ABACC and JRC Cooperation on 3D Laser Range Finder (3DLR) for Design Information Verification

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I – ABSTRACT

Design Information Verification (DIV) is a very important activity in verifying the operator declaration to detect possible changes that may represent diversion scenarios in nuclear installations or their misuses. Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC) has become involved in the application of safeguards to complex and sensitive facilities, where the physical verification of the design present status is sometimes complex and a long task. The methodology to carry out the DIV has been improved recently. However, the way to execute some tasks is still relying on the expertise and technical background of the inspectors.

One of the tools that is currently available to increase the effectiveness of the DIV process is the 3D Laser Range Finder (3DLR) developed by the European Commission's Joint Research Centre (JRC). This tool is currently used by the IAEA, and ABACC considers it is a very promising tool to be used at facilities having numerous pipes, tanks and accessories. Besides, the technology applied contributes for non proliferation because the information can be kept at the facility, and requires less intrusive access to the plant.

ABACC and JRC started cooperating on the 3D Laser Range Finder (3DLR) for Design Information Verification within the scope of the general ABACC-EURATOM cooperation agreement.

This paper presents the advantages of the technology, the applications envisaged by ABACC, and the technical features of the 3DLR system for these applications. The paper also describes the operational aspects of the application and the necessary procedure to be agreed among operator, States and Safeguards agencies (ABACC and IAEA). The paper addresses also the status of the ABACC/JRC cooperation in this field.

II - Introduction

It is not uncommon to apply safeguards in installations where the diversion scenarios are implemented through the physical changes in the plant equipment, piping, valves, and accessories. Covering these scenarios, the inspectorate has to verify if changes or new elements relevant to safeguards are introduced into the facility operating conditions and/or its layout. This means to keep what we can call as **configuration control** of the process and facility.

Enrichment and reprocessing processes are usually processes with a bit large number of these elements. In addition, to turn the problem more complex, both are sensitivity processes where non-proliferation matters are relevant for operators and inspectorate.

During the initial verification of the facility design information or its configuration, a process expert, usually the facility officer or country officer is to accompany the inspectors to the plant and time and questions do not pose as main constraints on the verification activities carried out by the inspector to verify the correctness and completeness of the design information provided by the State.

The periodic re-verification of the facility design information or the configuration control verification will become an easy or a complex task, depending on the complexity of the plant. If it is an easy system the problem can be handled by most of the inspectors. Otherwise, the job will be a challenge for the inspectors. The pressure of inspection environment, the limited period of time during which all inspection activities must take place and the knowledge of the individual will determine the success of the configuration control verification.

To make easy the task proposed the usual tools up to the moment are:

- To rely on the **expertise** of the inspectors (visual observation). Even though the agencies can use it for some special occasions it cannot be considered as being always available;
- To apply **containment to** all over the process. However, this is very intrusive for the operator and not practical for application;
- To use **photos or recording** the original configuration as a baseline and compare with future images (visual observation). It is usually a time consuming activity and the comparison methodology is cumbersome and subject to human misinterpretation and error. Further, for better results, image acquisition parameters should be constant, i.e., images taken always from the exact location and using the same optics (not to mention illumination).

III – The Laser technology to be applied for configuration control

The potential application of laser technology for configuration control is the capability of the system to measure accurate distances of objects, and between objects, in a given scene and be able to distinguish three dimension (3D) measurements (i.e., 3D scene change detection). Further, 3D visualisation tools help an inspector to interpret the spatial changes, their origins and impact. The system should be able to remount a 3D model independent from the capture point of the system.

Traditional optical surveillance gives the notion of depth when image is projected. However, can not prevent undetected masks, even in cases where one use double images. Technologies like the Laser range finder, Laser triangulation, Solid state focal plane cameras and Stereo vision can be used to generate 3D measurements.

Characteristics of the 3DLR system such as self-illumination, independence of ambient lighting, high spatial resolution, high accuracy, fast speed acquisition, well defined measurement parameters such as: distance, size, speed, motion orientation and easy interfacing, make this type of system suitable for the proposed application.

