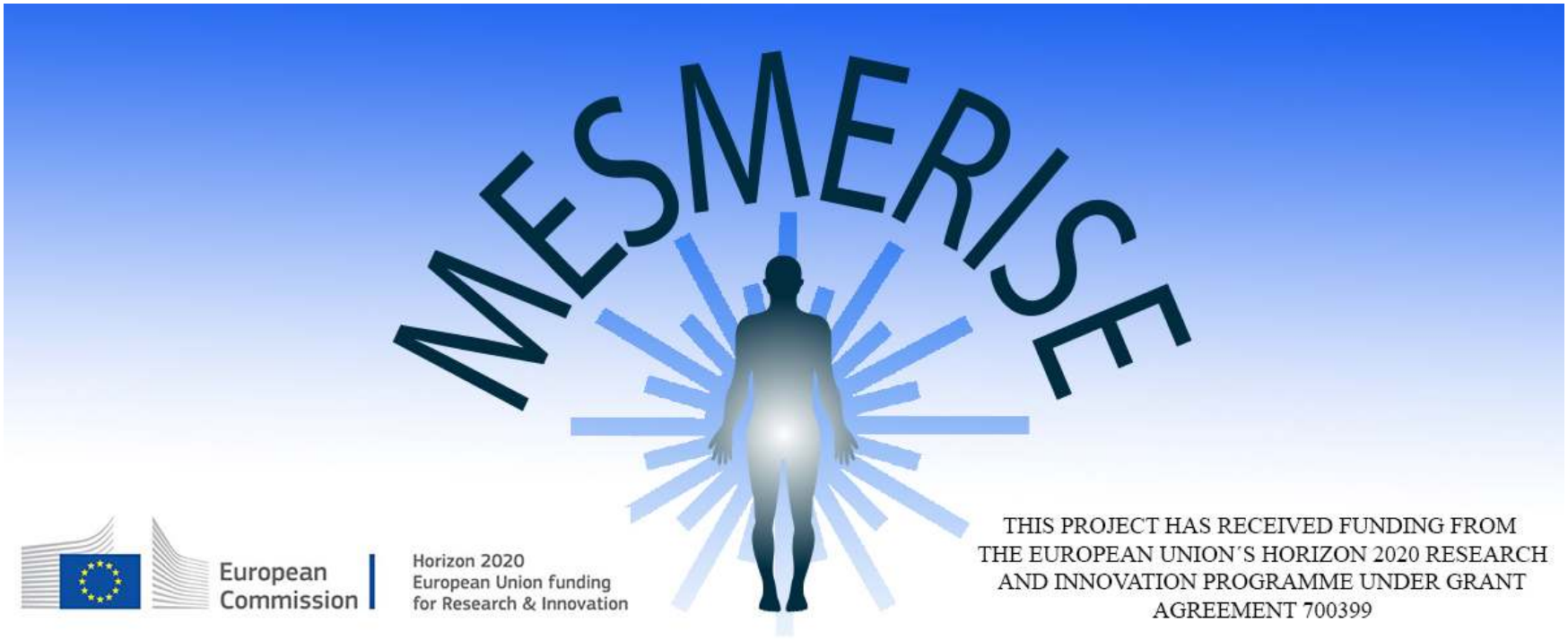
Multi-Energy High Resolution Modular Scan System for Internal and External Concealed Commodities

MESMERISE



June 6th 2017

www.h2020mesmerise.eu

MESMERISE

MESMERISE

European Commission

Horizon 2020
European Union funding
for Research & Innovation

THIS PROJECT HAS RECEIVED FUNDING FROM THE EUROPEAN UNION´S HORIZON 2020 RESEARCH AND INNOVATION PROGRAMME UNDER GRANT AGREEMENT 700399

Universidad de Alcalá · MULTIX · ADANI · cea leti · UNIVERSITAS GALATIENSIS · Home Office

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The main challenge of MESMERISE is to develop a **new scanning technology improving the respect for intimacy and privacy rights as well as the efficiency and reliability**.

The first objective is to develop a high-resolution non-intrusive scanner able to automatically detect and identify both internal and external concealed prohibited or restricted commodities sought by customs such as drugs or explosives and to discern them from natural body tissues, food waste or benign materials.

Mesmerise proposes two complementary technologies: ***ultra-low dose Multispectral X-ray transmission and Infrasonic interrogation***. Both systems have the goals of improving privacy, convenience, sensitivity and reliability posing no risk for users, providing automatic identification or classification and assuring that no human operator needs to watch privacy-breaking images.

www.h2020mesmerise.eu

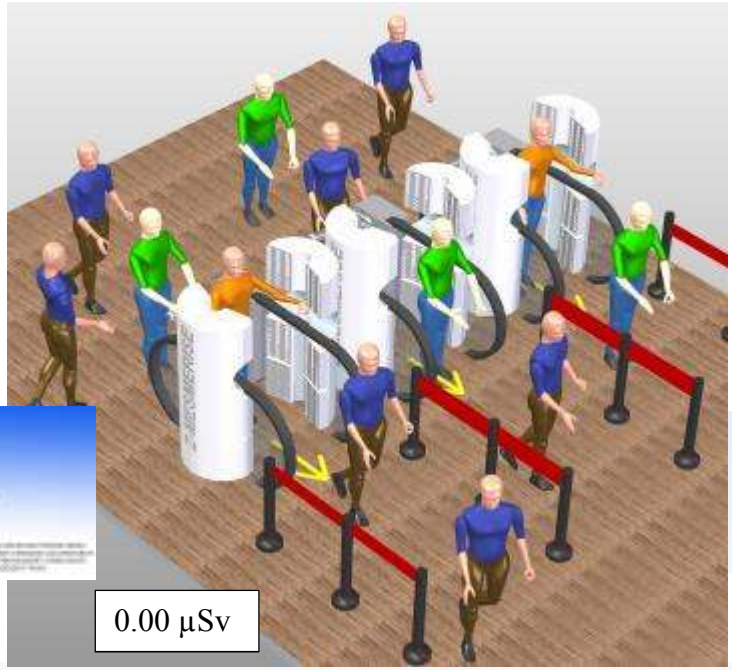
Scenario 1:
Internally concealed commodities

X+Z MESMERISE: Internal and external detection.

Restrictions to the use of Ionizing Radiation may apply

Scenario 2:
Externally concealed commodities

Z-MESMERISE: External detection.
Highly non-disruptive.



No restriction

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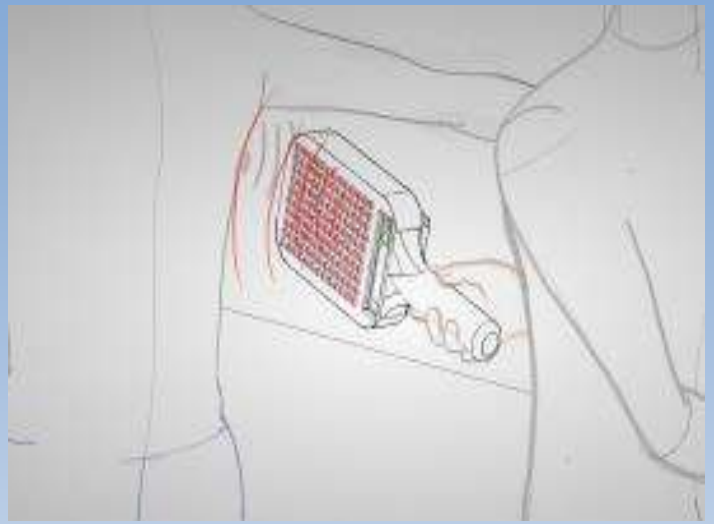
Z-MESMERISE: External detection. Highly non-disruptive.



Acoustic Near Field holography (ANFH)

