Non-intrusive inspection of cargo containers using the C-BORD Rapidly Relocatable Tagged Neutron Inspection System

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Abstract: The European H2020 project, entitled "effective Container inspection at BORDer control points" (C-BORD), aims to develop a framework of Non-Intrusive Inspection (NII) technologies, for containers and large-volume freight at the EU borders. In this article the first results of the field trials of the Rapidly Relocatable Tagged Neutron Inspection System (RRTNIS) are reported. The tests were carried out at the customs administration of the Netherlands' (DCA) facility in the seaport of Rotterdam, the Netherlands. For the tests mock-up cargo containers were prepared. The containers were analyzed using the whole set of NII subsystems of the C-BORD framework. Each container underwent a session of subsequent scans with all the subsystems, in order to realistically reproduce the normal flow of inspections at the customs facility. The RRTNIS was tested under these realistic conditions, as well. The system was able to separate and identify the target materials, in mock-up containers, and improve the state-of-the-art in terms of the detected quantities.

1 Introduction

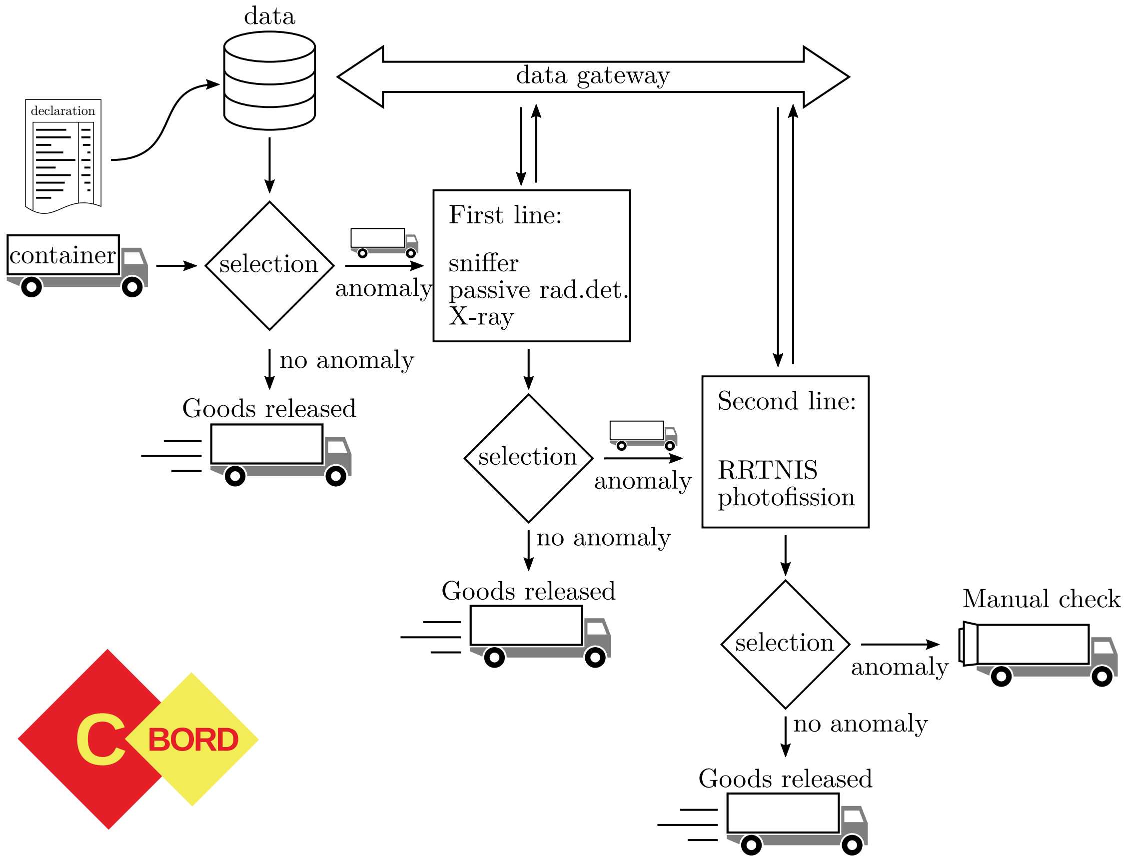
The European project C-BORD (effective Container inspection at BORDer control points) was aimed at developing and testing a comprehensive cost-effective solution for the generalized inspection of large-volume freight containers [23, 26, 10, 19, 22, 24, 27, 20, 18, 21] [1]. In order to contribute to the protection of EU borders, the C-BORD collaboration developed a framework of Non-Intrusive Inspection (NII) technologies. The requirement to develop NII techniques is justified by economical and safety reasons, since physical inspection of suspected containers is time-consuming and expensive. Moreover an inspection might put operators at risk of injuries and exposure to threat materials. The broad range of threats that were investigated in C-BORD included: explosives, chemical warfare agents, illicit drugs, tobacco and special nuclear materials. The main technical objective of C-BORD was to develop a comprehensive toolbox of first-line & second-line subsystems, employing different NII techniques, including passive as well as active technologies. The desired Technology Readiness Level (TRL) of the resulting system was TRL-7, that correspond to a prototype demonstration in operational environment. As a final result, the project developed a unified data management system for all the technologies, with data fusion capabilities and decision support components, facilitating the quality of the interpretation of the data from the NII subsystems. A common data format was defined among all the technology developers as well as a common Graphical User Interface (GUI); both were developed according to the end-users specifications and requirements. The involved technology developers were partners of the C-BORD consortium [26].