Further, and this is important from an application viewpoint, the distance measurement process is contactless, i.e., there is no need for an inspector to be close to the object being measured. When modelling a given scene the right set of variables parameters such as: the time of acquisition, the spatial resolution, resolution and portability make the 3DLR an efficient tool to model the scene to be controlled. The tool is very precise and any minor changes in the environment (within an inspector defined distance variation threshold) can be easily automatically detected.

Coupled with computer dedicated software, the 3DLR technology turns to be an easy and a straight tool to be used in safeguards. The present advanced status of development and implementation of this technology allows its application in safeguards activities.

IV – Operational and administrative aspects for the technology

Any new tool developed for safeguards applications and, in particular, when it is related to sensitive installations, has incorporated into it factors and boundary conditions to be analysed and discussed among the involved parts in order to demonstrate that its application is technically feasible and fulfils with the agencies and plant requirements.
Concerning the operators, they always have raised points related to (a) intrusiveness, (b) inspection effort and (c) whether the safeguards technology could or might interfere with the process or security systems at the installation. Besides, dealing with sensitive facilities, the issue of confidentiality is always a relevant point to be evaluated before the introduction of any new safeguards measure.

In this regard, the interference with the process, mainly those related with different frequencies that the laser 3DLR could emit was also discussed. In principle, it appears not to be a problem since the 3DLR uses the frequencies on the same spectrum of illumination that is used at the facilities. Safety restrictions were also discussed and it was showed that the laser is not harmful for humans and there is no effect on eyes impact for short period of time. It was also presented the safety procedures for the application of that technology related to the persons operating the equipment.

The 3D Laser Range Finder has the following advantages over the traditional tools like photos, movies or human visual observations for comparison:

Related to confidentiality and intrusiveness:

- Since it is not dependent of a fixed special position to be installed at each time to acquire a scene for inspection verification and the time to acquire data, pending the resolution, the intrusiveness is much reduced considering the traditional Design Information Verification activities, taking into account that it will require less time of the inspectors at the restricted areas;
- The original data from the baseline configuration may be stored and kept at the installation under containment to be used as reference configurations files during the DIV inspections. The data acquired during inspections and comparison of results may also be kept in electronic format at the installation. That preserves the confidentiality of the all

data obtained through the verification process. Keeping all data at the installation is an improvement for data security;

- The verification performed through electronic devices reduces the inspector working time and his/her presence at sensitive areas turning the inspection less intrusive.

Related to the safeguards agencies procedures and inspection effort:

- It provides a faster data analysis and conclusion of data acquired, reducing the inspection effort;
- It does not require high inspector knowledge of the process or familiarity with a specific installation to identify changes;
- It avoids misinterpretation of the data obtained since the differences are acquired by software for analysis of results. The task of the inspectors is to verify the differences and solve any discrepancy. Unsolved points may be recorded for future analysis.
- Since the system is fully authenticated before being used and the data (baseline and acquired) is secured, in case of more than one safeguards agency be performing the design verification activities the data acquired fulfil the requirements for ABACC-IAEA Joint Use Agreement;
- The data obtained can be analyzed by each of the agencies to reach its own independent conclusions;
- Its use increases the inspector confidence during the inspection since the data presented by an automatic process is kept as a back up for the design verification conclusions.
- In case of amplifications or clarifications of any design verification inspection report become necessary, it can be used to provide a faster conclusion expending a much reduced inspection effort.

