immunochemical reaction-based testing.

Technologies for field analysis of samples

Technology	Indication of lower limit of detection (order of magnitude)	Practical limitations	Safety, health and environmental issues	To be used for
Infrared spectroscopy	Sample of ± 1 g 0.1 - 1 g	<ul style="list-style-type: none"> Library dependency Mixtures not in library 	<ul style="list-style-type: none"> Sample taking Possible exposure to risk Laser equipment 	<ul style="list-style-type: none"> Organics, specific
Raman spectroscopy	Sample of ± 1 g 0.1 - 1 g	<ul style="list-style-type: none"> Library dependency Mixtures not in library 	<ul style="list-style-type: none"> Sample taking Possible exposure to risk Laser equipment 	<ul style="list-style-type: none"> Organics, specific
X-ray fluorescence	Sample of ± 1 g 0.1 - 1 g	<ul style="list-style-type: none"> Library dependency Mixtures not in library 	<ul style="list-style-type: none"> Sample taking Possible exposure to risk Laser equipment 	<ul style="list-style-type: none"> Metals, specific
Chemical colorimetric tests	Sample of ± 1 g $10^{-8} - 10^{-9}$ g	<ul style="list-style-type: none"> Operator dependency Limited scope 	<ul style="list-style-type: none"> Sample taking Possible exposure to risk 	<ul style="list-style-type: none"> Organics, some specificity
Biochemical colorimetric tests	Sample of ± 1 g $10^{-9} - 10^{-10}$ g	<ul style="list-style-type: none"> Limited scope 	<ul style="list-style-type: none"> Sample taking Possible exposure to risk 	<ul style="list-style-type: none"> Organics, specific
Fluorescence-based test	Sample of ± 1 g $10^{-9} - 10^{-10}$ g	<ul style="list-style-type: none"> Operator dependency Limited scope 	<ul style="list-style-type: none"> Sample taking Possible exposure to risk 	<ul style="list-style-type: none"> Organics, some specificity

C.3 Trace-detection technologies

Ion mobility spectroscopy (IMS)

This trace technology is used by most customs administrations as an indicator of contact with a specific commodity (explosives or narcotics). Trace technology deals with amounts not visible to the naked eye. The quantities this technology measures are typically measured in nanogrammes and should be used together with other evidence, such as risk selection.

Small particles can easily transfer from person to person. A drug user that brushes against a second passenger can dislodge particles from their clothing. This can lead a customs officer to suspect the second individual. However, it may be assumed that the actual carrier of risk material will demonstrate the highest levels of risk material. Before using this technology, it is advised to determine the background levels of the risk material in the environment it is to be used in. It is also advised to decide on what is a usual or 'normal' amount of the risk material, so that the presence of risk material above normal limits can be acted upon with a greater degree of confidence. Customs intervention for levels below the normal amount of risk material (also known as the 'background' amount) will yield few results and possibly undermine confidence in the technology.

In IMS systems, the sample is heated up to a gas and the resulting moving particles are charged and timed over a distance between two points. This time of flight is compared to a library of spectra. If a benign substance has a particle of a similar size and speed to a narcotics (or explosives) threat, a false positive will be registered, although the operator might not know this. It can be useful to have some knowledge of the types of benign items that could cause false positives, particularly to maintain the confidence level of the operator in the equipment. IMS equipment comes in smaller sizes than was the case a few years ago. The use of a radiating source to ionise the material is no longer always necessary, as alternative ionisation methods have been introduced.

Canine trace detection

Canine trace detection is widely used within customs administrations. Dogs can be trained by specialists to find specific concealed risk materials in given situations. Using this training to cover a larger number of risk materials, quantities and concealments can decrease the dog's performance if these risk materials, quantities and concealments are not regularly encountered by the dog in daily work.. Training dogs to recognise new risk material is a significant investment of both time and expertise.

Remarkable results have been published about the qualities of individual dogs. However, ensuring an entire customs dog population can operate at predetermined quality levels (intended to minimise the existing quality differences within the population) requires a significant investment of time and expertise. In addition, it takes considerable effort to monitor the ongoing quality of that unit.

Limits to canine trace detection are inherent to the fact that the dog is an animal that has been trained by humans. A framework of activities dedicated to maintaining the quality of the sniffer dog and its handler may support consistent quality output.

