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# Radiometric survey with remotely piloted land vehicle in chemical, biological, radiological, and nuclear defense operations

Azevedo[a], A.M.; Gonçalves[a], J.L.; Salazar[a], A.P.; Cardoso[a], D.D'O.; Gonzales[a], P.V.; Ferreira[a], V.A.V.; Nunes[a], W.V.

[a] *Instituto Militar de Engenharia - SE-7, 22290-270, Urca, Rio de Janeiro, Brazil*

*e-mail address of the corresponding vallory@ime.eb.br*

## ABSTRACT

**This article addresses the development of a remotely piloted vehicle for the chemical, biological, radiological, and nuclear army defense system, able itself to perform radiometric surveys remotely favoring the process of local mapping and investigation of possible dispersions of radioactive materials in radiological and nuclear accidents and incidents. Tests were carried out to verify the efficiency of the developed prototype and it can be verified that the vehicle has a great applicability and optimizes the radiological protection process.**

***Keywords:*** **radiological detection, remotely pillage vehicle, radiation protection.**

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# INTRODUCTION

The objective of the work is to contribute to the needs of the Brazilian Army in the Chemical Biological, Radiological and Nuclear Defense System, given that the built system has reached the research demonstration or prototype stage, it is safe to say that, at some stage of the future development, Artificial Intelligence will make a decisive contribution considering that through a neural network, previously trained, it becomes possible to identify the radionuclide present in the environment [1] allowing the solution of the most diverse military problems[2] that are guided by the basic principles of radiological protection [3], namely: justification of the practice, optimization of radiation protection and limitation of individual doses. To this end, a robotic system [4] was developed, remotely controlled, capable of navigating through different terrestrial environments, for detection and recognition of ionizing radiation through the on-board monitoring equipment. This, in turn, uses a computational algorithm [5] qualified to carry out all the control of the robotic system in order to obtain the reading of doses rates "in loco" provided by the radiation detector. The system can be used in accidents/incidents where the release of radionuclides has occurred with potential danger to the human health and the environment. To this end, detectors were installed in the robotic system, so that it is possible to record the dose level from the existing radiation in the environment and the identification of the radionuclide.

# 1. MATERIALS AND METHODS

## 1.1. Materials

Initially, the Geogebra [6] software was used to design the support and locomotion mechanism of the robotic system. The model chosen was the mechanism by Theo Jansen [7]. Once the necessary measurements were obtained for this mechanism, it was necessary to choose the material that best suited the proposed project. Aluminum sheets interconnected with screws, washers and nuts were used as base material. The robotic system is controlled through an Arduino board. The Arduino allows the development of projects that witness the control of devices, actuators, through step-by-step instructions using the C language [5]. The experimental analyzes are carried out with the SpiR-ID (NaI) vibrating detector, which has a data retransmission system that allows the operator to visualize the data collected in the field.

### 1.2. SpiR-ID Scintillator Detector

The SpiR-ID Scintillator detector (Figure 1) [8] is a NaI:TI type detector, which has a temperature range from -20 ºC to 50 ºC and humidity up to 100%, is resistant to vibration, shock and drop, in addition to being in MIL461D EMI compliant and features IP65 for dust and water ingress. It has a built-in charger, making the detector rechargeable with an autonomy of up to 10 hours, with a battery compartment in case you need immediate power.

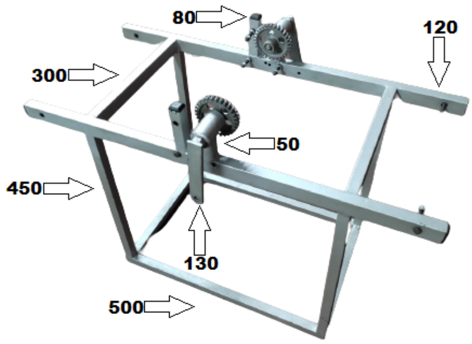
**Figure 1 :** SpiR-ID Scintillator detector
Source : SpiR-ID manuals [8]

The SpiR-ID measures 320 x 145 x 175 mm with a weight of 3.7 kg. It operates in a range of varying energy from 25 keV to 3 MeV, when dealing with gamma radiation, with a measurement amplitude <0.01 μSv/h to 10 mSv/h. It also supports MCA 1024 digital channels for communication and data transfer. Since the acquisition of continuous spectra and stabilization are performed without the need for field calibration, in addition, it calculates the real dose rate by weighting the spectra created based on a dead time of 5 μs [8].

