Laser Curtain for Containment (LCCT) advance technology: Testing for dual use as a component at spent fuel dry storage in Atucha I NPP.

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ABSTRACT

Safeguards implementation at the Atucha-I dry storage system currently under construction will require a dual containment and surveillance system (C&S). The main surveillance system will be composed by Next Generation Surveillance System (NGSS) Digital Camera Module-C5 (DCM-C5) connected to a Digital Camera Recorder / Digital Camera Interface (DCR-1/DCI) server.

Considering this spent fuel dry storage, a difficult-to-access area, the secondary system will consist of a 2D Laser Curtain for Containment named LCCT that can identify and track all intrusive events of specific objects within a pre-defined area of interest. The LCCT will be composed of 2D Laser heads connected to data consolidation servers. The LCCT data can be reviewed at the same station of the DCR-1/DCI without the need of entering the controlled area.

The LCCT is a new containment concept that was developed based on facilities with similar requirements of Atucha-I dry storage building. Although laser system technologies have been used as security devices, the approach followed by LCCT is to include tracking and form detection capabilities.

This paper describes the near full-scale test carried out in a storage facility in Argentina to check the functionality of the LCCT system for transfer flask tracking and intrusion-occlusion objects detection to confirm the suitability of the system for use in the above referred new dry storage facility.

INTRODUCTION

The Brazilian and Argentine nuclear facilities are under the safeguards of the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC) and of the International Agency of Atomic Energy (IAEA) under a comprehensive safeguard agreement (CSA) known as the Quadripartite Agreement (1) applied to both States and of which ABACC is also a fundamental party. Cooperation is the basis for the implementation of safeguards. In this framework, ABACC and the IAEA, together with the countries, cooperate for an effective and efficient application of the safeguards.

A dry storage facility for a long-term storage of irradiated fuel elements at the Argentine Nuclear Power Plant of Atucha-I, is currently under construction. To effectively safeguard this storage, a dual containment surveillance system (C/S) is required. Such a system could serve as a basis for drawing adequate safeguards conclusions. Taking into account the features of the storage under consideration, ABACC and the IAEA have been working in the development of a dual system concept based on surveillance and LCCT components.

In June 2018, IAEA, in cooperation with ABACC and the Argentine Nuclear Regulatory Authority (ARN) and with the support of the facility Operator, conducted a first field test of the LCCT. The aim of this test was to confirm the LCCT suitability for use as one of components of the dual Containment and Surveillance System (C/S) for the dry storage facility at the Nuclear Power Plant of Atucha-I. This test was conducted under the framework of the Argentine Support Program to the IAEA safeguards (MSSP) (2).

The field test, conducted in the spent fuel pond of Atucha-I, had the goals of collecting data and verify the presence of items entering a preset region of interest (ROI). Although the proposed goals of the test were achieved, it showed that additional tests should be conducted to address important issues observed at that time before considering its use as a component of the C/S system.

During 2019, the IAEA setup a LCCT test bed at its own premises in Vienna to perform further tests. The results were shared with ABACC. After a comprehensive review and analysis of the data, both agencies decided to conduct a near full-scale joint test to confirm the adequacy of the LCCT system for use at Atucha-1 dry storage facility (3).

This ABACC/IAEA functionality joint test was conducted in November 2019 in an Argentine facility which features were ideal to simulate the Atucha I NPP storage, with the cooperation of ARN under the MSSP. The Division of Technical and Scientific Services of Department of Safeguards of the IAEA (SGTS) and ABACC´s Technical Support unit were deeply involved in all the phases of this test.

The challenge was great, as it involved testing a new technology in terms of safeguards uses and for an application at a difficult-to-access area of this dry storage. However, ABACC and the IAEA decided to consider it due to the advantages presented by this technology.

DESCRIPTION OF THE EXPERIMENT

The dry storage facility at Atucha-1 NPP is composed by a square silo field of approximately 13.5 by 13.5 meters. Inside this area there is a grid of 18 by 18 silos. The structural arrangement accommodates 316 silo positions for one storage unit with 9 fuel elements each.