Acoustic Near-Field Impedance Holography

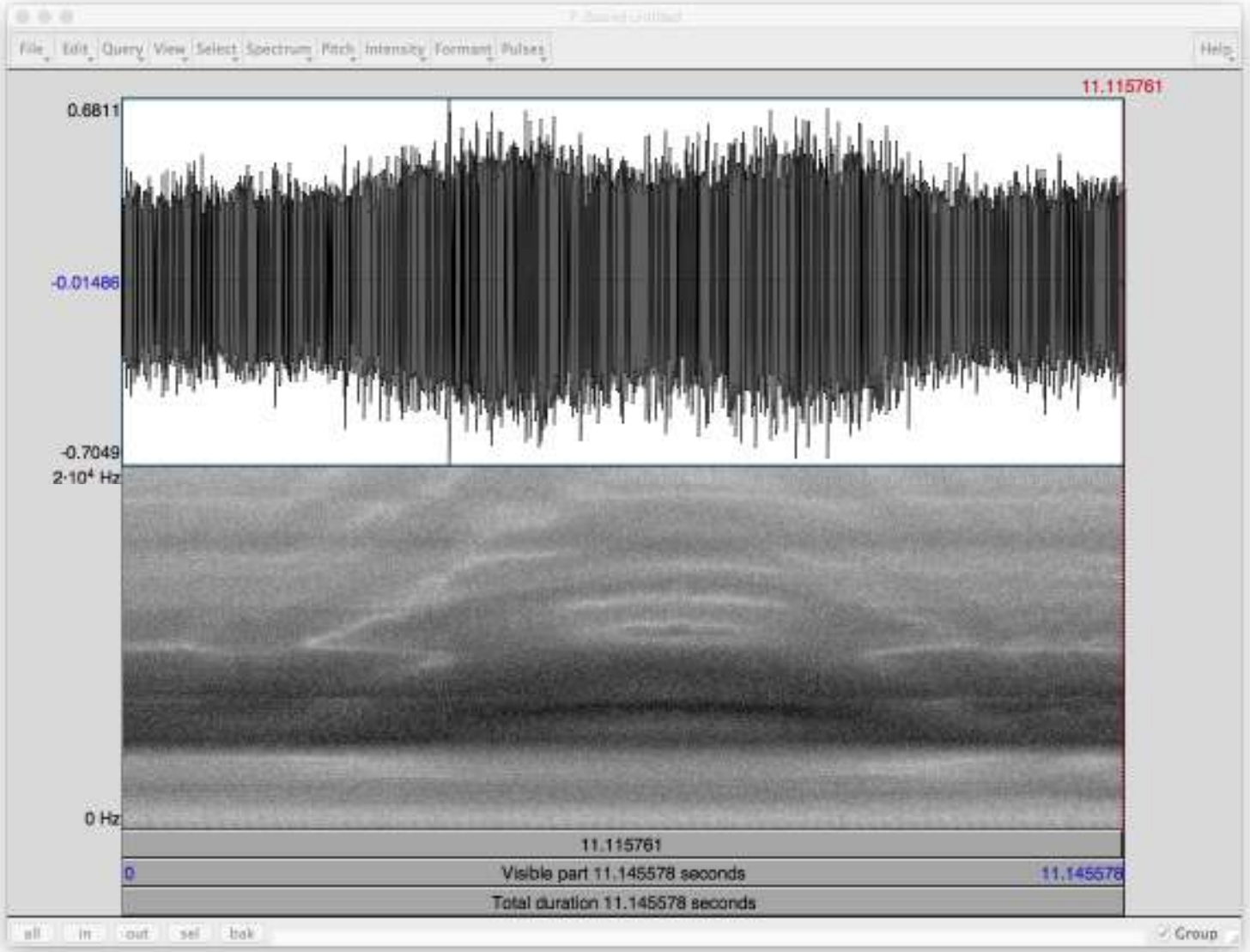
Low frequency MEMS arrays

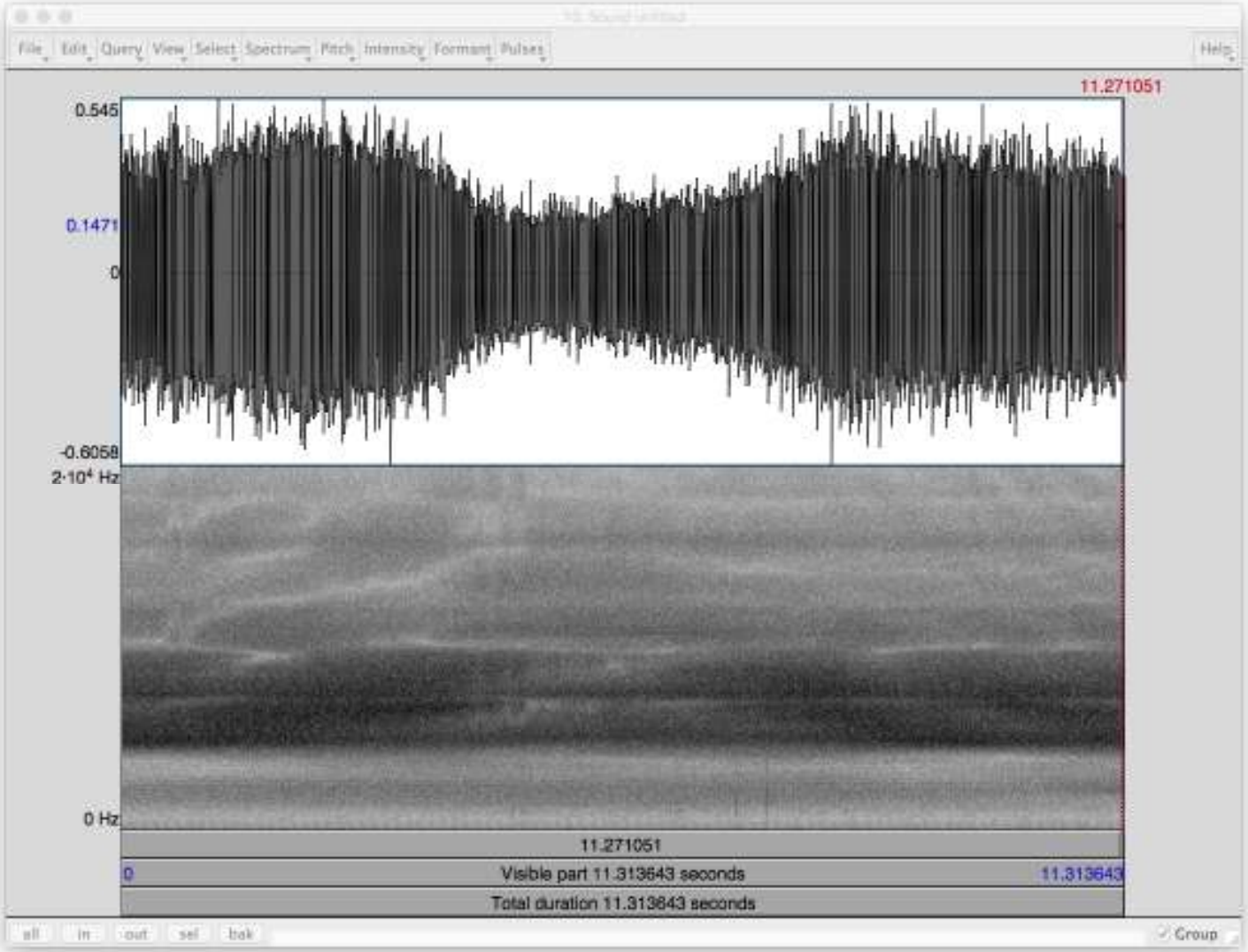
Z-MESMERISE: A **non-intrusive, non-disruptive, no health risk, pat down**, based on sound waves for externally concealed commodities detection

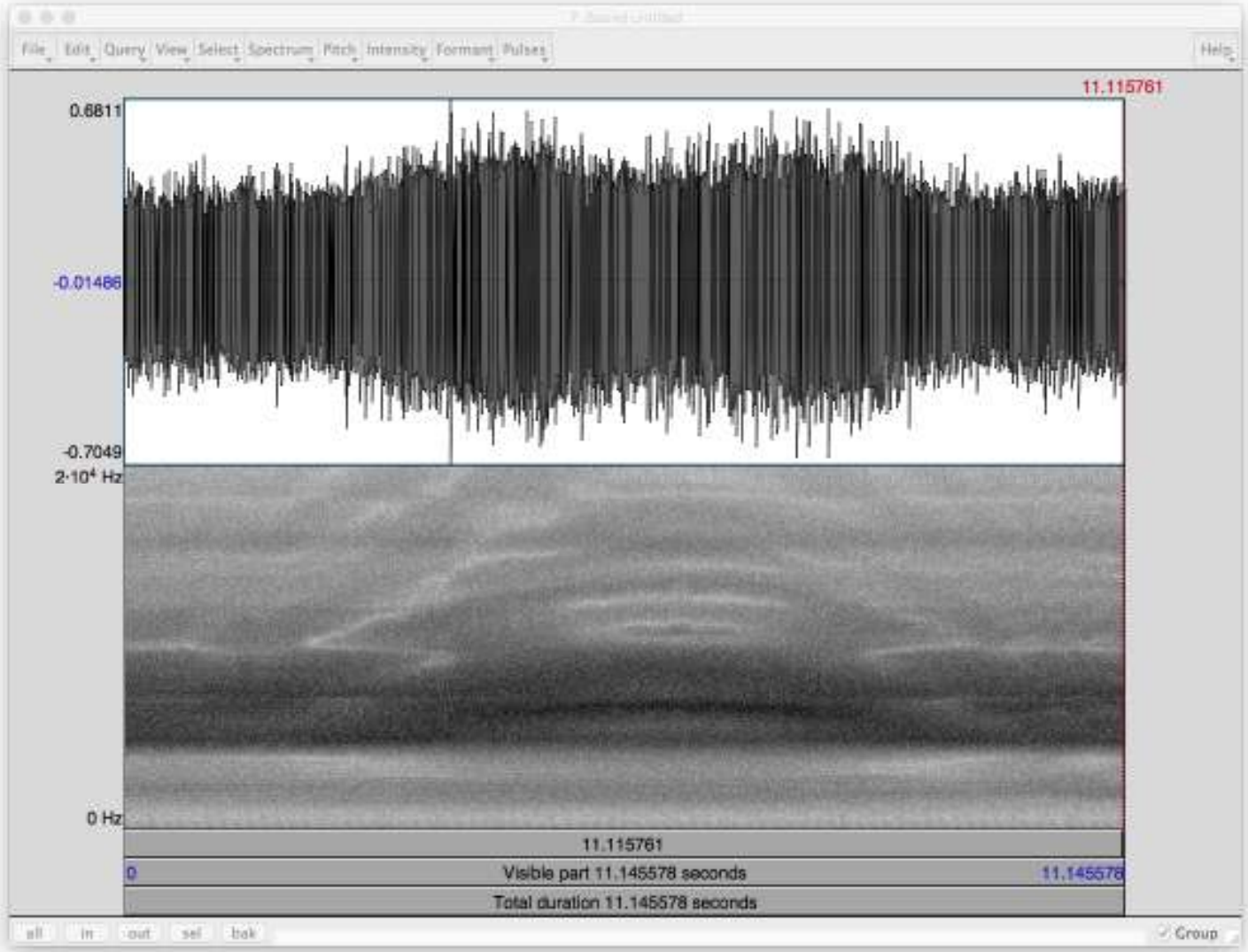
Non-intrusive because it is completely contactless and because the ATR shows the alert the operator not being necessary to exhibit and visually construct the image. This is particularly relevant considering gender matching customer and operator being in any case a better solution than the current practice

No risk to particular groups such as pregnant because is based on sound waves
The automated target system allows to alert and identify

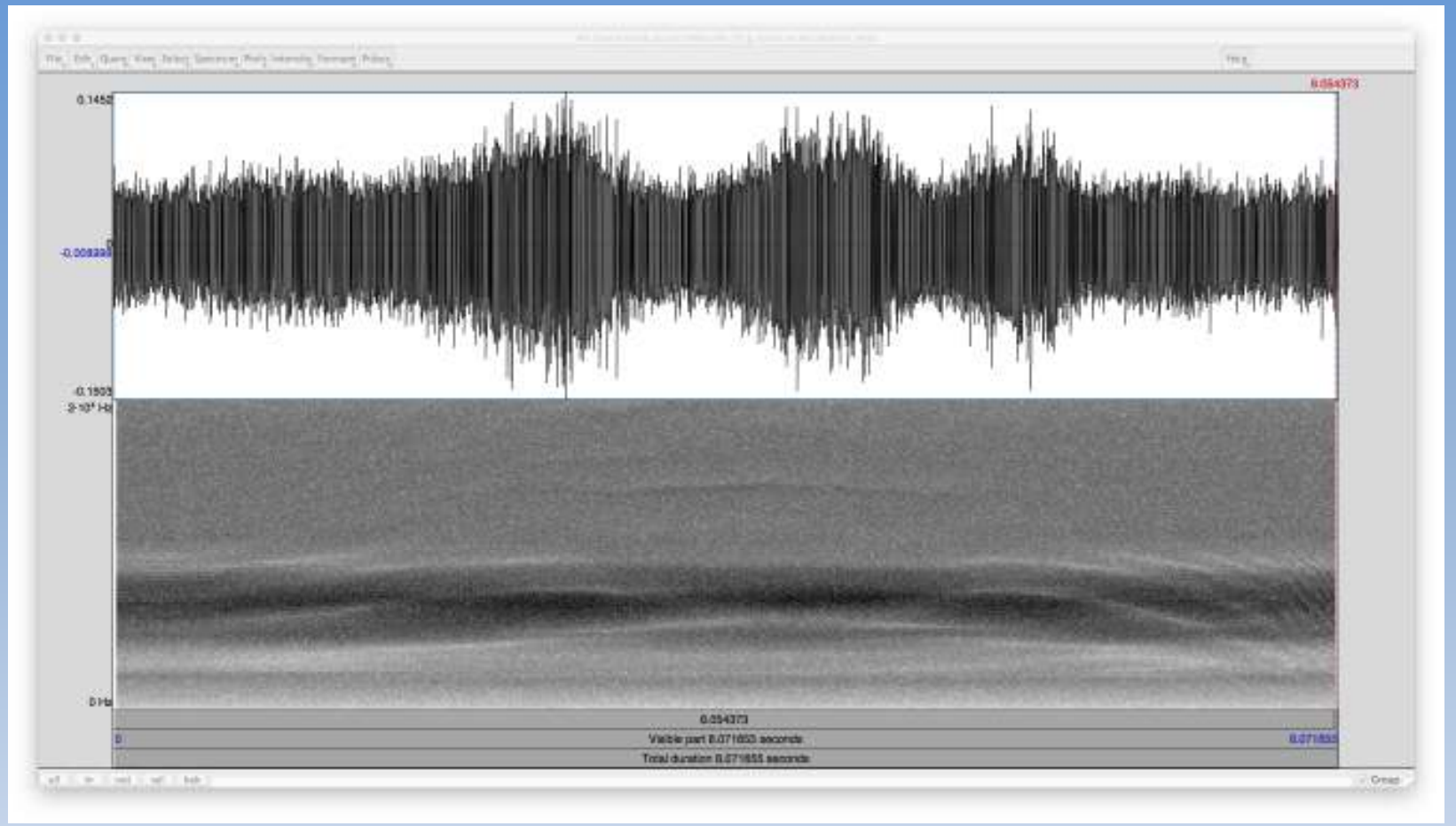
Current Progress




File Edit Query View Select Spectrum Pitch Intensity Formant Pulses Help
11.271051
0.545
0.1471
0
-0.6058
2·10⁴ Hz
0 Hz
11.271051
0
Visible part 11.313643 seconds
11.313643
Total duration 11.313643 seconds
all in out sel bak
Group



16 g Pink Salt Tea Bag on the thigh.



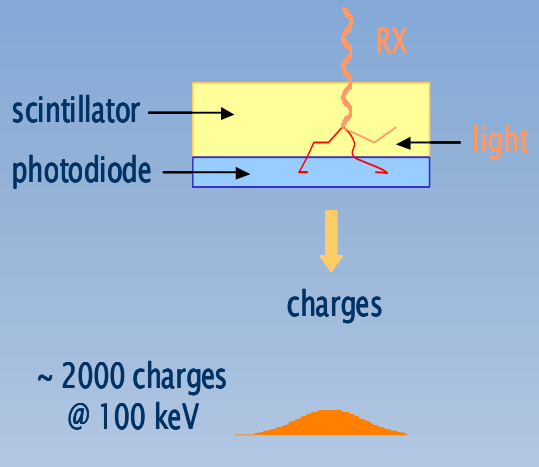
Tea bag with 16 g of refined sugar on the thigh.