### 1.3. Methods

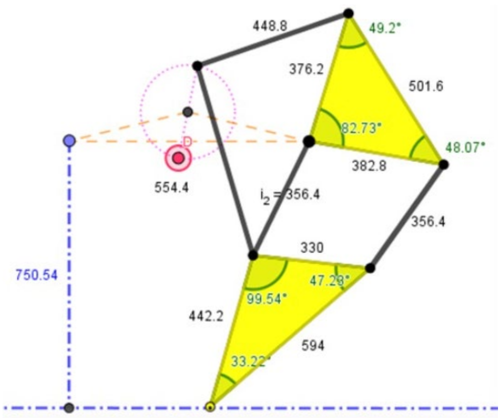
The construction of the robotic system began with the analysis of the dimensions needed to accommodate the equipment: 2 batteries, SpiR-ID detector, Arduino, controllers for the actuators and actuators. Therefore, an iron housing in the form of a parallelepiped was developed. For this, a square metal wall 20 mm wide and 2 mm thick was used. Also, it was necessary to extend the parallelepiped to fix the articulated system, in addition to four supports, two of which for the bearings of the bearings of the motor reduction set (4:1) and two for fixing the actuator. All dimensions, in millimeters, are shown in Figure 2. Also, 2 mm acrylic sheets were fixed on the sides and on the upper and lower bases of the hunting in white to fix the system and soften the absorption and incidence of heat in the electronic components are inserted into the robot.

**Figure 2 :** Robotic system housing




Subsequently, based on the dimensions of the carcass, 8 legs were made with GeoGebra [6] so that the need to maintain a free span of 300 mm from the ground was considered, allowing the robotic system to cross small obstacles with dimensions, in millimeters, presented in Figure 3.

**Figure 3:** Paw geometry
Source : Geometria das patas - Victor [9]




The joints were fixed with 8 mm screws and nuts with washer, so that only the vertex that has contact with the ground has the screw fully tightened. In the other vertices where there is articulation, minimum gaps were maintained. The material used to make the paws was aluminum, 1 inch wide by 1/8 inch thick (Figure 4 and Figure 5).

**Figure 4 :** Making the paws

**Figure 5 :** Robotic system in operation

## 2. RESULTS AND DISCUSSION

The command of the robotic system was performed through Arduino [10]. For this, an existing project by Leandro Lisura [11] was used. The maximum range, in open field, obtained with the system was 600 m.

The methods used to perform measurements with the scintillator detector based on NaI consists of simulating a scenario of radiological accidents where the robotic system will operate. The robotic system will be used for recognition and delimitation of probable contaminated areas, in which radiological or nuclear incidents/accidents may have occurred.

The initial planning foresaw the displacement of the robotic background measurement system (BG) in an area close to a certain building with the presence of naturally enriched uranium. Then the robotic system would be moved to other points in the building, close to known sources of Cobalt 60 and Cesium 137 to measure the intensity of the radiation and identify the radioisotope.

Measurements were performed with the scintillator detector installed in the central part of the robotic system, with the instrument positioned at a height of 30 cm from the ground.

On the morning of June 10, 2022 - a rainy day with a maximum temperature of 25 °C in the city of Rio de Janeiro, inside a Brazilian army installation, the NaI-based scintillator detector was positioned 1 m from the access door to the food radiator; 1m from the food radiator; 2m away from a sealed source of Cs-137; and therefore, used to perform measurements of energy and spectra of the radioisotope emitted by these sources. Then the Cs-137 source was exposed, and the BG was checked again, and a point in a room distant from the source was measured. Continuously, the Co-60 source was exposed to perform measurements and comparisons between the initial BG and the exposed source.

Table 1 presents the conditions under which the measurements were performed, which will be related to the energy spectra collected by the NaI-based scintillator detector.