As part of the safeguards approach of the dry storage facility of Atucha I, the C/S system will be composed by a surveillance component of two DCM-C5 cameras installed at the opposite corners of the silos field and by a containment component (LCCT) of four 2D laser heads, located at each corner of the silo field, connected to 2 application servers. This arrangement provides redundancy for the surveillance and for the containment components of the dual C/S.

Based on the characteristics of the storage facility, the LCCT, used as a component of the dual C/S system, has to provide information about the transfer flask path from the spent fuel pond area to the destination silo during the loading process of the storage unit and it has also to provide information about occlusive or intrusive objects in the silos field.

The tests aimed at confirming the suitability of LCCT to verify the intrusion or occlusion of an object, determine its size, form, path and location in a predefined region of interest in the testing area using two 2D laser heads. The experiment verified the ability of LCCT acquisition software to show each silo position in the facility. The loading of a storage unit in a silo position is treated by the system as an intrusion of the ROI.

The Central Store for Special Irradiated Fissionable Material (DCMFEI) is an Argentine facility (4), designed to store spent fuel assemblies discharged from the research reactors. It has been selected for the tests, because its dimensions and features were considered similar to the dry storage facility of Atucha I, allowing to test several possible configurations. For testing purposes, only two 2D laser heads have been installed. The laser heads were placed 2.5 meters high to avoid detecting personnel and facilitate flask shape simulation. The two DCM-C5 cameras were also mounted at the same height at the opposite walls, as show in Figure 1.

The data acquired during the test was consolidated in an application server. The LCCT application provided raw data from the laser heads, intrusion, occlusion and perimeter change events notifications, a 2D schematics of the area and the track of the objects in test area. The tests simulated as much as possible the dry storage facility dimensions.

During the design of the experiment some milestones were defined: check overnight system behavior; define several testing positions on the floor to simulate silos grid dimensions; move paperboard boxes of 90x90x60cm of different colors (black, white and aluminum) raised at 2.5 meters by sticks to simulate the transfer flask movements and positioning; test the worst positions and orientation of the boxes for the LCCT to correctly identify the shape and position of the transfer flask; move two boxes to simulate an occlusion tentative of an intrusive object.

EXPERIMENT OUTLINE AND RESULTS

The IAEA and ABACC teams installed two 2DLaser sensors and a server for data acquisition and two NGSS cameras and a DCR/DCI for following up of the experiment (Figure 1 & 2). The first activities after the initial setup of the experiment were acquisition of the perimeter data, setup the region of interest and configuration of the simulated position of the silos (Figure 3).