X-MESMERISE

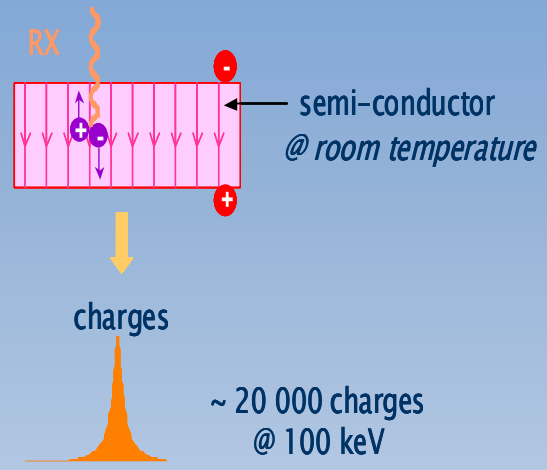
Ultra Low-Dose X-Ray emission system
X-Ray collimation system
Gantry
Transport system
X-ray detection system
Automatic Recognition system

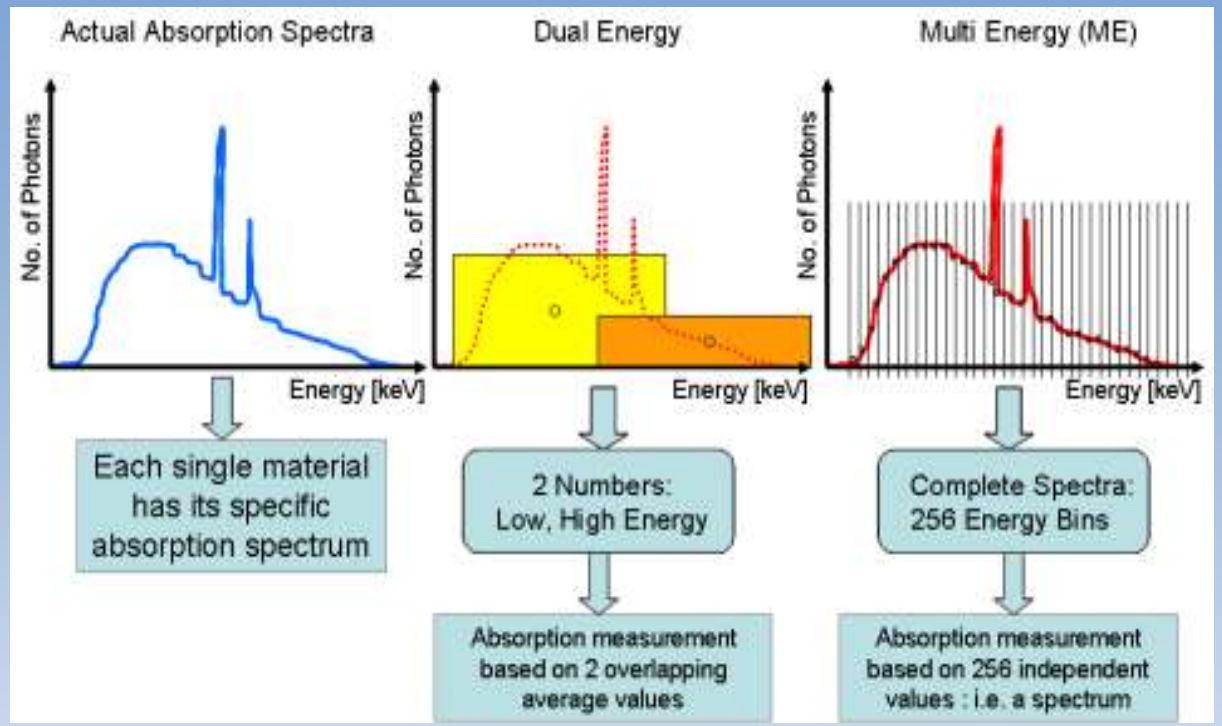
0.25 µSv

2-stage detection
standard solution



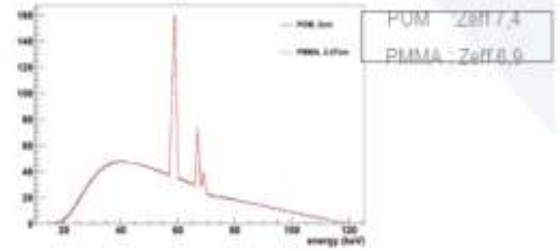
direct detection
CdTe solution




Actual Absorption Spectra
Dual Energy
Multi Energy (ME)
No. of Photons
Energy [keV]
Each single material has its specific absorption spectrum
2 Numbers: Low, High Energy
Absorption measurement based on 2 overlapping average values
Complete Spectra: 256 Energy Bins
Absorption measurement based on 256 independent values : i.e. a spectrum

MULTIX
Xray Spectrometric Imaging

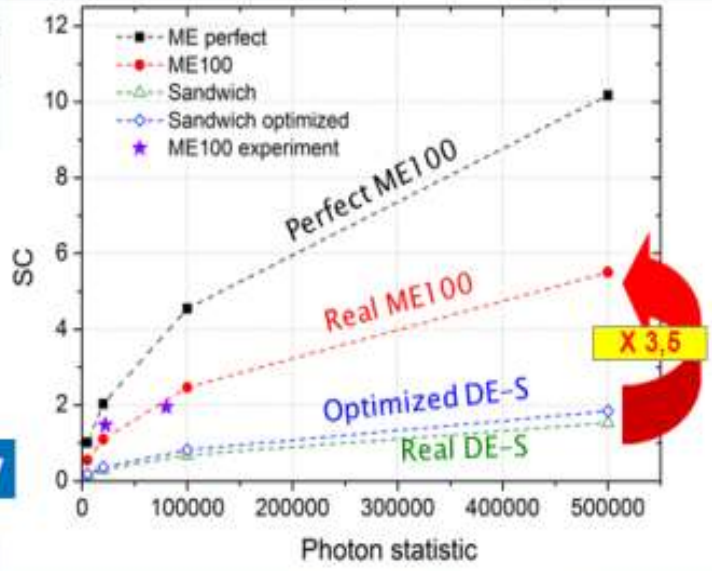
Evaluation of Separability Criterion with photons statistics(1)



$$SC^2 = \sum_{i=1}^{k} \frac{(att_i^1 - att_i^2)^2}{(\sigma_i^1)^2 + (\sigma_i^2)^2}$$

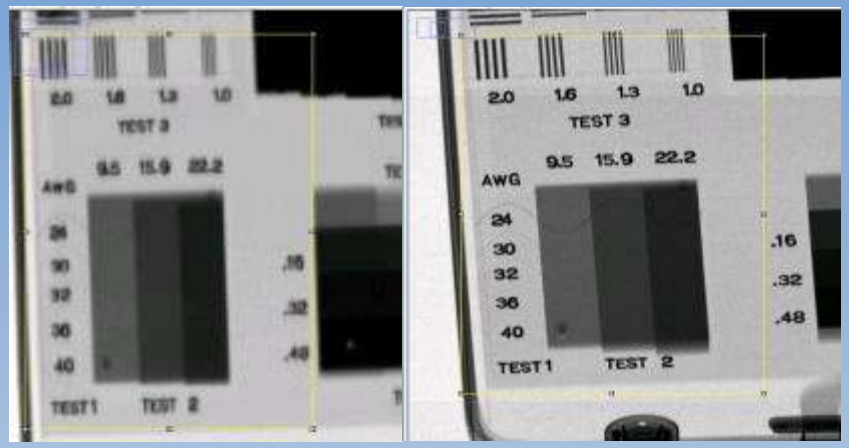
SC ⇔ Z separability

$$Separation = \frac{|Z_1 - Z_2|}{\sqrt{\sigma^2(Z_1) + \sigma^2(Z_2)}}$$



Material separability improvement with ME100 spectral information

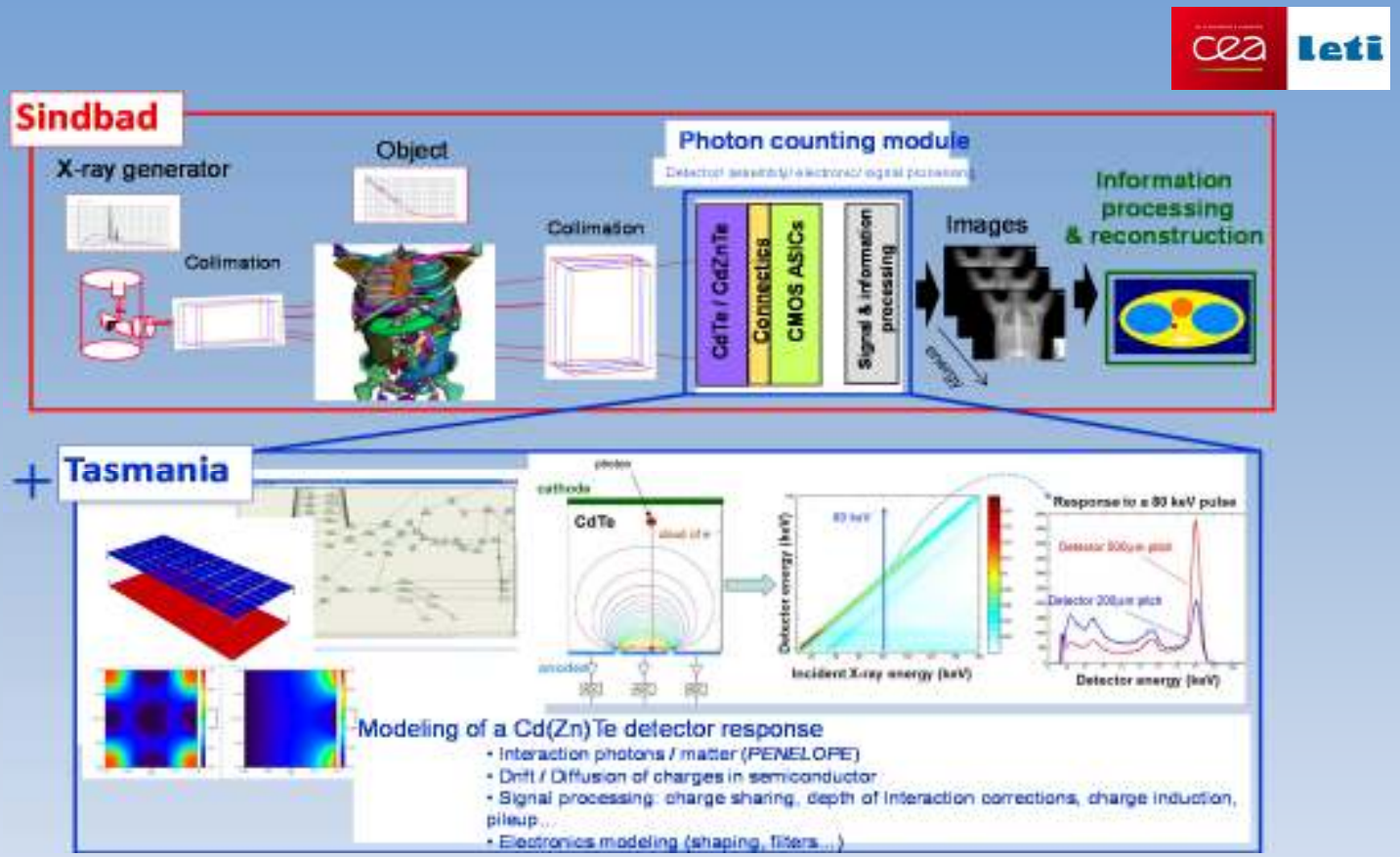
Image resolution



Test	Conventional	ME100
Wire visible in air (AWG)	32	40
Wire visible under 9.5mm Al (AWG)	24	32
Spatial Resolution (mm)	1.6x1.3	1x1
Penetration of steel (mm)	22-26	26-28

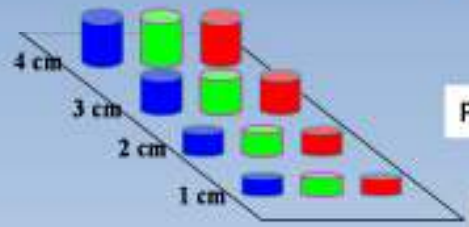
Detailed view of an image from the ASTM F792 test piece acquired by a conventional detection system (left) and the multiple energy detector (right) with same acquisition parameters.