This article specifically reports that part of the final field tests that concerns the performance of the Rapidly Relocatable Tagged Neutron Inspection System (RRTNIS). Although other neutron inspection systems have been reported [1, 16, 29], the RRTNIS is the first example of a rapidly relocatable (operational within 48 hours) inspection system for cargo containers. The tagged neutron technique [23] employs a neutron generator, that essentially is a particle accelerator that induces the fusion of deuterium and tritium. Sometimes the neutron generator is referred as an associated particle generator [15]. In the process, a 14 MeV neutron is produced together with an alpha particle. The two particles are created with linear momenta that are approximately aligned. The alpha particle is then used to tag the neutron, both in time and direction. *I.e.* the signal of the alpha particle sets the time origin for the neutron Time-of-Flight (ToF). The neutrons then interact with the materials in the container, mainly by means of inelastic scatterings with the nuclei that make up the materials, producing prompt gamma-rays

[1]The project received funding from the EU H2020 Research and Innovation Program, under grant agreement n. 653323.

coming from the de-excitation of the nuclei. The energy spectrum of those gamma-rays is then employed to determine the material's composition, which together with the spacial and angular information, using the ToF and the alpha particle direction, offers the benefit of being able to identify classes of materials with also spatial information [16].

2 C-BORD systems overview



Slika 1: Flow of cargo containers as defined in the C-BORD framework. The selection stages identify cargoes that have to be further inspected or can be released. Anomalies might be threats or an incongruence in the goods declarations.

For practical and economical reasons, only a fraction of the millions of freight containers can be subjected to non-intrusive inspection (NII). A first selection is carried out based on the customs declaration, intelligence and other data collected by the customs authorities. In addition random inspections are carried out. If a container is selected, the C-BORD toolbox is employed for an accurate non-intrusive inspection of the container and its content. C-BORD technologies are subdivided into two categories: first-line and second-line inspection systems (Fig. 1). C-BORD first-line inspections are capable of quickly analyzing containers and thereby keeping the disruption of the flow of the goods through the port at a minimum. They are employed to signal items, or regions that appear anomalous, inside the sealed containers. The time required for a first-line scan depends on the specifics of the container, and might vary between minutes and tens of minutes. C-BORD second-line inspections are complementary technologies that can identify the anomalies that could not be identified by interpretation of the first-line subsystems' data. If anomalies are still not cleared, after the second-line inspections, a physical inspection is called on the container.

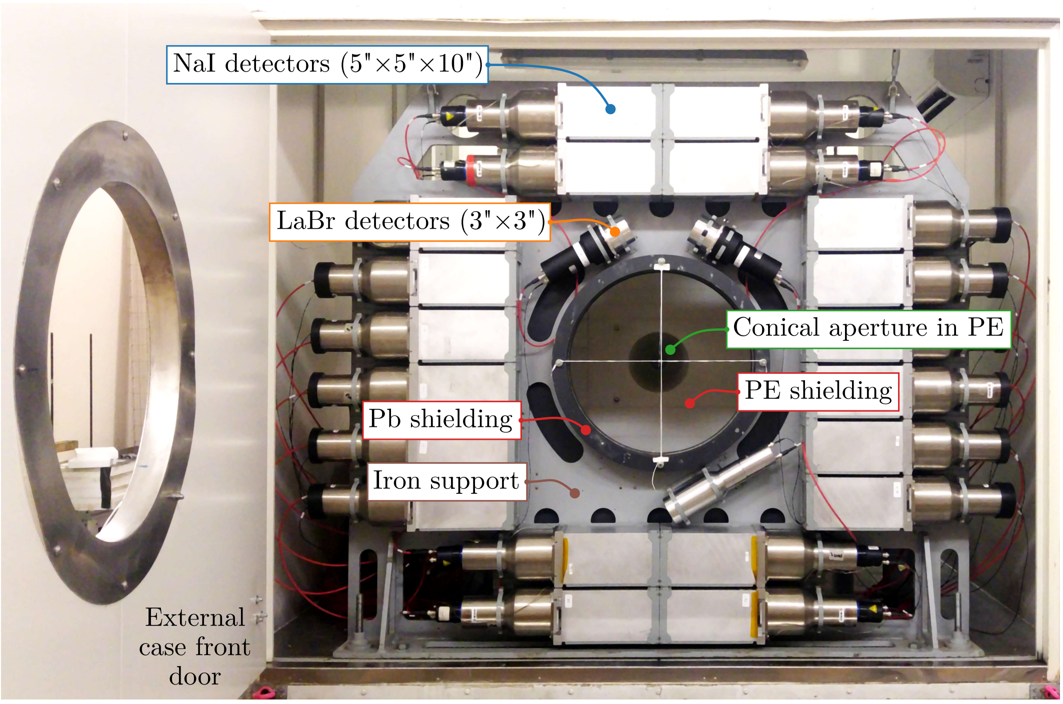
The C-BORD set of first-line technologies consists of: Advanced Radiation Management, Next Generation Cargo X-Ray, and Evaporation Based Detection. The second-line technologies consists of: Tagged Neutron Inspection, and photofission. The evaporation based detector (also called "Sniffer") is the first inspection performed on the container. It samples and analyzes the air inside the container detecting specific chemicals. The advanced radiation management technology is composed of Radiation Portal Monitors (RPM), that are equipped with advanced algorithms for radioisotope sources identification. The RPMs are the second inspection system that is used. Finally the container is scanned with X-rays. All the data collected in the first-line inspection is analyzed and interpreted to determine the second-line technology to be selected.

If anomalies cannot be cleared in the first-line, the second-line technologies (RRTNIS or photofission) are selected and employed, depending on the density and atomic number of the anomaly. The RRTNIS is used to detect contraband of explosives, illicit drugs and chemical agents in specific voxels within the container [10, 19, 23, 22, 20, 24]. Voxels are elementary volume units, *i.e.* the minimum volume element that can be analyzed due to the spatial resolution. Due to contractual obligations and security reasons, the voxel dimensions cannot be published. The additional value of the RRTNIS is the ability to distinguish between organic substances, that may have similar and low densities and atomic numbers, and thus look similar on X-ray radiographies (*e.g.* explosives vs. narcotics vs. benign materials). The photofission technology is employed to detect special nuclear materials (SNM) [27], so, high density materials. First, a specific zone of the container is irradiated with X-rays (bremsstrahlung spectrum with the end-point energy at 9 MeV). The photofission subsystem is activated immediately after the X-rays are turned off, detecting [12] high energy delayed gamma rays, delayed neutrons and prompt neutrons by means of Threshold Activation Detection (TAD) [25].