Main assets and drawbacks of sniffer dogs:

Assets	Drawbacks
Ready for operation at short notice	Subject to biological rhythm limitations
Transportable in almost any vehicle	Reliant on teamwork with the handler
Flexible and therefore deployable in small spaces and in large areas	Considerable training for dog handler and sniffer dog to cover operational variation

No technical limits such as dense materials that hinder x-ray technology	Not able to work 24/7 (tiredness, reducing concentration, disinclination to play, etc.)
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SIFT-MS trace detection

SIFT-MS trace detection has found an application in the recognition of fumigated containers by sampling and analysis of air from the container contents. Thorough validation has found that quantitative presentation of the measurement results may need independent calibration before use.

High-volume sampling followed by trace detection immunoassay

Operational testing and validation for cocaine by customs administration has been successful and resulted in deployment of the technology in a container process. The technology focuses on only one type of drug at a time. Trace contamination has been found to be an issue, which could be mitigated by recurrent cleaning of the sampling equipment.

Trace detection technologies

Technology	Indication of lower limit of detection (order of magnitude)	Practical limitations	Safety, health and environmental issues	To be used for
Ion mobility spectrometry trace	$10^{-8} - 10^{-9}$ g	<ul style="list-style-type: none"> Library dependency Limited scope Operator dependency 	<ul style="list-style-type: none"> Sample taking Possible exposure to risk Radiation safety may apply 	<ul style="list-style-type: none"> Organics, some specificity
Canine trace detection	$10^{-7} - 10^{-8}$ g	<ul style="list-style-type: none"> Limited scope Human interpretation Operator dependency 	<ul style="list-style-type: none"> Biological rhythm 	<ul style="list-style-type: none"> Organics, some specificity
Selected ion-flow tube mass spectrometry (SIFT-MS)	$10^{-5} - 10^{-6}$ g	<ul style="list-style-type: none"> Limited scope 	<ul style="list-style-type: none"> Sample taking Possible exposure to risk 	<ul style="list-style-type: none"> Organics, specific

C.4 Radiation detection and nuclide identification technologies

Radiation detection and monitoring equipment

Over the last few years, there have been considerable improvements in radiation detection and monitoring equipment. Up until recently, little information could be given on the nuclide identity, but nowadays more specific information can be produced. The information enables the classification of nuclides. However, full identification of nuclides is still beyond the scope of this equipment.

Developing swift and effective methods to detect the trafficking of illicit materials has become an issue of increasing importance to both national security and trade. An important technique in this field is the use of ionizing radiation to actively interrogate cargo vessels at maritime ports or terrestrial borders for detection of radiological or special nuclear materials.

The main benefit of this active inspection method resides on the ability to penetrate large amounts of attenuating material, which would normally shield standard radiological emissions. Unfortunately, standard techniques like scintillation also produce a large flux of high-energy photon and/or neutron emissions, posing a serious threat to the integrity of the cargo, and of the detection equipment itself. Other difficulties include the toxicity of filling gases used in the ionizing chambers, insufficient particle discrimination and device scalability. Another significant concern regarding the helium-3 gas detectors is the global shortage of helium-3 isotope. The current supply is limited by annual production of tritium, which is primarily produced in nuclear reactors.

Recognising the problems above, alternative technologies for building the next generation of devices for fissile materials detection are forced to exploit, by moving from a gas to a solid state detection material

Spectrometric radionuclide identification equipment

The current technology has now become available as a piece of portable equipment. Further miniaturisation of the equipment is needed to improve flexibility. In the future, the increased use of alternative detector compositions may promote more practical (and cheaper) portable applications. In addition, nuclide identification is not without error. Sometimes false-positives occur and the identification of naturally occurring radiation material could be improved.