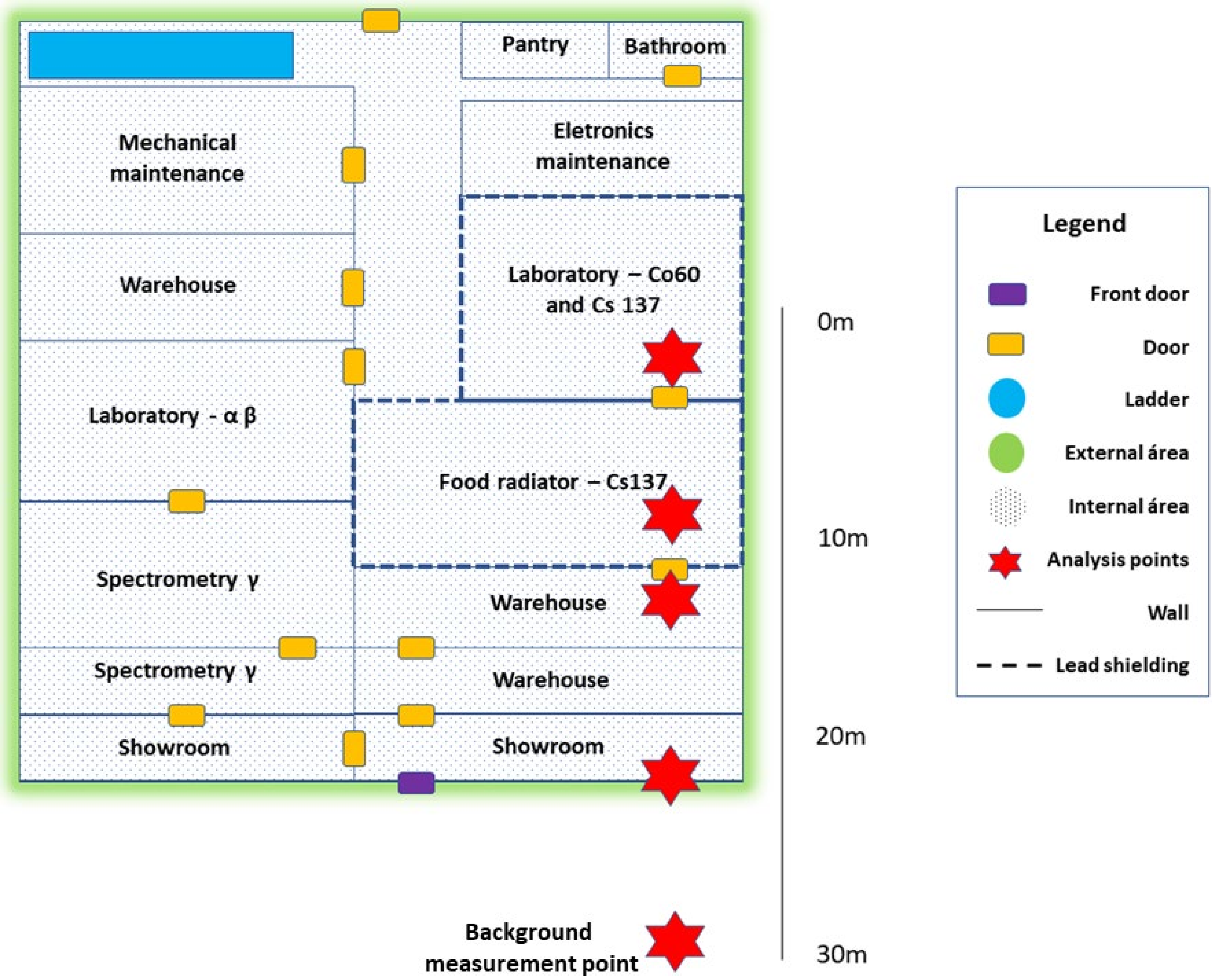
The radiometric survey time for all 10 measurements was approximately 3 minutes of real time. The distances between the detector and the source ranged from 1 to 30 meters. It was not possible to precisely define the real time because the equipment did not have the automatic stop option. Energy Analyzes were performed by Nucléide-Lara [12].

**Table 1:** Data collected from the NaI Scintillator on 06/10/2022.

| Place | Distance from the source (meters) | Start time of collection (hours) | End time of collection (hours) |
|---|---|---|---|
| External building | 30 | 10:58 | 11:01 |
| Near the Food radiator | 1 | 10:28 | 10:31 |
| Food radiator | 1 | 10:33 | 10:36 |
| Cesium-137 sealed | 2 | 10:36 | 10:39 |
| Cesium-137 exposed far away | 20 | 10:41 | 10:44 |
| Cesium-137 exposed | 10 | 10:49 | 10:52 |
| Cobalt-60 exposed | 10 | 10:53 | 10:56 |
| Cobalt-60 exposed far away | 20 | 11:05 | 11:08 |

In addition, a sketch (Figure 6) was made in order to facilitate the understanding and visualization of the points that were analyzed.

