An innovative platform allowing digitization of operative Radioprotection measurements and to characterize NORM, TENORM and nuclear waste

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Abstract. A novel Platform for the digitization of the information produced during the characterization of radioactive waste, contaminated objects, and in general radioprotection measurements has been developed by CAEN S.p.A. The Platform is based on a gamma spectroscopic handheld instrument integrating RFID technology, 1D/2D reader, camera, voice recorder, and geo-localization, a selection of radiation tolerant RFID tags tested up to 300 Gy integrated dose, ruggedized portable RFID readers and a secure database framework capable to accept and collect data also from external sources such as high resolution gamma spectrometry systems or surface contamination probes. The Platform allows the operator to perform real-time measurement of dose rate, radiation spectroscopy, tagging, tracking and inventorying of items. All data produced by the Platform are securely stored into the non-volatile memory of the RFID tags and in the database for both onsite and remote access to the information by operators. The paper presents the current development of the Platform and shows the advantages of such approach in NORM activities which are increasingly requiring management procedures a reliable items traceability, storing optimization, and a structured methodology for radiation measurements, improving the QA/QC as increasingly required by Safety Authorities. In the paper will be explored and proposed some examples of application of the Platform for NORM and TENORM management operations and radioprotection of the personnel involved in. More in general, the Platform can address the needs of all plants, research laboratories and facilities that are looking to improve their Safety Standards by enhancing the ALARA principle for the personnel and the population as well as decreasing operational costs and having a precise knowledge of the contaminated environment and objects.

KEYWORDS: Radioactive Waste, Digitization, NORM, TENORM, Digiwaste, RadHAND

1 INTRODUCTION

The management of Naturally Occurring Radioactive Materials (NORM) and their Technically-Enhanced forms (TENORM) is increasingly requiring [1,2] the identification and the application of structured procedures aiming to improve quality management, increase operators' safety and optimize operational costs. As for the activities involving the management of artificial radiological sources and nuclear waste, e.g. in the Decommissioning & Dismantling operations of a nuclear facility, the NORM management requires to handle properly a lot of data and the current lack of a self-consistent and easy method for digitizing the large amount of information produced in operational activities is still an unsolved challenge. One of the limiting factors to achieve this goal is the use of instruments from various sources that are not able to share information each other and send coherent data to a comprehensive central repository. Consequently, operators are forced to use different devices and take notes of their measurements on logbooks and spend a significant amount of efforts in post processing the information. It results in a not optimized operational process, increased risk of mistakes and loss of data that can lead to the need of repeating measurements on the same items multiple times, extending the operational time required to efficiently complete a reliable site characterization and therefore costs. At the same time, the lack of an easily access a complete digitized set of data makes difficult to reduce as low as possible operators' exposure to radiation, not allowing therefore for an effective adoption of the ALARA safety principle. Moreover, the inhomogeneity of best practises that each Company of an activity related with the NORM management in the same field (e.g. Oil & Gas Industry) follows, results in a general poor Quality Assurance.

2 DIGIWASTE PLATFORM

To address these needs, CAEN S.p.A. has developed a complete platform to perform a real-time digitization of all information produced in all those operations involving measurement and tracking of radioactive items. The Platform, called DigiWaste, consists of the following components:

- RadHAND an innovative hand-held instrument based on the integration of spectroscopic radiation inorganic scintillation detector and Ultra High Frequency Radio-Frequency Identification (UHF RFID) technology
- RadBASE, a specific designed database, for data storage and integrated customized processes
- RadRFID, a set of radiation tolerant RFID tags, to store locally the data associated with a measurement
- RadREAD, ruggedized portable UHF RFID reader family

The complementary use and the integration of such tools as a Platform allows operators to simultaneously characterize radioactive items, tag them by using UHF RFID tags, store the most sensitive data into tags memory and push all the information to a central database. According to the different use case scenarios, the users can define a representation of distinct parts of an industrial site or facility in which they are operating as well as the form factors and the materials which are dealing whit. In this way, operators have a very intuitive interface for an optimal tracking of their activities. In the next sub-sections follows a description of each Platform component.

