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LASER CURTAIN FOR CONTAINMENT AND TRACKING

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ABSTRACT

This paper focuses on new safeguards techniques designed to be applied in the European dry Spent Fuel Storage Facilities (SFSF). The number of spent fuel assemblies stored in the SFSF is constantly increasing. This has resulted in a situation where the currently implemented containment and surveillance techniques providing Continuity-of-Knowledge (CoK) are not anymore well suited for the purpose, causing disproportionately high workload for both DG ENER and IAEA inspectorates on applying them. Further, the big number of spent fuel containers is causing a considerable radiation dose intake for the inspectors applying these techniques, as well as for the facility operator staff accompanying the inspectors.

The paper presents a novel system for automated remote inspections, the Laser Curtain for Containment and Tracking (LCCT). LCCT consists of one or more laser scanners mounted on site structures, e.g. walls, railings. It is an active system that continuously monitors in real-time user-specified areas of interest, creating a virtual "box" (that can be quite complex in structure) around items to be safeguarded. Any intrusion into the areas of interest by an object larger than a specified limit is automatically detected and recorded. Such intrusion can trigger event alarms and additional safeguards measures like cameras. This system can also be used to track movements of objects within a given area, e.g. movement of spent fuel containers in a facility.

The paper illustrates the concept of the LCCT for different types of existing and future nuclear facilities in Europe.

1. Introduction

Safeguarding Spent Fuel Storage Facilities (SFSF) is becoming an increasingly important task for the international safeguards authorities. For example, Germany will phase out its nuclear reactors by 2022 and is expected to transfer all spent fuel to interim storages by 2027. Once the fuel transfer is completed, the German storage facilities will have a total inventory of more than 1000 casks and will remain quasi-static for several decades, i.e. no cask shipments are expected and only limited movement within the facility will be necessary for maintenance purposes [1].

The safeguards authorities need to maintain continuity of knowledge on the spent fuel over the entire life time of the SFSF. The present IAEA procedures require a dual C/S system, because the nuclear material is enclosed in the cask and re-verification would be very challenging [2]. In practice, the casks in the German SFSFs are currently sealed with two passive seals (COBRA and/or metal seal), which need to be regularly verified and replaced. Since the casks are spatially very close and the radiation level is high, this obligation has a significant impact for both, operators and inspectors [3].

The IAEA and Euratom are currently discussing alternative technologies for maintaining the continuity of knowledge in spent fuel storage facilities, which could ease the burden of the current safeguards concept. This paper describes the *Laser Curtain for Containment and Tracking (LCCT) system* that is considered as core component of a future monitoring system. LCCT is an active continuous surveillance system based on real-time laser scanners, which allows an automatic, event-based monitoring of the storage facility without the need of inspector reviews. It is proposed as the primary layer of a future safeguards concept and provides complete monitoring during normal operation.