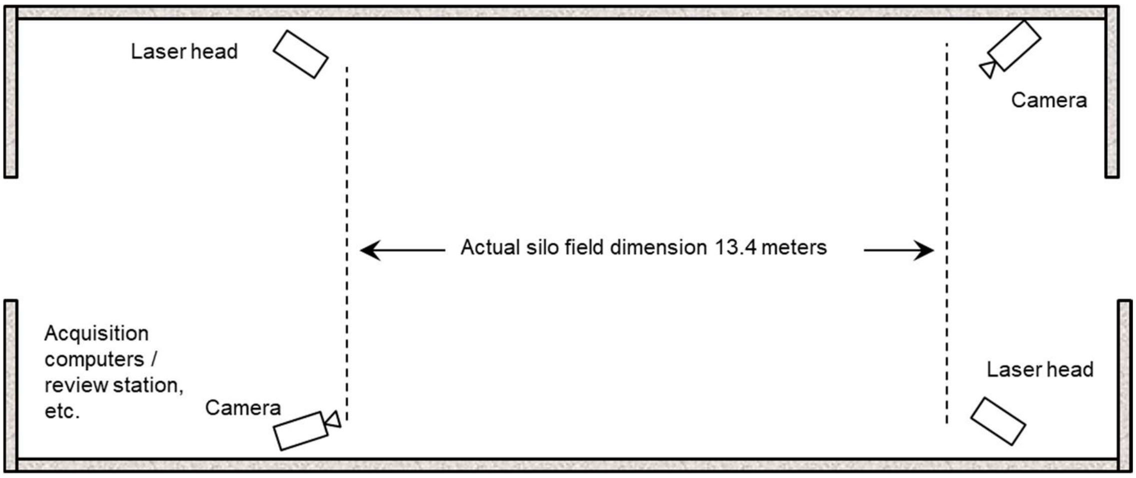


Figure 1 – schematic of the experiment location

The teams verified the synchronism of the data from the two 2DLaser sensors and the suitability of the LCCT to precisely assess the transfer flask position when loading a spent fuel canister and conducted an overnight test of the system.

A mockup of the flask was simulated using 90 x 90 x 50 cm carboard boxes. The boxes were covered with white, black and aluminum papers (Figure 4).

Figure 2– Perimeter acquisition and ROI setup

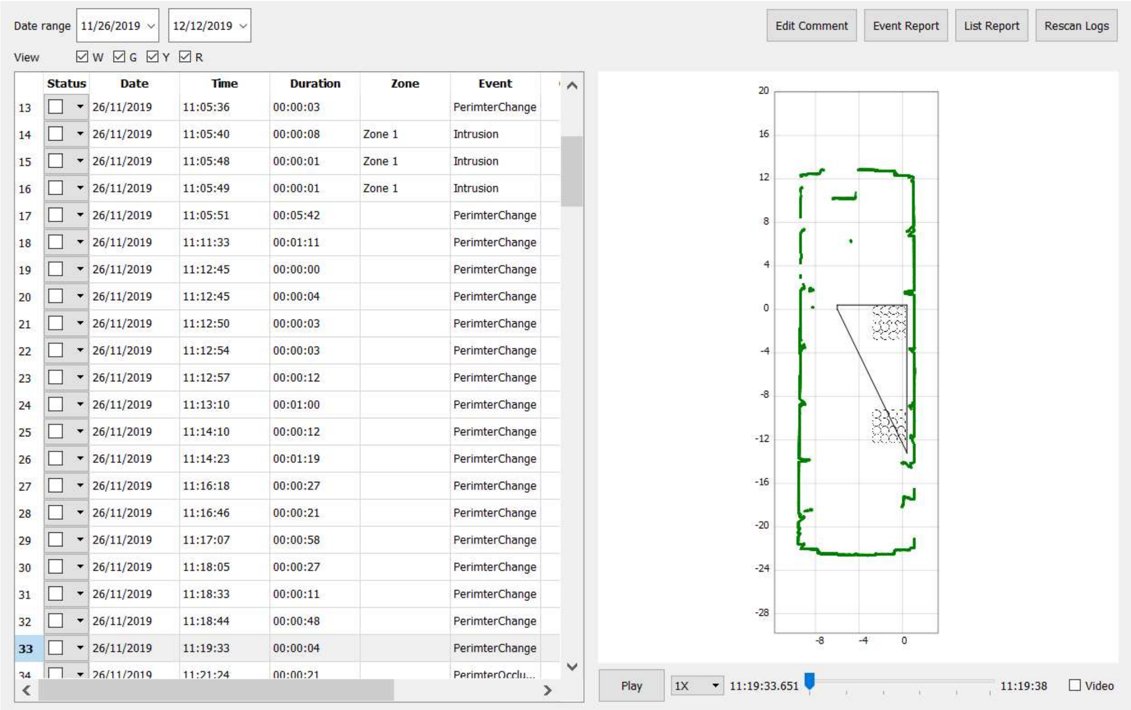


Figure 3– Perimeter acquisition and region of interest setup

Figure 4– White and black boxes used to test the response of the LCCT

The ABACC/IAEA teams defined a virtual grid of 4x4 and 5x4 circles, representing silos positions in the test area, and a region of interest delimiting the area where intrusion events were considered. More than one configuration of regions of interest were tested, including one with shape and dimensions similar to the arrangement of the silos at the dry storage of Atucha I.