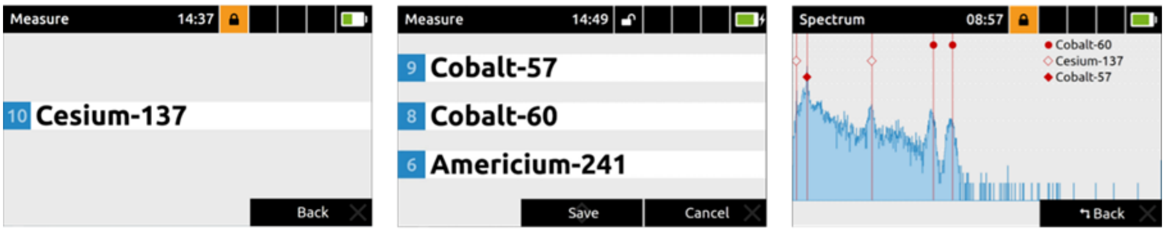
2.1 RadHAND, the innovative Spectroscopy Handheld instrument

RadHAND (Fig. 1) is an innovative hand-held instrument designed to perform both spectroscopic radiation measurements and UHF RFID tagging of radiological objects.

Figure 1: RadHAND is a novel handheld instrument designed and developed to merge in a single device, both radiation spectroscopy and UHF RFID technology.

For what concerns the radiological part, it consists of an inorganic scintillation detector coupled to a high efficiency PhotoMultipier Tube (PMT) for detecting gamma rays emitted by radionuclides. The pulses output are digitized on real time and processed via dedicated Digital Pulse Processing (DPP) algorithms by an embedded computer that take cares of building energy spectra, analysing the data and stabilizing the detector against temperature drifts and natural detector ageing. In this way, RadHAND continuously measures the dose-rate and can identify the detected radionuclides among those existing in the internal library (Fig. 2). For the safety of the operator the handheld can issue visual and acoustic alarms whenever a safety threshold on the measured dose rate is exceeded.

Figure 2: Example of results of spectroscopy info: (left) one or (center) multiple identified radionuclides; (right) example of gamma spectrum visualized at the end of identification.



Regarding the UHF RFID technology, RadHAND is provided with a compact RFID reader and a circular polarized, quadrifilar antenna. RadHAND, therefore, can scan for the presence of UHF RFID tags, get their unique identification number, and read and write information in their memories. The unit is also provided with a compact 1D/2D barcode scanner able to decode most of the commonly used symbology. RadHAND is also equipped with a camera for taking pictures of the items on which operators are working. This helps to remove any possible ambiguity in the description of the measured items. In addition, users can record vocal notes to add comments as short notes of the measurement. Both pictures and notes are transferred to the central database and associated to measurements and items. Concerning the controls, the instrument is provided with several communication links, including USB, Bluetooth and Wi-Fi. The instrument is equipped with only four buttons (one for power on/off and three to manage it and navigate the menu) making it very simple to use and handle also to not so expert workers. The handheld can be controlled either locally thanks to a simple, three physical buttons interface, or remotely through a dedicated web interface. By using the latter, RadHAND works in stand-alone mode being placed on a tripod for fixed geometry measurements and remotely accessed by operators. RadHAND is provided with GPS for georeferenced measurements. Operatively, RadHAND is battery powered and can cover a whole operator shift of 8 hours without need of battery change. Its weight is less than 2 kg and is characterized by IP65 housing of compact size (31 x 17 x 11 cm^3). It is ideal for in-situ gamma survey application. It has been designed and tested to work between -10° C and +50°C. The instrument is equipped, moreover, of internal memory (32 GB) where temporarily store acquired data.