3 Detailed description of the Rapidly Relocatable Tagged Neutron Inspection System (RRTNIS)

The core of the RRTNIS is a DT neutron generator (Sodern GENIE TPA17 CBORD), that produces fast neutrons (E = 14 MeV) by means of the deuterium-tritium fusion reaction (^{2}H + ^{3}H $\rightarrow n$ + ^{4}He). Neutrons are tagged in time and direction. This is realized by detecting the associated alpha particles, using a YAP:Ce scintillator coupled to a position-sensitive multi-anode photomultiplier (PMT). The neutron generator is encased in a polyethylene (PE) radiological shielding, to ensure that the tagged neutron beam escapes through a conical aperture (total angular width of 20°) [23]. Characteristic de-excitation gamma rays are emitted in all directions when fast neutrons interact, mostly by inelastic scattering, with nuclei belonging to the encountered materials. The gamma detection system measures the gamma energy spectrum and the time distribution between the alpha emission and the gamma detection [10, 19, 23, 18]. The alpha-gamma time difference allows determining the neutron Time-of-Flight (ToF), and subsequently the interaction distance. Therefore, by selecting a window on the ToF spectrum and a particular neutron direction, it is possible to obtain the energy spectrum of the gamma rays emitted from a chosen voxel in the container. Finally, the gamma spectrum of the voxel of interest is unfolded into a linear combination of elemental gamma spectra. The neutron-induced elemental signatures were measured during the RRTNIS calibration phase with pure element targets [22, 20].

The RRTNIS gamma detectors are twenty (20) large-sized parallelepiped-shaped (5"×5"×10") NaI:Tl scintillation detectors, and three (3) cylindrical (3"×3") $LaBr_3$:Ce scintillation detectors (Fig. 2). NaI detectors are used to detect the higher energy gamma rays (*e.g.* oxygen's 6.6 MeV). $LaBr_3$:Ce detectors are used to detect the lower energy gamma radiation (down to approximately 500 keV) with a sufficient energy resolution to separate these gamma rays [23]. The detectors are mounted on an iron frame, that includes lead shielding, to reduce the background generated by neutron capture on the hydrogen nuclei of the PE shielding. The RRTNIS is designed to have a backscattering configuration, in order to have a more compact system than previous EURITRACK Tagged Neutron Inspection System (TNIS) [15]; that had detectors above the container and in transmission position, at the opposite side of the generator. A second reason is to improve detection efficiency, when inspecting bottom parts of the containers [2, 16, 3, 23]. The RRTNIS can scan only one side of a container at a time (~1.5 m depth), therefore for a double-sided scan the container has to be repositioned after the first scan. This happens mainly because incident neutrons are significantly attenuated by cargo materials before reaching the other side of the container, besides, gamma-rays suffer attenuation due to the scattering with the materials inside



Slika 2: Front view of the RRTNIS detection system, with the front door open. The YAP detector is not visible, because it is inside the neutron generator. Its position is aligned with the neutron cone. The external case dimensions are: 2.4 $m \times 2.8\ m \times 2.3\ m$.

the cargo [15, 2]. On the other hand, as detectors are close to the neutron generator in the C-BORD RRTNIS, they are protected by a 40 cm thick polyethylene (PE) shield and 5 cm thick lead plates (Fig. 2). Preliminary simulations foresaw that the maximum expected counting rate on each detector is 100 kcps (kilo counts-per-second). Custom-made NaI:Tl detectors were assembled in order to achieve an energy resolution between 6.5% and 8% (at 662 keV), as well as linearity and gain stability up to counting rates of 250 kcps. The assembled $LaBr_3$:Ce detectors exhibit an energy resolution of ~3.5% (at 662 keV), and linearity and gain stability up to 140 kcps [10, 19].

The nuclear electronics chain for signal processing is a modern and compact system based on fast digitizers. It is composed of:

- Two CAEN V1730 VME Digitizers, 16 ch, 14 bit, 500 MS/s (with a Digital Constant Fraction Discriminator, DCFD, embedded in the firmware for precise timing measurements);
- Five CAEN V6533 VME HV supply, 6 ch (NEG), 4 kV/3 mA;
- One CAEN V2718 VME-PCI Optical Link Bridge.
- Optical fiber connections using the CAEN CONET2 protocol for fast acquisition (CAEN A3818 PCI Express CONET2 Controller).
- A computer with an open source data acquisition software called ABCD (Acquisition and Broadcast of Collected Data) [**?**, 8, 11].

The two digitizers are treated as independent modules and no synchronization between the two is performed. Each digitizer internally validates the collected interaction events only if it detects a coincidence between the alpha signals and at least one of the gamma detectors. With such a configuration and a production rate of $7 \cdot 10^7$ neutrons/s, the system collects around $4 \cdot 10^5$ events/s per digitizer. The data acquisition system (DAQ) was proven to be able to sustain rates of up to $4 \cdot 10^5$ events/s in similar conditions to the experimental tests, with a dead time of 1% [9]. The system produces around 700 MB/min of data during a RRTNIS scan. ABCD was published as an open source project in the spirit of the H2020 open access research[2]. ABCD is composed of a set of independent software modules that communicate through network sockets [13]. Each module is dedicated to a single task (*e.g.* HV management, digitizer management, data filtering, data storage), in order to simplify their design and implementation. This design proved to be very versatile, since it has been used also in other experiments both in high-performance as well as in resource constraint data acquisition systems [11, 14, 17, 28, 7].