Specific method to identify the materials



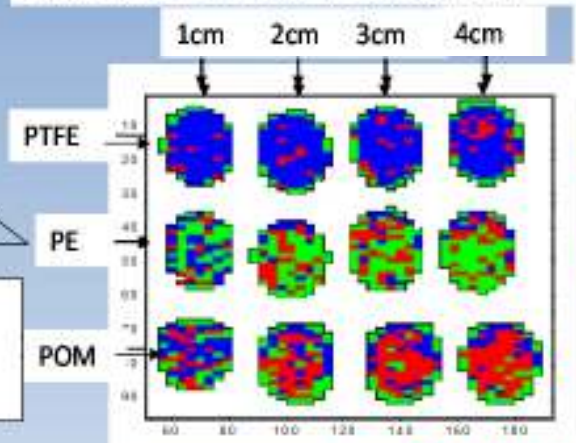
Information processing

- ME calibration, superposition
- Method using probability density
- Density & Zeff identification

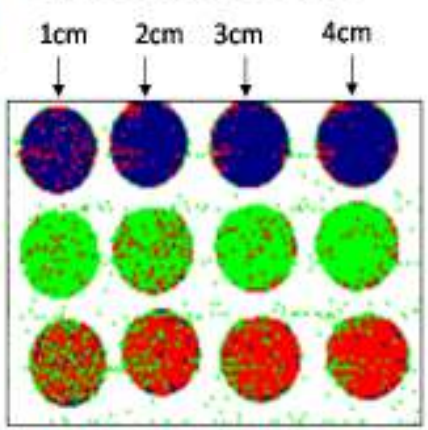


- blue : PTFE (teflon)
- green: PE (polyéthylène)
- red: POM (delrin)

Dual-energy detector (« sandwich »)

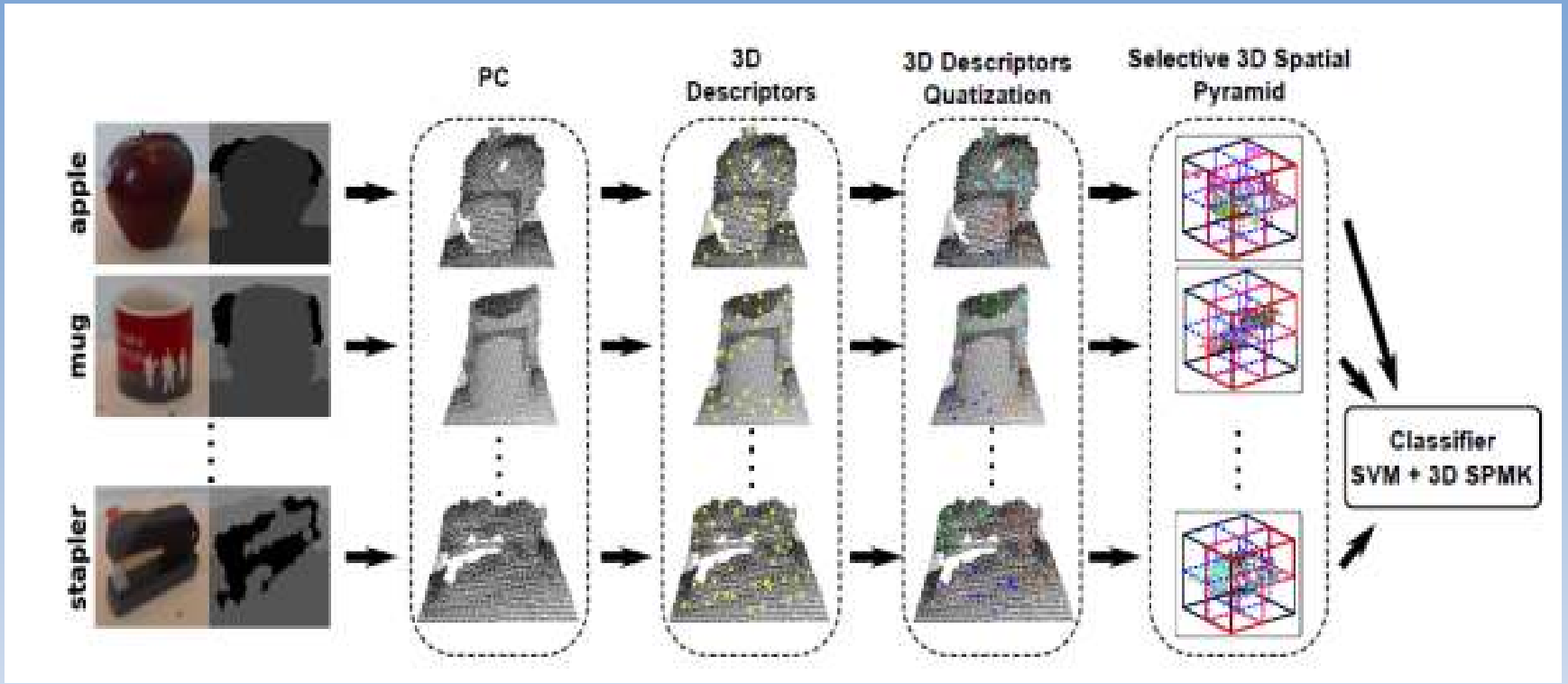


Spectrometric detector



False detection rate decrease

Automated Target Recognition System



X-MESMERISE expected features:

A **full body non-divest non-intrusive quick non-disruptive ultra-low dose x-ray scanner** (FBS), usable upon consent by the final user, for internally and externally concealed commodities detection identifying the object and warning the operator:

Non-divest: the final user does not need to divest outer clothes or belongings from pockets, etc.

Non-intrusive: it is completely contactless and because the ATR shows the alert, it is not necessary to render and display an image to the operator

Quick: the whole operation could be deployed in a very convenient layout for both the customer and the security service, taking less time than the current systems

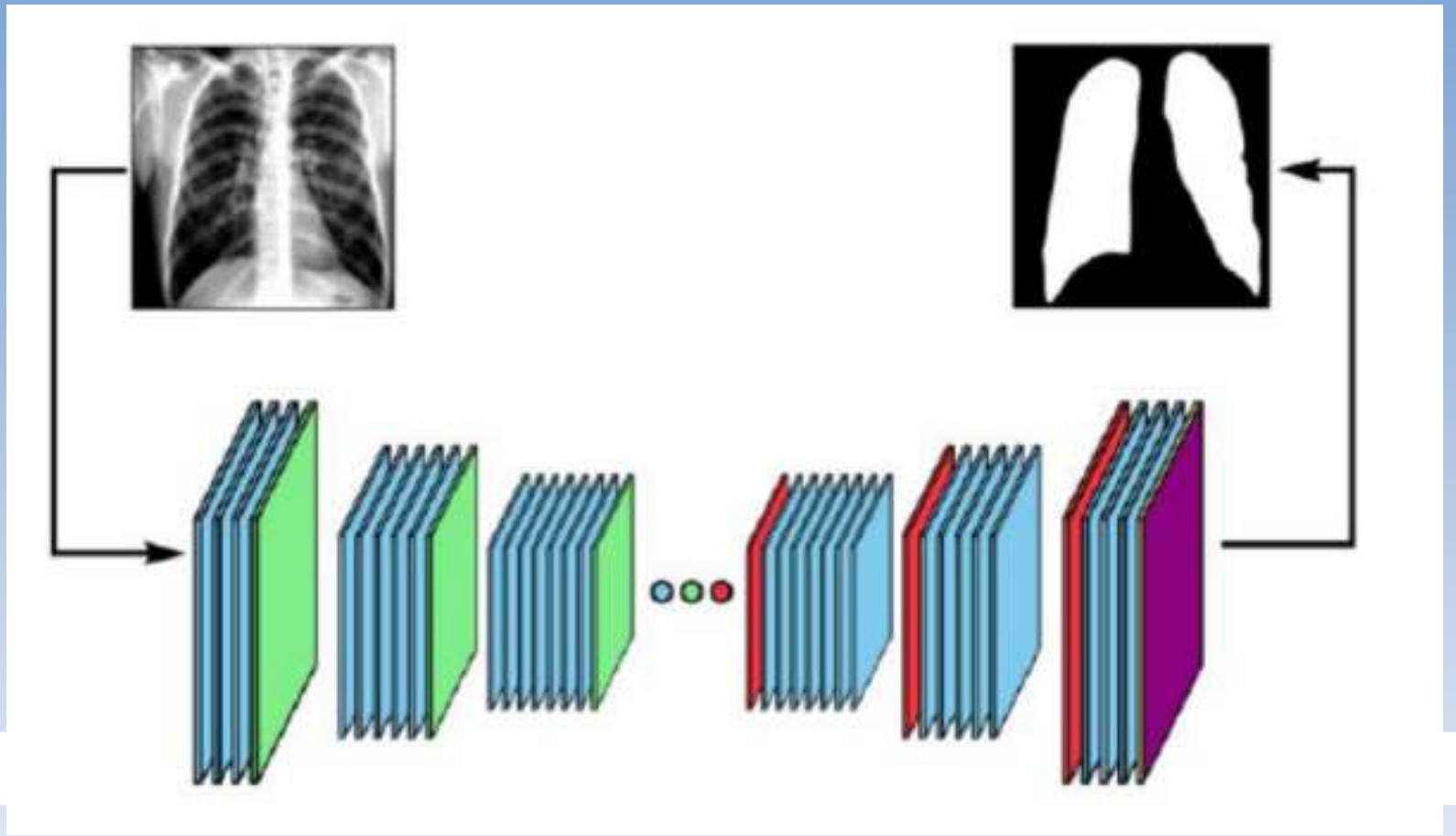
Non-disruptive: the operation takes place in a continuous moving belt maintaining a constant flow of passengers

The dose per scan is under the limits according to the EU standard limits (1mSv per year)

Automated Target Recognition System

Inspired by tumor segmentation models

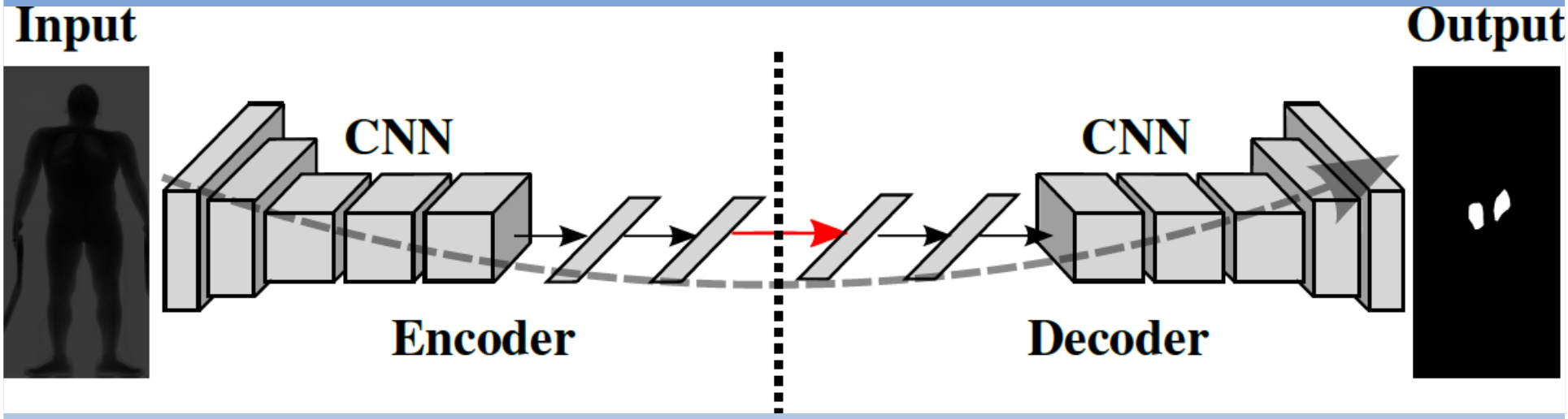
Train a CNN (Convolutional Neural Network) model for Semantic Segmentation.