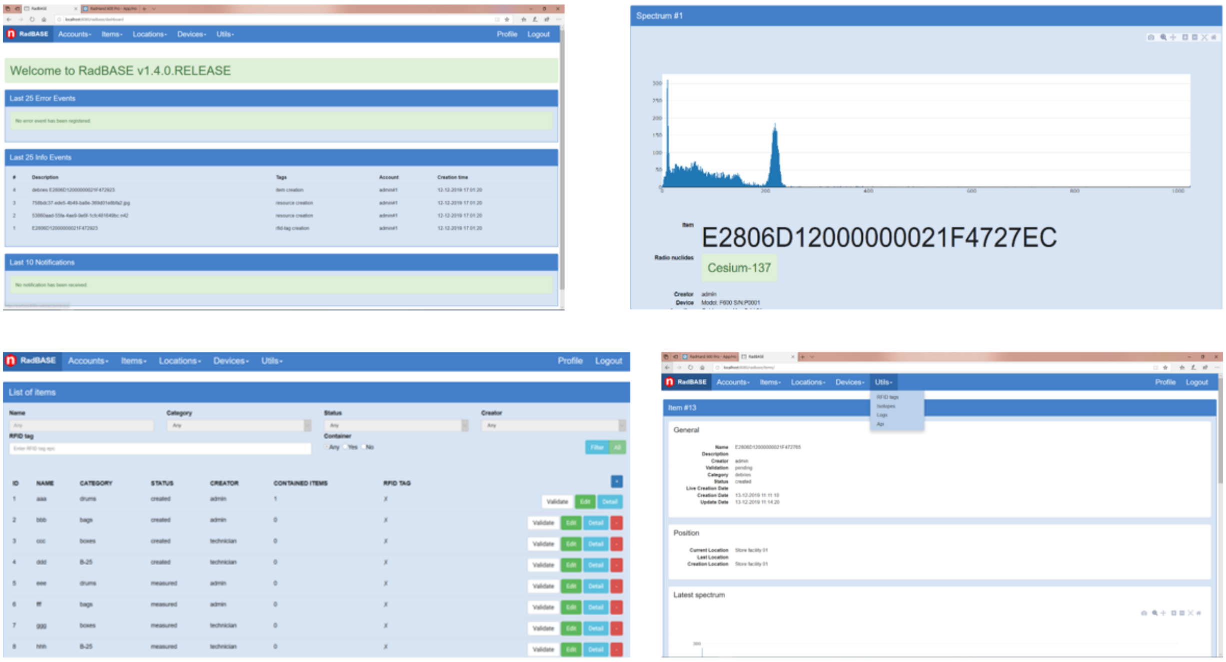
2.2 RadBASE, the specifically designed Database

To achieve a coherent digitization of the waste information, it is important to rely on a centralized database where to collect and merge data coming from different sources and make the information promptly available to all users. RadBASE has been specifically designed to accept and store all the relevant information related to a radiological measurement. It consists of a data management framework supporting the tracking and integration of key information of radiological item measurement activities coming from the connected devices. It is based on a secure Representational State Transfer (REST) web service employing high level data encryption and a multi-layered user access approach to ensure safe and secure network management. User-specific access levels determine the type of data an operator can retrieve as well as the level of interaction with the database. Network administrators have complete access to the dataset, including the history of each item, control of all the devices and their status, position of the instruments thanks to the GPS information, real time monitoring of the measured radioactivity levels and alarms, notifications of the completion of tasks by operators and inventory of the RFID tagged items. RadBASE is composed by two fundamental blocks consisting of a double-layer structure. The lower layer is server-based working on API REST service process. The upper layer is the Graphical User Interface (GUI) that is a web interface through which the user can access, visualize and retrieve all data[1] (Fig. 3). Being based on such a structure, RadBASE

[1] Two different web interfaces have been developed for the Platform: the one through which the user can remotely control the RadHAND and the other one through which the user can access to the RadBASE. They can be visualized contemporarily.

can be easily integrated in already existing IT infrastructures by managing Authentication and Authorization services.

Figure 3: Example of RadBASE GUI windows.



2.3 RadRFID, a set of radiation tolerant RFID tags, to store locally the data associated with the measurement

There are several reasons why UHF RFID technology has been selected for the development of DigiWaste Platform. First, it is a technology already and extensively used in the logistics since several years with success. According to the UHF RFID tag type, they can be read without the need of line of sight up to a distance of 2 meters for handheld readers and several meters for fixed readers. Then, multiple tags can be read at the same time allowing for a quick inventory of many items in one shot. Finally, UHF RFID tags have internal memory allowing to have the most valuable information stored in. So that, the operators can access locally to such most valuable information without a connection with the central database. Different UHF RFID tags, named RadRFID, have been selected according to the material where they are applied (either metals or non-metals), the kind of information they must keep in their internal memories, and the environmental conditions where they operate (Fig. 4**Figure 4**). Since applications of DigiWaste Platform concern the nuclear waste produced from industrial activities, RadRFID tags need to sustain decent radiation doses without any degradation of the data stored in with consequently issues in the data reliability. For this reason, they have been tested extensively under the beam produced by a radiotherapy accelerator and the result was that no data was affected up to a total dose of 300 Gy. Concerning their functionality, each tag is provided with a unique ID number, namely Electronic Product Code (EPC), which distinguishes one against the others. Consequently, this leads, in the RadBASE, to an univocal digital association of the item where the tag is attached. However, as previously mentioned, RFID readers can interrogate multiple RFID at the same time. This leads to the fact that, if multiple tags stay inside the interrogation cone of the reader, all of them will communicate their presence and ID to the reader, making not so easy to spot the desired tag among the others. There are several techniques to avoid ambiguities in the ID readout in case of presence of multiple tags. RadRFID tags show a printed barcode on their surface. The idea is to encode in the barcode the same unique ID number of the RFID tag. In case of ambiguity, an operator can optically scan the tag barcode of his interest, get its unique ID number and then proceed with read and write operations via RFID protocol. By knowing the ID number, the RFID reader will access only the desired tag, no matter if other tags are around.