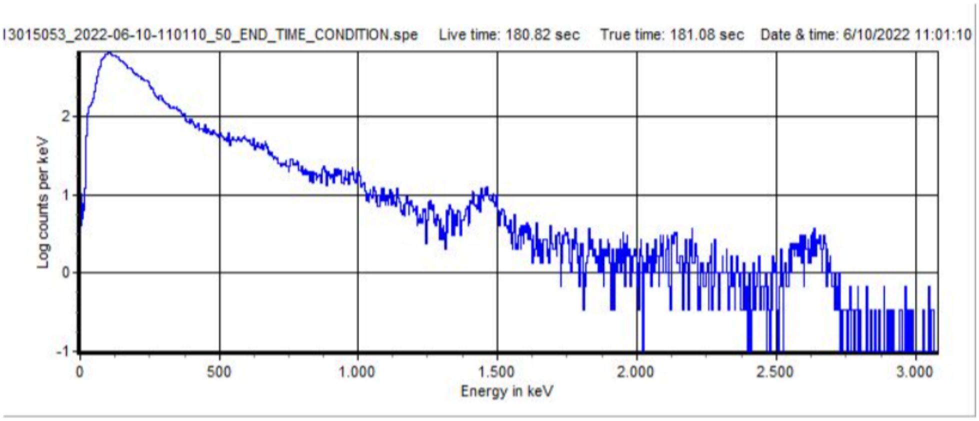
**Figure 6 :** Sketch




Next, it exposes the spectra obtained by the NaI-based scintillator detector, according to data in Table 1.

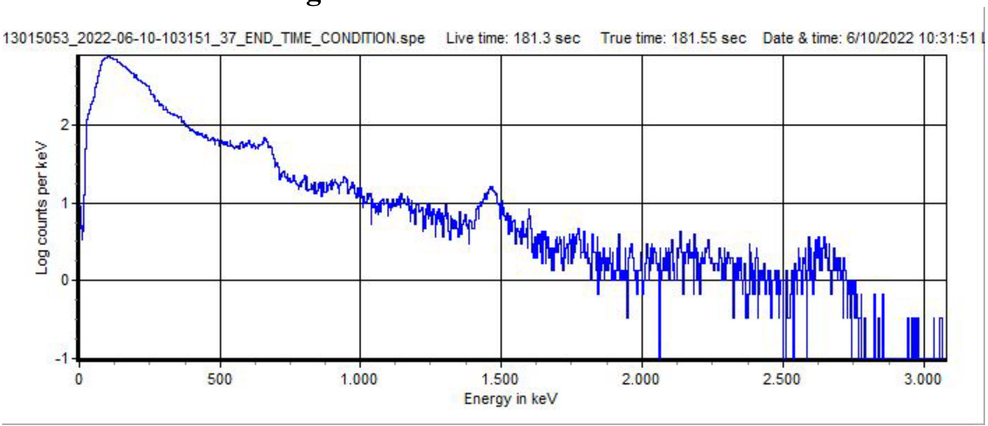
The background analysis (BG) allows identifying characteristic energy emissions in the environment, so that when analyzing the radiometric survey, these emissions will be less considered. The BG count was performed at the External Building point, as shown in Figure 6. Also, Figure 7 shows the spectra obtained at that point. In the BG analysis it was possible to observe the presence of Potassium-40 (1460 keV), Thallium-208 (2615 keV) and emissions from the characteristic X-ray (88 keV). It is noteworthy that K-40 and Tl-208 are radiation from the environment.