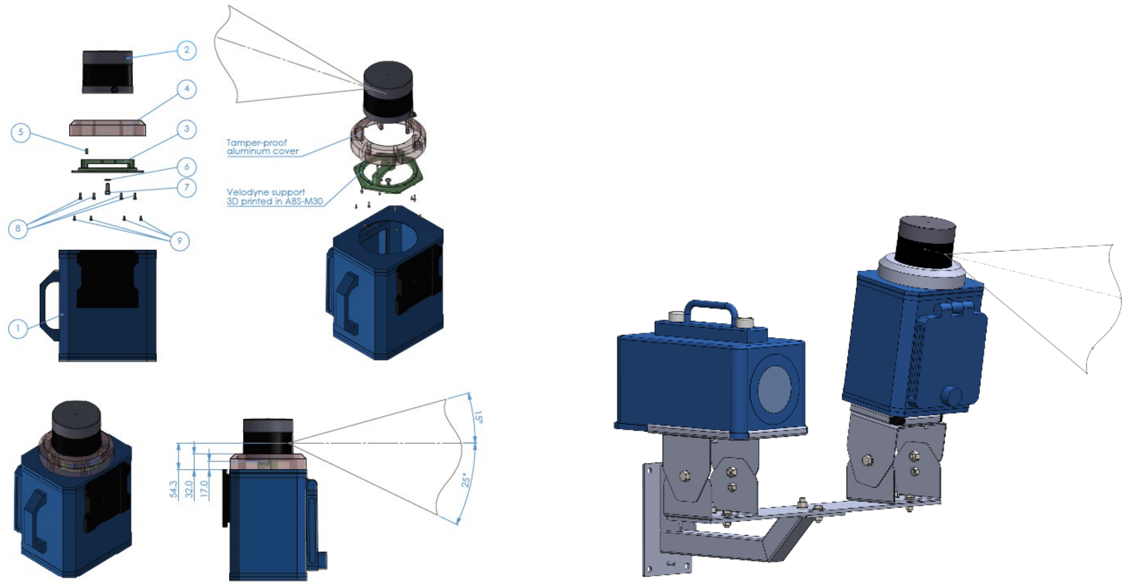
As part of a field trial, LCCT will be installed in September 2021 at the spent fuel storage facility in Gundremmingen, Germany. Operational use of the system is planned in several existing and new facilities in Germany, Belgium, Finland and Slovakia.
Section 2 provides an overview of the LCCT and illustrates how it can be applied for safeguarding a spent fuel storage facility. Section 3 provides conclusion followed by a summary and outlook to future activities in section 4.

2. Laser Curtain for Containment and Tracking (LCCT)

The LCCT is a fixed installation based on multiple real-time laser scanners that continuously acquire depth information to monitor an area of interest. The sensors use the time-of-flight (ToF) principle to acquire the distance to an object by emitting a laser pulse and measuring the time for the signal to be returned.

Each sensor is composed by multiple laser-detector pairs arranged along the vertical axis that are continuously rotating to generate several scans per second. The laser scanner that is used in the current configuration (Velodyne Ultrapuck VLP-32) has 32 lines with a vertical field of view of 40 degrees. It has a configurable frame rate of 5Hz to 20Hz, a maximum range of 200m and an accuracy of 3cm [4].

The LCCT sensor is mounted in an NGSS (XCAM) camera housing with a custom front plate and aluminum cover to guarantee tamper proofing. The housing also contains a DC/DC converter, a VPN for data encryption and – in case an optical fibre cable is used – a media converter. See Figure 1a.



(a) (b)

Figure 1: LCCT (a) Tamper proof mounting; (b) Mounted on pre-existing camera mountings

One of the main advantage of using 3D scanners instead of 2D scanners, as originally proposed in [5], is to reduce the number of sensors needed and the possibility to have more freedom on the mounting of the lasers. This allows the use of the existing infrastructure and specially the mountings of the pre-installed cameras (see Figure 1b).

Figure 2 illustrates a typical spent fuel storage facility. Figure 3 shows a coarse CAD model of the SFSF in Gundremmingen – WTI-concept [6], the positions of the laser scanners (L1-L4) proposed for the field trial and the simulated laser data.

Figure 2: Image of spent fuel casks at the SFSF Unterweser, Germany (*source*: bgz.de).