Radiation detection and nuclide identification technologies

Technology	Indication of lower limit of detection (order of magnitude)	Practical limitations	Safety, health and environmental issues	To be used for
Personal radiation monitor	<ul style="list-style-type: none"> According to standard 	<ul style="list-style-type: none"> Human interpretation 	<ul style="list-style-type: none"> Possible exposure to risk 	<ul style="list-style-type: none"> Radiating material, some specificity
Radiation detector, handheld	<ul style="list-style-type: none"> According to standard 	<ul style="list-style-type: none"> Human interpretation 	<ul style="list-style-type: none"> Possible exposure to risk 	<ul style="list-style-type: none"> Radiating material, some specificity
Radiation monitor, portal	<ul style="list-style-type: none"> According to standard 	<ul style="list-style-type: none"> Human interpretation 		<ul style="list-style-type: none"> Radiating material, some specificity
Spectrometric handheld radionuclide identification	<ul style="list-style-type: none"> According to standard 		<ul style="list-style-type: none"> Possible exposure to risk 	<ul style="list-style-type: none"> Radiating material, specific
Spectrometric portal radionuclide identification	<ul style="list-style-type: none"> According to standard 			<ul style="list-style-type: none"> Radiating material, specific

C.5 Technologies indicating hidden objects on humans

X-ray transmission system

Typically this system is used to identify smuggled items inside a person, such as ingested narcotics. However, some manufacturers configure a version with lower dosage, which is optimised for external concealments only. The person being scanned stands upright and moves through the x-ray beam on a platform or a belt. This type of system is low-dose (3-5 microsieverts) and settings are usually fixed. There are fewer privacy concerns, as the image produced is a skeletal one. The operator needs to be familiar with human physiology to be able to identify smuggled items. Radiation safety issues may apply.

X-ray backscatter portal

This is a low-dose technology which provides an image from the x-rays which are scattered from the person being scanned. This results in a high-quality image. This in itself can lead to problems with privacy, so a filtering system may be available, which obscures certain body parts, or superimposes threats on to a representation of a human, rather than a real one. With this type of system, the only area imaged is that which is presented to the emitter.

X-ray backscatter also does not image objects beneath the skin. As an example, objects concealed under the arms are not displayed if the arms are at the side, but only when arms are raised. Most devices only produce a snapshot for review by the operator of the part of the body facing the system. It is necessary to reposition a person and take another scan in order to image a whole person. Radiation safety issues may apply.

Millimetre wave (passive)

This low-resolution technology is similar to infrared and relies on the human body as a source of millimetre wave energy against which objects of different contrast are shown on a display screen. Basically, this means that if a person has a concealed item on their body, it prevents the millimetre wave energy from being seen and displays as an anomaly to the operator. As the technology relies on the human as the greatest source of energy (the 'lamp', so to speak), it has to be deployed with an awareness of the environment it is to be used in. If located close to windows, the technology suffers from interference from the sky. It may be that it picks up energy from hidden radiator pipes, which will degrade performance. It is best suited to indoor-only operations.

As each human will be a source of this type of energy, it is best to isolate others from the field of view when scanning an individual. The passive technology only images items on the body that are facing the camera. It cannot see through the body, so if an object is covered by another part of the body, such as under the arms, it will not image it. Concealed organic materials such as drugs absorb heat/energy from the body. If these organic materials have the same temperature as body temperature, then they will become invisible to the system. This could happen to small packages, but is less likely with large commercial concealments.

Terahertz wave (passive)

This technology is similar to passive millimetre wave systems in terms of how it works and in terms of the potential problem of packages at body temperature not being detected. However, in the case of terahertz wave technology the higher frequency permits use both outdoors and indoors. If these systems are of interest to a customs administration, it is important to experiment with packages strapped to the body to see how these packages may change in appearance over a given period of time. It is important to understand the difference in contrast temperature that a manufacturer's system can detect (i.e. the difference in temperature between an object and the human body). For example, a 1 kelvin system would be better than a 3 kelvin system.

Millimetre wave (active)

Active systems illuminate the subject with energy, which makes for a higher-quality image compared to passive technologies. This can lead to problems with privacy, so a filtering system may be available, which obscures certain body parts, or superimposes threats on to a representation of a human, rather than a real one. As with all millimetre wave systems, the only area imaged is that which is presented at the emitter. Millimetre wave technology cannot see through objects or skin. The subject being scanned is instructed to turn their body towards the emitter and spin. It is important that those areas of interest are clearly imaged.

As an example, objects concealed under the arms are not displayed if the arms are at the side, but only when arms are raised. Some devices may produce a snapshot for review by the operator. If the scanner does not complete a 360 degree image, then there will be a 'dead' spot on the body, where any threats will not be imaged. If people are instructed to stand in a certain position, perhaps by using bright colours to paint a pair of feet on the ground, then this dead-zone will be consistently in the same position and may be known to potential smugglers, enabling threats to be hidden.