[2]The source code is available in the official repository `https://github.com/ec-jrc/abcd`

Slika 3: RRTNIS inspecting a standard 10 ft cargo container during the Rotterdam field trials.

Tablica 1: Cover loads used to build the mock-up containers.

Cover load
Compacted aluminum scrap
Cigarettes in metal boxes
Fertilizer
Bananas

The neutron generator, the radiological PE-Pb shielding, the gamma detection frame and the DAQ system were integrated in a waterproof, temperature-controlled external case (Fig. 2). The whole loaded external case (˜5 tons) was placed over a lifter which is able to elevate the external case up to a height of 2 m (Fig. 3). The center of the neutron cone can be positioned from a height of 1 m up to 3 m, in respect to the ground. With the lifter, any height inside a 10 ft container can be inspected with the neutron beam (external height of a 10 ft container is 2.6 m, plus $\tilde{0}.5$ m for the truck base). The lifter is also able to move the external case closer or further away from the external wall of the cargo container (max 30 cm). Such movement is crucial, for safety reasons, during cargo container alignment with the RRTNIS.

4 Rotterdam field trials

The tests were carried out at a customs administration of the Netherlands' (DCA) facility in the seaport of Rotterdam, the Netherlands. X-ray transmission images, produced with DCA-owned equipment, were used as reference images for the C-BORD technology. For instance, the RRTNIS was aimed

Tablica 2: Characteristics of the simulants used for the field trial of the RRTNIS.

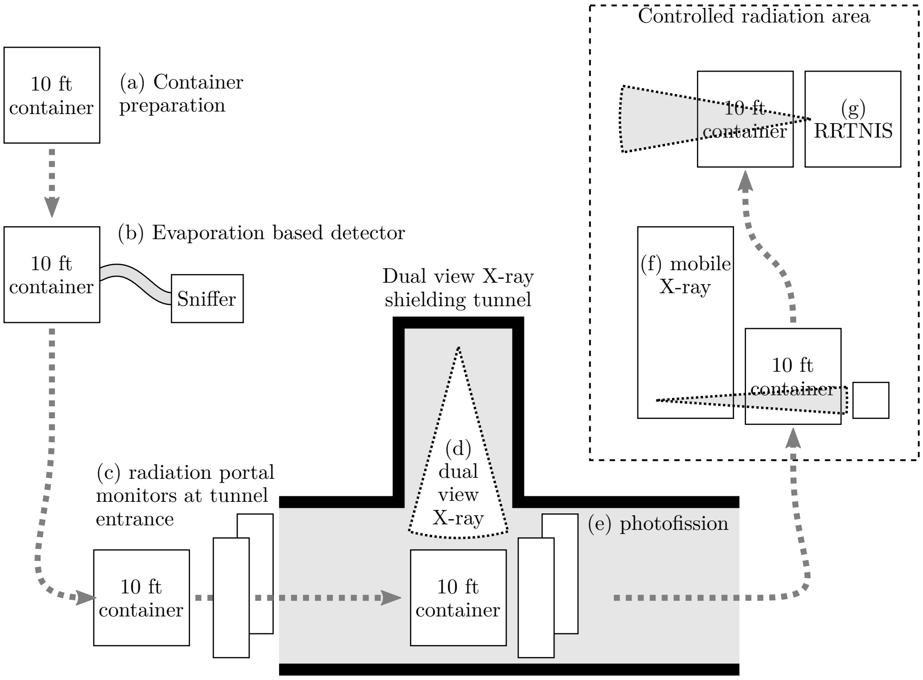
Threat	Density [g/cm^3]	C [%]	H [%]	N [%]	O [%]	Cl [%]	Si [%]	S [%]
Drug (cocaine)	1.3	37.8	48.9	2.2	8.9	2.2	-	-
Explosive (C4)	1.0	16	30	21	22	-	11	-
Sulfur mustard gas	1.3	31	47	-	-	15	-	7

at particular locations pinpointed on the X-ray image. Only mock-up containers were used in the tests. Ethical considerations opposed the use of commercial containers. It would not have been possible to contact the containers owners during the short time frame of the C-BORD field trials, thus informed consent to scan the goods would not have been available. Some practical reasons in favor of mock-up containers are: more variability of content and positioning. A total of 52 mock-up cargo containers (10 ft) were prepared with four different cover loads (Table 1). Simulants for drugs (cocaine), explosives (C4) and chemical weapons, with effective atomic number, density, and atomic ratios resembling those of actual illicit materials, were used as threat items during the field trial (detailed characteristics in table 2). Varying quantities of the simulants were placed at different height and depth inside the containers. Positions and quantities were selected in order to cover a broad range of threat scenarios. Overall the field trial was conducted in one month of which two weeks were used for container inspection.

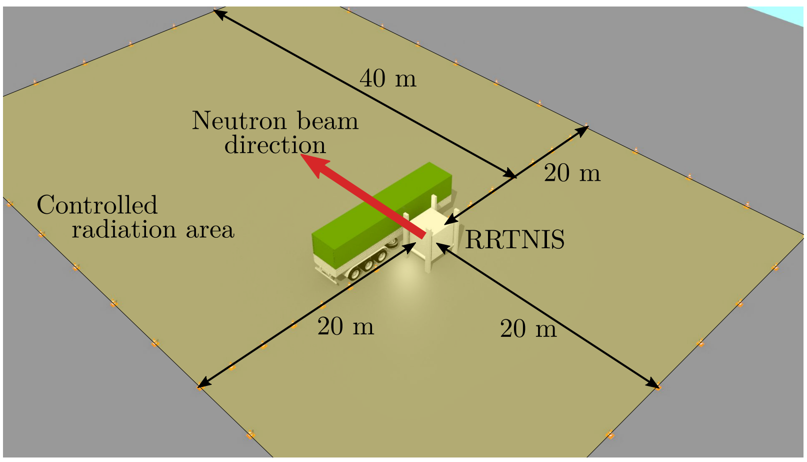
The containers were analyzed using the whole set of NII subsystems of the C-BORD framework. Most containers underwent subsequent scans with all the subsystems, in order to realistically reproduce the normal flow of cargo in the customs facility. But not all the second-line subsystems were employed on each container.