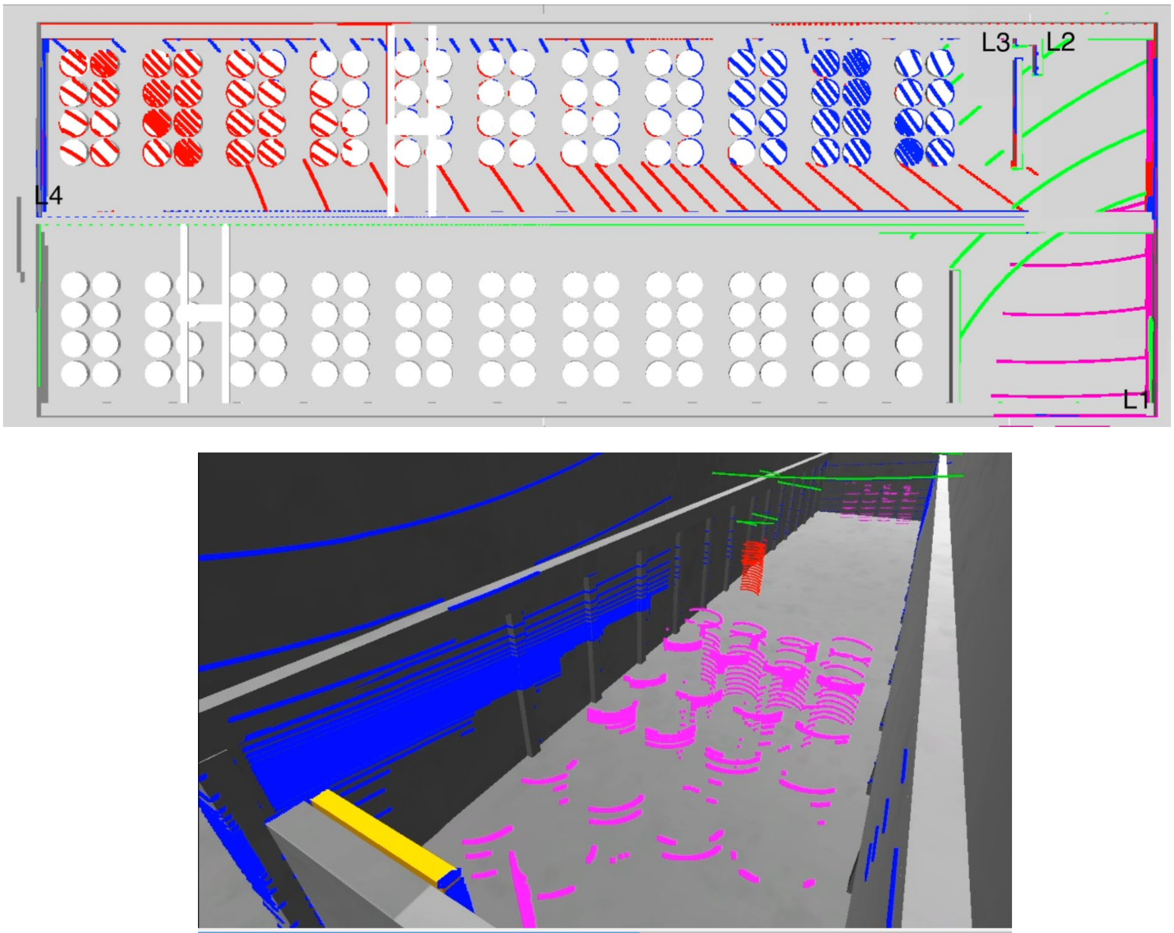


Figure 3: *Top:* Top-down view of the Gundremmingen CAD model, the proposed positions of the laser scanners (L1-L4) and the simulated laser data. The field trial covers only one storage hall and the entrance area. In an operational case two additional lasers would be installed in the second storage hall. *Bottom:* Perspective view of the simulated laser data obtained with L3 and L4.

On a local server running at the SFSF, all laser data is fused into a single 3D data set and analysed in real-time to monitor and track the movements of the spent fuel casks. Since the analysis works on geometric measurements in 3D space, event detection can be restricted to a pre-defined area of interest. Furthermore, the measurements are based on an active laser light and therefore the analysis is much more robust than event detection based on optical video surveillance (which is influenced by ambient light conditions).

The area of interest is divided in multiple monitoring zones and an event is triggered when an object is entering a zone. Figure 4 shows an example for the zones in a storage facility; they can be defined to cover small areas (e.g. the parking position of a single casks) and on different levels (e.g. one level for the cask and one for the crane). Any activity in the monitored areas will trigger an event and the sequence of events can be used to verify declared activities such as the transport of a cask to a specific parking position.