Radar interaction-based detection

This technology is still in the development stage. There has not yet been any independent customs evaluation of this technology. It is an active system capable of signalling the presence of anomalous material in a watery environment.

Technologies indicating hidden objects on humans

Technology	Indication of lower limit of detection (order of magnitude)	Practical limitations	Safety, health and environmental issues	To be used for
X-ray backscatter, portal	10-100 g	<ul style="list-style-type: none"> • Position subject • Limited human interpretation 	<ul style="list-style-type: none"> • Radiation safety may apply 	<ul style="list-style-type: none"> • Organics, non-specific • Inorganics, non-specific • Metals, non-specific • Shape anomalies
Terahertz passive	100-1000 g	<ul style="list-style-type: none"> • Position subject • Human interpretation 		<ul style="list-style-type: none"> • Organics, non-specific • Inorganics, non-specific • Metals, non-specific • Shape anomalies
Millimetre wave passive	100-1000 g	<ul style="list-style-type: none"> • Position subject • Human interpretation 		<ul style="list-style-type: none"> • Organics, non-specific • Inorganics, non-specific • Metals, non-specific • Shape anomalies
Millimetre wave active	10-100 g	<ul style="list-style-type: none"> • Position subject • Limited human interpretation 	<ul style="list-style-type: none"> • Radiation safety may apply 	<ul style="list-style-type: none"> • Organics, non-specific • Inorganics, non-specific • Metals, non-specific • Shape anomalies

C.6 Technologies indicating hidden objects in cars, trucks and constructions; technologies indicating subjects in areas

Optic fibre cameras

Optic cameras are mainly employed for inspection of (outside) areas for people and for the inspection of small spaces by means of a fibre. Images can be very sharp, but optic cameras used outside may be weather sensitive.

Ultra-sonic detection

Current ultra-sonic detection equipment delivers a variable audible signal. This signal leaves plenty of room for interpretation. The interpretation of the signal also relies on the operator knowing what the inspected subject is. The retrieved signal is not specific for any risk material.

Gamma backscatter

Current gamma backscatter detection equipment delivers a variable audible signal. This signal leaves plenty of room for interpretation. The interpretation of the signal also relies on the operator knowing what the inspected subject is. The retrieved signal is not specific for any risk material. Radiation safety issue may apply.

IR cameras

Optic cameras are mainly employed for inspection of outside areas for people. Customs administrations also use the cameras to inspect for external concealments. Standard IR cameras can yield rather unclear images, and image quality is subject to influences from some types of weather. High-definition cameras may prove to have fewer of those limitations.

Ultra-violet (UV)/VIS cameras

At present, UV/VIS cameras are intended for the inspection of surfaces (e.g. walls, car doors) to detect contamination or anomalies. The cameras cannot yet be used on larger objects and in outside areas. Visibility in UV is usually limited to a significant amount of anomalous material.

Technologies indicating hidden objects in cars, trucks, constructions; technologies indicating subjects in areas

Technology	Indication of lower limit of detection (order of magnitude)	Practical limitations	Safety, health and environmental issues	To be used for
Optic fibre camera	0.1 - 1 g (fibre)	<ul style="list-style-type: none"> Human interpretation 		<ul style="list-style-type: none"> Organics, non-specific Inorganics, non-specific Metals, non-specific Shape anomalies
Ultra-sonic detection	10-100 g	<ul style="list-style-type: none"> Human interpretation 		<ul style="list-style-type: none"> Organics, non-specific Inorganics, non-specific Metals, non-specific Shape anomalies

Gamma backscatter	10-100 g	<ul style="list-style-type: none"> Human interpretation 		<ul style="list-style-type: none"> Organics, non-specific Inorganics, non-specific Metals, non-specific Shape anomalies
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Other visualisation technologies

Technology	Indication of lower limit of detection (order of magnitude)	Practical limitations	Safety, health and environmental issues	To be used for
IR Camera		<ul style="list-style-type: none"> Human interpretation 		<ul style="list-style-type: none"> Organics, non-specific Inorganics, non-specific Metals, non-specific Shape anomalies
UV/VIS Camera	10^{-5} - 10^{-6} g	<ul style="list-style-type: none"> Human interpretation 		<ul style="list-style-type: none"> Organics, non-specific Inorganics, non-specific Metals, non-specific Shape anomalies

C.7 Metal detection

Current metal-detection technology can detect desired levels of metal concealed on a human body. The metal detectors are not able to separate one metal from the other. This form of detection may be advantageous for certain applications (such as detecting the illicit import and export of banknotes).