Fig. 4 shows a schematic representation of the field trial procedure:

1. Mock-up container (10 ft) preparation;
2. Evaporation based detection (sniffer);
3. Passive detection with radiation portal monitors;
4. Dual-view (side and top) X-ray scanner (owned by DCA, not a C-BORD technology);
5. Photofission measurement with DCA dual-view system as X-ray source [27];
6. Mobile X-ray system;
7. Tagged neutron inspection with RRTNIS.



Slika 4: Schematic representation of the field trial procedure at the customs administration of the Netherlands' (DCA) facility in the port of Rotterdam, the Netherlands.

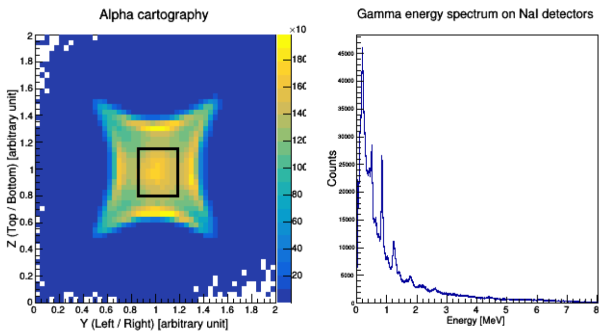


Slika 5: Diagram of the RRTNIS installation and controlled radiation area (40 m×60 m) at the Rotterdam seaport test facility of DCA.

The mobile X-ray system and RRTNIS were placed outdoor in a controlled radiation area (Fig. 5).

5 RRTNIS analysis

Each inspection measurement of a container lasted around 20 minutes, consisted of two runs of 10 minutes each one. The total nominal neutron generator emission rate in both scans was $5 \cdot 10^7$ neutrons/second (in all directions, not only in the 20° tagged beam). During neutron emission, acoustic and visual signals were employed to warn operators about the presence of radiation in the area.



Slika 6: Data reconstruction of a RRTNIS measurement in an empty container [21, 18]. Left: alpha map as reconstructed with the position sensitive YAP detector, with a selected region that identifies a direction in the neutron beam. Right: Gamma energy spectrum corresponding to the selected neutron beam.

The procedure to perform the complete analysis of a single measurement is as follows.

1. The data is acquired from the two signal digitizers with the ABCD data acquisition software [8].

2. The alpha event distribution is reconstructed with the position sensitive YAP detector (Fig. 6, left) [21, 18].

3. The neutrons direction is defined selecting a specific area on the alpha map.

4. The 2D map corresponding to ToF and gamma energy correlation is built (example gamma spectrum in Fig. 6, right).

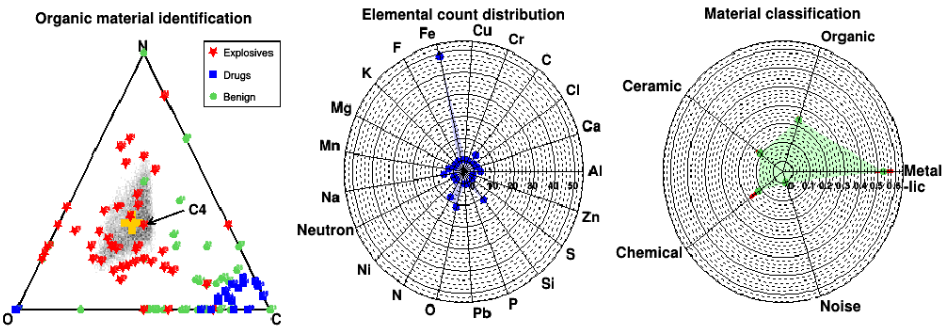
5. Selecting regions in the ToF spectrum makes possible to identify the energy spectra of the materials inside a voxel.

6. The background correction is performed to eliminate random, non-physical, events and correlated contributions, caused by tagged neutron interactions on the surrounding materials. See [20, 21] for more details.

7. The neutron flight path spectrum is sliced in sections.

8. The unfolding procedure is applied to all the energy spectra obtained by the slicing.

9. Finally the elements distribution is constructed.



Slika 7: Material classification plots. Left: CNO barycentric triangle representation of selected region. Shaded area corresponds to a probability distribution taking into account measurement uncertainties (counting statistics, neutron and gamma attenuation in cargo materials). Center: Elemental composition in selected region. Right: Coarse material classification.

In order to perform a coarse material classification (Fig. 7, right), each pure element of the database is associated with a material type: chemical (calcium, chlorine, fluorine, *etc.*), ceramic (silicon), metallic (aluminum, iron, chromium, *etc.*) or organic (carbon, nitrogen and oxygen). It is important to further refine the identification of organic materials, in order to distinguish between illicit drugs, explosives, and benign materials (such as wood, cotton, paper, *etc.*). To do so, the weights of carbon, nitrogen and oxygen, determined by the unfolding procedure, are transformed into chemical ratios, using conversion factors, that were determined by Monte Carlo simulations using the MCNP6 code [23, 22, 20]. The 2D likelihood histogram, associated to the N/C and O/C fractions, is represented in a barycentric triangle representation (Fig. 7, left) [4]. The so-called CNO triangle is valid to classify only organic materials. The N/C and O/C chemical ratios of common explosives, illicit drugs and benign materials are also projected in the triangle representation, which allows to define areas corresponding to these three types of materials.