Figure 4: Example of RadRFID tags selected for the DigiWaste Platform.

2.4 RadREAD, ruggedized portable UHF RFID reader family

DigiWaste Platform includes a suite of UHF RFID readers named RadREAD (Fig. 5), able to access the central database and read and write RadRFID tags. The purpose of these readers is to provide operators not involved in nuclear measurements with portable, user friendly devices able to communicate with the central database and share with UHF RFID tags applied on items on which they are working. Example of operational cases, not only limited to the NORM field, are those involving fast checking or routine verification of information linked to the item where the UHF RFID tags are applied, e.g. quality controls performed by a Supervisor or a Site Manager or physical check of samples measured in a certain period. RadREAD characteristics are different according to the needs of application. They are ruggedized, portable devices embedding UHF RFID readers, 1D/2D barcode scanners, as well as wired and wireless communication interfaces. Physical buttons and touchscreen pens help in using these devices even wearing gloves. According to the specific needs, they can run different Operative Systems (OS) to be easily integrated in existing IT infrastructures. By using RadREAD devices, operators can always retrieve the most useful and essential information from RadRFID tags applied on the items, as item ID, measured dose rate, detected nuclides, item creator and location, even if they are not connected to the central database because of a lack of connectivity.

Figure 5: Ruggedized, Portable UHF RFID Readers. These devices provide operators not involved in nuclear measurements with access to the central database and UHF RFID tags.

3 OPERATIVE SCENARIOS

The DigiWaste Platform is perfectly suitable for several kind of different operative scenarios such as the Oil & Gas industry, the Radon measurements in soil samples, the in-situ gamma dose rate survey and so on. In the following, as example, we will describe the Oil & Gas industry one.