Metal detection

Technology	Indication of lower limit of detection (order of magnitude)	Practical limitations	Safety, health and environmental issues	To be used for
Metal detection	1-10 g	<ul style="list-style-type: none"> False positive reactions 		<ul style="list-style-type: none"> Metals, non-specific

Annex D: Emerging technologies

The description given for each technology is derived from a number of sources, including preliminary testing, presentations of producers at conferences, demonstrations by the producers and expert opinion of customs experts. It is advised to thoroughly test any new technology for Customs applications as most of this technology is developed for security purposes. Wherever possible it is advised to coordinate testing with other EU Member States to reduce the workload on both customs administrations and technology producers.

New technology will undoubtedly change the way that customs administrations currently work. X-ray and other NII technologies will provide some degree of automated detection and material recognition. Nevertheless, human interpretation of these images will still be necessary. Moreover, algorithms will also need maintenance. Trace detection technologies will become so sensitive that we will worry about the background levels of risk material at customs facilities. These background levels could risk triggering an alarm every time the detection machine is turned on. This will also lead to questions about the likelihood of physical detection from such a low trace amount. Even now with regular trace systems, users have to adjust the alarm thresholds at each facility they are deployed at.

Customs administrations will hopefully decide to validate detection equipment and its operators for the work they are supposed to do. Validation results and statistical performance measures will enable customs administrations to pursue a more risk-oriented approach.

One of the greatest potential influences on the way that customs administrations work with detection technology may not even come from the detection technology itself. Computer networking technology is also likely to increase in capability, and will enable centralised and specialised interpretation to take place.

Annex E: X-ray and gamma ray-based screening technologies; other non-intrusive inspection technology (NII)

X-ray computed tomography (CT)

Employing CT x-ray may resolve some of the overlay issues that exist with conventional x-ray. In CT, an object is irradiated from a large number of angles, offering the possibility to isolate individual aspects of the content based on their 3D shape and their effective atomic number (Zeff). The technology and the necessary automated-detection algorithms have been developed for security purposes. Recently, some manufacturers have started developing CT x-ray devices for customs applications. A first evaluation of these new devices for customs purposes has recently taken place with support of some EU customs administrations.

Low-energy transmission x-ray followed by an automated detection algorithm

Currently, the first evaluation of these algorithms is underway. Preliminary results indicate that development and implementation of the algorithms requires a significant investment. International joint development could make life easier, as would a decision on standardised quantities of illicit goods to search for. Algorithms for normal goods may prove as important as algorithms for illicit goods. The development of algorithms may be less effective for some customs purposes than for security purposes. However, they may be helpful for detecting pre-defined shapes of a minimum size. Automated detection may be less helpful for new nondescript shapes, since they make material discrimination difficult.

High-energy transmission x-ray followed by an automated detection algorithm

First evaluations of these algorithms have taken place. Results indicate that development and implementation of algorithms has been successful in some areas, while more work is needed in other areas. Significant research and development is needed to prepare a market-ready product. This technology may work for detecting pre-defined shapes large enough to be recognised. However, automated detection may be less helpful for nondescript shapes, since they make material discrimination difficult. International, joint development could improve this technology, as could taking a decision on what standardised quantities of threat materials should be sought. Algorithms capable of screening out normal goods may prove to be as useful as algorithms for detecting illicit goods.'

Thermal neutron activation-based detection (TNA)

This technology has not yet been tested by customs administrations. There is limited evidence of its use in other applications. The technology was developed for baggage, post and parcels. It may be able to automatically detect explosives, due to the presence in explosives of nitrogen in relation to the presence of other atoms, such as oxygen, hydrogen and carbon. The technology may be of only limited use in the detection of narcotics. The only drug this could potentially detect is cocaine hydrochloride, but this is only because it could detect the chlorine. Equally, it would potentially provide a false positive to materials with similar characteristics (materials that also contained chlorine). There may be radiation safety issues.