In order to facilitate interpretation by non-experts end users, the results are summarized in a material distribution profile. The material profile is a plot that reconstructs the composition at each depth interval (*e.g.* Fig. 8). The reconstruction is along the tagged neutron beam direction, which is used to represent the evolution of the material type as a function of the depth (in arbitrary units) in the container. The profiles are shown approximately starting from the wall of the cargo container.

6 RRTNIS case studies

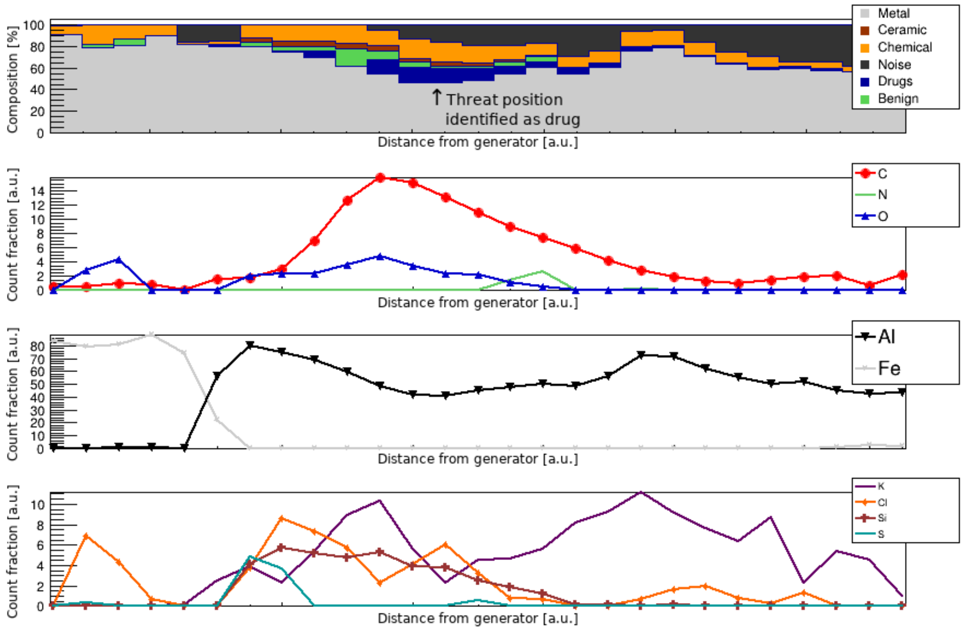
Tablica 3: Case studies reported in this article.

ID	Cover load	Threat
1	aluminum	cocaine simulant (20 kg)
2	aluminum	sulfur mustard gas simulant (20 kg)
3	cigarettes	cocaine simulant (40 kg)
4	fertilizer	explosive (C4) simulant (20 kg)
5	bananas	none

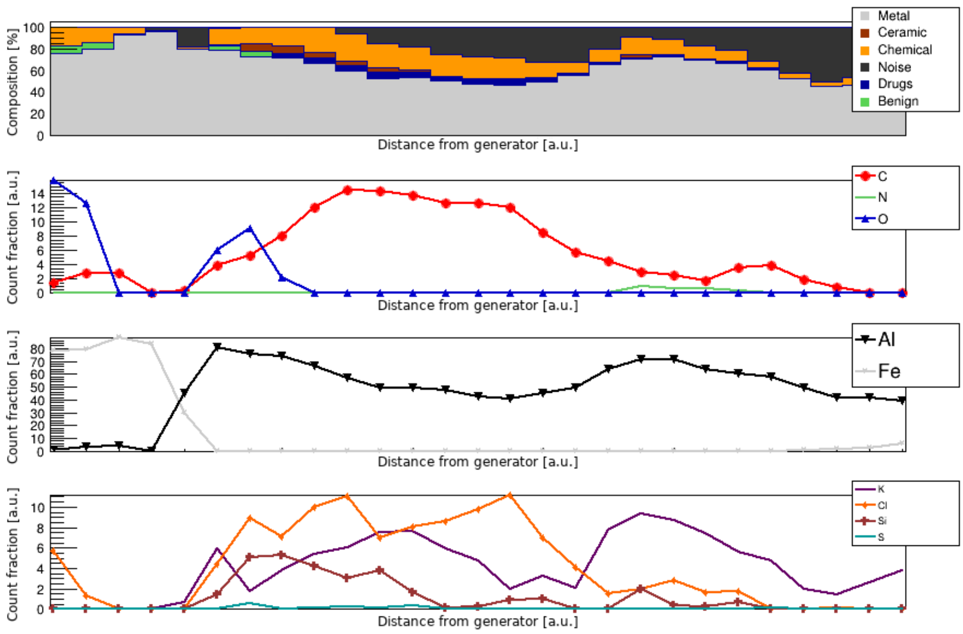
Among the 52 scanned containers, we stress the fact that only five indicative cases (Table 3) are presented and discussed in this article. Overall the RRTNIS performance is reproducible. The amounts of threat simulants, discussed in this paper, do not represent the minimum detectable quantities (MDQ) of the RRTNIS. The depth of the retrieved signal in this paper is given in arbitrary units.

6.1 Case 1: Aluminum cover load with drug simulant

Cocaine simulant was hidden, close to the container wall, in a 10 ft cargo container loaded with aluminum scrap. Fig. 8 shows the material distribution profile along the tagged neutron beam. The presence of the drug is clearly identified on the profile color plot and by the presence of a carbon excess on the count fraction plot (with an amplitude of ~15%). The position of the threat is identified. The container wall can be inferred from the sudden change in the count fraction plot with aluminum and iron (Fig. 8). Despite the fact that an illicit material located close to the wall of the container could represent an "easy" case to study, actually, from the point of view of the customs officers experience, it is the one of the most uncomfortable case to manage. With a suspicious item close to some wall of the cargo (identified for example from the X-ray image), during the intrusive inspection the whole cargo has to be unloaded.