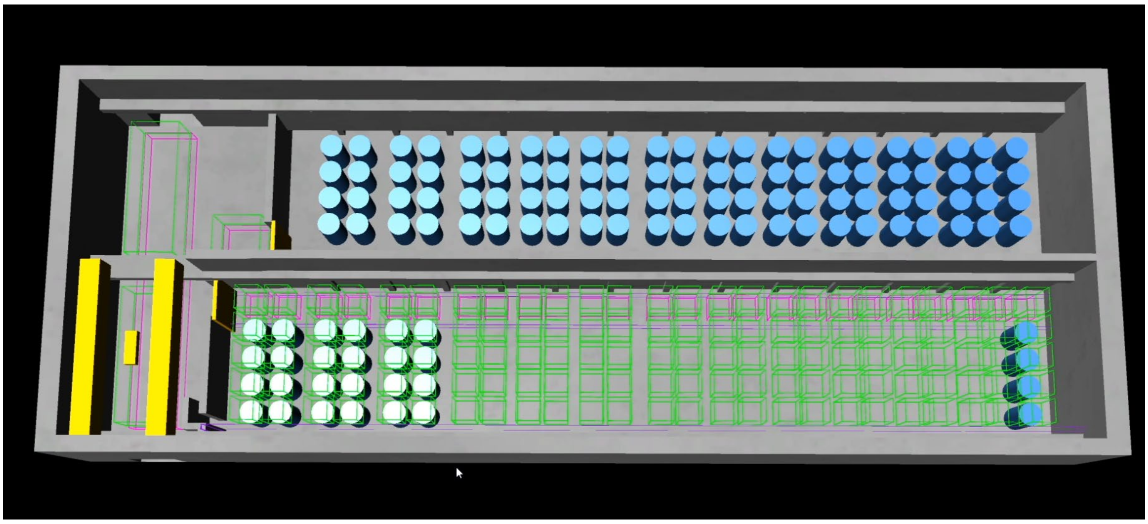


Figure 4: *Monitoring zones defined in a storage facility on two levels (pink and green)*. The position and size of the zones depend on the expected activities, i.e. in larger zones in the receiving area monitor the arrival of the transport vehicle and the unloading of the truck, small zones in the storage area allow to detect movements within specific parking positions of the casks.

When an event is detected, LCCT records the meta information (event type, time stamp and zone id) and streams the corresponding laser data to file. It also allows triggering safeguards surveillance cameras to facilitate later analysis. The LCCT surveillance application continuously runs in an unattended mode on the local server without the need for any user interaction. The event metadata and corresponding 3D data is stored locally for later review.
A separate review application allows to view and analyse the recorded data a posteriori. It can be executed locally or –preferably– at the inspectors headquarter without the need of inspector presence on site. In the latter case, the recorded data needs to be transmitted via Remote Data Access before review. The analysis can be carried out on different levels: by verifying the event sequence against the declared activities or by reviewing the raw laser data and/or surveillance imagery for a single event. The review application uses the timestamps of the event metadata and raw data to facilitate the integrated review of all information (see Figure 5). The event information can also be exported to other safeguards review tools such as iRAP[7], CASCADE or NGSR.