**Figure 7 :** External building



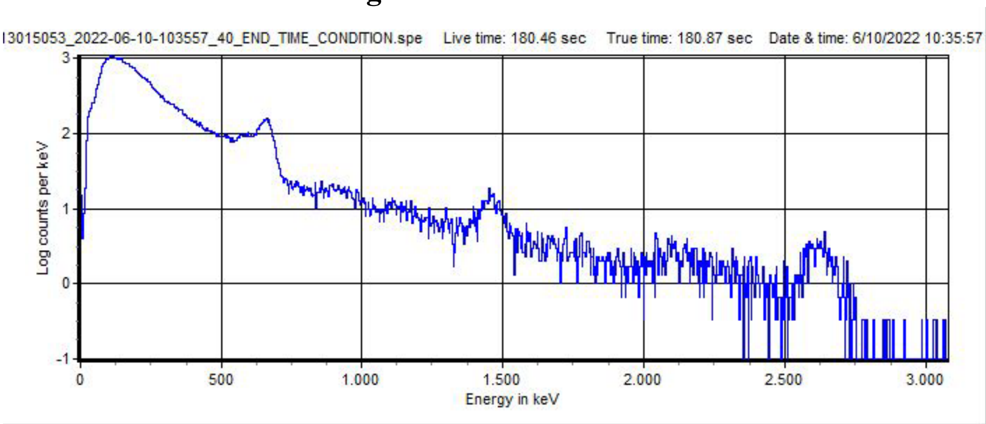

As can be seen in Figure 8, at the point near the food radiator, it is possible to identify the presence of Cs-137. Even so, it was possible to observe the K-40 and the Tl-208.

**Figure 8 :** Near the food radiator




In the analysis carried out, in which the detection system was not positioned in front of the access to the food irradiator (Figure 9), it was possible to identify a greater number of counts when compared to (Figure 8). This possibly occurred due to a lower saturation of the system.

**Figure 9 :** Food radiator




In the analysis carried out with Cs-137, it was possible to clearly observe, in Figure 10, the presence of the characteristic energy of 662 keV when the analysis was carried out with sealed cesium. However, in the analysis with exposed cesium (Figures 11 and 12), it is possible to observe with less discretization and number of counts the Gaussian that composes the energy of Cs-137. When comparing the spectra (Figures 11 and 12) it is possible to identify that the reason for the lower counting rate is due to saturation in the system, since in the survey carried out at a greater distance, it was possible to obtain a better definition of the Gaussian relative to Cs-137.