During the experiment, the ABACC/IAEA teams verified the response (size, shape and synchronism) of the LCCT to the movement and positioning of the boxes (white and black) inside the virtual grid area. In Figure 5 a square signature is viewed from a static white box. Figure 6 shows the signature of the black box inside the area. This smaller signature is explained by the higher absorption of light by the black surface of the box.

In all the test runs the boxes were rotated 360°. It was also observed in the table of Figure 5 that sometimes the intrusion event is registered as a perimeter change or as a perimeter occlusion. This behavior was observed when the LCCT started the recording of a new event with the box, that is considered an intrusive object, already inside the region of interest.

The black box movement tracking showed a LCCT smaller signature and only a perimeter change alarm was registered when the box was positioned in the axis formed by the sensors' heads with its vertices oriented towards the sensors, as seen in Figure 7.

During the experiment, the response of the LCCT was also tested to the following events: black box outside of the ROI to simulate an occlusion to an intrusion event; tracking of a white box to test the synchronism of the 2 sensors ; cylinders of 28 x 38 cm covered with white, black and aluminum papers to test the signature of smaller objects.

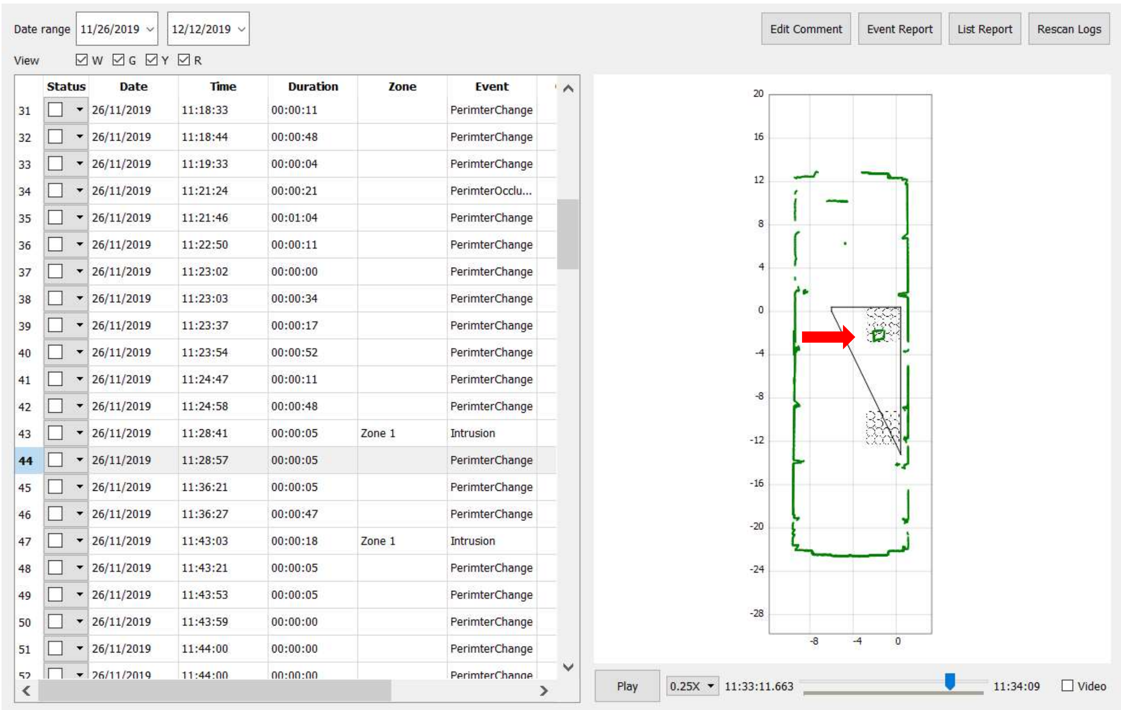