Our model

Overall Architecture: Deep Encoder-Decoder CNN-based

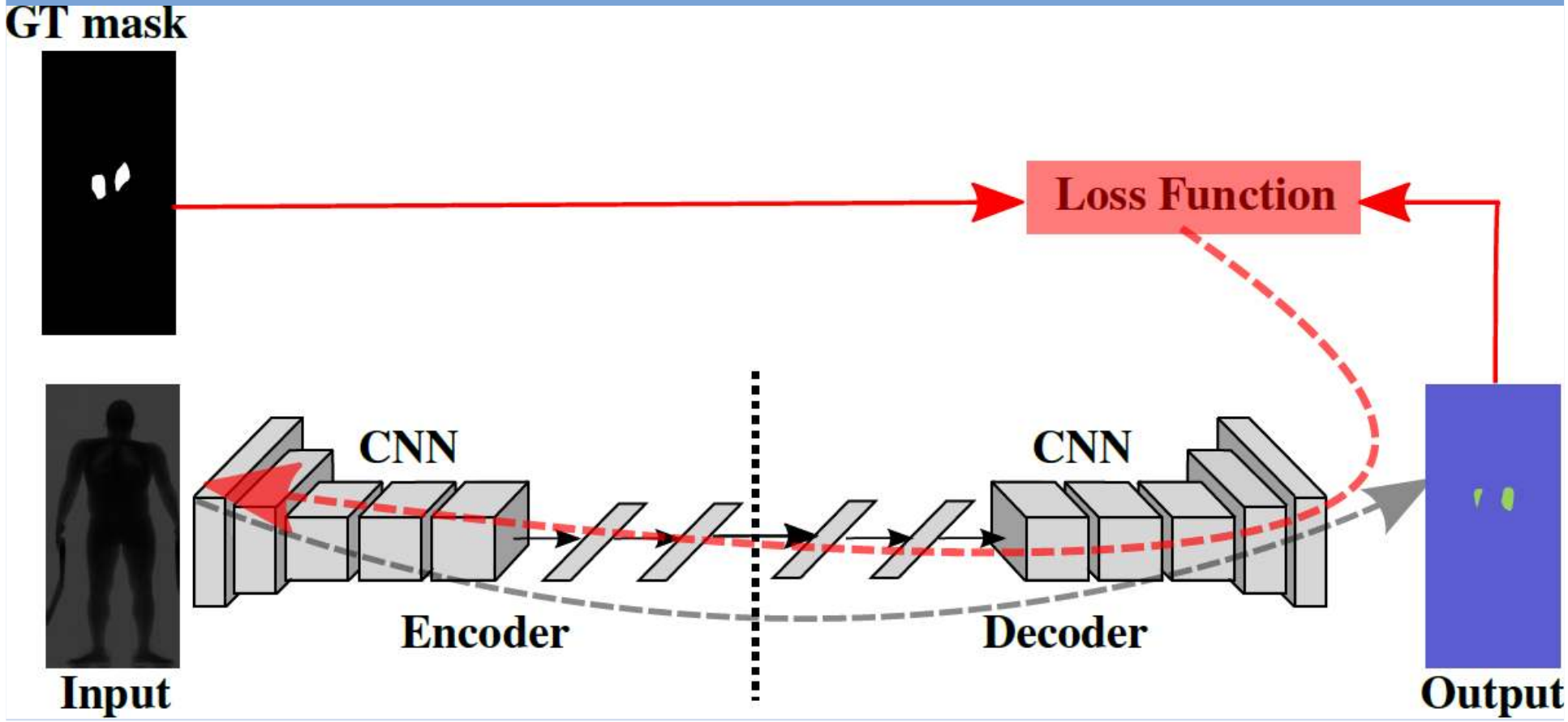
(Convolutional Neural Network CNN)



Given a feature representation obtained from the encoder network, dense pixel-wise prediction map is constructed through decoder network.