Slika 8: Case study 1: Aluminum cover load with cocaine simulant. Material distribution profile along the tagged neutron beam.

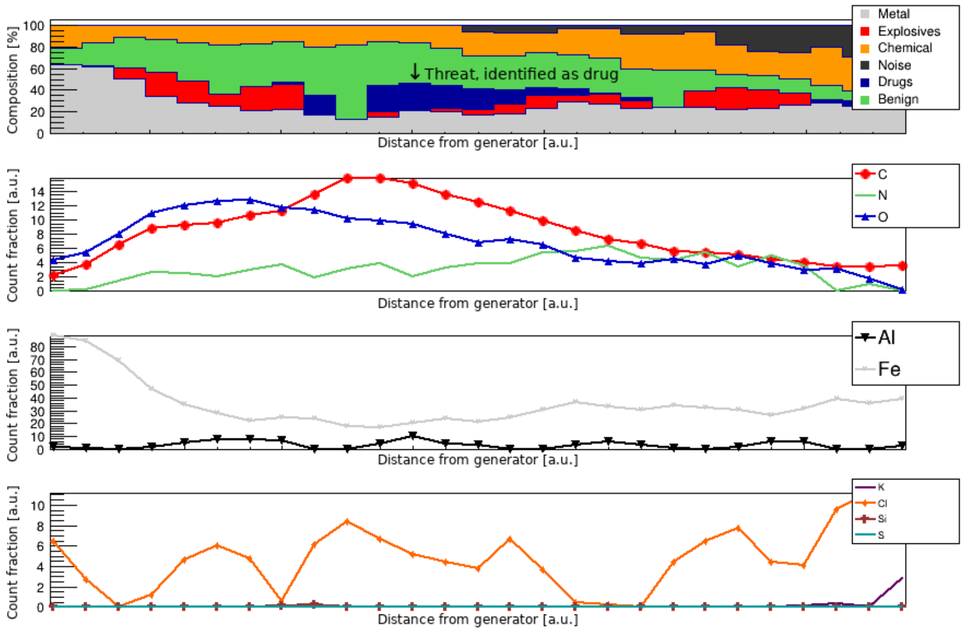


Slika 9: Case study 2: Aluminum cover load with sulfur mustard gas simulant. Material distribution profile along the tagged neutron beam.

6.2 Case 2: Aluminum cover load with sulfur mustard gas simulant

Sulfur mustard gas simulant was hidden in a 10 ft cargo container loaded with aluminum scrap. Fig. 9 shows the material distribution profile along the tagged neutron beam. As it can be seen in the coarse material classification, there is not a clear presence of the threat, at least not in a determined position. However, the rises in carbon and chlorine proportions, and the negligible presence of oxygen at the same level of the profile, allow the identification of the sulfur mustard gas simulant, close to the container wall. An improvement of the analysis software could help the user in the observation of this cargo.

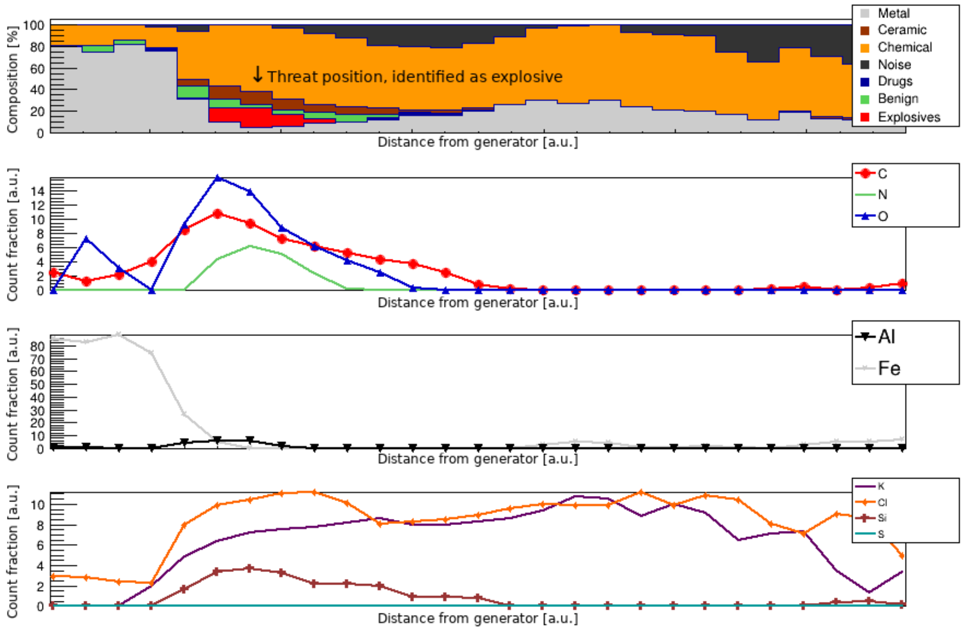
6.3 Case 3: Cigarettes cover load with drug simulant



Slika 10: Case study 3: Cigarettes cover load with cocaine simulant. Material distribution profile along the tagged neutron beam.

Cocaine simulant was hidden in a 10 ft cargo container loaded with a cigarettes cover load. Fig. 10 shows the material distribution profile along the tagged neutron beam. The coarse material identification profile clearly shows the threat position. Strong signals of elements which are present in organic compounds are measured (C, N, O). Overall there is also a high iron count fraction, which is explained by the fact that cigarettes were packaged in metal boxes.