Figure 5 – Data and signature of a white box inside the ROI

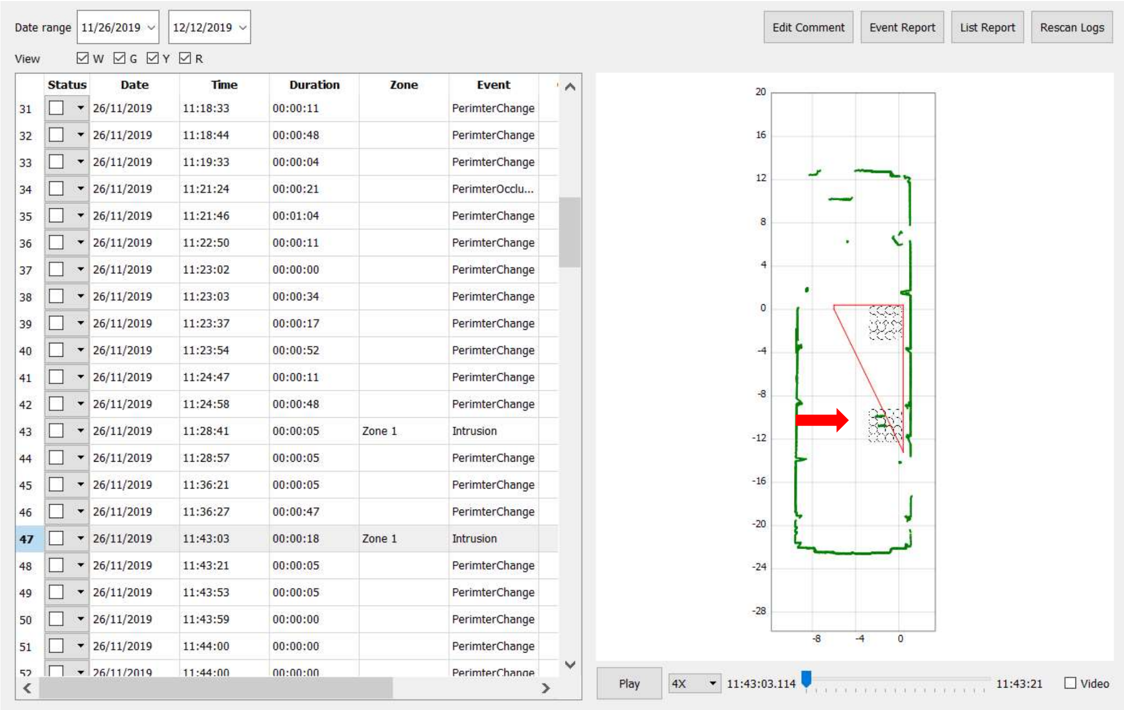


Figure 6 – Data and signature of a black box in the test area

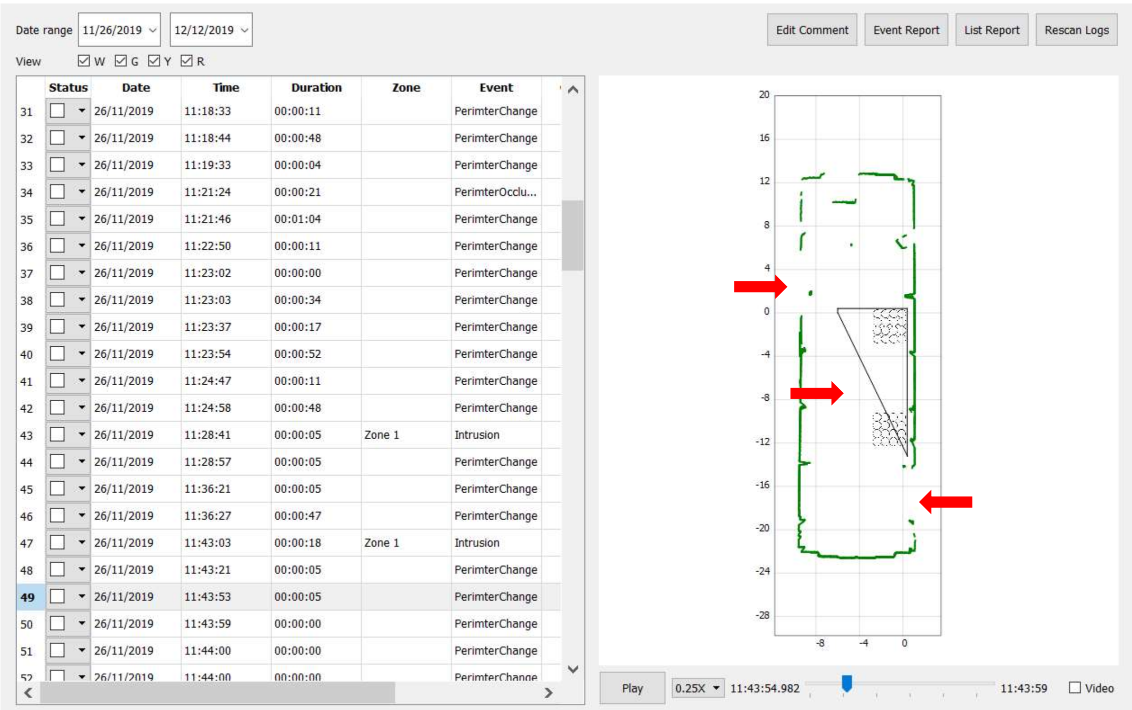
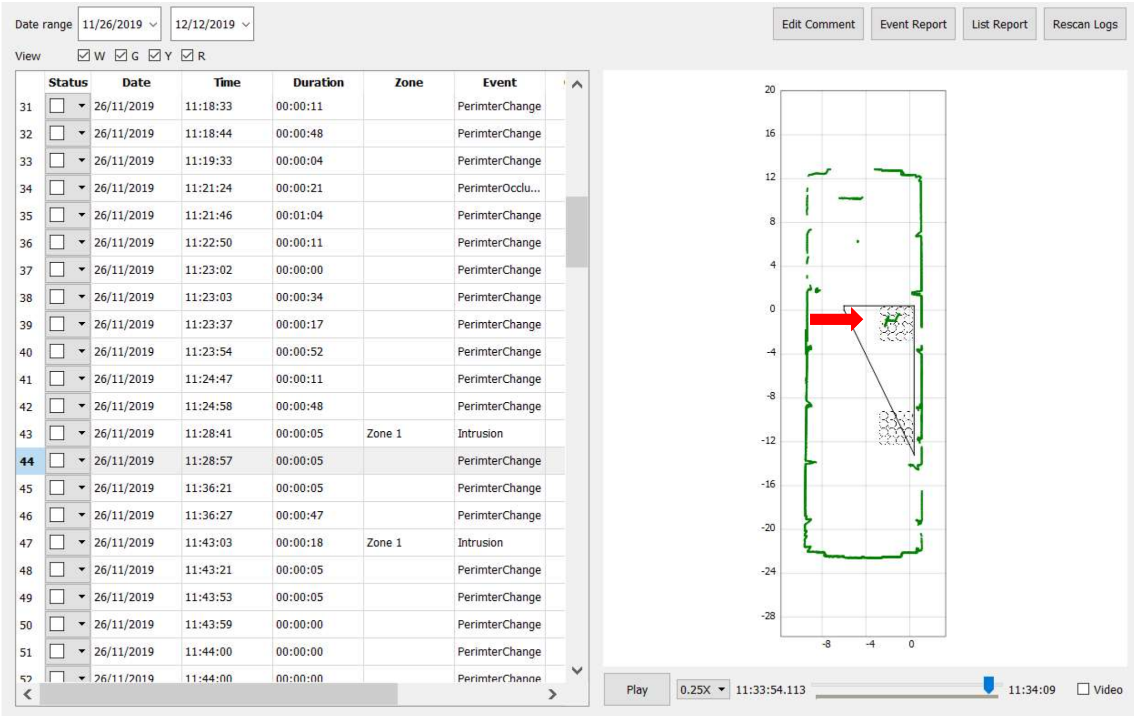


Figure 7 – Data and signature of a black box inside the ROI with vertices oriented towards the laser heads

The tracking of the movement of the white box inside the area of interest showed a 2-second lack of synchronism in the data acquired in real time from the two 2Dlaser sensors. This can be observed in Figure 8 as a distorted signature of the box, with the two sides of the box detected by one sensor appearing ahead of the sides detected by the opposite sensor.