Our model

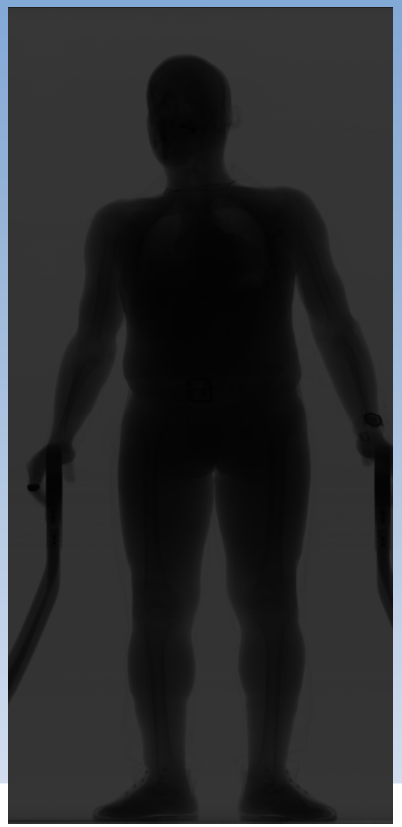
Training Process: Optimization



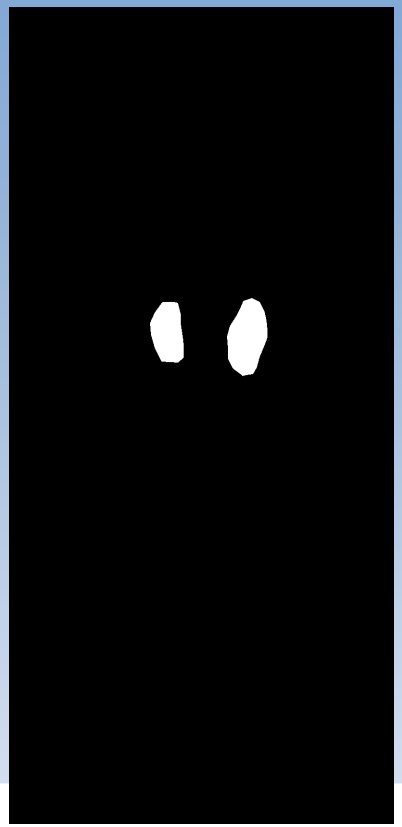
Mesmerise Dataset

Number of X-ray images (from London & Oslo scanners): 57

Raw X-ray image

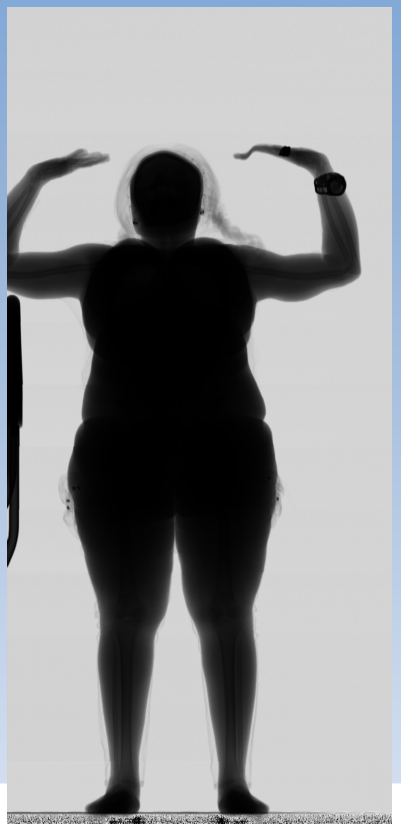


Mask

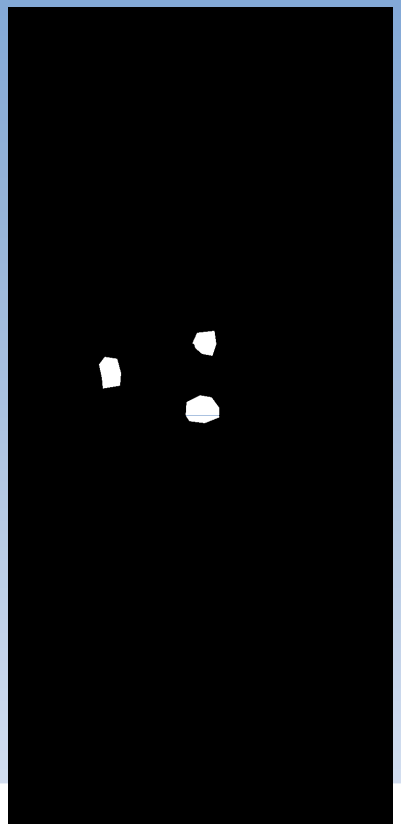


London

Raw X-ray image

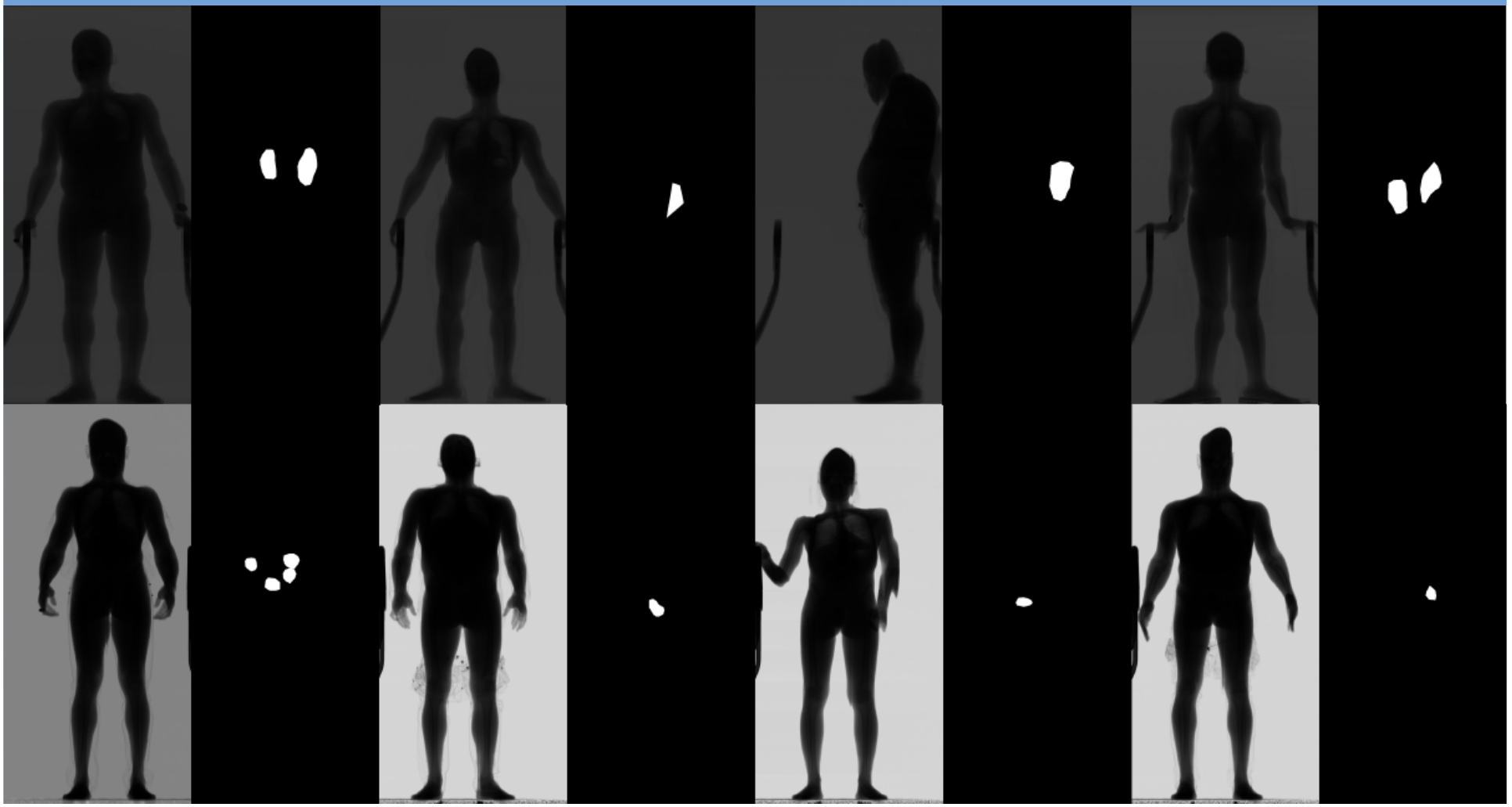


Mask



Oslo

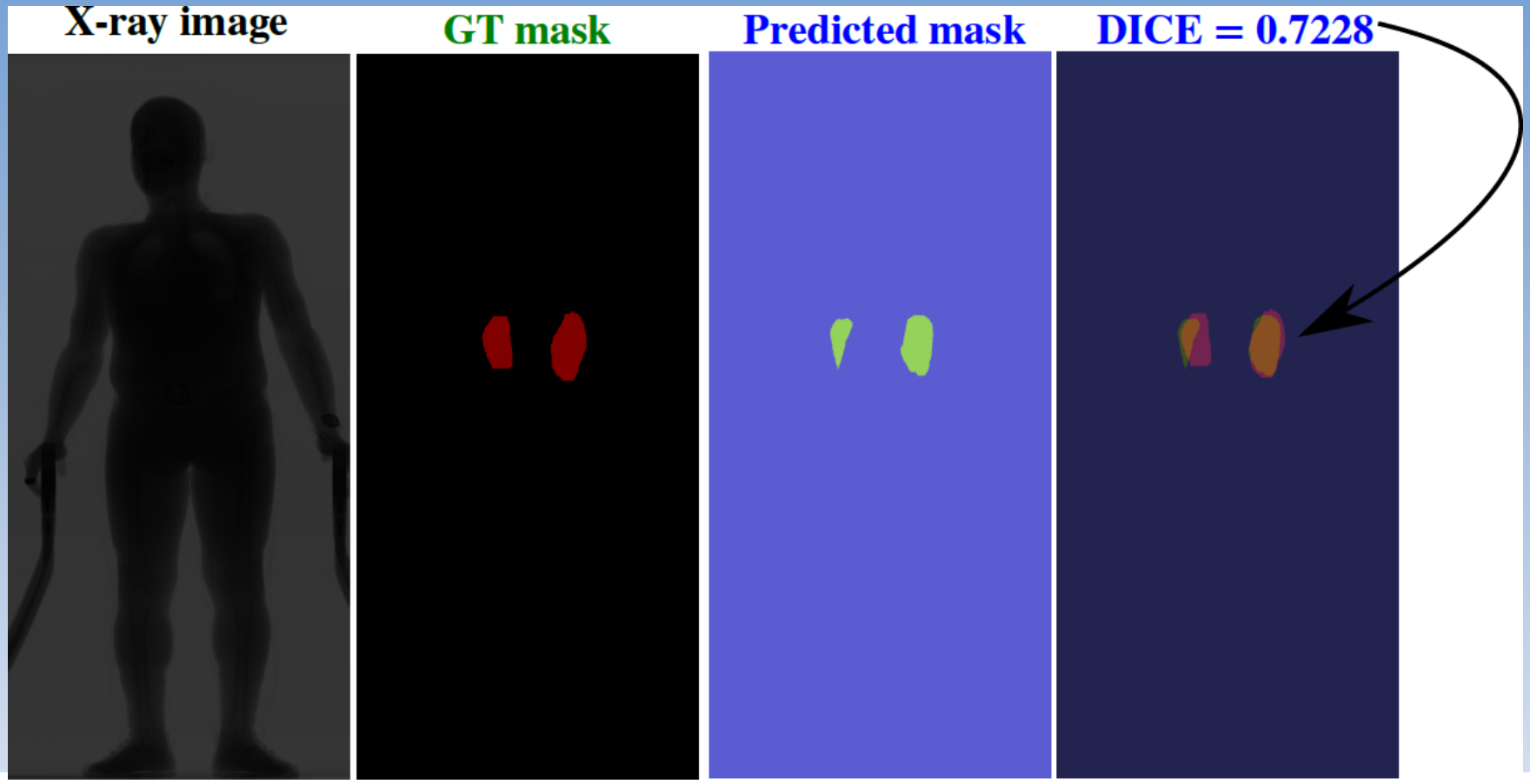
Mesmerise Dataset



Results on Mesmerise Dataset

Ground Truth

Sorensen-Dice coeficient



4.1 Quantitative Results

Setups:

Set 1:

- **Training images: 49**
- **Validation images: 8**

Set 2:

- **Training images: 29**
- **Validation images: 28**

Evaluation metrics:

Global Accuracy (GA) – Pixels right
Class Average Accuracy (CAA) – Proportion of Right Pixel per Class
Intersection over Union (IoU) – Overlap between GT and Predicted Masks
Dice coefficient (D) – Overlap with class 1 (narcotics positive)

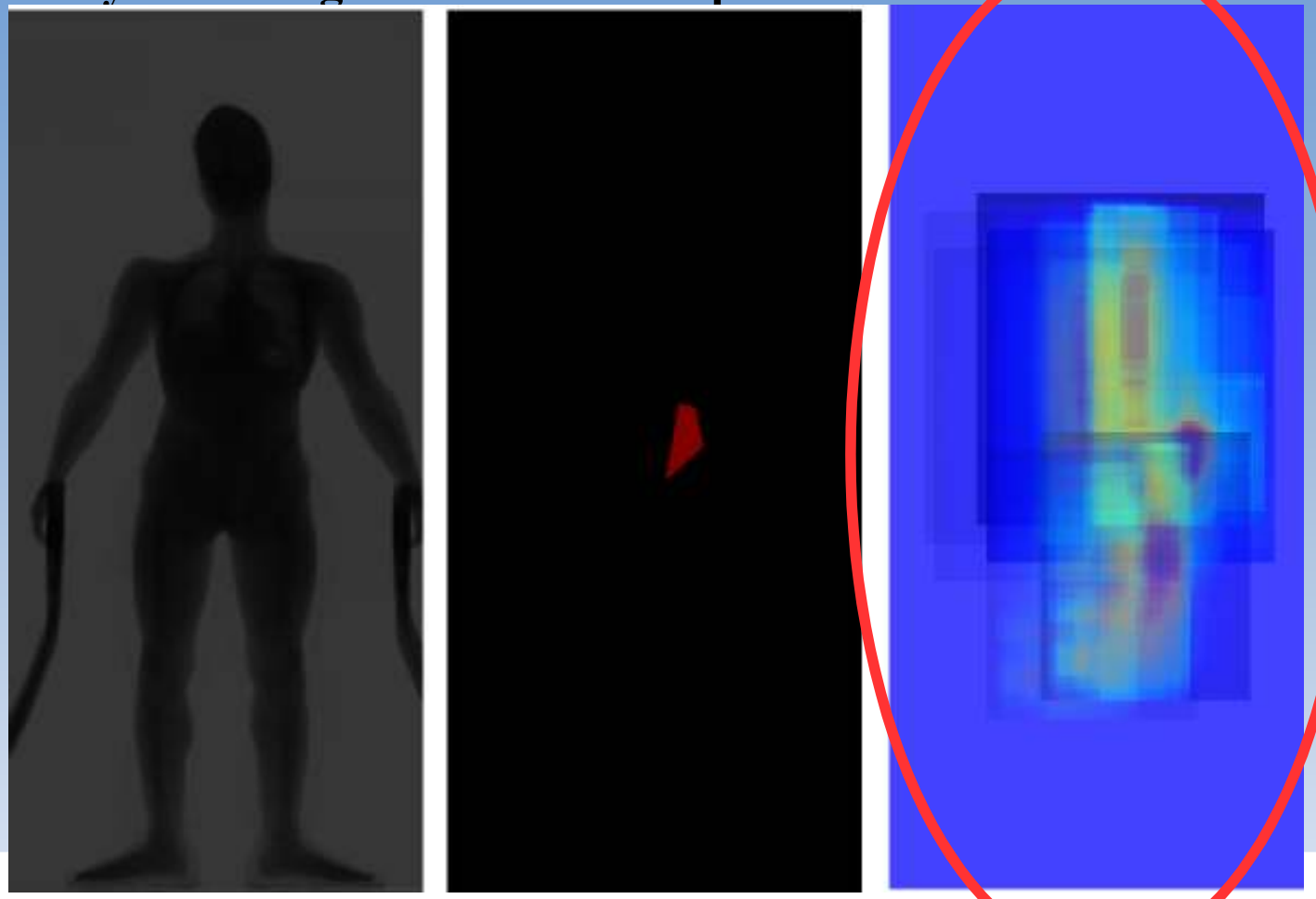
4.1 Quantitative Results

The importance of the number of training images

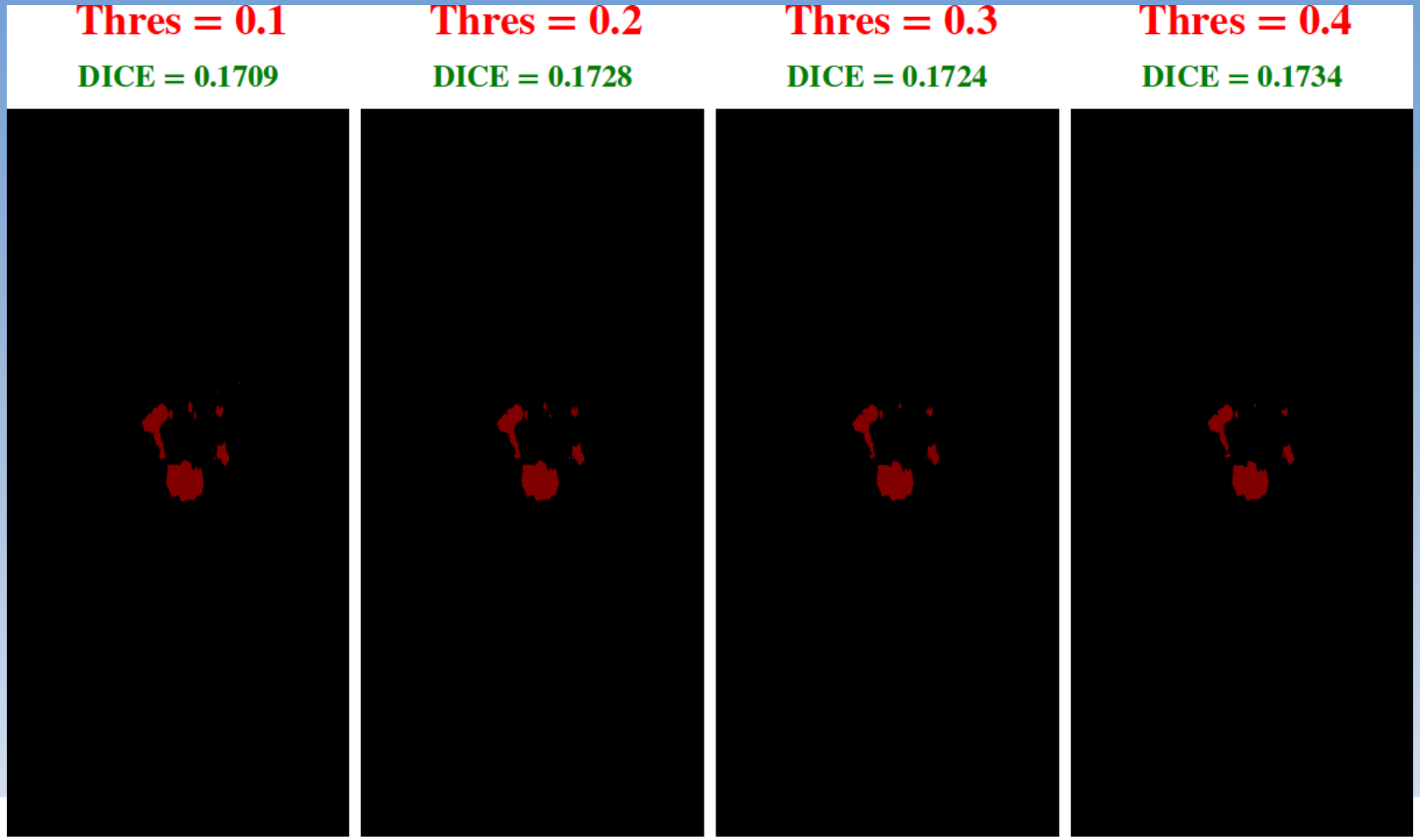
Setups	GA (%)	CAA(%)	IoU	D
SET 1 (49 training images)	99.16	**71.10**	**0.6212**	**0.3519**
SET 2 (29 training images)	99.16	64.41	0.5761	0.2725