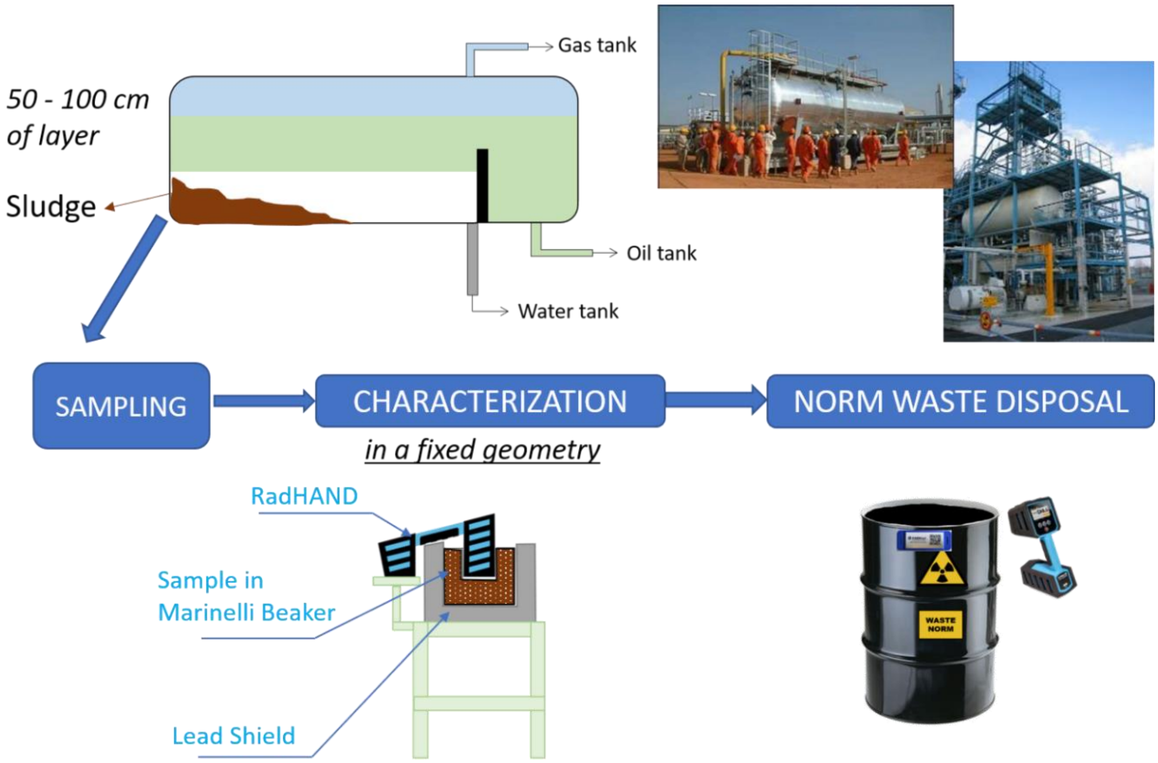
3.1 Oil & Gas Industry

Uncontrolled work activities involving NORM can lead to unwanted exposure and dispersal posing a risk to human health and the environment. These risks, proportional to doses originating from the exposition to NORM, can be reduced by adopting optimal working procedures and methodologies able to identify and track if and where NORM is present. [3]. One of the main work activities involved with NORM management is definitively the Oil & Gas industry. It is worth to point it out that different radioactive wastes are produced in such industrial activity [4] (e.g. spent and disused sealed sources, tracers, contaminated items, etc) other than NORM wastes but for the latter don’t exist yet a common international law defining very well the approach to use, so that each Country adopts, as general principles, best working practices in the area where NORM are present. The Digital Platform can be easily introduced to enhance the quality of best practices. Under normal operational condition, for example, for each site measurement point identified by radiation experts, an UHF RFID tag can be associated and the most relevant information can be stored in (e.g. dose rate value measured at 1 m from a specific pipe section or valve, date & time of the measurement, the operator who performed the measurement). Contemporarily, the entire set of data (including gamma spectrum, picture, audio note) is securely transferred to the RadBASE (Fig. 6).

Figure 6: Example of normal operation during pipe section or valve inspection procedure with Digiwaste in NORM management process for Oil & Gas Industry.

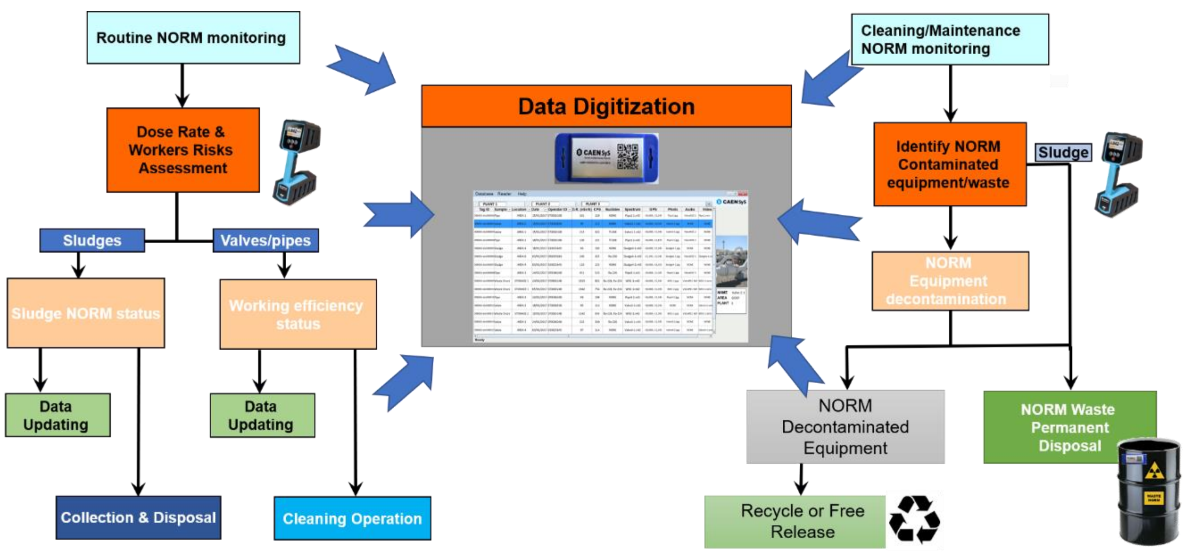
In this way, RadBASE collects the results of all the periodic measurements while the information stored in the local tag memory is refreshed at any new measurement. Thanks to this approach, Site Managers or HSE managers can easily get warned of any significant difference in consecutive measurements of the same spot and monitor the correct execution of the tasks by the operators. RadBASE can then show trend plots of the measurements and automatically generate reports. Under maintenance and/or cleaning conditions, operators can look for contaminated items by means of the RadHAND instrument. By monitoring the dose rate values, in fact, operators can easily spot possible radiation contamination and immediately start the isotope identification. Once the measurement is complete, a RadRFID tag is applied on the measurement item or on the drum containing the contaminated item and the operator can read back its unique ID number either via RFID or barcode scanning. Fig. 7 shows and example of this operative scenario.