(Pulsed) Fast neutron activation-based detection (FNA)

This technology has not yet been tested by customs administrations, but it is commercially available for air-freight scanning. There is limited evidence of its use in other applications, although the US customs administration trialled its use for truck inspection in 2005. The technology was mainly developed for maritime and air-freight containers, and may be able to automatically detect explosives, due to the presence of nitrogen in relation to the presence of other atoms, such as oxygen, hydrogen and carbon. The technology may be of only limited use in the detection of narcotics. The only drugs this could potentially detect are cocaine hydrochloride and heroin hydrochloride, owing to the presence of chlorine in both compounds. Equally, it would potentially provide a false positive to materials with similar characteristics (materials that also contained chlorine). Extensive radiation safety requirements apply.

Nuclear quadrupole resonance (NQR)

NQR works by emitting a weak radio pulse at a very precise frequency on the target substance, so that it causes a molecule to rotate. The scanner picks up the weak return signal. Each commodity would require a signal of varying duration and frequency. Where multiple substances are sought, the signals are run concurrently. NQR can be used to detect explosives, and the signal for heroin freebase is known and tested. It is not possible (yet) to detect hydrochloride forms of drugs (heroin/cocaine), as their precise frequencies have not been identified. Because this technology is based on radio waves, it cannot penetrate metal. EU-funded work is taking place to test this technology on counterfeit pharmaceutical detection, and the Japanese customs administration has used the technology to detect internally concealed methamphetamine.

Cosmic radiation interaction-based detection technology

A commercial application of this technology is implemented in Singapore (with Immigration and Checkpoints Authority). The technology works by extracting information from the deflection angle of cosmic radiation that traverses the inspected object.

The penetration capability of cosmic-ray particles is very high compared with photons from x-ray inspection systems. This means dense materials can be investigated. There is limited evidence of its use in other applications. The technology is currently used to detect shielded radioactive sources hidden in cargo containers. The technology is currently being developed so that it can in the future detect organic material.

Nuclear resonance fluorescence in combination with x-ray transmission

There are limited examples of what this technology could do for customs purposes. Potentially, it could add a layer of material discrimination to x-ray inspection owing to x-ray fluorescence. The technology was developed for maritime and air-freight containers and for scanning luggage. In the future, it may be able to automatically detect explosives and drugs, due to the specific signals from characteristic atoms in these materials.

X-ray and gamma ray based screening technologies; other non-intrusive inspection technology

Technology	Indication of lower limit of detection (order of magnitude)	Practical limitations	Safety, health and environmental issues	To be used for
X-ray computed tomography	1-10 g	<ul style="list-style-type: none"> Limited human interpretation Library dependency 	<ul style="list-style-type: none"> Radiation safety may apply 	<ul style="list-style-type: none"> Organics, some specificity Inorganics, non-specific Metals, non-specific Shape anomalies
X-ray transmission, low energy i.c.w automated detection	10-100 g	<ul style="list-style-type: none"> Limited human interpretation Library dependency 	<ul style="list-style-type: none"> Radiation safety may apply 	<ul style="list-style-type: none"> Organics, some-specific Inorganics, non-specific Metals, non-specific Shape anomalies
X-ray transmission, high energy icw automated detection	1-10 kg	<ul style="list-style-type: none"> Limited human interpretation Library dependency 	<ul style="list-style-type: none"> Radiation safety may apply 	<ul style="list-style-type: none"> Organics, non-specific Inorganics, non-specific Metals, non-specific Shape anomalies
Thermal neutron activation (TNA)	100 g - 1 kg	<ul style="list-style-type: none"> Limited human interpretation Library dependency 	<ul style="list-style-type: none"> Radiation safety may apply 	<ul style="list-style-type: none"> Organics, some specificity Inorganics, non-specific Metals, non-specific
Fast neutron activation (FNA)	100 g - 1 kg	<ul style="list-style-type: none"> Limited human interpretation Library dependency 	<ul style="list-style-type: none"> Radiation safety may apply 	<ul style="list-style-type: none"> Organics, some specificity Inorganics, non-specific Metals, non-specific