V – Status of application in the ABACC system

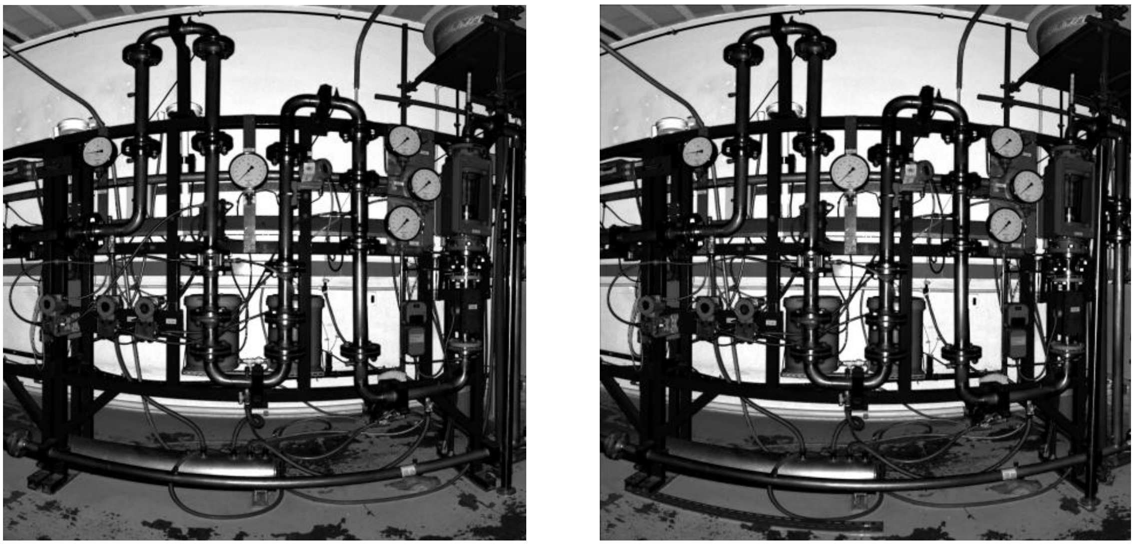
Recognizing that the technology has a well defined and efficient application, within the framework of the Cooperation Agreement between the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC) and the European Atomic Energy Community represented by the European Commission ABACC initiated a technical information exchange with JRC to know better and to evaluate the system for safeguards application at South America.

After initial exchange of information the first step was to sign an action sheet for training the ABACC officers, taking the opportunity of a course given at JRC-Ispra for IAEA inspectors.
Afterwards, a second action sheet was signed to disseminate information about the 3D laser scanning system developed by JRC-Ispra among the Argentinean and Brazilian Safeguards Authorities and facilities operators, which is currently being used by the IAEA for design verification purpose.

A seminar held on November 2008 in Rio de Janeiro, Brazil, with 24 attendees aimed to approach two main aspects: a system presentation and theoretical introduction to the new technology conducted at ABACC-headquarters, and a practical workshop to demonstrate the use of the 3D Laser Range Finder (3DLR) conducted at a Brazilian facility.

During the practical part of the workshop two scans were taken for verification of changes from the baseline configuration. The first one using medium resolution scanning was used for illustrating the change detection capability of the system. Changes in the position of some objects were introduced: the re-positioning of pipe sections, plastic recipients and a gas cylinder. Some pipes and the gas cylinder were not on the front view of the scanning (main view), but they were registered on the 360 degrees angle scanning. The addition of pipes and plastic recipients was used to demonstrate the ability of the system to detect the addition of objects into the environment. The system could detect the changes and intentionally some changes were made where there was no baseline information and no conclusion could be derived. However, the DIV software did report the existence of changes.

Also, a set of 3D images was evaluated, taking advantages of experiments using High Resolution Scanning at the panel station of a complex piping and accessories system, in which a number of pipes of different diameters and sizes are connected. The experiments consisted of introducing additional tubes with different shapes and diameters into the configuration of connected pipes. For the size and diameter proposed the scanning could recognize the changes introduced. Figure 1 shows the baseline and the verification images for the high resolution scanning.



(a) Reference   (b) Verification

Figure 1: Reference and Verification Scans

Figure 2 shows the results form the software interpretation visualized in color schemes.