**Figure 10 :** Cesium-137 sealed

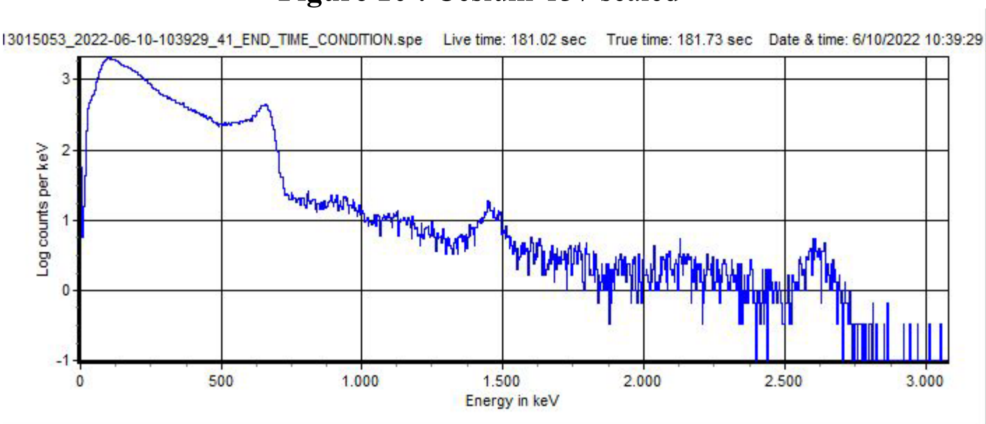


**Figure 11 :** Cesium-137 exposed

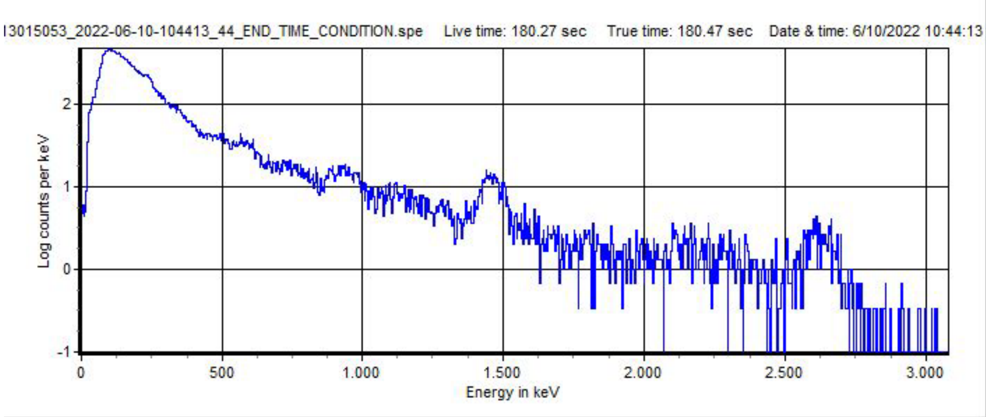
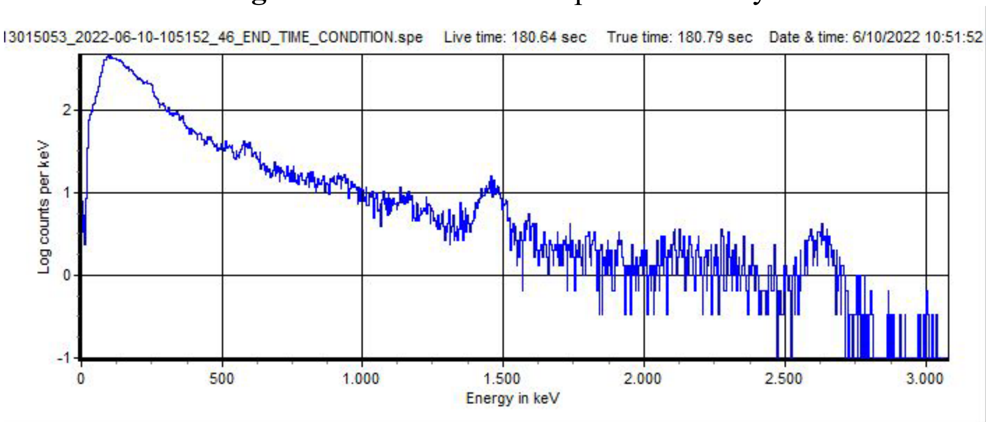



**Figure 12 :** Cesium-137 exposed far away




The latest analysis, made with Cobalt-60, were very satisfactory. Figures 13 and 14 show the energies of 1170 keV and 1330 keV, originating from Co-60 gamma emissions, with excellent definition and discrimination. Due to the high count rate, and good definition of the Gaussians, in Figure 14 it was not possible to observe the K-40, on the other hand, in Figure 13 it was possible to identify it.

**Figure 13 :** Co-60 exposed

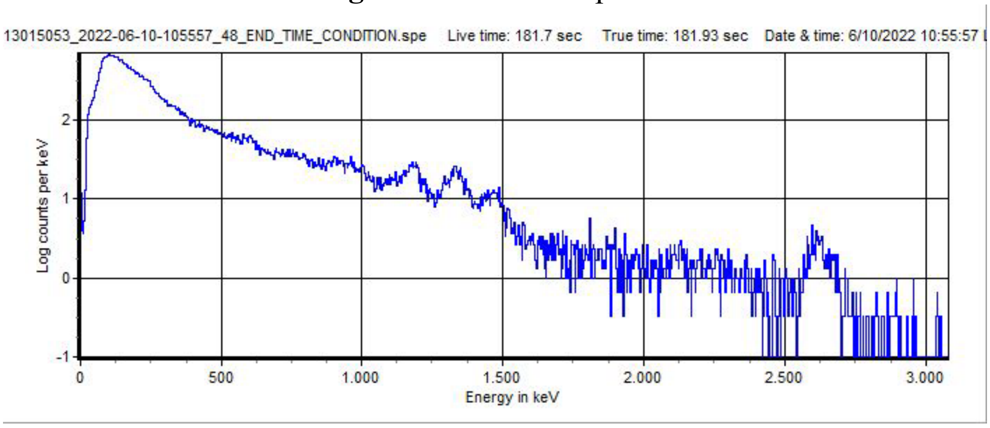
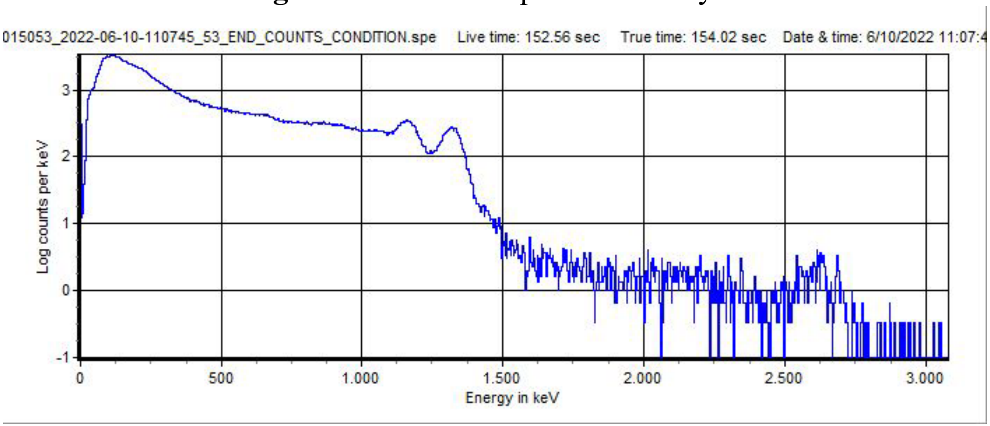