4.2 Qualitative Results: Probabilistic Output

Probability of finding narcotics in that pixel

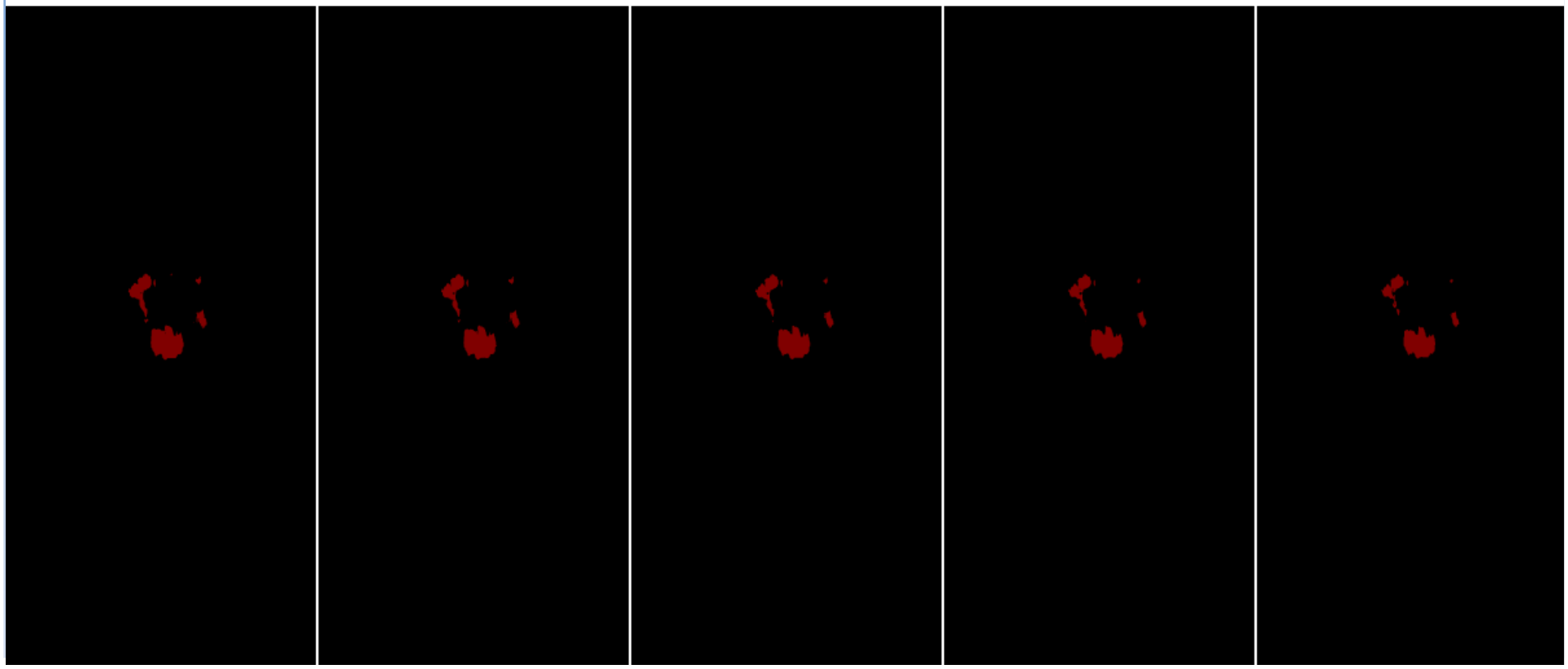


4.2 Qualitative Results: Probabilistic Output



4.2 Qualitative Results: Probabilistic Output

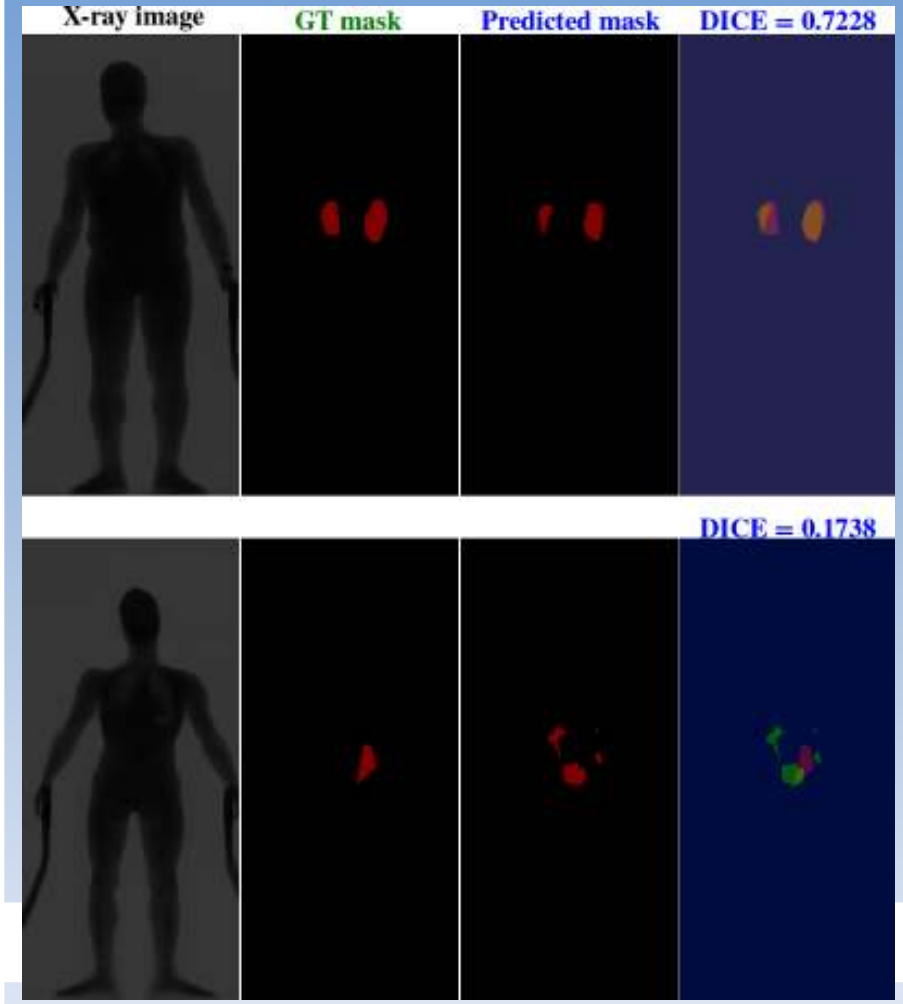
Thres = 0.5	Thres = 0.6	Thres = 0.7	Thres = 0.8	Thres = 0.9
DICE = 0.1738	DICE = 0.1737	DICE = 0.1740	DICE = 0.1750	DICE = 0.1756