Nuclear quadrupole resonance (NQR)	100 g - 1 kg	<ul style="list-style-type: none"> Limited human interpretation Library dependency 	<ul style="list-style-type: none"> Radiation safety may apply 	<ul style="list-style-type: none"> Organics, some specificity Inorganics, non-specific Metals, non-specific
Muon tomography	100 g - 1 kg	<ul style="list-style-type: none"> Limited human interpretation Library dependency 		<ul style="list-style-type: none"> Metals, non-specific
Nuclear resonance fluorescence icw. x-ray transmission	100 g - 1 kg	<ul style="list-style-type: none"> Limited human interpretation Library dependency 		<ul style="list-style-type: none"> Organics, some specificity Inorganics, some-specificity Metals, non-specific

Annex F: Technologies for field analysis of samples

Spectroscopic technologies have undergone considerable miniaturisation in the last few years. Handheld special-purpose equipment has now become available. However, the limited scope of the special-purpose devices may not satisfy customs administrations, because the large variety of risk materials requires the simultaneous use of a number of recording modes and databases. Networked equipment may enable specialised back-up to help with more complex interpretation.

Problems with the selectivity of the colorimetric tests are can be solved by using a larger number of reactions at the same time. This combination of reactions will increase the selectivity significantly, but will inherently make the task of interpretation more complex. Some automation will be needed to effectively interpret the results. Networked equipment may enable specialised back-up to help with more complex interpretation.

Technologies for field analysis of samples

Technology	Indication of lower limit of detection (order of magnitude)	Practical limitations	Safety, health and environmental issues	To be used for
IR and Raman	0.1 - 1 g	<ul style="list-style-type: none"> Somewhat limited scope Library dependency 	<ul style="list-style-type: none"> Sample taking Possible exposure to risk 	<ul style="list-style-type: none"> Organics, specific
Colorimetric tests	$10^{-8} - 10^{-9}$ g	<ul style="list-style-type: none"> Somewhat limited scope 	<ul style="list-style-type: none"> Sample taking Possible exposure to risk 	<ul style="list-style-type: none"> Organics, some specificity
Gas chromatography (GC)	$10^{-5}-10^{-6}$ g	<ul style="list-style-type: none"> Somewhat limited scope 	<ul style="list-style-type: none"> Sample taking Possible exposure to risk 	<ul style="list-style-type: none"> Organics, some specificity
GC with mass spectrometry detector	$10^{-5}-10^{-6}$ g	<ul style="list-style-type: none"> Somewhat limited scope 	<ul style="list-style-type: none"> Sample taking Possible exposure to risk 	<ul style="list-style-type: none"> Organics, highly specific

Annex G: Trace detection technologies

High-volume sampling followed by trace detection DMA-MS

Testing has shown that this technology has potential for use in customs applications alongside its existing security applications. However, the extreme sensitivity of this technology calls for a shift in approach by customs administrations. The increased sensitivity reveals higher levels of risk material, making it essential to set up protocols that set out the levels at which to take action.

High-volume sampling followed by trace detection IMS

Preliminary testing has shown limited potential for this technology in customs applications alongside its existing security applications. Influence from background contamination and a limited ability to analyse all relevant risk materials needs improvement. Further tests will be necessary to make estimates on its potential.

High-volume sampling followed by trace detection canine

This technology has not yet been tested for customs purposes. Security applications exist. All limits mentioned for canine detection may apply.

Trace detection, amplifying fluorescent polymer (AFP)

This technology has not yet been tested for customs purposes. Security applications exist. The technology is suitable for detecting explosives, but is not yet suitable for detecting illicit drugs. Currently a limited number of risk materials can be analysed per sampling routine.

Trace detection, multiple sensor platforms

This technology has not yet been tested for customs purposes. No other applications for this technology have been found. Its performance for customs purposes will depend on how it is integrated into customs processes.