	Status	Date	Time	Duration	Zone	Event
31		26/11/2019	11:18:33	00:00:11		PerimterChange
32		26/11/2019	11:18:44	00:00:48		PerimterChange
33		26/11/2019	11:19:33	00:00:04		PerimterChange
34		26/11/2019	11:21:24	00:00:21		PerimterOcclu...
35		26/11/2019	11:21:46	00:01:04		PerimterChange
36		26/11/2019	11:22:50	00:00:11		PerimterChange
37		26/11/2019	11:23:02	00:00:00		PerimterChange
38		26/11/2019	11:23:03	00:00:34		PerimterChange
39		26/11/2019	11:23:37	00:00:17		PerimterChange
40		26/11/2019	11:23:54	00:00:52		PerimterChange
41		26/11/2019	11:24:47	00:00:11		PerimterChange
42		26/11/2019	11:24:58	00:00:48		PerimterChange
43		26/11/2019	11:28:41	00:00:05	Zone 1	Intrusion
44		26/11/2019	11:28:57	00:00:05		PerimterChange
45		26/11/2019	11:36:21	00:00:05		PerimterChange
46		26/11/2019	11:36:27	00:00:47		PerimterChange
47		26/11/2019	11:43:03	00:00:18	Zone 1	Intrusion
48		26/11/2019	11:43:21	00:00:05		PerimterChange
49		26/11/2019	11:43:53	00:00:05		PerimterChange
50		26/11/2019	11:43:59	00:00:00		PerimterChange
51		26/11/2019	11:44:00	00:00:00		PerimterChange
52		26/11/2019	11:44:00	00:00:00		PerimterChange

Figure 8 – LCCT synchronism issues

COMMENTS AND RECOMMENDATIONS

All the occlusion, intrusion and perimeter change events were identified. Additional efforts to deal with the synchronism issues observed from the laser sensors information will help to improve the analysis of the LCCT data.

The system was setup to record data only when an event is triggered, e.g., intrusion, occlusion or perimeter change, generating an amount of approximately 700 Mbytes in a two-day test period. As a component of a dual C/S system, installed in a difficult-to-access area, it is recommended that a raw data recording function in a given period, e.g. 1 min, be included in the application, even without a triggered alarm.

In some particular conditions, when the black box was positioned in the axis formed by two 2Dlaser sensors and with the box vertices oriented to the sensors, the LCCT did not detect any signature of the box (Figure 7), although, a perimeter change alarm was seen instead of an occlusion or intrusion alarm. Image reconstruction algorithms based on such perimeter changed data can be designed to address this issue.

Inspectors´ review software should be improved with a more friendly interface, including the visualization of the related camera images. This functionality is planned, but not yet implemented in the review software. The use of terms “occlusion”, “intrusion” and “perimeter change” in the report of the viewer´s application should be carefully described, avoiding misunderstandings from the reviewers.

CONCLUSIONS

The proposed active containment system based on 2DLaser - LCCT, worked properly and reliably during the experiment without undesirable restarts or shutdowns. The LCCT identified the final locations of the simulated spent fuel storage unit in the virtual grid.

The field test in the DCMFEI demonstrated that the LCCT can be used as one of the dual Containment and Surveillance safeguard system components as it can identify all intrusive events of a given object within a defined area of interest.

The LCCT adequately tracked the path of objects in the test area and reported alarms for movements inside the region of interest and for changes in the perimeter. It is noteworthy that when the LCCT system deals with black square-shaped surfaces, depending on the orientation of the object towards the LCCT sensors, the event was only recorded as a perimeter change.

The information collected during this functionality test indicated that the LCCT´s viewer´s application needs some improvements to make it more user-friendly.

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