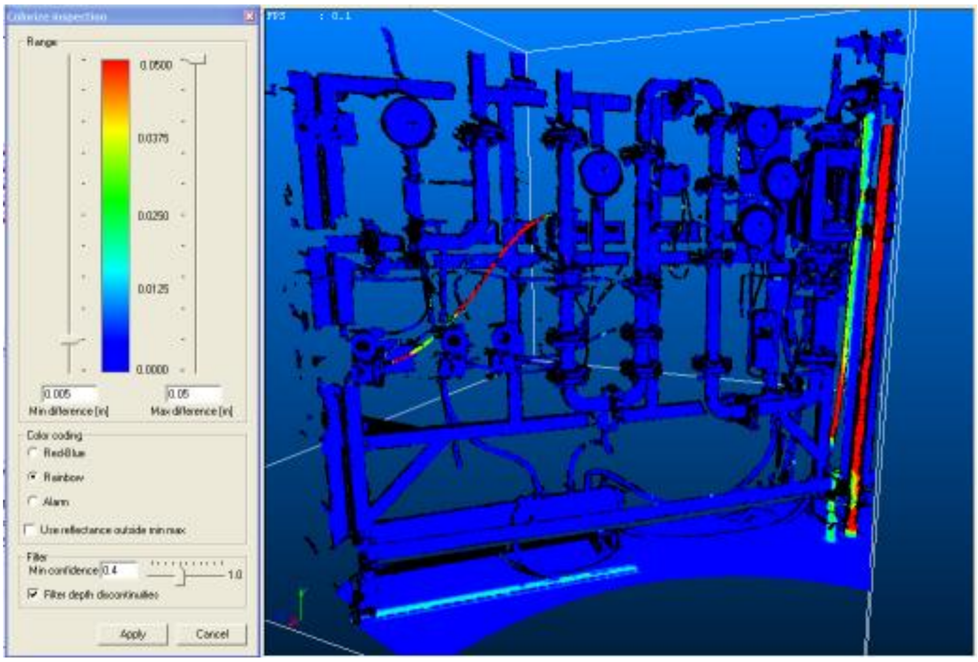


Figure 2: Identified 3D Changes visualised in colour code schemes

The results of the 3D-DIV system evaluation using the images obtained with Low Resolution were enough accurate to detect changes of objects in the size range proposed by the equipment. However, for the application such as small tube diameters, the system could not clearly indicate minor changes in the environment since the error effects caused by the borders of the structure could lead the inspector to wrong conclusions.

Differently, using the High Resolution Scanning, the images obtained were much better displayed with a good precision to detect the addition of other pipes and the movement of pipes into the complex configuration of connected pipes in the panel station of the water loop.

The conclusion from the presentation was that an accurate and complete baseline needs to be performed before the application of the system. Main safeguards areas must be chosen to perform a complete baseline. With good reference the chances to lost information and false conclusion are minimized.

It was also concluded that for the application of changing small pipes in a complex system, like the ones with cumbersome valves and pipes, the high resolution improve the answers given by the 3D-laser.

The objective of the seminar in technically presenting the advantages of the 3D Laser Range Finder (3D LFR) was fully accomplished. Moreover, the participation of operators and national authorities contributed for their understanding on the technology and to build confidence on the application of this technology for safeguards purposes.

The present status of the technology application is the discussion with the member states where the 3D LFR could be applied. In the case, ABACC envisage using it at the enrichment facilities, in which small pipes in a complex system and a number of other elements impose difficulties and time consuming to the inspector to confirm the validity of the information provided in the facility design information and verify that no modifications or changes have been introduced into the facility configuration.

Using the 3DLR technology, it is also envisaged to enhance the design verification without disclosing any sensitive information.

VI – Future applications

ABACC is now also involved with DOE laboratories and JRC-Euratom in a collaborative effort to analyse the feasibility of coupling of optical special images with radiation imaging systems using gamma or neutron measurements.

Another desirable future event is the application of laser to identify unique safeguards characteristics of items or verify if a system or equipment remain unchangeable from the original status for safeguards use. Both applications may be interpreted as a feature to verify the fingerprint of such items.

Further applications like outdoor verifications for security purposes and 3D modeling of critical infrastructures at specific locations of interest are also in the scope of the technology.

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