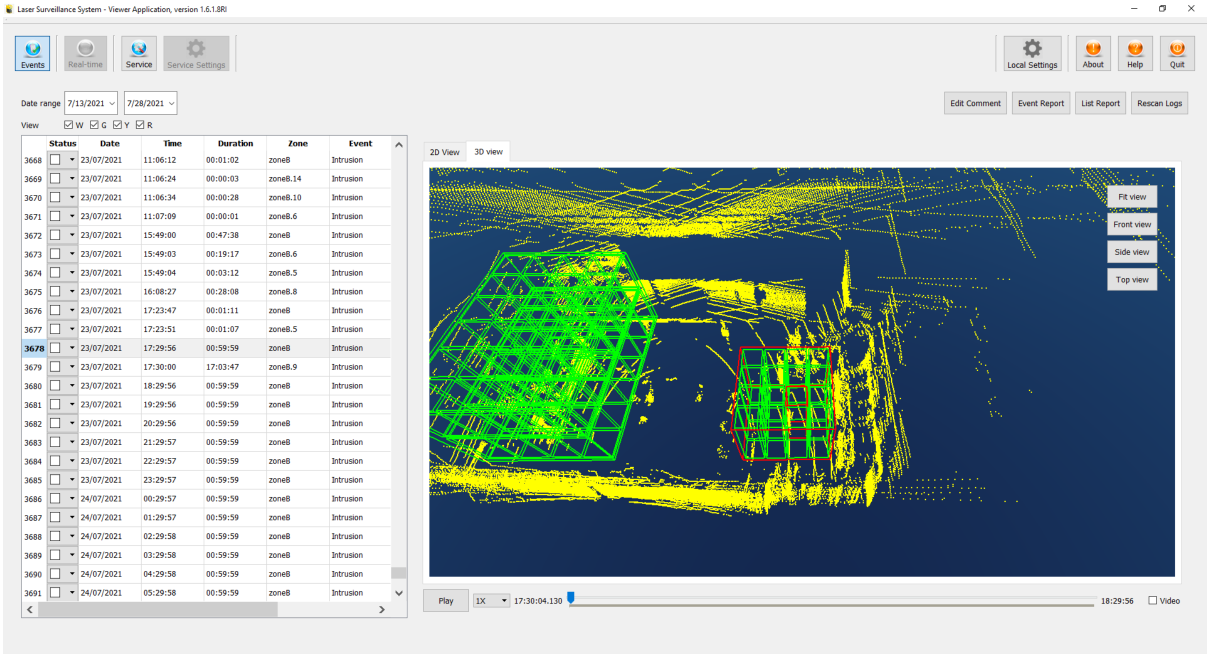


Figure 5: Snapshot from the review application. Data from a mockup installation at the JRC integrating 4 LCCTs and monitoring 48 different areas.

3. Conclusions

The LCCT is a 24/7 intelligent, modular and configurable surveillance/virtual sealing and tracking system, capable of:

- Unattended Monitoring: Spent fuel casks, immobilized objects, perimeter of buildings
- Tracking: Movements detected and interacting with NGSS cameras and other surveillance systems
- Event Detection: Automatic to iRAP and other systems for replay and analysis
- Unattended Verification: Automated Material Flow Monitoring

In the specific case of SFSF it enables to automate:

- Cask movement tracking in the reception/storage area
- Cask movement tracking in the store passage area
- Continuous verification of cask presence
- Crane movement tracking above the cask level
- Perimeter monitoring of outer walls

4. Summary and Outlook

The number of interim Spent Fuel Storage Facilities (SFSF) will increase significantly over the next years. The facilities will be quasi-static once the fuel transfer is completed, but will remain under nuclear safeguards for several decades. The current approach for maintaining continuity of knowledge is based on two independent sealing systems for each spent fuel cask. The requirement for periodic validation and/or replacement of the seals and the relatively high radiation levels in the proximity of the casks constitute a significant issue to the inspectors and facility operators. Therefore, Euratom and IAEA have started discussing alternative technologies that can significantly reduce the inspection effort for safeguarding quasi-static SFSFs.

LCCT can be a core technology of an unattended monitoring system that requires less inspector presence. It allows to continuously monitor the spent fuel casks and automatically notify the inspectors through remote data transmission in case any safeguards-relevant events are detected.

It is planned to be deployed in several EU nuclear facilities during the coming years. A field test is currently under preparation in a German spent fuel storage facility which is expected to show the benefits and robustness of the system. The event analysis software will be further developed to increase the automation of the verification process and to include events originating from other safeguards equipment. This will be particularly important to automatize more complex monitoring tasks, as for example in the Finish encapsulation plant that will go in operation in the coming years.

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