**Figure 14 :** Co-60 exposed far away




## 3. CONCLUSION

The vehicle developed for chemical, biological, radiological and nuclear defense managed to reach the fourth level of technology readiness (TRL4) [13], so that it can be applied in possible accidents and incidents involving the dispersion of radioactive elements, provided that the radiation to be analyzed is greater than the background radiation. It is noteworthy that even with the dose rate, the operational limits were respected.

Although some spectra showed saturation in the detector system, the objective of identifying the radionuclide was achieved.

Also, it is important to highlight that with the implantation of artificial intelligence, it will be possible for operations teams without knowledge in nuclear generation to be able to identify the transmission of textual information, which can be faster in the response and intervention process. For this, an already developed neural network [1] can be implemented in a device that accepts to be programmed in Python Raspberry Pi [14].

## REFERENCES

[1] SILVA, M. M. A. **Redes neurais artificiais aplicadas na classificação de radionuclídeos a partir da espectroscopia gama e simulação computacional** / Márcio Magalhães de Andrade Silva – Rio de Janeiro, 2021.

[2] SOUTO, R. A. **Inteligência Artificial**: Conceitos Básicos e aplicações Militares, Defesa Nacional, n. 732, pp 144-160, 2020.

[3] XAVIER, A. M; MORO, J. T.; HEILBRON, P. F**., Princípios Básicos de Segurança e Proteção Radiológica.** Site: https://www.gov.br/cnen/pt-br/acesso-rapido/centro-de-informacoes-nucleares/material-didatico-1/principios-basicos-de-seguranca-e-protecao-radiologica-terceira-edicao-revisada.pdf

[4] NIKU, Saeed B. (Saeed Benjamin) **An introduction to robotics**: analysis, control, applications / Saeed Niku. 2nd ed. p. cm, 2010.

[5] STEVAN JUNIOR, Sergio Luiz. **Automação e instrumentação industrial com arduino**: teoria e projetos / Sergio Luiz Stevan Junior, Rodrigo Adamshuk Silva. 1. ed. São Paulo: Érica, 2015. 296 p.

[6] **GeoGebra**, Site: <www.geogebra.org> access in: May 23, 2022.

[7] JANSEN, Theo. **Theo Jansen Mechanism**, Site: https://www.strandbeest.com/ Accesss in: May 18, 2022.

[8] **Product Datasheet SpiR-ID**. Site: <https://www.southernscientific.co.uk/data/file/e/6/SPIR-ID-Datasheet-EU-Version-1.0-1.1670597205.pdf> Acess in May 20, 2022.

[9] Victor, **Geometria das patas**. Site: <https://www.geogebra.org/m/czbgkchy> Acess in May 23, 2022.

[10] **Arduino descriptions**. Site : <https://docs.arduino.cc/hardware/uno-rev3> Acess in : March 20, 2023.

[11] LISURA, L. **Projeto carrinho sem fio usando Arduino Uno**. Site:m <http://leandrolisura.com.br/projeto-carrinho-sem-fio-usando-arduino-uno/> Acess in July 10, 2022.

[12] **Nucléide – Lara (Laraweb).** Site: <http://www.lnhb.fr/Laraweb>. Acess in : October 22, 2022.

[13] **Technology Readiness Level Definitions and Descriptions.** Site : <https://www.dst.defence.gov.au/sites/default/files/basic_pages/documents/TRL%20Explanations_1.pdf> Acess in : 20 March 2023.

[14] **Raspberry Pi**. Site: https://www.raspberrypi.com/products/raspberry-pi-4-model-b/ Acess in: December 10, 2022.