Trace detection technologies

Technology	Indication of lower limit of detection (order of magnitude)	Practical limitations	Safety, health and environmental issues	To be used for
HVS-DMA-MS	$10^{-14} - 10^{-15}$ g	<ul style="list-style-type: none"> Somewhat limited scope, extreme sensitivity 	<ul style="list-style-type: none"> Sample taking Possible exposure to risk 	<ul style="list-style-type: none"> Organics, specific
HVS-IMS	$10^{-11} - 10^{-12}$ g	<ul style="list-style-type: none"> Limited scope 	<ul style="list-style-type: none"> Sample taking Possible exposure to risk 	<ul style="list-style-type: none"> Organics, some specificity
HVS-Canine	$10^{-9} - 10^{-10}$ g	<ul style="list-style-type: none"> Limited scope 	<ul style="list-style-type: none"> Sample taking Possible exposure to risk 	<ul style="list-style-type: none"> Organics, some specificity
AFP	$10^{-9} - 10^{-10}$ g	<ul style="list-style-type: none"> Limited scope 	<ul style="list-style-type: none"> Sample taking Possible exposure to risk 	<ul style="list-style-type: none"> Organics, some specificity
Multiple sensor system	$10^{-8} - 10^{-9}$ g	<ul style="list-style-type: none"> Limited scope 	<ul style="list-style-type: none"> Sample taking Possible exposure to risk 	<ul style="list-style-type: none"> Organics, specific

Annex H: Radiation-detection and nuclide-identification technologies

The market for radioactive-material and nuclear-material detectors is highly standardised. The newest equipment is not necessarily any more sensitive than slightly older equipment. The main developments that have taken place in this technology are that the monitoring equipment has become more selective thanks to improvements made to the detectors, and that more (cheaper and easier to work with) alternatives have become available for spectrometric detectors.

Annex I: Technologies indicating hidden objects on humans

Body scans have been the subject of an intense privacy debate. Nowadays these scans are configured so that they respect the privacy of the inspected subject. The next step in development of the technology will be material discrimination. This will be especially advantageous for customs administrations because it will allow items such as externally concealed bank notes and drugs to be better separated from their background. Image interpretation will become only somewhat more complex, because a degree of automated screen interpretation is already part of the privacy-protection features installed in the scans.

Annex J: Technologies indicating hidden objects in cars, trucks and constructions; technologies indicating subjects in areas

IR/UV/VIS cameras

Hyper spectral imaging will produce combined images and datasets that can be interpreted from the IR spectrum, through the visible spectrum, and on into the UV spectrum. This development may not be useful for standard security applications, but it may prove beneficial in more complex areas such as green borders, blue borders, crime scenes, etc. Image interpretation will become significantly more complex as this technology develops.

Ultra-sonic detection

Ultra-sonic detection with screening options will become available in the near future. This will help customs officers to find concealments hidden in cars, buildings, etc. Some producers have even hinted at the possibility of some degree of material discrimination. 'If material discrimination is added to this technology, then interpretation issues will arise.

Gamma backscatter

Gamma backscatters with screening options will become available in the near future. This will help customs officers to find concealments hidden in cars, buildings, etc. Common issues with image interpretation will also arise with the gamma backscatter.

Technologies indicating hidden objects in cars, trucks, constructions; technologies indicating subjects in areas

Technology	Indication of lower limit of detection (order of magnitude)	Practical limitations	Safety, health and environmental issues	To be used for
Ultra-sonic detection	1-100 g	<ul style="list-style-type: none"> Human interpretation 		<ul style="list-style-type: none"> Organics, non-specific Inorganics, non-specific Metals, non-specific Shape anomalies
Gamma backscatter	1-100 g	<ul style="list-style-type: none"> Human interpretation 		<ul style="list-style-type: none"> Organics, non-specific Inorganics, non-specific Metals, non-specific Shape anomalies

Other visualisation technologies

Technology	Indication of lower limit of detection (order of magnitude)	Practical limitations	Safety, health and environmental issues	To be used for
IR/VIS/UV		<ul style="list-style-type: none"> Human interpretation 		<ul style="list-style-type: none"> Organics, non-specific Inorganics, non-specific Metals, non-specific Shape anomalies

Annex K: Metal detection

Metal detectors that are able to detect separate metals have been developed. However, this equipment is still in the early stage of development. Metal detectors that are able to discriminate between different types of material would result in a wider variety of risk materials that can be detected and a somewhat more complex screening process.

Technology	Indication of lower limit of detection (order of magnitude)	Practical limitations	Safety, health and environmental issues	To be used for
Metal detection		<ul style="list-style-type: none"> Limited human interpretation 	<ul style="list-style-type: none"> 	<ul style="list-style-type: none"> Metals, some specificity