6.4 Case 4: Fertilizer cover load with explosive simulant



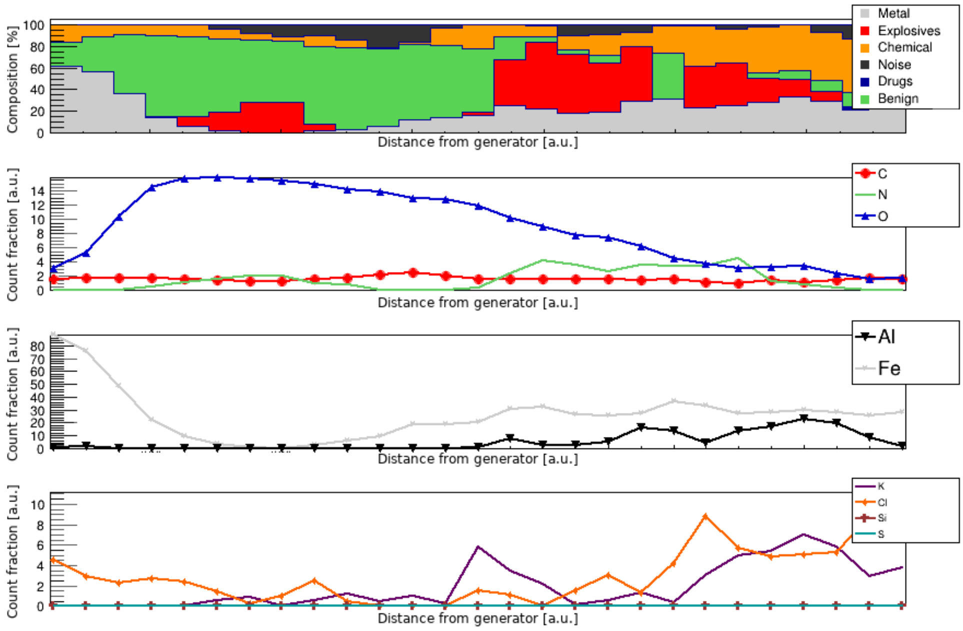
Slika 11: Case study 4: Fertilizer cover load with explosive simulant. Material distribution profile along the tagged neutron beam.

C4 explosive simulant was hidden in a 10 ft cargo container loaded with a fertilizer cover load. Fig. 11 shows the material distribution profile along the tagged neutron beam. The presence of the threat close to the container wall is evidenced by the highlighted region. The region in which the explosive simulant is recognized is characterized by a high count fractions of C, N, and O. Strong signals of potassium (K) and chlorine (Cl) along the container depth are observed because of the cover load (fertilizer).

6.5 Case 5: Bananas cover load with no threat

The last case study, which is the first reported case of neutron interrogation of food products, reports the measurement of bananas cover load with no threat present. Fig. 12 shows the material distribution profile along the tagged neutron beam. False positives of explosives can be identified in the materials profile.

The erroneous threat determination was caused by the difficulty to unfold the gamma ray spectra, produced in dense organic matrices. Indeed, random coincidences with scattered neutrons, interacting in the surrounding organic matrix, overwhelm the gamma ray spectrum. In addition, the pure element spectra, that have been measured with 14 MeV neutrons, are less relevant for materials deep in the matrix, due to neutron slowing down. Finally,



Slika 12: Case study 5: Bananas cover load with no threat, false positives of explosives are highlighted. Material distribution profile along the tagged neutron beam.

counting statistics are poor due to neutron attenuation caused by the organic matrix. These issues could be addressed by using a larger neutron flux, and/or a longer acquisition time. Moreover, the unfolding database and the unfolding procedure should be adapted with pure element spectra associated to neutrons below 14 MeV.

The radiation level was measured before and after the RRTNIS inspection, in the proximity of the food products in the container at the spot where the neutron beam was the most intense. Two detectors (Symetrica NaI Verifinder and Ortec HPGe Detective X) were used before and after the 10 minutes irradiations to look for signs of activation. No detectable change of the environmental radioactive background occurred, as a consequence of the neutron irradiation. Should a change in the measured background be registered, this may suggest that activation of the cargo by the neutron irradiation has taken place.

7 Conclusions

The Rapidly Relocatable Tagged Neutron Inspection System (RRTNIS) developed during the C-BORD project aims at providing an effective, compact neutron non-intrusive interrogation system. The RRTNIS is the first example of a rapidly relocatable (within two days) neutron inspection system for cargo containers. The dedicated RRTNIS data acquisition system allows the acquisition of 20 NaI(Tl) scintillation detectors with the YAP detector that serves to tag the 14 MeV neutrons, produced by a DT neutron generator. The neutron Time-of-Flight provides an information on neutron interactions in the depth of cargo materials, and gamma energy spectra of selected voxels (elementary volume unit) are unfolded in order to identify their elemental compositions. The RRTNIS data processing allows labeling voxels' materials as organic, metallic, ceramic or chemical. Organic materials are further classified as benign, explosives or illicit drugs depending on their carbon, oxygen and nitrogen chemical proportions.

Field tests were carried out at customs administration of the Netherlands' (DCA) facility in the seaport of Rotterdam, the Netherlands. The tests demonstrated that the system is able to identify less than 20 kg of explosives and narcotics in metallic, organic or chemical cover loads. Such performances constitute a dramatic improvement, compared to previous EURITRACK's Tagged Neutron Inspection System designed to detect 100 kg of TNT in the middle of a 0.2 g/cm^3 iron cargo [2, 5, 6]. Further refinements of the data processing are foreseen to improve material identification, as a function of depth in the cargo container, in particular with organic cargo materials. Moreover, the artificial intelligence techniques employed in the material classification [24] will be improved.

8 Acknowledgments

We thank the JRC Ispra, Italy, and its team (Vittorio Forcina, Bent Pedersen, Tatjana Bogucarska, Giovanni Varasano, Federica Simonelli, Hamid Tagziria and Franco Cioce) for welcoming the commissioning and first laboratory tests of the RRTNIS.

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