4.2 Qualitative Results SET 1: Thres = 0.5. Positive tests

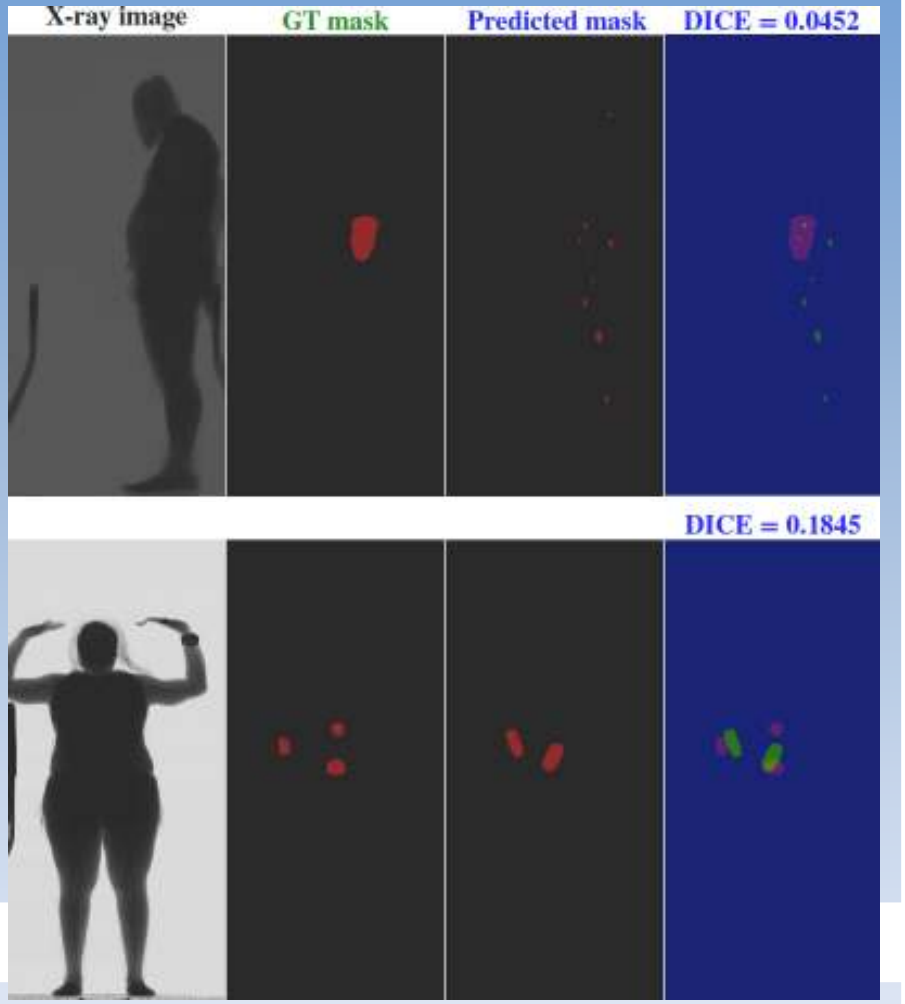
Human operator

Machine recognition



Human operator

Machine recognition



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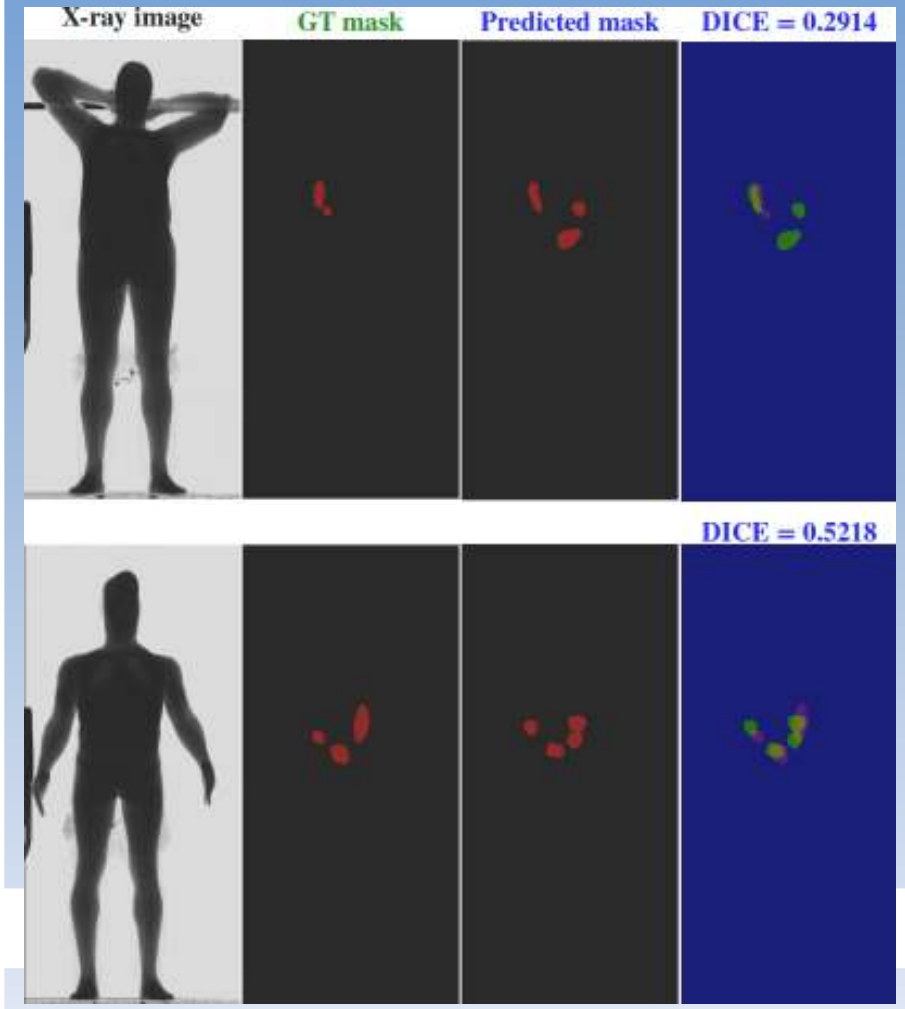
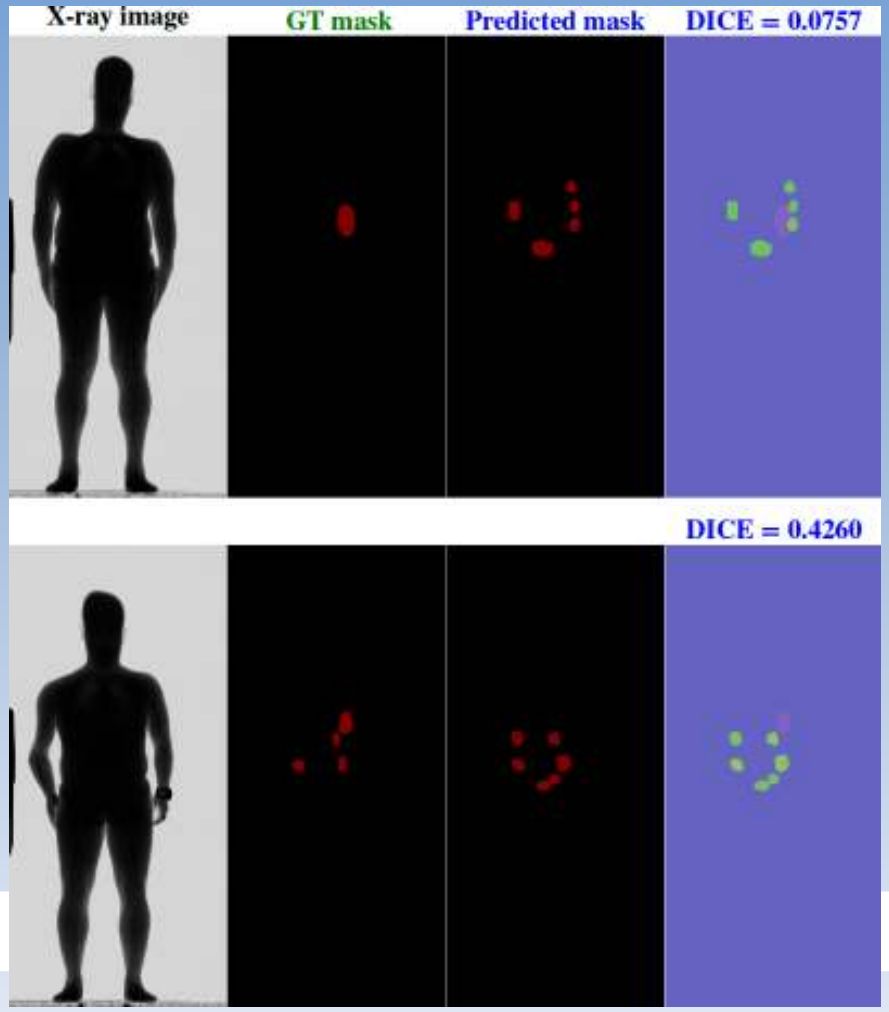
Human operator

Machine recognition



Human operator

Machine recognition



May 2016

April 2019

WORKPACKAGE DESCRIPTIONS		DURATION CRITICAL PATH																																	
Partner name		YEAR 1												YEAR 2												YEAR 3											
Partner number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
PROJECT PERSON MONTH																																			
WP 1	AILED SPECIFICATIONS OF TARGETED PROHIBITED OR RESTRICTED GO																																		
Tas 1. 1	Definition and preparation of the survey																																		
Tas 1. 2	Implementation of a secure procedure for answering the survey																																		
Tas 1. 3	Survey with end users and external advisors																																		
Tas 1. 4	Survey data processing and analysis																																		
Tas 1. 5	Classification of targeted internal and external commodities																																		
Tas 1. 6	Prosthetics research																																		
Tas 1. 7	Classification of prosthetics elements and licit goods most likely carried by passengers																																		
WP 2	PRELIMINARY DESIGN																																		
Tas 2. 1	Preliminary General Design																																		
Tas 2. 2	Mechanical Design																																		
Tas 2. 3	Calibration and Reference Test campaign definition																																		
Tas 2. 4	TRL5 test campaign definition																																		
WP 3	PROTOYPE OF MULTI-ENERGY X-RAY BODY SCANNER (X-MESMERISE)																																		
Tas 3. 1	Design and manufacturing of multienergy sensor																																		
Tas 3. 2	Design & manufacturing of scanner prototype frame																																		
Tas 3. 3	Scanner prototype assembly and set-up for testing																																		
Tas 3. 4	Radiation dose assessment																																		
WP 4	OPTIMIZATION of X-Ray MULTIENERGY METHOD																																		
Tas 4. 1	Design of the multi energy method																																		
Tas 4. 2	Simulation of the body scanner device and typical cases																																		
Tas 4. 3	Adaption and optimization of the multi energy method																																		
Tas 4. 4	Experimental validation																																		
WP 5	Contactless Local Pat-down System (Local Z-MESMERISE)																																		
Tas 5. 1	Theoretical model																																		
Tas 5. 2	Optimization of emitters and sensors.																																		
Tas 5. 3	Electronics Engineering																																		
Tas 5. 4	Breadboard & local prototype design, manufacturing and setup																																		
Tas 5. 5	Experimental local validation																																		
WP 6	Non-Disruptive Contactless Full Body Pat-down System (Z-MESMERISE)																																		
Tas 6. 1	Theoretical model for near-field infrasound scattering on bodies																																		
Tas 6. 2	Model for multi-layered bodies infrasound scattering.																																		
Tas 6. 3	Model for non-disruptive simultaneous infrasound scattering on a set of bodies																																		
Tas 6. 4	Inverse Scattering algorithm and information reconstruction																																		
Tas 6. 5	Micro-machined Ultra-low frequency Sensor Array design, simulation and optimization																																		
Tas 6. 6	Set up and preparation of tools for micromachining																																		
Tas 6. 7	Manufacturing of sensor array design and integration on chip																																		
Tas 6. 8	Design and Engineering of Non-disruptive Contactless Full Body Prototype																																		
Tas 6. 9	Construction and set up of Prototype																																		
WP 7	SMART ALGORITHM FOR AUTOMATIC DETECTION OF LISTED PROHIBITED OR RESTRICTED GOODS																																		
Tas 7. 1	Reference data feed module																																		
Tas 7. 2	Identification of characterizing treats and patterns X-MESMERISE																																		
Tas 7. 3	Anatomy/Cavity/location Module																																		
Tas 7. 4	Identification of characterizing treats and patterns Z-MESMERISE																																		
Tas 7. 5	Module for combination of technologies and Alert warning																																		
Tas 7. 6	Smart Module																																		
Tas 7. 7	Data manager module																																		
Tas 7. 8	User interface software																																		
Tas 7. 9	Integration of software and set up.																																		
Tas 7. 10	Implementation Tests of software. Debugging of software & security assessment																																		

May 2016

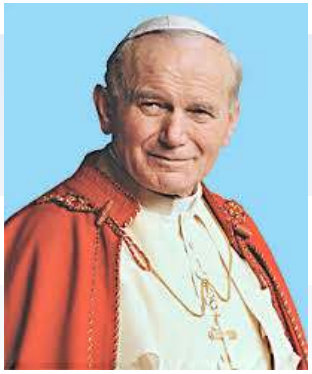
April 2019

WORKPACKAGE DESCRIPTIONS		DURATION CRITICAL PATH
	Partner name	YEAR 1 / YEAR 2 / YEAR 3
	Partner number	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
	PROJECT PERSON MONTH	
WP 8	EXPERIMENTAL REFERENCE /LEARNING & FEEDBACK	
Tas 8. 1	Reference tests for internal concealed prohibited and permitted commodities X-ray X-MESMER	
Tas 8. 2	Reference tests for external concealed prohibited and permitted commodities X-ray X-MESMER	
Tas 8. 3	Reference tests for external concealedcommodities using the Pat-down System Z-MESMERIS	
Tas 8. 4	Analysis of experimental results and preparation of procedures	
WP 9	TRL5 VALIDATION TESTS	
Tas 9. 1	Transport, Set up of equipment and samples	
Tas 9. 2	Procedures and Training	
Tas 9. 3	Validation tests for External Concealed (Drugs) in CAST -Horsam- (HO)	
Tas 9. 4	Validation tests of external concealed goods (explosives) in Valdemoro (GC explosives unit)	
Tas 9. 5	Validation for internal concealed goods in London Heathrow Airport	
Tas 9. 6	Validation for internal concealed goods in Adolfo Suarez Madrid Barajas Airport	
WP 10	DISSEMINATION AND COMMUNICATION	
Tas 10. 1	Press release, Leaflet and information for end-users.	
Tas 10. 2	Information and organization of Workshops with end-users and authorities	
Tas 10. 3	Exhibitions in Trade-fairs	
Tas 10. 4	Scientific and technological dissemination	
WP 11	IP PROTECTION AND EXPLOITATION	
Tas 11. 1	Patentability analysis	
Tas 11. 2	Technological surveillance of possible competitors	
Tas 11. 3	Intellectual Property Protection	
Tas 11. 4	Detailed Exploitation& bussiness plan	
WP 12	PROJECT MANAGEMENT	
Tas 12. 1	Administrative and financial management	
Tas 12. 2	Data management	
Tas 12. 3	Secure Management of Information. Classification assesment.	
Tas 12. 4	Safety	
Tas 12. 5	Ethics management	
Tas 12. 6	Legal and adminsitrative permits and clearances	
Tas 12. 7	External advisor committee management	
Tas 12. 8	Procurement of samples and definition of procedures for legal and safe tests	
Tas 12. 9	Personal Data Protection	
	TOTAL	
	DELIVERABLES	D1.1, D12.1 · D2.1 · D2.2 · D4.1 · D3.1 · D5.1, D6.1 · D3.2, D3.3, D4.2 · D6.2 · D6.3 · D8.1, D8.2 · D7.1, D8.3, D8.4 · D11.1, D11.2 · D9.1, D9.2, D9.3 · D10.1
	PROGRESS AND FINAL REPORTS	
	MILESTONES	MS1 · MS2 · MS3&4 · MS5 · MS6

“Scientists, precisely because they ‘know more’, are called to ‘serve more’. Since the freedom they enjoy in research gives them access to specialized knowledge, they have the responsibility of using that knowledge wisely for the benefit of the entire human family”

John Paul II

Address to the Pontifical Academy of Sciences, 11 November 2002



MESMERISE

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