Figure 7: Example of normal operation during sample contamination inspection procedure with Digiwaste in NORM management process for Oil & Gas Industry.



At this point, an unambiguous association between the item and the related RFID tag is established. RadHAND writes into the tag memory the most important set of information regarding the measurement, as dose rate and identified nuclides, identity of the operator who performed the measure, date and location. At the same time, the user can take a picture of the object, record a vocal note and submit all the data to the central database. Once the assessment is complete, operators dedicated to the clean-up and disposal can access the site, scan the RFID tags using the RadREAD devices and retrieve all the useful information from the database and the tags to complete their tasks. The waste storing can be planned according to the data collected from the previous operations and desired selection criteria (e.g. for permanent disposal or recycling/clearance). Fig. 8 shows a scheme of such operative scenario.

Figure 8: Example of DigiWaste Platform application workflow in NORM management process for Oil & Gas Industry.



A structured approach, as the one just described, could lead to an improvement of the quality of NORM management represented by a substantial reduction in the data acquisition operating time (i.e. no need of multiple instruments to acquire all data of interest) and post processing (i.e. no need to manually transfer data from the field to the office), with a consequently reduction of human related errors; an easier creation and management of items inventory and a faster retrieval of information; a better tracking of potentially hot-spot(s) with consequently optimization of ALARA principle for the workers safety, and finally an easier data verification for the Quality Assurance.

4 CONCLUSION

A comprehensive platform for the digitization of radiation measurements and, more generally, of all information produced in nuclear applications has been developed. The platform relies on an innovative handheld instrument, RadHAND, that combines state-of-the-art radiation measurement capabilities with the possibility to read and write radiation tolerant UHF RFID tags, RadRFID. The digitized information produced by operators' activities is continuously uploaded and stored into a customizable database framework, RadBASE, and easily accessed by users thanks to dedicated portable UHF RFID readers, RadREAD. The platform addresses the operational needs of NORM management activities such in the Oil & Gas Industry, uranium mining prospection or RADON in soil assessment, increasing the Quality Assurance of the processes, or reducing operational costs, and enhancing the adoption of the ALARA principle for the safety of operators. Thanks to the flexibility of RadBASE and its capabilities in fusing various information from diverse sources, the natural evolutionary step of the platform is to move towards augmented reality for operators by integrating 3D models of the working environment. This can be achieved in several ways by taking advantage of commercially available and reliable techniques for the 3D reconstruction of areas as LIDAR scanning and stereo cameras. UHF RFID tags can therefore be used as markers for retrieving all the information about tagged items and their position within the 3D model, boosting further the effectiveness of data digitization in nuclear applications. This novel digitization approach can significantly transform operations as currently performed. Digitization of nuclear measurements and radioprotection activities makes more information available to personnel from the plant floor to the boardroom, enhancing not only day-to-day operations. The ability to make critical business decisions today, planning for the coming days, weeks, months, and even years is strongly improved, creating a more productive and successful enterprise overall. This very innovative platform can bring the kind of innovation needed to excel in quality, methodologies, safety, and management of nuclear measurements data.

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